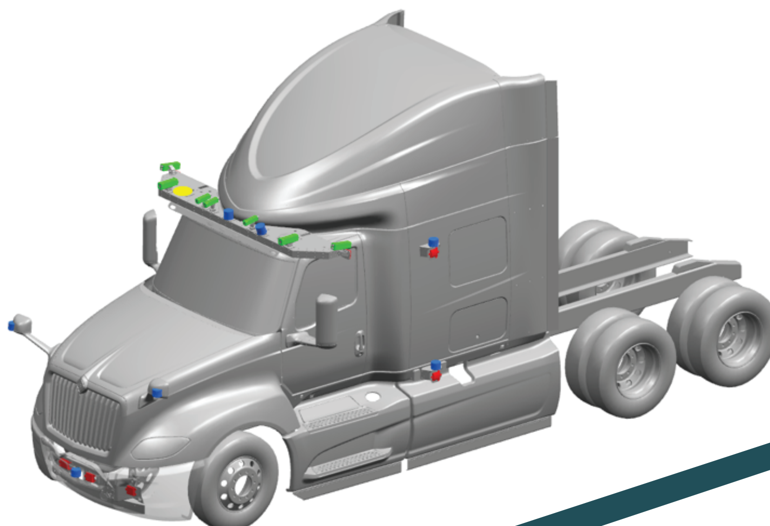
Connected Autonomous Commercial Truck Safety

Application to the

USDOT Automated Driving Systems Grant



Submitted by: St. Joseph County • 227 W. Jefferson Blvd., South Bend, IN 46601

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ST. JOSEPH COUNTY
ESTABLISHED 1830

DEPARTMENT OF INFRASTRUCTURE, PLANNING & GROWTH

March 21, 2019

The Honorable Elaine Chao
Secretary of Transportation
U.S. Department of Transportation
1200 New Jersey Avenue SE
Washington, D.C. 20590-0001

Dear Secretary Chao:

St. Joseph County, Indiana, in collaboration with Navistar, Inc., Pruv Mobility Ecosystem, The University of Notre Dame, Roush Engineering and the Center for Automotive Research (CAR), are proud to present this project proposal in response to the U.S. Department of Transportation's Notice of Funding Opportunity Number 693JJ319NF00001 for Automated Driving System Demonstration Grants. This collaborative effort, named the Indiana Commercial Vehicle Technology Partnership (ICVTP), is made up of industry experts who will strive to provide the necessary safety data and information to inform future policymaking in this burgeoning industry.

Our project entitled "Connected Autonomous Commercial Truck Safety" will focus on how commercial freight vehicles (Class 7) equipped with Level 3 or greater sensors and technologies interact with other vehicles and objects along the roadway. Potential demonstration tests include interactions with similarly sized vehicles, passenger vehicles, and instances that are intermittent in nature, such as emergency first responders or school buses. Additional tests will include understanding interactions with stationary objects, such as bridges/overpasses, highway work zones, and railway crossings. As a unique advantage to the St. Joseph County region, true four-season variations will be woven through the demonstrations to increase the scalability of the technology to the entire nation. To more clearly provide information to the Nation and the public, the Center for Automotive Research will host workshops over the course of the performance period to measure perception towards autonomous vehicle technology.

On behalf of St. Joseph County and the partners of the ICVTP, and with the support of Governor Holcomb, the Indiana Department of Transportation, and local leaders, we look forward to moving this proposal forward into actionable items to begin working towards a new future in automotive innovation. We strongly believe this demonstration project is a comprehensive yet concise plan to aid policymakers in developing new safety rules for the road. Thank you for this opportunity.

Sincerely,

William S. Schalliol
Executive Director, Economic Development

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SUMMARY TABLE

Project Name/Title	Connected Autonomous Commercial Truck Safety
Eligible Entity Applying to Receive Federal Funding	St. Joseph County Department of Infrastructure, Planning and Growth County-City Building, 11th Floor South Bend, IN 46601
Point of Contact	Bill Schalliol Executive Director of Economic Development 574-235-9812 bschalliol@sjcindiana.com Christian Brown Economic Development Specialist 574-235-7840 cmbrown@sjcindiana.com
Proposed Location	Navistar Proving Grounds, New Carlisle, IN
Proposed Technologies for the Demonstration	LIDAR, On-Board Camera Systems, On-Board Sensors, Radar, Microwave Utilization, Object Positioning Systems (GPS, DGPS), infrastructure sensors, high definition 360-degree cameras and 3D high definition maps
Proposed Duration of the Demonstration	42 Months (3.5 Years)
Federal Funding Amount Requested	$10,000,000
Non-Federal Cost Share Amount Proposed, if applicable	$19,302,803
Total Project Cost (Federal Share + Non-Federal Cost Share, if applicable)	**$29,302,803**

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PART 1.1 - EXECUTIVE SUMMARY

1.1.a: Vision, Goals and Objectives

In response to the United State Department of Transportation (USDOT) Automated Driving System (ADS) Demonstration Grant, the Indiana Commercial Vehicle Technology Partnership (ICVTP), led by St. Joseph County, IN, is pleased to offer our proposal entitled "Connected Autonomous Commercial Truck Safety."

ICVTP presents a balanced, comprehensive approach to help achieve the vision of safety and operational efficiency on the Nation's roadways for the people who depend on them.

ICVTP understands that the goal of the ADS Demonstration Program is to develop a testing program that enables data collection and sharing related to freight-vehicle usage of ADS technologies at an L3 level, as defined by SAE J3016[1]. This level of conditional automation would reflect real-time dynamic driving by the Connected and Automated Vehicles (CAV), with a human driver responding appropriately to requests by the system in the case of intermittent obstacles or signals.

Our objective is to examine how connected commercial tractors interact with other vehicles and infrastructure it that may be encountered on roadways. Because tractors and their complementary trailer loads have limited maneuverability and require longer stopping times, understanding how they behave in dynamic situations and non-ideal conditions is critical to design and implementation of safe, efficient automated driving systems.

1.1.b: Key Stakeholders, Partners, and Team Members

The ICVTP brings together a strong, diverse team committed to the success of the ADS Demonstration program, led by the following stakeholders.

- St. Joseph County, Indiana – The Department of Infrastructure, Planning and Growth combines the County's Public Works, Area Plan Commission and Economic Development divisions under one umbrella organization.
- Navistar (Illinois) and Navistar Proving Grounds (Indiana) – International manufacturer of commercial trucks, buses, and engines, and recognized leader in ADAS technology. The Proving Grounds includes a 3-mile oval test track with three lanes of asphalt road surface to carry heavy truckloads of up to 32,000 pounds per axle and is operated by a highly capable staff experienced in executing rigorous testing program and supporting customer requirements.
- Pruv Mobility Ecosystem (Indiana) – Privately held corporation that develops smart infrastructure test beds for connected, autonomous, and advanced propulsion technologies, vehicles, and associated components.
- The University of Notre Dame (Indiana) – One of America's leading undergraduate teaching institutions and a Tier 1 Research Campus. Notre Dame's Center for Research Computing will assist with curation and analysis of test data.

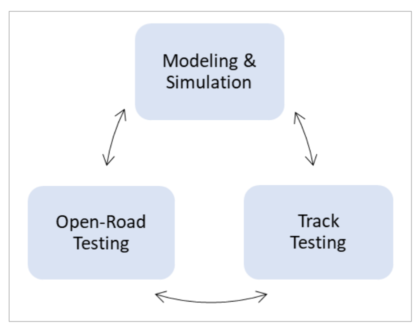
- Roush Engineering (Michigan) – A leader in engineering solutions within the automotive industry, including testing and development, prototyping and manufacturing.
- Center for Automotive Research (Michigan) - An independent, non-profit organization producing industry-driven transportation research and fostering dialogue on issues facing the industry and other stakeholders.

Partners working jointly in tandem include:
- Michiana Area Council of Governments (Local Metropolitan Planning Organization, South Bend, IN).
- Indiana Department of Transportation (Indianapolis, IN).
- Indiana Economic Development Corporation (Indianapolis) – Governor Eric Holcomb is the IEDC Board Chairman (see Part 4 Letters of Support).

1.1.c: Issues and Challenges

The key to the ADS Demonstration Program's success is data methodology, and the ICVTP team offers a program to provide demonstration data through:
- Proven technological leadership in vehicle development, testing, data collection and management, and application of analyzed data to further the safety, performance, and maintainability of autonomous vehicles
- A validated, on-road testing facility at Navistar Proving Grounds (New Carlisle, IN)
- Collaboration with local, state, and Federal governmental entities; public and private sector companies; a respected university; recognized consultant in the automotive; and the people we serve
- Strong program management capabilities and experience in community relations

ICVTP's overall approach uses a proven three-step process (used in parallel or in an iterative process) that provides the most reliable data set through:
1) **Modeling and Simulation** (M&S), which informs test requirements and prioritizes test scenarios
2) **Track or Closed-Loop Testing** on the Navistar Proving Ground (New Carlisle, IN), with a wide variety of driving surfaces, configurations, and ability to handle different vehicles
3) **On- / Open-Road Testing** that allows further data collection in real-world conditions



The information gathered from the testing events will be collected, stored, processed, analyzed, and used to answer the following question:

What information is needed to further refine ADS systems and processes to achieve the safety goals for those operating, riding in, or affected by vehicles on roadways, city streets, and in other scenarios?

The key technologies to be explored during this project will involve the use of existing technologies:

- LIDAR (Light Detection and Ranging)
- On-Board Camera Systems
- On-Board Sensors
- Radar
- Microwave Utilization
- Object Positioning System (DGPS & GPS)
- Infrastructure Sensors
- High Definition 360 Degree Cameras
- 3-Dimensional High Definition Maps

Additional technologies will be required based on the demonstration test plan.

These technologies will be used to study how current tractors (Connected and Automated Vehicles [CAV]) interact with other vehicles, pedestrians, and those who share the roadways

Our two primary focus areas under the Vehicle-To-X (V2X) umbrella are:

- <u>Vehicle-to-Vehicle (V2V)</u> interaction, which requires constant communication between vehicles and the driver to understand the best response in a given situation, such as:
    - First Responder Vehicles and their effect on traffic in emergency conditions
    - School Buses and Public Transportation and their effect on daily traffic, with somewhat predictable peak periods in morning and afternoon
    - Traffic Convention at Intersections (Stop signs, Stop lights, cross walks).

- <u>Vehicle-to-Object (V2O) interactions, with more static conditions that can alter the autonomous vehicle's</u> pathway and require a different type of sensor-based scene identification to inform the driver of upcoming changes in the vehicle's path, including:
    - Smart Road Development – addressing technology dealing with roadways / surfaces, technology-enabled signage, overhead technology elements (e.g., drones, signage, fiber canopies), on-/off-ramps, bridges, overpasses, toll booths, and end-of-roadway segments
    - Highway Work Zones – speed reductions, lane departures, barriers/lane restrictions, and sensing stopped traffic to allow for advanced braking procedures or transfer to driver to react to situations
    - Railroad Crossings – interactions with rail corridors and crossing, which present significant safety issues
    - Pedestrian and Bicycle – interactions with pedestrians along the roadside and at intersection points.

ICVTP expects the ADS Demonstration Program to produce incremental improvements as we develop, implement, and test new processes, procedures, components / systems, and materials for use in the continuing evolution of automated vehicles.

1.1.d: Geographic Area/Jurisdiction of Demonstration

As noted above, ICVTP has built a team with a strong presence in the Midwest that draws on experience and capabilities on a global scale.

The ability to demonstrate the proposed technologies within the areas of interest in four distinct seasons, on a diverse range of roadway types (urban, suburban, rural; asphalt and concrete) creates a comprehensive view of autonomous truck safety that can be extrapolated for Federal policy decisions.

The Navistar Proving Grounds, located at 32104 State Road 2, New Carlisle, IN, will be the main test bed for the proposed demonstrations. State Road 2 is a designated heavy-haul route in rural northern Indiana, and, with the Indiana Department of Transportation's support, is ideal for potential on-road testing should the technologies demonstrated in this project mature to that level. Additional access to nearby rural/suburban areas of New Carlisle and urban areas of South Bend could also support future on-road test beds as research in the autonomous transportation progresses.

1.1.e: Proposed Period of Performance

ICVTP proposes a period of performance for the ADS Demonstration Program of 3.5 years (42 months) from the date of award, with an additional five years of data storage, access, and security, as shown in Figure 1.1-1, *Detailed Schedule Listing Required Deliverables and Tasks*.

		Year 1				Year 2				Year 3				Year 4				Yr 5	Yr 6	Yr 7	Yr 8	Yr 9
Activity Description	RESPONSIBLE	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th					
Program Management	SJC																					
Budget Review Submission - Annual	SJC				X				X				X									
Progress Reports - Quarterly	SJC																					
Program Closeout	SJC															X						
System Design / Development	NAV/NPG/PRUV/CAR																					
Vehicle Selection, Maintenance & Updates with sensors	NAV/NPG			X	X																	
Implement Infrastruture Additions Test Roads	NAV/NPG																					
Establish Mobile Data Center	PRUV																					
Develop Test Plan	SJC/NAV/NPG/PRUV/CAR																					
Data Management Plan	PRUV																					
Vehicle Track Simulation Development	NAV/NPG																					
Data Collection / Vehicle Evaluation	NAV/NPG																					
Data Analysis	PRUV																					
Data Reporting	PRUV						X		X		X		X		X							
Public Relations / Communication	CAR																					
Public Workshop 1	CAR			X																		
Public Workshop 2	CAR								X													
Public Workshop 3	CAR													X								
Data Storage / Data Access Management	PRUV																					

Figure 1.1-1: Detailed Schedule Listing Required Deliverables and Tasks

The ability to concentrate on the two main thematic areas, with the advantage of seasonal weather testing in each area, will provide robust data to inform safety considerations moving forward.

ICVTP's schedule takes advantage of the many different seasonal variables (e.g. average, below/above average temperatures; average, below/above average snow conditions, ice and rain, spring and summer storms, wind, etc.) to generate significant data for analysis and application to determine the factors that affect how ADS systems interact with a wide range of obstacles.

PART 1.2 - GOALS

ICVTP has reviewed the NOFO and structured our ADS Demonstration Program to conform to the specified goals, as detailed in the remainder of this section – in line with comments from USDOT Secretary Elaine Cho:

> "…integration of automation across our transportation system… **has the potential to impact safety significantly**—by reducing crashes caused by human error, including crashes involving impaired or distracted drivers, and **saving lives**…
> The public has legitimate concerns about the safety, security, and privacy of automated technology… [need] a **path forward for the safe testing and integration of automated driving systems…**
> *Automated Vehicles 3.0: Preparing for the Future of Transportation*

In fact, the first item in the U.S. DOT Automation Principles states:

1. <u>We will prioritize safety.</u>
   Automation offers the potential to improve safety for vehicle operators and occupants, pedestrians, bicyclists, motorcyclists, and other travelers sharing the road. However, these technologies may also introduce new safety risks. U.S. DOT will lead efforts to address potential safety risks and advance the life-saving potential of automation, which will strengthen public confidence in these emerging technologies.

1.2.a Safety

ICVTP is committed to achieving the goals established for the ADS Demonstration Program, starting with the foundational requirement – **safety** – and has organized our program accordingly.

ICVTP understands that the goal of the ADS Demonstration Program is to develop a testing program that enables data collection and sharing related to freight-vehicle usage of ADS technologies at an L3 level, as defined by SAE J3016[1]. This level of conditional automation would reflect real-time dynamic driving by the Connected and Automated Vehicles (CAV), with a human driver responding appropriately to requests by the system in the case of intermittent obstacles or signals.

This focus is the natural result of studying the statistics on vehicle safety, as shown in the Safety by the Numbers graphic, Figure 1.2-1.

Safety by the Numbers

- An estimated **39,141** people lost their lives on all modes of our transportation system in 2017. The vast majority—37,133 deaths—were from motor vehicle crashes[A,B]
- *Driver Factors:* Of all serious motor vehicle crashes, **94 percent** involve driver-related factors, such as impaired driving, distraction, and speeding or illegal maneuvers.

  In 2017:
  - Nearly **11,000** fatalities involved drinking and driving.[B]
  - Speeding was a factor in nearly **10,000** highway fatalities.[B]
  - Nearly **3,500** fatal crashes* involved distracted drivers.[B]
- *Commercial Vehicles:* **13 percent** of annual roadway fatalities occur in crashes involving large trucks.[B]
- In 2017, **82 percent** of victims in fatal large truck crashes were road users who were not an occupant of the truck(s) involved.[B]
- *Professional Drivers:* Professional drivers are **ten times** more likely to be killed on the job, and nearly nine times more likely to be injured on the job compared to the average worker.[C]
- *Pedestrians:* **5,977** pedestrians were killed by motor vehicles in 2017, representing 16 percent of all motor vehicle fatalities.[B]
- *Highway-Rail Grade Crossings:* Over the past decade, highway rail grade crossing fatalities averaged **253** per year, representing about one-third of total railroad-related fatalities.[A]

Sources:
A U.S. Department of Transportation, Bureau of Transportation Statistics, special tabulation, September 8, 2018
B NHTSA 2017 Fatal Motor Vehicle Crashes: Overview (DOT HS 812 603)
C Beede, David, Regina Powers, and Cassandra Ingram, *The Employment Impact of Autonomous Vehicles*, U.S. Department of Commerce, Washington, DC: http://www.esa.doc.gov/sites/default/files/Employment%20Impact%20Autonomous%20Vehicles_0.pdf

* This number is likely underreported.

Figure 1.2-1 Sobering statistics about safety on the Nation's roads
(from the USDOT *Automated Vehicles 3.0: Preparing for the Future of Transportation)*

With this Program, we plan to examine how connected commercial tractors interact with other vehicles and infrastructure that may be encountered on roadways. Because tractors and their complementary trailer loads have limited maneuverability and require longer stopping times, understanding how they behave in dynamic situations and non-ideal conditions is critical to design and implementation of safe, efficient automated driving systems.

ADS has the potential to affect every person who travels, regardless of method, location, or distance. Safety concerns drive everything on the ADS Demonstration Program, including:

- Planning for the phases of Modeling & Simulation (M&S) and both Closed-Loop Testing at NPG and On-Road Testing in a variety of settings and environmental conditions
- Delivering, equipping, and maintaining the test vehicles – Class 8 tractor-trailer combination, Class 8 tractor only, and a Class 6 mapping vehicle.
- Performing tests
- Collecting, processing, analyzing, and storing data
- Maintaining communications with ICVTP team members across three states; local, state, and Federal governmental entities; suppliers; and, most importantly, the public.

Factors to be addressed and incorporated in the Program Plan include:

- Safety metrics
- Data needed to develop metrics, including:
    - Operational: speed limit, traffic conditions, signage, roadway users, non-roadway user obstacles/objects
    - Environmental conditions: weather, weather-induced roadway conditions, particulate matter, illumination)
    - Connectivity
    - Vehicle types
    - Traffic density information
    - Remote fleet management systems
    - Infrastructure sensors
    - V2X communications and interactions
- Combining data and metrics to baseline human safety and ADS operational safety
- Preparations for future safety analysis – part of the iterative development process
- Applying these processes throughout the spectrum of vehicles from motorcycles and passenger vehicles, to all classes of commercial trucks

ICVTP recognizes this opportunity to further strengthen safety factors on the vehicles, procedures and processes, and data protection on the ADS Demonstration Program. We are pleased to contribute to the body of knowledge for ADS safety performance assessment, thus ensuring the safety of passengers and road users.

1.2.b Data for Safety Analysis and Rulemaking
Improvements have been made through engineering innovation, public education, industry agreements, safety regulations, and safety-rating programs; however, as usage of automated technology grows, the need for improving safety grows even faster and significant room for improvement remains.

ICVTP understands that the goal of the ADS Demonstration program is to collect and share data related to freight-vehicle usage of ADS technologies at an L3 level, as defined by SAE J30162. This level of conditional automation would reflect real-time dynamic driving by the autonomous vehicle, with a human driver responding appropriately to requests by the system in the case of intermittent obstacles or signals.

This project will examine how connected commercial tractors interact with other vehicles and infrastructure it that may be encountered along future on roadways. Because tractors and their complementary trailer loads have limited maneuverability and require longer stopping times, it is imperative to understand how they behave in dynamic situations and non-ideal conditions – critical to design and implementation of safe ADS.

The ADS Demonstration project will explore sensor-based and scene development in two main areas: vehicle-to-vehicle (V2V) interactions and vehicle-to-object (V2O) interactions.

1.2.c Collaboration
Using multiple Autonomous vehicles, ICVTP proposes a data-gathering scheme which can be used to develop simulations and soft targets. An additional major benefit of this data collection is also the information that can be derived from analysis and then used to help develop processes, best practices, guidelines, and regulations associated with mobility.

We recognize that coordinated Federal, state, and local regulations are essential to enhancing and further developing applicable legislation, rules, and regulations related to safety. Organizations such as USDOT and National Highway Traffic Safety Administration (NHTSA), and governing documents, including Federal Motor Vehicle Safety Standards (FMVSS) and other specifications, are fundamental to increasing safety on the road for cars, buses, and commercial vehicles, such as Class 7 and 8 trucks.

Our approach is to bring diverse elements together, working to continue improving safety and operational efficiency in the ADS arena. Critical to this process are the testers and implementers, such as law enforcement; suppliers / vendors, people facing challenges to mobility, school transportation systems, and the public.

1.3 Focus Areas
ICVTP has reviewed the NOFO and structured our ADS Demonstration Program to deliver information in support of the following Focus Areas.

1.3.a Significant Public Benefit

This project is focused specifically on Automated Driving Systems (ADS) (Level 3 and above) for Class 7-8 commercial vehicles and their relationships with other vehicles and the surrounding environment.

The logistics industry is a major part of the United States economy and depends on trucks to deliver nearly 70 percent of all freight transported annually in the U.S., accounting for $671 billion worth of manufactured and retail goods. The numbers rise when $295 billion in truck trade with Canada and $195.6 billion in truck trade with Mexico are included. Truck drivers drive an estimated 140 billion miles every year, with a single semi traveling about 45,000 miles a year on average and long-distance trucks traveling upwards of 100,000 miles a year. Forty-two percent of all miles driven by commercial vehicles are driven by semi-trucks.[1]

Two local stories helped to drive the formation of this grant. The first was a crash between a truck and a school bus while the school bus was stopped at a rail crossing (no train/gates up) causing the death of a student on the bus. The second example was a situation where a truck passed a stopped school bus that was waiting to load three children, who were killed by the passing truck.

1.3.b Addressing Market Failure and Other Compelling Public Needs

During the last decade, there have been considerable developments in automated driving technology within the passenger car / light truck section. The Defense Advanced Research Projects Agency (DARPA) Challenges in the mid-2000s helped move the automotive industry forward in research and development for ADS projects[2]. Industry development has moved the next level forward with increased efforts from a number of industry players by the development of auto-testing facilities and the testing of Google self-driving cars on public roads.

The automotive industry has raced forward to embrace this technology, while the truck industry has spent similar time doing ADS development for vehicle platooning and related technologies. The scope of this grant will create truck-centric research and data that will help to advance the technology for the truck industry. With assistance from Roush and CAR, this team leverage the knowledge base gained from advances in ADS within the passenger car/light truck market segments into the commercial trucking arena.

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[1] Data from HDS Truck Driving Institute https://hdstruckdrivinginstitute.com/2014/04/05/semi-trucks-numbers/

[2] International Journal of Transportation Science and Technology, Volume 6, Issue 3 September 2017

1.3.c Economic Vitality

The proposed project that is the subject of this grant will create economic vitality at the national and regional level, leading to possible increase in economic benefits for domestic companies supplying the technology, increased collaboration between private and public partners, and end-user installation of technologies. Creating a safer and more pleasant driving environment may help bolster a current shortage of drivers within the trucking industry.
This grant includes using domestically produces vehicles from Navistar, headquartered in Illinois, with vehicle testing conducted at Navistar's proving grounds facility in Indiana. The testing activities will be conducted by businesses based in Indiana (Pruv Mobility) and Michigan (Center for Automotive Research and Roush Engineering) and will coordinate with University of Notre Dame for analytics and data processing and review.

1.3.d Complexity of Technology

The grant anticipates creating scenarios for V2X evaluations. Evaluating the performance of ADS Level 3 or greater technology with the most current instrumentation / sensors available at the time is the target of this proposal. The testing scenarios will be created in such a way to take advantage of the four-season climate at the testing facility; the testing cycle is proposed to be 3.5 years in length.
The variety of testing scenarios and the term of the grant through multiple weather situations will allow for large amounts of data to be collected that will lead to broader results over the period of the testing. Additionally, due to the size and nature of the facility, the range of complexity of testing can be accommodated on-site with minimal impact to their regular testing activities.

1.3.e Diversity of Projects

As this grant is designed, testing scenarios are proposed for development that will use the truck as the constant when developing V2X testing scenes.

The grant proposes a diverse set of testing scenes to include highway travel, rail crossings, highway construction zones, highway entrance/exit/toll booth facilities, bridge/low clearance situations, and intermittent and random stopping vehicles (i.e., school buses, delivery vehicles, and emergency vehicles). The testing will simulate highway, urban road, rural road, industrial park road, and other design configurations to allow for a maximization of testing and data collection.

1.3.f Transportation Challenged Population

The outcome of this proposal will benefit the general population with the added value to those areas with transportation congestion or challenges. The essence of this grant is to study truck ADS applications in a variety of settings to develop safety protocols and new technologies to allow trucks to operate more safely on roads as they inter-relate with other trucks, as well as with school buses, trains, emergency vehicles, and other vehicle types that service a variety of populations.

1.3.g Prototypes

For purposes of activity within this proposal, a Class 7-8 production tractor will be upfitted with a prototype ADS system and associated instrumentation. Likewise, the infrastructure (road structure and objects) will be designed specifically to support ADS functionality.

PART 1.4 - REQUIREMENTS

To meet the US DOT's ADS Demonstration project requirement to test the safe integration of Automated Driving Systems (ADS) into the Nation's on-road transportation system, ICVTP has structured a team that combines:

- St. Joseph County, serving as the prime applicant providing project management and oversight.
- Navistar, a proven original equipment manufacturer (OEM) of commercial trucks and engines, and owner of the Navistar Proving Grounds, the proposed location for all testing and demonstrations.
- Pruv Mobility Ecosystem, with expertise in all aspects of data management (i.e., collection, analysis and storage).
- The University of Notre Dame, offering capabilities in research and analysis.
- Roush Engineering, offering base data modeling, guidance on Nvidia PX/ Drive, object detection, high-definition road mapping, and cyber security capabilities.
- Center for Automotive Research (CAR), offering global automotive and mobility industry expertise, literature review, data collection for publication, and working group coordination.

1.4.a Research and Development of Automation and ADS Technology

To ensure that the US DOT Automated Driving System (ADS) Demonstration program will fulfill the requirements specified in the Notice of Funding Opportunity (NOFO), ICVTP will draw on a broad base of technological and operational leaders to continue the development of this technology so important to our Nation.

Our project will focus on Level 3 or greater technology in connected commercial freight vehicles (i.e., heavy-duty, over-the-road commercial trucks; Class 7 and 8), and their interaction with other vehicles on the road. Level 3 ADS, as defined by SAE, indicates the drivers of these vehicles are not required to monitor the environment, but to take control of the vehicle in response to changing conditions (e.g., weather, traffic, road conditions, etc.) Specifically, this project's purpose is to understand and demonstrate how current and future technologies can analyze these dynamic conditions and notify the driver to resume control of the vehicle.

Commercial vehicles present an interesting challenge from a safety aspect due to their weight and lower maneuverability in quickly evolving situations; current Level 3 technologies need to be adapted to account for these factors. Given Navistar's experience in commercial autonomous vehicles and the availability of Navistar's 675 acre proving grounds, the project will model a wide range of environmental and situational changes that can occur.

ICVTP's primary focus areas are Vehicle-To-Vehicle (V2V) and Vehicle-To-Infrastructure (V2I), critical for gathering, analyzing, and applying data to better understand and meet the evolving safety and operational requirements we face.

V2V Interactions

- We will examine how larger freight tractors interact with other, similarly sized vehicles and with light duty vehicles on a variety of roads (e.g., interstate highways, two-lane roads, intersections; asphalt, concrete; etc.).
- This examination includes vehicles that intermittently stop, such as emergency first responders, school buses, commercial delivery vehicles, and public transportation.

V2I Interactions

- To proactively prepare for increasing vehicle automation, we will
    - Identify how Level 3 tractors interact with changes in roadway conditions, such as lane-configuration changes, highway work zones, railroad crossings, cross walks; as well as awareness of other road users such as bicyclists and pedestrians.
    - Determine which smart-road development and communications are needed now and the near future

Underlying the technical requirements is the environments in which the demonstration must be conducted. As requested in the ADS Demonstration document, the ability to test and demonstrate prototype technology in a wide range of seasonal changes is fundamental to promoting nationwide policies in this emerging field. On-road testing in real-world conditions during all four seasons is available in the St. Joseph County / Northern Indiana region.

We believe that the integration of automation across our transportation system can increase productivity and facilitate freight movement. In principle, automation has the potential to impact safety significantly by reducing crashes caused by human error, including crashes involving impaired or distracted drivers, and saving lives.

1.4.b Description of Physical Demonstration

Evaluations associated with this Proposal (for Planning, Research and Demonstration of Level 3 or greater Autonomous Vehicle Systems) include physical demonstrations in the form of evaluating a primary Level 3 test vehicle, in response to other *physical* vehicles and objects.

Per SAE International, J3016_201806, Level 3 Automation is described as "*Conditional Automation;* The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene."

In the beginning of the project, all vehicle evaluations will be conducted at the Navistar Proving Grounds, located in New Carlisle, IN. One goal of the project is to evolve into testing Level 3 or greater vehicles on the public roads, if confidence in the performance of the ADS system per the involved stakeholders, can be established.

Figures 1.4-1 and 1.4-2 provide overall and detailed photos of this industry-known facility.

Figure 1.4-1: Navistar Proving Grounds Test Track

Figure 1.4-2: Navistar Proving Grounds Vehicle Dynamics Pad with High Speed entrance from Oval Track, Low Coefficient Surfaces and 500' Radius

Navistar Proving Grounds is located approximately 12 miles west of South Bend and occupies 675 acres. It was designed for testing heavy vehicles including the following vehicle evaluation events:

- 3-lane, 3-mile oval with banked curves.
- Vehicle Dynamics Handling pad with low-coefficient surface friction surfaces.
- Durability course with hills, unimproved roads, dirt roads, gravel roads, undulating pavement, resonance bumps, impact bumps, chatter bumps, staggered bumps, chuckhole, cobblestones.
- Curved roads with hills.
- Up/down hill paved and unpaved grades (12%, 20%, 30%).
- 88,000 sq. ft. of garage space.

NPG provides a safe, secure and comprehensive vehicle-testing and development environment available to all vehicle, component, and related automotive-industry manufacturers and component suppliers. NPG recognizes the proprietary and confidential nature of clients' activities and is dedicated to maintaining and enforcing policies designed to provide necessary vehicle and program security.

In addition to having road infrastructure and the equipment to maintain surfaces for driving in all seasons, NPG can also provide garage facilities and supporting labor. The facility is staffed with experienced drivers who are trained to operate vehicles on varied road surfaces as well as in all weather conditions. Anyone interacting with a Level 3 or greater ADS vehicle will receive appropriate training for interacting with the system, in accordance with NPG's current accreditation to ISO 9001 quality standards.

Provided confidence can be established within the closed track environment, the demonstration activity will be extended to area public roads. State Road 2 is a designated heavy-haul route in rural northern Indiana and, with the Indiana Department of Transportation's support, is ideal for potential on-road testing should the technologies demonstrated in this project mature to that level. Additional access to nearby rural/suburban area of New Carlisle and urban areas of South Bend could support future on-road test beds as research in the autonomous space progresses.

The Proving Grounds allows facility rental to 3rd parties and can serve as a location for other entities to evaluate ADS technologies using the improvements funded by this ADS Demonstration Grant. The infrastructure will allow others to test technology which will ultimately available to consumers.

1.4.c Data Collection, Storage, and Sharing – Reference Part 3 Data Management Plan.
The Indiana Commercial Vehicle Technology Partnership (ICVTP) will utilize a broad array of data collected to support V2X interactions: Reference Data Management Plan for details.

Focus will be in the following areas: V2X interactions and data sharing, in support of advanced driver assistance, vehicle distance utilization, object detection, identification, and avoidance, in utilizing automated braking systems.

Data Security – Cybersecurity
Utilizing 5G beam forming and IP indexing, known devices will be allowed access to any network associated with this project. Create Virtual Private Network, along with traditional platform firewall definitions.

Data Security – From Collection through Five-Year Storage
We will utilize an onsite mobile data center with backup of secured cloud storage, including standard security measures of account management, password access, and file/data management controls (read only, create, update, delete, download, upload).

Data Format
Data collected (by volume) will be used to create virtual and published data models. The data will be documented and stored, utilizing secured cloud data storage. Some of the data collected will be textual in nature within the project, and will be saved as text, MS Word, and pdf documents (e.g., supplementary info, experimental notes). Any tabular data collected will be captured in data bases, data matrix, data arrays, and/or data tables. Access will be available through API (application program interfaces) on the web site. In addition, presentation data such as PowerPoint and project files will be archived, utilizing cloud storage.

Access to Data and Data-Sharing Practices and Policies (Details in Data Management Plan)
Data will be made available through several mechanisms. During the data and information gathering portion of the project, relevant data will be available to all project participants via password-controlled data access. Development of a website that links to the cloud storage, with appropriate tools to allow visualization of the data will be included.

As noted in Amendment 1 of the NOFO document, ICVTP shall negotiate and sign a mutually agreeable data-sharing agreement with the USDOT ensuring at a minimum the above-required data accessibility for at least the minimum defined period (i.e., five years after program conclusion).

Policies and Provision for Re-Use, Re-Distribution and Products of Derivatives
Our policy towards accessing the data will be structured so that it is available upon request, for project members, including DOT. Re-use and/or re-distribution of this data MUST be reviewed and approved by primary data owners, as project participants will be utilizing private intellectual data, that will remain private.

Archiving and Preservation of Data
In addition, to support the DOT requirement, all preliminary, project, and generated data, will be stored for a 5-year period, from the conclusion of the project. Data sharing via website and/or other tools will continue to be provided during that time.

1.4.d Description of Input/Output User Interfaces on the ADS and Related Applications
The Automated Vehicle will have all necessary Human-Machine-Interface that will allow the users to input information on desired route, as well as display all information that will be generated by the sensors for driver situational awareness. The interfaces may include but are not limited to:

1. Main cockpit info from vehicle cluster
2. Input switches for activation
3. Lights for status indication

4. Touchscreen interfaces
5. Auxiliary screens
6. Auditory warnings/indications
7. Additional Lighting (external/internal)

The main use of the interfaces is to provide the driver and surrounding individuals with a sense of the vehicle state and vehicle intended state.

1.4.e Scaling of ADS Demonstration

Safety is our highest priority at every step of the research, development, and deployment process. It begins with a laser focus on safety methodology that emphasizes robustness and redundancy in the design, validation, verification, and support of the autonomous system. To this end, we aim to utilize best-in-class solutions in our equipment, facilities, processes, products, and safety architecture.

In order to be safe, the ADS demonstration will have 3 stages:

1. Simulation demonstration of ADS
2. Proving ground demonstration of ADS
3. On-road demonstration of ADS

At each stage, the system is built up to be more complex and capable. Each stage also builds up the infrastructure to be able to support the same or more level of functionality and will have data to create a valuable lesson for the cases demonstrated after. The infrastructure set up in the proving grounds and on the public roads can be then used to scale up to demonstrations at a larger scale with more vehicles.

1.4.e.1: Applicability for National Use

Since the demonstration and data collection will be conducted in an area with four seasons (Spring/Winter/Summer/Fall), the tests can easily be used to scale up to other cases/places at a national level. As stated in Section 1.4.a, this project's purpose is to understand and demonstrate how current and future technologies can analyze these dynamic conditions and notify the driver to resume control of the vehicle. It is expected that data taken and analyzed from our V2X interaction evaluations will be instrumental in the development of regulations, standards, protocols and procedures for Level 3-equipped commercial vehicles, which can then be translated into more widespread (product line, geographic region, additional vocations) commercialization.

1.4.e.2: Outreach to Ensure Technical and Knowledge Transfer

Efforts to communicate to the stakeholders and general public will be approached from multiple angles including but not limited to website content and workshops. The website content will be updated with general information as well as project progress and outcomes, as sharable.

Workshops to highlight vehicle technology advancement to the general public will be conducted at the Navistar Proving Grounds throughout the project. These workshops will be important to gauge perspective of emerging vehicle technology, and also to help familiarize lawmakers, DOT and the general public with ADS vehicle operation.

Public Discovery Workshop Series at NPG

For ADS technology to proliferate, it must have technological acceptance from the general public. Because the technology is not yet deployed in any significant way, most people have little-to-no experience with it. In many cases, their only awareness of ADS technology is what they learn from the media, which has generally focused more on the potential benefits the technology can bring without fully exploring the potential challenges to deployment.

PRUV Mobility Ecosystem and the Center for Automotive Research (CAR) will organize and chair a series of workshops on public perceptions of automated vehicles and trucks. These workshops will proceed as follows:

- First workshop: ~ 6 months from project initiation
- Second workshop: ~ 24 months from project initiation
- Third workshop: ~ 38 months from project initiation

CAR will work with local stakeholders to identify and invite workshop participants. Researchers will target a group size between 20-40 people per workshop to ensure it is large enough for varied viewpoints but small enough to encourage discussion. CAR will also leverage its Automotive Communities Partnership program, whose members are in the Midwest and southern regions of the country, to extend the geographic reach of invited attendees and information gathered. Efforts will be made to ensure workshop attendees represent a diverse population (age, gender, ethnicity). Researchers will present attendees with the state-of-the-art on ADS technology, as well as potential benefits and drawbacks. The proposed workshop flow is as follows:

- Discussion of attendees' understanding of automated driving systems and its potential benefits and challenges
  - What is the technology capable of?
  - What problems might it solve?
  - What problems might it create?
- Presentation of automated driving systems, including an overview of the technology, its application, and thoroughly researched potential benefits and challenges
- In latter workshops, researchers will ascertain thoughts on the demonstrations

themselves, to gain public perceptions on those specifically

- Discuss and document the public's response to the information presented
    - How perceptions change, if at all?
    - What concerns still exist?

CAR will summarize information gleaned from these workshops and will track how perceptions have changed over the course of the project. CAR will then recommend strategies on how best to communicate information on the technology, assuage concerns, and identify ideas for technological development based on public input.

A Vehicle Review Center situated next to the Proving Grounds track and vehicle dynamics pad will provide a venue for viewing demonstrations. Test data to illustrate repeatable and predictable vehicle performance, along with the opportunity to witness ADS system operation will be available to all stakeholders. Exposure to ADS system operation and test data will allow stakeholders to safely grow their confidence level in ADS technology. Vehicle performance evaluations at a closed track will ensure prototype ADS' are vetted in a controlled environment with consideration of public safety.

PART 1.5 - APPROACH

The following outline is a framework of how ICVTP will approach and execute the project.

- Safety awareness & analysis of ADS vehicles and interactions
- Create Program Management Plan and Program Schedule
- Planning and procurement
    - NPG infrastructure, materials, vehicles, autonomous parts, sensors, data storage devices and equipment
- Prototype vehicle and systems development and production
- Upfit purchased vehicles:
    - 1 x Class 8 – Tractor
    - 2 x Class 8 – Truck – automated attenuator vehicles
    - 1 x small mapping vehicle
- Test plan and simulation development including full version of Data Management Plan
- Vehicle testing (closed track and public road demonstrations)
    - Navistar Proving Grounds
    - Midwest location (e.g., Indiana) for variation in operational scenarios over long distances

  - Four seasons / Range of conditions
  - Interaction with variety of vehicles
  - Explore options that enable a range of travelers with challenges who to have needs addressed (e.g., older, disabilities)
- Data analysis, and reporting
- Public Communication / Workshops

1.5.a Technical Approach for Demonstration Implementation and Evaluation

The test plan will assume use of three dedicated vehicles for this project:

- Class 7 or 8 Tractor with Level 3 ADS and necessary instrumentation sensors.
- Class 7 or 8 Truck - automated attenuator/road construction vehicles.
- Light vehicle for mapping.

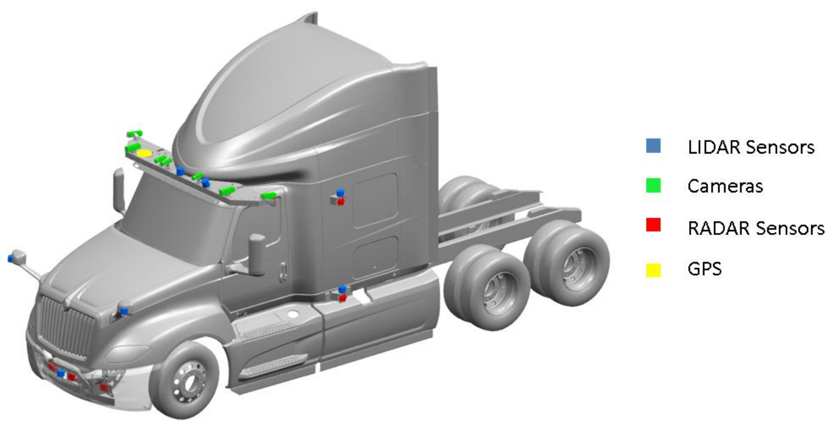

Figure 1.5-1: Potential Sensor Set and Locations

Navistar, with input from the DOT and all stakeholders participating in the project, will develop and conduct a comprehensive test plan to include evaluations within each of the following common ADS test core aspects.

- Tactical maneuver behaviors (immediate control related tasks)
- Operational Driving Decision elements (variable of the operating environments)
- Object and Event Capabilities (variations of objects and events)
- Failure mode behaviors (ADS hardware failure or inadequate information)

The test scenario outline offered by NHTSA's publication of DOT HS 812 623 "A Framework for Automated Driving System Testable Cases and Scenarios" (issued September 2018) will serve as a starting point for selecting appropriate demonstrations. Test planning will be approached with a methodology to identify and address as many of the tactical and operational maneuvers possible at a closed test track with priority on those which will substantiate confidence of Level 3 Commercial Vehicle ADS systems on the open road. Identifying the ADS driving features most important to Level 3 Commercial Vehicles, will allow Navistar engineers and project partners to select and plan tests to substantiate the range of performance, in addition to vetting any potential failure modes.   A Sample list of test cases along with the related input variables and outputs is shown in Table 1.

Table 1.5-1: Sample Test Plan Framework for Level 3 Automation

Test Case / Maneuver	**Variables** (Operational Driving Decision Inputs)	**Output / Result** Object / Event Detection and Response (OEDR)
Lane Change / Low Speed Merge	Road type, road surface, road direction and grade, lane marker type, ambient conditions.	Can vehicle detect and react to optional objects & vehicles?
Vehicle Shadowing / Following	Road type, road surface, road direction and grade, lane marker type, vehicle speeds, ambient conditions.	Will vehicle lead / follow and react reliably in all conditions including safe following distance?
Lane Exit / Park	Road type, road surface, road direction and grade, lane marker, ambient conditions.	Does vehicle exist lane and successfully park?
School Bus and Emergency Vehicles	Road type, road surface, road direction and grade, sensor condition, lane marker type, vehicle speeds, ambient conditions.	Does vehicle identify and respond appropriately to inputs from School Bus and Emergency vehicles? Does a system protocol exist for emergency override to transfer control to a human in case of emergency?
Encroaching Vehicles	Vehicle speeds, sensor output quality, ambient conditions.	Can vehicle detect and react appropriately to oncoming vehicle from any direction?

Table 1.5-1: Sample Test Plan Framework for Level 3 Automation

Test Case / Maneuver	**Variables** (Operational Driving Decision Inputs)	**Output / Result** Object / Event Detection and Response (OEDR)
Pedestrians / Objects	Object type, object movements, ambient conditions.	Does vehicle react appropriately, in enough time to all potential objects? When and how accurately do sensors identify object? What is the range of identification for sensors?
Intersections	Intersection type, number and movement of other vehicles.	Can vehicle safely navigate intersections of all types?
Failure Mode Evaluation	Integrity of sensor hardware.	How does vehicle react if sensors are broken, worn or stop operating?
Failure Mode Evaluation	Integrity of sensor message.	How does vehicle react if sensor signal is not complete?

The following is a list of anticipated outputs from vehicle tests. This list may be expanded based on identified needs of the stakeholders or data analysts.

- Vehicle States
  - Vehicle path
  - Vehicle trajectories/motion
  - Vehicle acceleration / deceleration cycles
  - Vehicle stopping distance
  - Vehicle position relative to other objects
  - Reaction time
  - Driver interface time and actions
- Surrounding Object Data
  - Location of object relative to vehicle
  - Distance between vehicle and object (based on Radar & Lidar signatures)
  - Camera data
- Failure Mode Identification & Mitigation

Both existing roads and events along with planned improvements will be included in the test matrix, to provide a wide selection of situational criteria for evaluation of ADS Operational Driving Decisions (ODD). Navistar engineers will select and plan vehicle tests that offer the widest representation of real-world user situations. Input and requests from all Stakeholders will be incorporated when developing test plans to assure appropriate deliverables (or results) will be valuable to all parties. Vehicle evaluations of both short and long-term durations will be conducted. Shorter term demonstrations will allow evaluation of controlled variables while longer term demonstrations will illustrate the effect of uncontrollable variables on vehicle performance. For example, Navistar can evaluate parking, lane changes, vehicle operation on varied road surfaces and navigating on/off ramps while changing only one variable at a time between measurements. All of these events can then be evaluated in multiple weather conditions throughout the year and with varied age of sensors and line markers to evaluate potential changes in performance. Conducting multiple days and shifts of the test route will indicate if uncontrolled variable such as seasonal influences (precipitation, temperature, ambient lighting, etc.) will affect sensor performance and communications.

Closed track testing will allow control and repeatability of variables that affect the inputs to ADS sensors while also exposing test articles to uncontrolled variables such as weather. Examples of each of these variables are shown in the Table 2.

Table 1.5-2: Examples of Controlled and Uncontrolled Variables.

Variable Type	Category	Example
Controlled Variables	Road Type	Divided, undivided, ramps, intersections, roundabouts, cross walks, rail crossing, overhead bridge, stoplight.
	Road Surface	Asphalt, concrete, gravel, dirt, chuckhole, pothole, speed bump, etc.
	Road Edges	Quality and type of line markings, barriers, curbs, barrels, cones.
	Visibility	Lighting – continuous and intermittent through tunnels.
	Objects	Signage, other roadway users (vehicles) and non-roadway users (animals, pedestrians)
Uncontrolled Variables	Precipitation / Wind	Snow, rain, sleet, hail
	Ambient Temperature	4 season (-20F - 100F)
	Ambient Lighting	Day / Night, Fog.

1.5.b Approach to Addressing Issues Affecting Demonstration

In addition to meeting any regulatory or statutory requirements, we agree with the U.S. DOT vision that entities testing and eventually deploying ADS technologies should employ a mixture of industry best practices, consensus standards, and voluntary guidance to manage safety risks along the different stages of technology development and will do so to ensure the proliferation of the national benefits of the work conducted. In addition to complying with federal and industry guidelines, we intend to practice open disclosure and collaboration with industry experts to ensure that we remain up-to-date on all current and future safety issues that may affect national deployment of autonomous technology.

1.5.b.i Exemptions from Regulations

Exemption 1: Over-width Test Vehicles

The DOT will be consulted prior to ICVTP conducting demonstrations on public roadways to determine if an exemption for over-width vehicles (due to on vehicle cameras and sensors) is required. The exemption may not be necessary if the DOT considers the vehicle prototype, per the FMVSS.

1.5.b.ii Exception to Buy American Act and/or Buy American and Domestic Vehicle Preferences

Because the ICVTP, including all stakeholders are based in the United States, with operations in multiple states, the ICVTP team complies with specified requirements.

1.5.c Collection and Evaluation of Data Related to Safety and Mobility Support

A data-gathering scheme using multiple ADS equipped vehicles is proposed to improve the efficiency of map generation and data richness development. In the proposed scheme, all the Autonomous vehicles will share their data via high-speed infrastructure/ communication channels (5G) within the proving grounds. This data can then be used to develop simulations, soft targets and regulation development for all mobility applications. This will also support vehicle to vehicle learning utilizing AI algorithms.

1.5.d Risk Identification, Mitigation, and Management

The ICVTP team recognizes the need for a Risk Mitigation and Management Plan, from the very beginning of the project. As such, we have listed preliminary risk scenarios below, with attendant likelihood, consequence, risk rating, and mitigation plan in Table 1.5-3**.**

Table 1.5-3: Risk Mitigation and Management

Risk Scenario	Likelihood	Consequence	Risk Rating	Risk Mitigation Plan/Owner
Project Management / Reporting	Possible	Major	Moderate	Monitoring and reporting progress by associates / SJC
Budgetary Issues	Unlikely	Major	Moderate	Scope planned within budget constraints and frequent reporting / All
Scheduling / Delays	Possible	Major	Moderate	Robust project plan & workarounds, use of simulation models / All
Legal & Regulatory	Unlikely	Moderate	Low	Early conversations, provisions / SJC
Technological	Likely	Major	High	Emphasis on early simulation / NAV, PRUV, ROUSH, UND
Security / Cyber Security	Unlikely	Major	Moderate	Leverage existing NPG policies & provisions and Data Mgmt Plan / NAV, PRUV, ROUSH
Data Integrity	Unlikely	Moderate	Moderate	Utilize skilled specialists with exhaustive plans for confirmation / PRUV, UND, ROUSH
Operational	Unlikely	Major	Low	Leverage existing NPG policies & resources/NAV
Safety	Unlikely	Major	Low	Leverage existing NPG policies and programs/ NAV

1.5.e Cost Sharing: Applicability

Table 1.5-4 illustrates the amount of in-kind resource support offered by stakeholders participating in this project.

Table 1.5-4: Summary of In-Kind Resource Contributions

Participant	Resource	Estimated Amount	% In-Kind
Navistar – NPG	Facility Usage – Garage and Track	$ 902,803	100%
Navistar - NPG	Site Prep for Vehicle Dynamics Pad (with Smart Asphalt)	$3,100,000	100%
Navistar – NPG	Vehicle Review Center	$3,000,000	100%
SJC	Sewer to SB WWTP	$6,200,000	100%
SJC	Water Connections	$5,100,000	100%
SJC	Service Road	$1,000,000	100%
	TOTAL ->	$19,302,803	