PNT Resiliency for Vehicles in GPS Degraded Environments

D. Application and Submission Information

iii. Project Narrative:

a. Overview/Project Description (1-2 pages)

The scope of the project is to establish an initial implementation that demonstrates system performance with positioning, navigation and timing (PNT) functionality when GPS is compromised or unavailable (a cybersecurity vulnerability). This would be demonstrated in urban environments around the city of Columbus, Ohio, and on the Ohio State University (OSU) campus. With a focus on improving connected and autonomous vehicular safety, this project is aligned with the Vision Zero Columbus commitment to improving the community by protecting lives and eliminating vehicular fatalities and injuries. Further, by providing safer and more redundant vehicle systems that predominately rely on GPS (which can be a single source of failure) with PNT resiliency for autonomous vehicles, this demonstration will be testing innovative technologies to address cybersecurity issues. OSU and NextNav will demonstrate the potential of using the NextNav TerraPoiNT system as a resilient, GPS independent positioning and timing solution for transportation vehicles. As part of this demonstration, OSU in partnership with NextNav will:

- Enable resiliency of existing connected/autonomous vehicle positioning systems for vehicle position and navigation use cases by incorporating signals from the TerraPoiNT system in combination with inertial vehicle sensors in a GPS-denied environment.
- Utilize the TerraPoiNT PNT network and vehicle receiver solution to identify GPS/GNSS signal loss and accuracy divergence when integrated in a multi-sensor vehicle system (GNSS, inertial, visual, other).
- Share learnings from the design and testing, including publishing a report with partners on vehicle positioning accuracy in GPS and GPS-denied scenarios, including performance of a terrestrial-based complementary PNT solution when integrated with inertial sensors.

There are several real-world issues to be addressed. First, vehicle positioning based solely on GPS can face numerous challenges, impacting accuracy, safety, and reliability. GPS vulnerabilities have been classified by the DHS as cybersecurity threats. Jamming and spoofing of GPS signals would greatly impact the safety of connected and autonomous vehicles and pose a risk to community safety, as intentional interference could impact autonomous vehicle navigation. Globally, GPS jamming and spoofing issues have caused numerous aviation and shipping related challenges, resulting in numerous mitigation strategies in both industries.

Additionally urban environments can cause signal interference and signal/multipath obstructions, further impeding safety. Automotive manufacturers can improve signal reliability in adverse conditions to ensure continuous and accurate positioning including in urban environments where tall buildings may lead to signal blockage or within indoor parking lots where a GPS signal is not available. Automotive standards for PNT resiliency with vehicle sensor integration are also a real-world challenge.

Notably, as a space-based system, GPS signals are over 100,000x weaker than terrestrial signals and therefore are susceptible to various factors including space weather such as solar flares. To enhance accuracy and reliability, automotive manufacturers often integrate or fuse other sensors

with GPS, but GPS is still the primary source for positioning and navigation. For more robust vehicle and positioning systems, a reliable and alternate source for GPS is needed to address the challenges mentioned above.

The proposed technology to be used is a terrestrial 3-D Positioning, Navigation, and Timing (PNT) system. NextNav's TerraPoiNT service delivers a resilient & secure (PNT) solution utilizing an architecture that consists of the TerraPoiNT network of transmitters, the TerraPoiNT receiver device, and the NextNav cloud, which together deliver a resilient PNT solution. TerraPoiNT provides precise horizontal positioning (latitude and longitude) and vertical positioning (altitude).

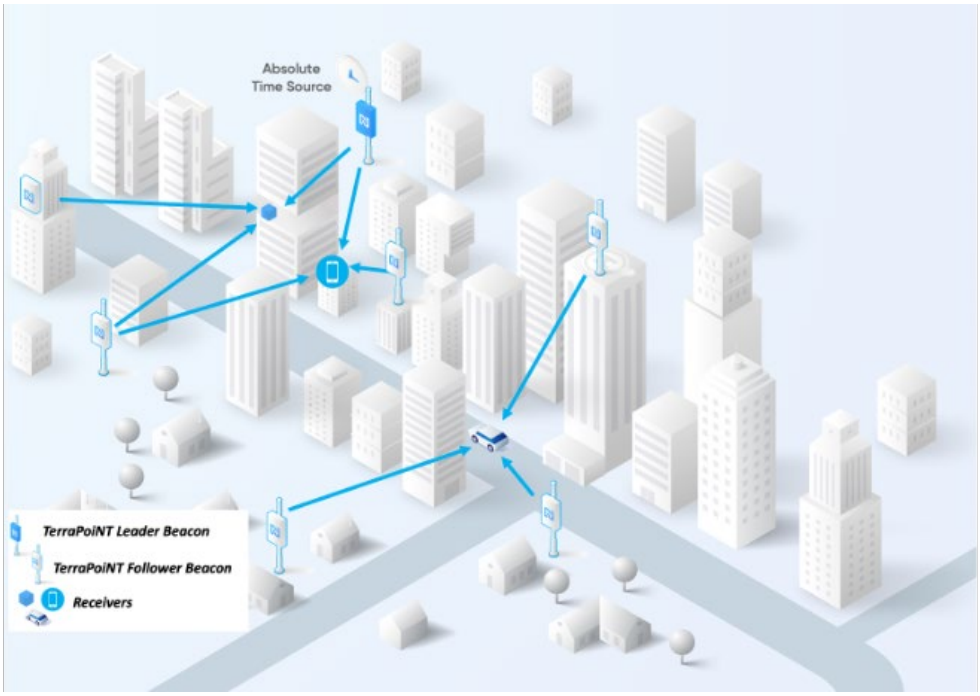


Figure 1: NextNav TerraPoiNT

In stage 1, a fused sensor system incorporating signals from the TerraPoiNT system in combination with inertial vehicle sensors will be used to assess the reliability and accuracy of vehicle positioning in a GPS-denied environment.

OSU and NextNav will demonstrate vehicle positioning accuracy resilience in a GPS denied scenario through testing at the OSU campus. The OSU campus and additional area in Columbus, Ohio, will serve as prototypes for urban testing of vehicle positioning accuracy resilience. As a Stage 1 deliverable, OSU and NextNav will plan and deploy the network, plan the prototype of a vehicle systems integration with TerraPoiNT, and publish a report on the vehicle positioning accuracy in GPS and GPS-denied scenarios. Potential Stage 2 activities and outcomes include additional testing in various GPS-denied scenarios, scaling the network with potential additional partners, vehicle positioning system resilience optimization, and documentation of system specifications needed for future vehicle system development, coupled with further knowledge sharing.

b. Project Location (1 paragraph)

The selected demonstration area, located primarily on the Ohio State University's campus is within an urbanized area of the City of Columbus, Ohio. The Ohio State University's campus is home to a diverse population of over 67,000 students, a research center and is a workforce hub for the region.

Due to the area's proximity to a busy six lane highway, bustling pedestrian facilities, a premier regional hospital, and a residential area, it is an accurate physical representation of urban areas across the country. Because the selected site sees high multimodal traffic and is a major attractor for the state, it makes sense to study the effects of a GPS-denied environment there.

Therefore, any related findings could easily be applicable in similar demonstration sites and potentially function as a primer for other SMART-related demonstration projects in the country.

c. Community Impact (1 paragraph)

The Columbus metropolitan area is not only one of the fastest growing in the Midwest but in the United States as well. As of 2021 it was estimated that the Columbus MSA has been growing by 60 people per day and that number is only expected to increase as major tech and logistic employers like Google, Intel, Meta, Honda, Amazon and numerous others continue to invest in Central Ohio.

These investments mean new jobs, residents, commuters, consumers, and therefore new potential safety issues. This can be especially true if there were to be disruptions to the heavily relied upon GPS networks. Studying the outcomes within the proposed demonstration area will aid local decision makers and business leaders in the development of implementable action items and better prepare all areas of Central Ohio for this growth.

For decades, The Mid-Ohio Regional Planning Commission (MORPC) has been the agency responsible for ensuring that the decisions made regarding transportation planning are done in a safe, fair and equitable manner. An adopted goal of MORPC is to *"Use Public Investments to Benefit the Health, Safety and Welfare of People*." Since the roll out of the Justice 40 initiative, MORPC staff have been utilizing this data to further assure regional partners, stakeholders, and the public that decisions will be made in an equitable manner and not adversely affect disadvantaged communities.

If given the opportunity to study these issues in the proposed demonstration area, it would allow local leaders and decision makers to easily replicate the outcomes and greatly benefit the underserved areas of the region as well.

d. Technical Merit Overview (2 pages)

Road vehicles, which are becoming increasingly autonomous, rely on accurate and reliable positioning, navigation, and timing (PNT) information to operate safely and efficiently. One of the most ubiquitous ways to obtain PNT data is by using GPS. However, GPS signals are vulnerable to various kinds of interference, especially in urban environments (where signals can reflect off of buildings), and in areas where there isn't a clear line of sight to space where GPS satellites are orbiting – including bridges or parking garages. And as a space-based service, GPS signals are also subject to space weather (such as solar flares) which can disrupt both satellites and their signals, rendering them unusable.

Arguably one of the biggest challenges with GPS signals is that they are vulnerable to jamming and spoofing from rogue state and non-state actors, and there have been notable instances of GPS jamming disrupting transportation both in the United States (around the Dallas airport in October of 2022) and around the globe (Russian spoofing of NATO ship positions in the Black Sea in 2021). In September of 2023, sophisticated spoofing of GPS signals has caused more than 20 aircraft flying near Iranian airspace to veer significantly off course – bypassing the aircrafts' sensors and leading to a complete loss of navigational capability. As both geopolitical and domestic terrorist threats continue with increasing sophistication of GPS jamming and spoofing techniques, having resilient PNT solutions in autonomous vehicles will be necessary for safety.

With both autonomy and driver assistance accelerating, there is a need for greater systems integration and GPS resiliency to ensure that all vehicles can operate safely, effectively, and smoothly in environments with various kinds of interference. Reliable 3D (horizontal and vertical) positioning and localization technologies are needed for increased autonomy. Further, vehicle manufacturers don't have the capabilities for alternative PNT systems to be able to provide GPS resiliency. To ensure that automotive solutions operate safely and effectively in different environments (urban, rural, indoor, outdoor) and overcome the vulnerabilities of GPS, complementary PNT systems are needed for integration into vehicle systems.

Complementary PNT systems can be integrated with inertial navigation systems (INS), which use sensors (e.g., accelerometers and gyroscopes), to measure a vehicle's motion and orientation, but there has been little testing done of how alternative PNT technologies can be leveraged and integrated with existing vehicular systems.

Appropriateness of Proposed Solution: NextNav's TerraPoiNT is a ground-based solution that provides resilient 3D location services that delivers accurate and secure PNT services to serve as a resilient layer to GPS. The TerraPoiNT system consists of long-range, low-cost, highly synchronized broadcast transmitters or "beacons" deployed on existing traditional wireless infrastructure (rooftops, cell towers) that transmit GNSS-compatible signals, and receivers that trilaterate those signals to compute time and/or navigation/position (both horizontal and vertical). TerraPoiNT network of terrestrial transmitters ("beacons") radiate a GPS-like signal on licensed spectrum (owned by NextNav) operating in the M-LMS band (919.75 MHz – 927.75 MHz). The use of two-way time transfer between beacons and the availability of a local atomic clock in each beacon enables timing availability with relative synchronization (needed for position and navigation) – in the absence of GPS/GNSS.

All beacons are connected to a wireless backhaul network for maintenance and telemetry information communication and managed from a central Network Operations Center (NOC). The NOC monitors and manages the network, including timing corrections when GPS is unavailable. Unique aspects that differentiate NextNav's TerraPoiNT product and services from others in the field include:

- Technology maturity: TerraPoiNT has a high level of maturity proven in multiple APNT trials and has been deployed and operated for over 10 years.
- Scalability: Terrestrial broadcast beacons provide wide area macro or campus coverage
- Secure: Resistant to spoofing and jamming; Signals are over 100,000x stronger than GPS signals, and signals are also encrypted
- Independent of GPS: built-in atomic clocks and ability of transmitters to self-synchronize
- Independently tested: A 2021 US Department of Transportation Report highlighted the superior performance of NextNav location technology in side-by-side tests of different technologies for resilient PNT. Across all eleven systems, tests were conducted to measure and rank systems in terms of timing and positioning for performance, ground broadcast and broadcast. TerraPoiNT was the only system able to produce a result in each category evaluated, and ranked in first place in every single test. Further, in a July 2021 test conducted by the Department of Homeland Security (DHS) Science and Technology Directorate, NextNav successfully demonstrated timing accuracy using its TerraPoiNT technology in a simulated 72-hour GPS outage. NASA has been using TerraPoiNT for drone testing in GPS-denied environments at both their Langley campus and Ames, including recent Beyond Visual Line of Sight testing.

When deployed broadly, NextNav's TerraPoiNT service will provide a resilient, supplementary signal for integration for vehicular use, where safety, security, and dependability are paramount.

Expected Benefits: This initial grant will provide the framework and network to create a complementary PNT testbed in the greater Columbus, Ohio region. Longer term, Ohio State University, would seek to understand how NextNav's TerraPoiNT – as a complementary PNT system – can:

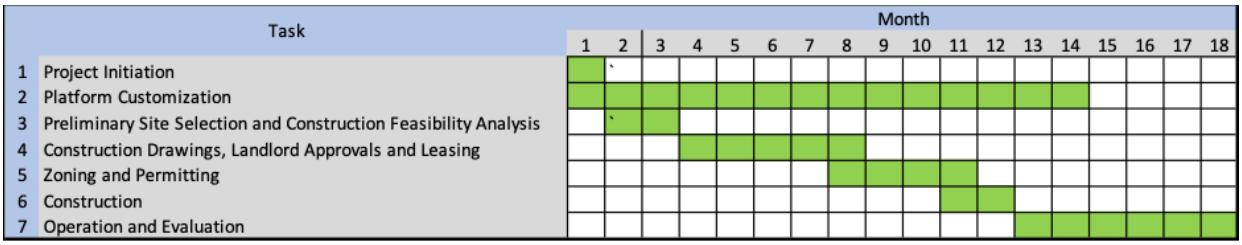
- Provide accurate positioning, navigation and timing information for autonomous vehicles
- Be integrated with inertial sensors to accurately and securely provide resiliency against intentional and unintentional PNT interference
- Understand how this PNT information can be applied to improve operational environments for the future of autonomous vehicles and aid in the development of a CPNT standards framework (per the 2023 DOT Complementary PNT Action Plan).

Outcomes from this initial planning phase will be aligned with the 2023 DOT Complementary PNT Action Plan, specifically around evaluating, enhancing, and implementing PNT solutions in GNSS denied or challenged environments. Additionally, with a focus on autonomous vehicle safety, the goals are aligned with the Columbus, OH Vision Zero project to eliminate vehicular fatalities and injuries. This will also further establish the region as a hub to accelerate the future of transportation and vehicle autonomy with an emphasis on safety and resilience, supporting the growth of the market of highly skilled, high wage, sustainable businesses.

e. Project Readiness Overview (2 pages)

Stage 1 of this project will be implemented over the course of 18 months with 7 major tasks to be completed by the project team. In collaboration with OSU, the majority of the work will be executed by NextNav and their site development contractors with program management, systems engineering, RF engineering, network deployment and operations expertise (See Appendix I for staff resumes). See Figure [1] below for the proposed timeline.

Figure [1]: Project Timeline



Task 1. Project Initiation, will occur after the execution of the grant agreement with a formal kickoff. This task will align milestones, key resources, and schedule initial site visits. The project team will establish regular meetings with OSU and NextNav (1 month).

Task 2. Platform customization, system quality metrics established for overall platform customization (4 months), TerraPoiNT receiver integration with vehicle sensor systems (3 months), validation, testing and performance analysis (6 months)

Task 3. Site Selection and Construction Feasibility, includes site visits with NextNav, NextNav's Architectural and Engineering firm and OSU personnel to determine antenna and beacon mounting locations as well as power availability (2 months). If the site is favorable, the information gathered in this task will result in construction drawings in Task 5.

Task 4. Construction Drawings, Landlord Approvals and Leasing, will run for 5 months seeking approval from the appropriate facilities managers (for OSU sites) or landlords (for 3rd party sites) to proceed with the proposed installation and if necessary, execute leases for non-OSU sites.

Task 5. Zoning and Permitting, will occur once the sites are approved in Task 5 if needed. This Task is estimated to run for 4 months but could vary depending on the final sites selected.

Task 6. Construction, will run for two months with an installation at each site. The installations will run serially with each installation taking 3-4 days and the schedule allowing for potential weather delays.

Task 7. Operation and Evaluation, overall system validation, testing, and analysis needed for project deliverable reporting (minimum 4 months)

This project is anchored in sustained partnerships and community engagement led by the project team for many years:

A Community-Centered Approach: This project will bring sustainable partnerships across the automotive and PNT sectors as well as with the Mid-Ohio Regional Planning Commission and local academic institutions (Ohio State University). Leading technical experts in PNT technology and automotive systems from industry and academia will collaborate with the Mid-Ohio Regional Planning Commission to address the community vehicular safety needs for the region leading to establishing broader national standards for automotive PNT resilience in Stage 2.

Public and Private Sector Partners: This proposal includes a Project Advisory Committee with representatives from long-standing partners, Ohio State University (OSU) College of Engineering, CARMEN, a UTC Center of Excellence on PNT and NextNav a leader in 3D PNT technology in support of the Mid-Ohio Regional Planning Council (MORPC).

Established Commitment: This proposal establishes the firm commitment of the identified partners. Letters of Commitment from Ohio State University (OSU) College of Engineering and NextNav are included in Appendix III. NextNav will be responsible for the customization of the TerraPoiNT platform as well as the deployment of required infrastructure. OSU will provide personnel and technical engineering expertise, share learnings from the design and testing, including publishing a report with partners on vehicle positioning accuracy in GPS and GPS-denied scenarios, including performance of a terrestrial-based complementary PNT solution when integrated with inertial sensors.

Leadership and Qualifications: The resumes of critical staff members for this project can be found in Appendix III. As referenced in the resumes, the project team will bring a deep level of technical expertise along with years of experience managing multi-stakeholder projects in industry/academia/standards bodies and demonstrated capability to maintain continuity and scale the project past stage 2.

iv. Appendices

a. Appendix I: Resumes – 3 pages or less

Key support personnel:

Dr. Cristina Seibert: Dr. Cristina Seibert is Vice President of Technology and Standards at NextNav where she heads the Standards department and directs research and development in resilient position, navigation and timing (PNT) solutions. She is a subject matter expert in wireless communication and networking, and the field of PNT. Dr. Seibert is an active member of various leading standard organizations and working groups including the IEEE P1952 where she is Chair of the Resilience Level Definition SG, at ATIS where she is Vice-Chair of the SYNC Committee, at CTIA where she is Chair of the OTA MBS Task Force, as well as at RTCA and 3GPP. Dr. Seibert holds a Ph.D. degree in Electrical Engineering from Stanford University, and MEng and B.S. degrees in Electrical Engineering and Computer Science from Massachusetts Institute of Technology.

David Knutson: David Knutson is NextNav's SVP of Network Operations and Deployment, responsible for manufacturing, designing, building and operating the NextNav network. David has more than 30 years of experience in wireless network design and deployment, including several years working for major carriers around the world. David earned a Bachelor of Science in Electrical Engineering from Virginia Tech.

Rob Rovetta: Rob Rovetta is NextNav's Vice President of Program Management, responsible for customer/partner program implementation. Rob brings more than 30 years of deep location technology experience, including experience with GNSS-based automated vehicle location systems, wireless system integration, and overall project management of complex end-to-end systems for both commercial use and R&D system trials / evaluations. Rob earned a Bachelor of Science in Electrical Engineering and RF Systems from University of California, Davis.

Additional support staff:
The support team includes other engineers and technical staff, deliverable support staff, and administrative support staff. Engineers and technical staff will assist with assisting in network design and deployment, equipment installation and integration, hardware and software integration, sensor integration, system validation and testing, monitoring, and analysis and evaluation. Administrative staff will track schedules and budgets and support other tasks as needed.

Joseph Garrity: Joseph Garrity is the Mid-Ohio Regional Planning Commission's Senior Director of Government Affairs and Community Relations at MORPC. He serves as the chief intergovernmental affairs officer and leads MORPC's government affairs, membership, and investment programs. Leading the Columbus Region Coalition (CRC), a diverse group of 16 regional organizations, Garrity collaborates with elected officials, business leaders and non-profit sector representatives, to strengthen the region by developing policies that ensure MORPC effectively serves its diverse 85 local governments. With over a decade of experience in public policy, Garrity has served at the state, federal, and regional levels of government. In 2022,

Garrity was selected by Columbus Business First as a 40 under 40 honoree and participated in the 2023 Leadership Columbus Class. Joe has a bachelor's degree in Specialized Studies from Ohio University, a Master's degree in Applied Politics from the University of Akron, and a Master's Degree in Public Administration and Leadership from The Ohio State University.

Mike Borger, AICP: Mike Borger is the Mid-Ohio Regional Planning Commission's Regional Engagement Manager. With over a decade of experience he has become a subject matter expert in the areas of multi-modal transportation and community planning. Mike has been instrumental in the development of many innovative planning activities in Central Ohio, including the development of the Central Ohio Rural Planning Organization (CORPO), numerous regional multi-modal transportation plans and data-related initiatives to name a few. As Regional Engagement Manager, Mike serves the Central Ohio community by delivering various planning products and services to MORPC's members, stakeholders, and the public.
Additionally, Mike holds a B.S. in Urban Planning and Policy from Virginia Commonwealth University and is a member of the American Planning Association's American Institute of Certified Planners (AICP).

Zak Kassas is a Professor in the Department of Electrical and Computer Engineering at The Ohio State University. He is also Director of the U.S. Department of Transportation Center: CARMEN (Center for Automated Vehicle Research with Multimodal AssurEd Navigation), focusing on navigation resiliency and security of highly automated transportation systems. He received a Ph.D. in Electrical and Computer Engineering from The University of Texas at Austin. He is an internationally recognized expert for his work in positioning, navigation, and timing (PNT) in GNSS-denied and GNSS-challenged environments by exploiting ambient terrestrial and space-based signals of opportunity (SoPs). He is a recipient of the 2018 National Science Foundation (NSF) CAREER award, 2019 Office of Naval Research (ONR) Young Investigator Program (YIP) award, 2022 Air Force Office of Scientific Research (AFOSR), 2018 IEEE Walter Fried Award, 2018 Institute of Navigation (ION) Samuel Burka Award, and 2019 ION Col. Thomas Thurlow Award.

b. Appendix II: Summary Budget Narrative – 3 pages or less

This budget breakdown and accompanying narrative is for informational purposes only.

Program Management Fees	$	370,000
System Customization	$	450,000
System Integration Testing	$	300,000
Site Development	$	150,000
Construction	$	222,500
Equipment	$	266,000
Site Operation: Rent, Utilities, NIST	$	75,000
Travel	$	75,000
Total	$	1,908,500

Program Management Fees, $370,000

- For the duration of the project, a senior program manager will lead the coordination of activities including interfacing with MORPC and OSU project leads, interfacing with external contractors, managing equipment logistics and deployment schedules, managing platform customization releases, driving system integration/test/evaluation tasks.
- Program management time for this project is estimated to be ~60 hours per month over the duration of the 18 month project.
- $100K placeholder for MORPC and OSU program management fees.

System Customization, $450,000

- Dedicated engineering resources over a period of 15 months to establish system quality metrics and oversee the systems engineering for vehicle system sensor fusion platform customization.

System Integration, $300,000

- Following network construction and system customization activities, engineering resources dedicated to overall system validation, testing, and analysis required for project deliverable reporting.

Site Development, $150,000

- Includes site visits with architecture firms and OSU personnel to determine antenna and beacon mounting locations as well as power availability, zoning, and permitting, and construction drawings required for construction.

Construction, $222,500

- Includes the labor for installation, construction materials, and construction material shipping costs required to build out the sites.

Equipment, $266,000

- Includes the physical network hardware required for the TerraPoiNT sites. The hardware components include transmitters, antennas, atomic clock(s), receivers, and TerraPoiNT equipment shipping costs.

Site Operations, $75,000

- Operational expenses for the site including rent, utilities, and clock synchronization services (NIST).

Travel, $75,000

- Covers an estimated 25 one-week trips required for personnel to travel to Ohio for site deployment, program management, and analysis activities.
- Includes 2 trips for travel to Washington D.C. for required meetings.

c. Appendix III: Letters of Commitment – no more than 2 pages per letter; no more than 10 pages for the complete Appendix III.

Below are Letters of Commitment from the following project partners:

- NextNav
- Ohio State University (OSU) College of Engineering

October 9, 2023

Mid-Ohio Regional Planning Commission SMART Grant Proposal: Position, Navigation and Timing (PNT) Resiliency for Vehicles in GPS Degraded Environments

To:
The Honorable Pete Buttigieg
Secretary
United States Department of Transportation
1200 New Jersey Avenue SE
Washington, DC 20590

Dear Secretary Buttigieg,

NextNav, a leader in resilient GPS, is committed to supporting the Mid-Ohio Regional Planning Commission (MORPC) and partnering with Ohio State University on the SMART Grant Proposal "Position, Navigation and Timing (PNT) Resiliency for Vehicles in GPS degraded environments". For more than fifteen years, NextNav has been focused on solving the challenges of GPS, specifically in GPS-degraded environments, and has deep engineering expertise in resilient PNT. The demonstration of a vehicular system with GPS equivalent functionality amidst GPS cyberthreats and interference (particularly in urban areas) will deliver extensive knowledge and information to further the safety of connected and autonomous vehicles, and will build on much of the work that NextNav has already done with resilient PNT systems and network deployment (including at both NASA Langley and NASA Ames for drone testing).

NextNav will offer the following services:

- Engineering and technical expertise for network deployment and operation
- Data gathering and analysis, in partnership with OSU
- Knowledge sharing from the network design, deployment and initial operation, including publishing a report with on vehicle positioning accuracy with a resilient PNT system integrated with inertial sensors in GPS-denied scenarios

NextNav's TerraPoiNT system has undergone extensive federal government testing, including by the DOT and the DHS. Through this SMART grant, the knowledge gained will further improve connected vehicle safety, both from cybersecurity threats and from general GPS interference in urban areas where GPS is vulnerable. All results will be aligned with the 2023 DOT Complementary Action Plan and with MORPC's Vision Zero Action Plan to eliminate traffic fatalities. Further, the demonstration network will be deployed in an urban area of Columbus - representative of other urban centers in the country - so the results will be replicable elsewhere.

NextNav looks forward to supporting MORPC and working with Ohio State University and the Department of Transportation on these initiatives. Thank you for your consideration.

Sincerely,

Ganesh Pattabiraman, Chief Executive ~~Officer~~

THE OHIO STATE UNIVERSITY

Center for Automotive Research

College of Engineering

930 Kinnear Road
Columbus, OH 43212

614-292-5990 Phone
614-688-4111 Fax
car.osu.edu

October 3, 2023

The Honorable Pete Buttigieg
Secretary of Transportation
U.S. Department of Transportation
1200 New Jersey Avenue, SE
Washington, DC 20590

Secretary Buttigieg,

The Ohio State University (OSU) College of Engineering, through its Center for Automotive Research and CARMEN+ University Transportation Center, a UTC Center of Excellence on PNT, is pleased to commit support to the Mid-Ohio Regional Planning Council (MORPC) for the SMART Grant Program Proposal "PNT Resiliency for Vehicles in GPS degraded environments."

OSU has deep expertise in navigation resiliency and security of highly automated transportation systems. The demonstration of a vehicular system that provides GPS equivalent functionality amidst GPS cyberthreats and interference (particularly in urban areas) will deliver a valuable bed of knowledge to further the safety of connected and autonomous vehicles. This demonstration builds on previous work conducted by OSU and CARMEN+ around autonomous vehicle safety.

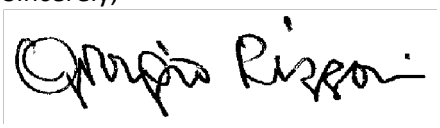
The OSU campus will serve as a prototype for urban testing of vehicle positioning accuracy resilience and provide a physical location on the campus in an urban area. OSU will work to utilize the assets proposed in this project with both existing and future research programs, further exploring and demonstrating the capabilities of terrestrial-based PNT.

The testing of a terrestrial-based PNT technology will undoubtedly provide knowledge that will improve safety in connected vehicles, specifically in urban areas where GPS is inaccurate and unreliable and vulnerable to cyberthreats, ensuring that resilient systems are properly tested, advanced, and ready for deployment.

If this project is funded, it will provide broad benefits that support Federal goals around safety and technology innovation and advance the safe operation of autonomous vehicles. All outcomes from this initial planning phase will be aligned with the 2023 DOT Complementary PNT Action Plan (specifically around evaluating, enhancing, and implementing PNT solutions in GNSS denied or challenging environments) and align with the Mid-Ohio Regional Planning Commission's Vision Zero Action Plan to eliminate traffic-related fatalities and injuries. This will also build upon the greater Columbus region as a hub to further accelerate the future of transportation and vehicle autonomy with an emphasis on safety and resilience, furthering the growth of the market of sustainable businesses.

Thank you in advance for your consideration of this application.

Sincerely,



Giorgio Rizzoni
The Ford Motor Company Chair in Electromechanical Systems
Director and Senior Fellow, Center for Automotive Research

d. Appendix IV: Project Location File

COLUMBUS PARTNERSHIP

ONE COLUMBUS
Partners for Regional Growth & Prosperity

150 S. Front St., Suite 200
Columbus, OH 43215

614-225-6063
columbusregion.com

October 9, 2023

The Honorable Pete Buttigieg
Secretary
United States Department of Transportation
1200 New Jersey Avenue SE
Washington, DC 20590

Dear Secretary Buttigieg,

I am writing today on behalf of The Columbus Partnership to offer support for the Mid-Ohio Regional Planning Commission's (MORPC) SMART Grant Program Proposal, "Position, Navigation and Timing (PNT) Resiliency for Vehicles in GPS degraded environments."

The Columbus Partnership is a non-profit, membership-based leadership organization of 80 chairpersons, chief executive officers and senior executives from the Region's leading businesses and institutions. Our members include Fortune 500 CEOs, as well as the leaders of top universities and the world's largest private, nonprofit research and development organization. The Partnership's goal is to provide a long-term vision for achieving greater economic prosperity and has positioned Columbus to be one of the strongest environments to attract businesses and investment in the world.

To keep pace with the Columbus Region's growth and trajectory, effective transportation will serve as a key building block to our region by providing for the safe and efficient movement of people and goods throughout our community. This grant will further reinforce the Columbus Region as a hub that will accelerate the future of transportation and vehicle autonomy with an emphasis on safety and resilience. It also provides a range of benefits that support both our state and local goals around safety and technology innovation while advancing the safe and efficient operation of autonomous vehicles.

All outcomes from this initial planning phase will be aligned with the Mid-Ohio Regional Planning Commission's Vision Zero Action Plan to eliminate traffic related fatalities and injuries. The testing of terrestrial-based PNT technology will lead us to safer connected vehicles and safer roads in our community, specifically in urban areas where GPS is vulnerable to cyberthreats, ensuring that resilient systems are properly evaluated, advanced, and ready for deployment.

The Columbus Region hopes to serve as a model of public, private and nonprofit partnerships. MORPC's partnership on this proposal with The Ohio State University, who have been at the forefront of research and development of complimentary and resilient GPS alternatives, positions our community to move forward together with the goal of making our region the most prosperous in the United States. MORPC and The Ohio State University have full support from The Columbus Partnership as we unite to strive for economic development advancement and success in the Columbus Region.

Very truly yours,

Kenny D. McDonald
President and CEO
KM/gb

33 N. High St.
Columbus, Ohio 43215
614-228-1776

October 10, 2023

The Honorable Pete Buttigieg
Secretary of Transportation
U.S. Department of Transportation
1200 New Jersey Avenue S.E.
Washington, D.C. 20590

Dear Secretary Buttigieg,

I am writing today on behalf of the Central Ohio Transit Authority (COTA) to offer support for the Mid-Ohio Regional Planning Commission's (MORPC) SMART Grant Program Proposal, "Position, Navigation and Timing (PNT) Resiliency for Vehicles in GPS degraded environments."

As the largest public transit provider in Central Ohio, the Central Ohio Transit Authority (COTA) collaborates with government, industry, and the community to increase access to equitable opportunities and to enhance the quality of life for area residents. We provide fixed-route, on-demand, and paratransit services to a region of more than 1.4 million people. By utilizing technology and data, establishing community partnerships, and applying sustainability principles, COTA provides equitable access to jobs, healthcare, and education.

To keep pace with Central Ohio's growth and trajectory, effective transportation will serve as a key building block to our region by providing for the safe and efficient movement of people and goods throughout our community. This grant will further reinforce Central Ohio as a hub that will accelerate the future of transportation and vehicle autonomy with an emphasis on safety and resilience. It also provides a range of benefits that support both our state and local goals around safety and technology innovation while advancing the safe and efficient operation of autonomous vehicles.

All outcomes from this initial planning phase will be aligned with the region's Vision Zero Action Plan to eliminate traffic related fatalities and injuries. The testing of terrestrial-based PNT technology will lead us to safer connected vehicles and safer roads in our community, specifically in urban areas where GPS is vulnerable to cyberthreats, ensuring that resilient systems are properly evaluated, advanced, and ready for deployment.

33 N. High St.
Columbus, Ohio 43215
614-228-1776

Central Ohio hopes to serve as a model of public, private and nonprofit partnerships. MORPC's partnership on this proposal with The Ohio State University, who have been at the forefront of research and development of complimentary and resilient GPS alternatives, positions our community to move forward together with the goal of making our region the most prosperous in the United States.

Sincerely,

Patrick Harris
Vice President, External Relations
Central Ohio Transit Authority (COTA)

UNION COUNTY
MARYSVILLE
ECONOMIC DEVELOPMENT

Union County Community Improvement Corporation
Economic Development Partnership

227 East Fifth Street
Marysville, Ohio 43040
Ph 93'7.642.6279
www.unioncounty.org

October 9, 2023

The Honorable Pete Buttigieg
Secretary of Transportation
U.S. Department of Transportation
1200 New Jersey Avenue S.E.
Washington, D.C. 20590

Dear Secretary Buttigieg,

I am writing today on behalf of the Community. Improvement Corporation to offer Stlpport for the Mid-Ohio Regional Planning Commission's (MORPC) SMART Grant Program Proposal, "Position, Navigation and Timing (PNT) Resiliency for Vehicles in GPS degraded environments."

The CIC oversees the community's Economic Development program. Working to attrnct and retain business, foster community partnerships and identify resources to improve the quality of life. The CIC works together with local, regional, and state partners to ensure that the community attracts balanced and sustainable industrial, commercial, and residential development.

To keep pace with the Central Ohio's growth and trajectory, effective transportation will serve as a key building block to our region by providing for the safe and efficient movement of people and goods throughout our community. This grant will further reinforce Centra Ohio as a hub that will accelerate the future of transportation and vehicle autonomy with an emphasis on safety and resilience. It also provides a range of benefits that support both our state and local goals around safety and technology innovation while advancing the safe and efficient operation of autonomous vehicles.

All outcomes from this initial planning phase will be aligned with our Vision Zero Action Plan to eliminate traffic related fatalities and injuries. The testing of terrestrial-based PNT technology will lead us to safer connected vehicles and safer roads in our community, specifically in urban areas where GPS is vulnerable to cyberthreats, ensuring that resilient systems are properly evaluated, advanced, and ready for deployment.

Central Ohio hopes to serve as a model of public, private and nonprofit partnerships. MORPC's partnership on this proposal with The Ohio State University, who have been at the forefront of research and development of complimentary and resilient GPS alternatives, positions our community to move forward together with the goal of making our region the most prosperous in the United States.

This commitment will support our growing region and has the full support of The Community Improvement Corporation.

Sincerely,

Eric S. Phillips
Executive Director