APPENDIX A: U.S. DOT SBIR Proposed FY24.1 Phase I Research Topics

Contents

Federal Highway Administration (FHWA)

About Us: FHWA's Research, Technology, and Education (RT&E) Program strives to generate new solutions, build more effective partnerships, and provide better information and tools for decision making, which will enable the nation to enhance and make the best investments in the U.S. transportation system.

FHWA's RT&E program supports research and development (R&D) to improve safety; the mobility of people and goods; stimulate growth, productiveness, and competitiveness; reduce congestion; improve durability and extend the life of transportation infrastructure, accelerate project delivery, and the transition to a transportation system that provides an equitable approach that serves all road users, including those in social and demographic communities that are underserved in access to mobility options and disproportionately represented in preventable and fatal injury.

The program accelerates the adoption of proven innovative practices and technologies as standard practices to significantly improve: safety, system efficiency, infrastructure health, reliability and performance, and a balanced approach to provide livable/sustainable communities across the Nation.

24-FH1: Next-Generation Sensing and Communication Technology for Cooperative Driving Automation

A suite of sensing and communication technologies is required to enable cooperative driving automation (CDA). While these systems often complement each other, it is still notable that multiple systems and varied physical devices are required on-board vehicles and within the infrastructure. The systems must be integrated, and data must be translated to ensure effectiveness. Given the limitations on the radio wavelength spectrum (generally within the 5.9 Ghz band), multiple and varied communication systems are required to overcome latency and demand/throughput challenges to ensure timely communication of critical information. To help with this, it would be beneficial to the surface transportation network if:

- Deployed CDA systems residing on both vehicles and infrastructure could be integrated into a single system with a smaller form factor, which could facilitate faster deployment.
- The sensing systems could save energy and computational resources by only focusing on 'relevant' objects while ignoring other ones (e.g., ignoring trees on the side of the road as those may be part of the internal map, but focusing on pedestrians, vehicles, and other non-static objects on or near the roadway).
- Alternative, non-traditional, reliable methods of communication could be available (e.g., using the light spectrum rather than the radio wavelength spectrum).

Such benefits would yield a small, computationally powerful, and energy-efficient sensing system that is also able to communicate with other systems without being restricted to the 5.9 Ghz band. These benefits allow for more efficient development and testing of CDA functions in support of Transportation Systems Management and Operations (TSMO) use cases, one of the goals of the Automation and Connectivity program as laid out in FHWA's Annual Modal Research Plan (AMRP).

If realized, such benefits have the potential to completely transform the surface transportation network. This supports the USDOT's Innovation principles by helping America win the 21st century by pursuing potentially transformative transportation technologies; by pushing for new and innovative solutions through experimentation; by leveraging advances in early-stage research; by providing opportunities to collaborate across modes; and by demonstrating flexibility to pursue new technological approaches as they become available.

The proposed solution would be a single, integrated device that can perform both sensing and communications functions to support CDA requirements. This includes environmental awareness, distance and velocity calculation, object identification and tracking, and the ability to communicate with other vehicles and the infrastructure. It is not a requirement that the system utilize existing sensing or communication standards. The system will also be manufactured and sold at a price point that will facilitate adoption at scale.

The proposed solution needs to be able to:

- Scan the environment to detect objects including vehicles, pedestrians, bicyclists, roadway obstacles (i.e., static or non-static entities on a road that would not be captured on a traditional high-definition map, such as debris), and certain roadway features and/or conditions (e.g., ice);
- Track all detected objects (to include position, velocity, orientation, and acceleration);
- Share vehicle, environmental, and basic safety information with vehicles and the infrastructure; and
- Have the ability to be energy and computationally efficient, as needed, only tracking and/or communicating about certain 'objects of interest'.

The proposed solution should be compatible with both on-board vehicle and infrastructure installations. The communication latency should be comparable to or better than Dedicated Short Range Communications (DSRC) / Cellular vehicle-to-everything (C-V2X) latencies to enable safety critical applications. In addition, the processing latency/ response time should be comparable to, and hopefully exceed, current sensing technologies. The sensing resolution should identify objects at a sufficient distance and accurately support safe, reliable deployment in an operational environment. The system must also securely send encrypted messages. Meaning, it should authenticate the identity of each sending entity such that only authorized entities are allowed to send and receive messages. The system must also have a method of ensuring data integrity such that it cannot be tampered with during transmission.

The potential market for this solution includes all system operators, original equipment manufacturers (OEMs), and suppliers that manufacture or deploy CDA-based sensing and communication technology. This would include vehicle manufacturers, including personal vehicles as well as buses, trucks, and all other highway transportation modes. It would also include manufacturers of infrastructure-based sensing and communication technologies. There is potential for integration into other markets as well such as aviation and national defense.

Expected Phase I Outcomes

At the end of Phase I, the awardee will identify the necessary sensing and communication parameters required to support CDA. The proof-of-concept report will:

- Provide technical specifications related to each parameter.
- Describe the final form factor and technical requirements for deployment in an operational environment
- Present a system integration plan that outlines how the system will support CDA requirements and how it can be integrated into vehicles and the infrastructure.

The awardee will also identify potential partners for development and testing in Phase II, including FHWA.

Expected Phase II Outcomes

At the end of Phase II, the awardee will provide final specifications and requirements for a fully operational system. Phase II shall develop and demonstrate a working prototype of the proposed system that meets the requirements. The awardee shall perform at least one demonstration of the operational system at the FHWA's Turner-Fairbank Highway Research Center. The awardee will also develop a final system integration plan that identifies the requirements for deployment in the operational environment. The system integration plan will include a description of the potential applications to support USDOT goals related to CDA, the entities required to facilitate deployment for each application, and the specific technical requirements for each application.

Technical References

Li, Y., & Ibanez-Guzman, J. (2020). Lidar for autonomous driving: The principles, challenges, and trends for automotive lidar and perception systems. *IEEE Signal Processing Magazine*, *37*(4), 50-6. https://arxiv.org/pdf/2004.08467

24-FH2: Carbonated Recycled Concrete Aggregate

Sustainability is becoming increasingly important for concrete pavements to remain competitive in today's pavement market. Virgin aggregates are becoming more difficult to locate within reasonable proximity of a job site; this is particularly so for locating aggregates of good quality. For example, some states in the southeast must transport aggregates considerable distances to produce concrete with good quality aggregates. The supply of high-quality aggregate is dwindling, and this resource scarcity can be mitigated by harvesting or recycling existing materials. The pavement industry historically has used waste materials and recycled materials to enhance performance and improve sustainability (i.e., use of supplementary cementitious materials (SCMs) and recycled asphalt pavement (RAP)). However, further opportunities exist for recycling existing concrete pavement into recycled concrete aggregate (RCA). RCA has been thoroughly researched and allowed in many state specifications because of the possibility of reducing materials waste transport and decreasing the environmental impact of concrete pavement. Despite these benefits, the implementation and utilization of RCA remain underutilized throughout the nation. The sustainable character of RCA not only resides in the possibility of reducing the use of virgin aggregates but also in sequestering carbon dioxide through carbonation. Introducing concentrated forms of carbon dioxide to RCA has the potential to react with the lime (calcium oxide or CaO) in existing cementitious products to promote mineralization or limestone development. Carbonated RCA therefore has the potential to further reduce embodied carbon emissions of concrete pavement by reusing waste materials, reducing landfill waste, reducing demand for virgin aggregates, and improving RCA quality. RCA also has a high technology readiness level and only requires buy-in from infrastructure contractors to allow for field implementation. Carbonating RCA could improve RCA performance further, making this the ideal technology for accelerating RCA's usage.

Overall, this SBIR topic seeks to create a device to carbonate RCA or a product of carbonated RCA that could be implemented in a field concrete transportation infrastructure mixture. A device for carbonating RCA should be limited to that which can be used and regularly maintained by a mechanic or typical concrete batch plant operator. This proposed solution will contribute to the Department's strategic objective of substantially reducing greenhouse gas emissions tied to transportation-related infrastructure and designing for the future by investing in purpose-driven research. This work supports the FHWA strategic objective of enhancing the performance of the nation's transportation system through research and accelerated development and deployment of innovative technologies by using carbonated RCA to replace virgin aggregates in concrete infrastructure mixtures. Specific stakeholders that could be involved in the evaluation and testing phase include the FHWA Office of Infrastructure R&D, one or more progressive state highway agencies, and academic institutions that are interested in implementing this technology.

The solution to this challenge is practical equipment and methodology that can be used by construction contractors to carbonate RCA existing on the jobsite or at the concrete production plant where construction debris and contaminants may be more readily separated. The use of equipment and methodology should result in an overall reduction of a concrete pavement's carbon emissions, and this reduction of carbon emissions should be quantified for the device and product. When quantifying the carbon emissions reduction for the product, the following should be considered:

- Processing needed to reduce the recycled concrete to appropriate gradations for aggregate,
- Processing needed to reuse the recycled concrete as an aggregate in a concrete mixture,
- Processing needed to inject or apply the carbonation,
- Processing needed to store the carbon dioxide for later injection or application,
- Transportation associated with the processing of the RCA, and
- Transportation of the carbon dioxide to the location of injection into the concrete aggregate.

Existing solutions utilize CO_2 in flue gases and necessitate transport of RCA to the flue gas source (e.g., power plant) for treatment followed by transport of carbonated RCA to a concrete production plant. In addition, the solubility of the CO_2 drops significantly in the presence of other gases (SO_2 and NO_x) thereby possibly limiting the effectiveness and lengthening the time required to carbonate the RCA. When quantifying the carbon emissions for the device, the following should be considered:

- The materials used in device creation,
- Processing used in device creation, and
- Operation of the device at a job site or batch plant.

The performance evaluation of the RCA should consider workability, freeze-thaw, chloride migration, water absorption, shrinkage, strength, and resistivity of a typical concrete pavement mixture using virgin aggregates compared to RCA.

The opportunity for commercialization in the U.S. is extremely high. Many public agencies reconstruct concrete infrastructure, allowing ample opportunity for recycling of concrete into aggregate for implementation into the next concrete mixture to be placed. This practice would reduce carbon emissions and the often significant costs associated with the transport of the RCA and virgin aggregates.

Expected Phase I Outcomes

The Phase I project is expected to result in a proof-of-concept report that (1) describes the evaluation of the product or device proposed with regard to performance and carbon emissions, (2) provides a detailed scientific basis for the operation of the product or device, and (3) shares a description of the proposed prototype(s). The report should:

- Include an estimated timeline for the prototype(s) production, evaluation, and accuracy verification;
- Provide recommendations for the nature of the RCA to be used in field implementation of the carbonated RCA product or device (i.e., what limitations in useful RCA can be anticipated? What happens to reinforcement or dowel bars found in the RCA? How portable or adaptable to existing concrete production plants?);
- Present an estimated market size of the final prototype;
- Discuss critical opportunities and obstacles to implementation;
- Describe the performance testing of the proposed product or on a product that used the proposed device to demonstrate that mineralization of the material occurs as a result of the carbonation of the proposed product or as a result of using the proposed device; and
- Illustrate a practical and tentative plan for verification and demonstration to be conducted in Phase II.

Expected Phase II Outcomes

Phase II will include the development and demonstration of a market-ready prototype for user testing and possible commercialization with the ability to demonstrate scalability of the technology for field implementation on a typical construction site. Phase II shall perform further refinement of the concept, design, and fabrication of the prototype(s) and conduct analytical and experimental verification. In order to increase the likelihood of effective implementation, the experimental verification will include experimentation with:

- A wide range of concrete mixture types (e.g., paving, structural bridge deck, pre-cast),
- Recycled concrete aggregate types (e.g., RCA from infrastructure older than 20 years, RCA from concrete with alkali-silica reaction, RCA from concrete with known chloride penetration, and RCA with no known history), and
- Different environments (e.g., severe or minimal freeze-thaw exposure, severe or minimal wet-dry cycling, hot and humid, hot and dry, cold and dry, etc.).

Another final outcome is the delivery of a final prototype device(s) or at least 400 lbs of product to FHWA for evaluation on shadow projects with owner agencies.

The device to carbonate the concrete material existing on the jobsite should be field implementable (able to be used at a typical concrete pavement construction site) and scalable to accommodate typical infrastructure construction project needs. Performance testing should occur to demonstrate that the mechanical and durability performance of a concrete with carbonated RCA is at least comparable to the performance of a concrete with virgin aggregates, and the workability of a concrete with carbonated RCA is at least comparable to the performance of a concrete with virgin aggregates.

Technical References

Jean Michel Torrenti, Ouali Amiri, Laury Barnes-Davin, Frédéric Bougrain, Sandrine Braymand, Bogdan Cazacliu, Johan Colin, Amaury Cudeville, Patrick Dangla, Assia Djerbi, Mathilde Doutreleau, Adelaïde Feraille, Marielle Gueguen, Xavier Guillot, Yunlu Hou, Laurent Izoret, Yvan-Pierre Jacob, Jena Jeong, Jean David Lau Hiu Hoong, Pierre-Yves Mahieux, Jonathan Mai-Nhu, Heriberto Martinez, Vincent Meyer, Vincent Morin, Thomas Pernin, Jean-Marc Potier, Laurent Poulizac, Patrick Rougeau, Myriam Saadé, Lucie Schmitt, Thierry Sedran, Marie Sereng, Anthony Soive, Glaydson Symoes Dos Reys, Philippe Turcry, The FastCarb project: Taking advantage of the accelerated carbonation of recycled concrete aggregates, Case Studies in Construction Materials, Volume 17, 2022, ISSN 2214-5095. https://doi.org/10.1016/j.cscm.2022.e01349

Sereng, M., Djerbi, A., Metalssi, O. O., Dangla, P., & Torrenti, J. M. (2021). Improvement of recycled aggregates properties by means of CO2 uptake. Applied Sciences, 11(14), 6571. https://www.mdpi.com/2076-3417/11/14/6571

Poon, C. S., Shen, P., Jiang, Y., Ma, Z., & Xuan, D. (2023). Total recycling of concrete waste using accelerated carbonation: A review. Cement and Concrete Research, 173, 107284. https://www.sciencedirect.com/science/article/abs/pii/S0008884623001989

Recycled Concrete Aggregates: Current Practice, Implementation Challenges and New Guidance, Tara L. Cavalline, PhD, PE, University of North Carolina at Charlotte. Presented at NIST Workshop: Fostering a Circular Economy and Carbon Sequestration for Construction Materials. June 8, 2022. https://www.nist.gov/document/circular-economy-cement-workshop-tara-cavalline-recycled-concrete-aggregates-concrete

FHWA Tech Brief, Advancing Concrete Pavement Technology Solutions: Use of Recycled Concrete Aggregate in Concrete Paving Mixtures, February 2022. https://www.fhwa.dot.gov/pavement/concrete/pubs/hif22020.pdf

The FastCarb project (Accelerated carbonation of recycled concrete aggregate), Website: https://fastcarb.fr/en/home/

24-FH3: Low-cost, Rapid Assessment of Bridge Deck Chloride Content in Concrete

Chloride infiltration into concrete is the major cause of corrosion-induced delamination in steel-reinforced bridge decks. Repairing delaminated concrete is a major cost factor in bridge deck rehabilitation. Knowledge of the quantity and location of chlorides in bridge deck concrete is an important factor in decisions relating to the type and extent of repairs. Few methods exist to determine chloride content in bridge decks. The most widely used method requires closing traffic lanes, extraction of large numbers of core samples, and laboratory testing for chloride. While providing quantitative information, this method is expensive and time-consuming, it slows traffic and can be a potential safety hazard. Because cores are discrete samples, they often produce inadequate information on the bridge deck condition and chloride quantities.

NCHRP IDEA project #208, *Determining Bridge Deck Chloride Quantities Using Ground Penetrating Radar*, investigated the use of ground-penetrating radar (GPR) methods for determining chloride quantity in bridge decks nondestructively. However, the work was limited to laboratory experimentation and theoretical modeling. This work recommended that additional research be conducted to further develop the GPR method independent of calibration core samples.

A method is needed that is fast, accurate, and low-cost and provides quantitative information on chloride content over the entire bridge deck. Such a method would permit improved repair strategies by identifying chloride-contaminated concrete and thereby improving the effectiveness of repairs. This project would further develop the GPR methods, as well as other nondestructive evaluation (NDE) method(s) and system(s) for measuring chloride content at the level of the reinforcing steel embedded in concrete and the chloride content profile, preferably without the need of calibrating core samples. The method should require minimal field work and be least disruptive to traffic. The method should account for variables that may affect the chloride content measurements. The work should include numerical modeling, laboratory experiments, and field work.

This study aims to provide bridge owners with detailed information on the quantity and location of chlorides in their bridge decks, thereby improving the effectiveness of repairs, reducing the cost of maintenance and repairs, and potentially increasing the lifespan of the bridge deck. Highway departments and bridge owners could save millions of dollars in repair costs, better prioritize repairs, and see extended lifespans for their bridges. The traveling public will benefit from improved safety as well as the potential avoidance of thousands of hours of traffic slowdowns and lane closures.

Expected Phase I Outcomes

Outcomes from Phase I include a detailed proof-of-concept prototype for NDE technologies that can rapidly measure the levels of chlorides at various depths in concrete bridge decks. The method(s) employed need to be rapid, accurate, repeatable, reliable, and economical, requiring minimal field work and traffic disruption. The report on this proof-of-concept should adequately describe:

- The proposed prototype, the unique needs and capabilities of the technologies, and how it will enhance current methods of chloride content assessment.
- The method(s) of testing in service.
- Any data algorithms developed to interpret, analyze, and visualize the data, and a framework for how the results can be applied for asset management of highway bridges.

Phase I outcomes should also demonstrate the prototype's technical feasibility and show a path toward Phase II hardware/software demonstration.

Expected Phase II Outcomes and Deliverables

Outcomes from Phase II include the development of a commercial, market-ready prototype of the necessary NDE hardware/software developed in Phase I for user testing and possible commercialization. The prototype should be further demonstrated on both a model and in-service bridge in a manner that demonstrates the rapid assessment of chloride content in the bridge deck.

Technical References

None

Federal Motor Carrier Safety Administration (FMCSA)

About us: The mission of FMCSA's Office of Analysis, Research, and Technology is to reduce the number and severity of commercial motor vehicle (CMV) crashes and enhance the efficiency of CMV operation by: 1) providing data, producing statistics, and conducting systematic studies directed toward fuller scientific discovery, knowledge, or understanding, and 2) identifying, testing, and supporting technology transfer activities and deployment of CMV safety technologies.

24-FM1: Commercial Motor Vehicle (CMV) Trailer Stability Sensor

Inspections on commercial motor vehicles are done by inspecting tire wear, tire inflation, lighting, brakes, etc. all as independent small systems. Each small system has a variance that is allowed by statute. However, many factors are not measured or evaluated in a roadside inspection. For instance, a trailer may have a worn suspension system. This creates a deflection of the axle system which places more load on the inside tires and less on the outer tires, likely resulting in a less stable vehicle as it moves down the roads. In addition, there is little attention to balancing the load on a commercial motor vehicle. This is especially true in Less than Truck Load (LTL). Full Truck Load (FTL or TL) can also experience load imbalance as product deliveries are made which shifts the load from balance while full to a “nose heavy” load.

The potential solution aims to ultimately create a low-cost device to measure trailer stability degradation over time. This system could eventually be an add-on or original equipment manufacturer (OEM) device for all trailers that accurately measures and compares trailer stability over time, warning the stakeholders of immediate changes in stability (something is broken) or slow degradation over time (something is wearing) and generating maintenance events before catastrophic system failures causing crashes, injuries, or death.

The goal of this project is to create a device that could measure the drivability or the “system performance” of a semi-trailer to alert the driver in advance of an issue. The solution should be able to measure the stability of the trailer by measuring attributes like flexing, swaying, leaning, bouncing, etc., as the vehicle moves. This device should have the means to measure and detect unsafe conditions (excessive lean, sway, etc.) and have some ability to notify others (law enforcement, driver, fleet owner, etc.) that an unsafe condition exists. Other mechanisms can be measured by inertia including braking systems and loose wheel carriage assemblies.

The system will need to be able to measure the following factors (additional stability measures are also encouraged):

- Side to side lean in degrees
- Movement in G forces in all directions: Jerking, Swaying, Bouncing, Flexing

System requirements include the ability to:

- Record movements to an internal memory source
- Have a wireless component to upload movement information to a cloud-based server.
- Have a notification method for (1) driver – preferably to the electronic logging device (ELD) and potentially to the power unit Controller Area Network (CAN) bus and (2) for others (fleet owner, dispatch, maintenance shop, perhaps law enforcement).
- Compare stabilization over time and indicate decreasing stability.

Expected Phase I Outcomes

The outcome of Phase I is a proof-of-concept report and prototype design that identifies how a demonstration on one trailer without trailer electronic stability control (can be an FMCSA-owned vehicle) can show the forces and flexing of the trailer while in operation. The wireless and cloud-based components to be used in Phase II should be identified in Phase I. The prototype design should include an approach for logged data to be downloadable and viewable with an explanation of the vehicle dynamics. A definition/specification of vehicle stability in all forms must be part of the initial report.

Expected Phase II Outcomes

The Phase II outcome requires both testing and demonstration on one trailer without trailer electronic stability control. The solution should be a professionally mounted sensor that obtains power from the power unit. It shall contain wireless notifications for remote stakeholders. It shall have a system for notifying the driver of trailer stability status and any changes that may occur due to aggressive driving, emergency maneuvers, equipment failure, load placement, load shifting, suspension wear, tire inflation changes, or other irregularities.

The system shall have a professional backend analysis tool that can assist fleet owners and maintainers in conducting predictive maintenance on trailers. The system may also provide a driver safety component that compares driver skills in maneuvering trailers (hitting curbs, hard strikes on loading docks, driving too fast around curves, etc.)

The solution may be tested with FMCSA-owned vehicles and will be coordinated further with the U.S. DOT upon Phase II award. Additionally, testing should involve possible stakeholders (e.g., users or buyers) to provide critical feedback on the viability of the solution for commercial use.

Technical References

Winkler, Christopher .B., 1999, Rollover of Heavy Commercial Vehicles. Society of Automotive Engineers, Warrendale, PA, 1999.

Federal Railroad Administration (FRA)

About Us: FRA's research, development, and technology (RD&T) mission is to ensure the safe, efficient, and reliable movement of people and goods by rail through basic and applied research, and development of innovations and solutions. Safety is U.S. DOT's primary strategic goal and thus, the principal driver of FRA's RD&T program. FRA's RD&T program also contributes to other U.S. DOT strategic goals because safety-focused projects typically yield solutions toward state of good repair, economic competitiveness, and environmental sustainability goals. The RD&T program also has an important role to play in workforce development.

FRA's RD&T program is founded on an understanding of safety risks in the industry. Hazard identification and risk analysis allows us to identify opportunities to reduce the likelihood of accidents and incidents, and to limit the consequences of hazardous events, should they occur. Key strategies include stakeholder engagement and partnerships with other researchers such as the Association of American Railroads, prioritization of projects, and conducting research through cost-effective procurement.

24-FR1: Portable Special Trackwork Measurement System

Special trackwork, defined as "trackwork requiring special attention such as turnouts, crossovers, slip frogs, and other material as required" represents large sections of railroad track nationwide. Special trackwork is involved in a high percentage of railroad derailments and accidents. Understanding and inspecting the state of good repair for this infrastructure component is essential to maintaining track in a safe manner. Presently much of this inspection and/or derailment investigation is done by performing manual measurements at special trackwork components. The measurement of the overall components such as rail profile, gage, clearances, and flangeway gaps, remains a largely manual process.

This topic seeks to develop a portable prototype inspection tool that is capable of continuously measuring dimensions of in-track special trackwork (including frogs and diamonds) components and retaining these measurements electronically to be used for modeling or analysis.

This research supports U.S. DOT's priorities to improve the state of good repair, safety, and efficiency by improving inspection techniques in assessing the external condition of special trackwork while in-track. When the prototype is designed, developed, and tested, this technology will be critical for the quantitative assessment of the condition of these critical track components. This will contribute to directly supporting increased safety in railroad infrastructure components.

The overall solution being sought is the design, development, and testing/validation of a portable tool, capable of continuously measuring in-track special trackwork requirements as described in 49 CFR 213.133 – 49 CFR 213.143.

Proposed solutions must:

- Be for the design, development, and testing/validation of a portable tool for inspecting in-track special trackwork.
- Include a portable tool, meaning operable by one person and of a weight less than 50lbs.
- Be mobile, i.e. on a cart or with rolling capability to move through special trackwork at a walking speed.
- Make precise continuous measurements and the measurement tolerance must be included in the proposal.

- Measure as many requirements as possible as listed in 49 CFR 213.133 – 49 CFR 213.143.
- Work through special trackwork, including turnouts, frogs, and diamonds.

The complete solution will record/report measurements taken to be used for modeling and/or analysis, in an automated manner. The ideal solution may eventually be used by field inspectors to record precise inspection measurements or to utilize actual measurements in derailment/accident investigations. The solution is expected to be capable of taking and recording measurements in one to two passes over the special trackwork. These measurements should be able to be electronically transferable to a wireless interface that includes the measurement coordinates, image, and relevant measurement data. The proposed solution must provide details on the length of power/charge of the solution available, in time duration to take measurements. These parameters are important to ensure the solution will be viable within the railroad industry application.

Commercialization potential for this solution includes railroads, contractors, and government. End-users will include railroad inspectors and accident investigators, for both freight and passenger rail.

Expected Phase I Outcomes

Phase I efforts shall include a proof-of-concept report and prototype design. The output from Phase I should be the prototype design and development plan to progress to a constructed prototype in a potential future phase. This plan shall include the scientific rationale for the technical approach and detail how the solution requirements described above will be met.

Expected Phase II Outcomes

Phase II efforts shall include prototype development and field testing/validation. Phase II will produce a detailed project report, test reports, and a product prototype.

Technical References

Code of Federal Regulations, 49 CFR 213.133 – 49 CFR 213.143, Track Safety Standards. https://www.ecfr.gov/current/title-49/subtitle-B/chapter-II/part-213?toc=1.

The FRA e-library system contains many technical reports documenting research into special trackwork at https://railroads.dot.gov/elibrary-search.

Federal Transit Administration (FTA)

About Us: The Federal Transit Administration's (FTA) mission is to improve public transportation in America's communities. In support of this mission, FTA's research vision is to advance public transportation by accelerating innovation that improves mobility, enhances transit operations, and ensures safety for all. The goal of FTA's SBIR program is to help small businesses grow by funding product development research in strategic areas such as safety, infrastructure, mobility, and other topics important to transit. The program helps invest in promising early-stage innovations that may otherwise be too high of a risk for private investors.

24-FT1: Electric Vehicle (EV) Battery – Improved Cooling/Heating Management System to Suppress Overheat and Fire

As more and more electric vehicles are coming to the market, the battery technology has seen significant improvement lately. Original Equipment Manufacturers (OEMs) and battery manufacturers have developed a variety of battery packs, but Lithium-ion batteries are the most prevalent because of their resiliency and benefits compared to other battery types. Still, there are many issues with every type of vehicle battery – including overall cost, service life, efficiency, and temperature control. Manufacturers use proprietary cooling and heating management systems that include both software and hardware to improve thermal efficiency, and potentially to control overheating. However, incidents of vehicle fires have happened in many places due to thermal runaway, floodwater, charger malfunction, or other unknown issues. There is limited understanding of the causes of battery fires, control systems, and the need for effective technologies for mitigation.

The primary goal of this project is to conduct a comprehensive review and analysis of research and data related to battery fire issues and design, and then develop a viable or conceptual solution to manage overheating and mitigate battery fires that may be hardware, software, or both. The product will apply to any battery packs used on electric vehicles or Battery Electric Buses.

This SBIR topic assumes the need for exploratory research initially - to collect industry data and analyze the most common root cause – in order to define the best solution to reducing battery overheating and fires in electric vehicles.

This SBIR topic has presents a large potential to benefit the EV industry if a real product, tool, or process is developed.

Expected Phase I Outcomes

The Phase I proof-of-concept report should define the concept solution with specification based on the exploratory research and chosen hardware or software solution.

Expected Phase II Outcomes

Phase II is intended to build on the Phase I concept with design, build, and testing. The Phase II awardee is expected to work with at least one transit agency to test and demonstrate how the product will work. Phase II is expected to include a prototype that was demonstrated and tested. This includes a battery management software, hardware, or both that shows significant improvement in the mitigation of battery fires; or a process, packaging and technology that suppresses fires.

Technical References

None

24-FT2: Mitigation of Cybersecurity Failures

Cybersecurity is a major and critical element of a public transit system. From operation, infrastructure, and technology to training and maintenance, information and information mediums play key roles in any agency. The safety and security of the system are vital. With advances in technology to access, communicate and share data, new vulnerable points have emerged in the transit system. Safeguarding and providing firewalls are very necessary whether it is small, medium, or large transit agencies. There are many types of cybersecurity software, hardware, and firmware available in the industry but identifying and blocking the failure or vulnerable points of a transit agency in advance is very important. The primary goal of this project is to design and develop a viable or conceptual product that may be hardware, software, or both to mitigate cybersecurity failures at public transit agencies.

This SBIR topic assumes the need for exploratory research initially and requires working with a transit agency to collect data and analyze the most common failure points in order to develop a strategy, process, and tool to identify and make these points safe from cybersecurity failure. Examples of failure points include: Battery Electric Bus Charging Infrastructure, Agency Webpage/Login Page, Database Management, Information Technology (IT) system, etc.

This topic's commercialization potential is vast and especially pertinent to transit given its dependencies on data processing, real-time operations, customer interface, and information technology.

Expected Phase I Outcomes

The Phase I proof-of-concept report should define the concept solution with specifications, which then can be designed, built, and tested in Phase II.

Expected Phase II Outcomes

Phase II is intended to build on the Phase I concept leading to a working prototype whether software, hardware, or a tool that was demonstrated and tested at a transit agency. The Phase II awardee is expected to work with at least one transit agency to test and demonstrate how the product will work.

Technical References

National Institute of Standards and Technology (NIST) Cybersecurity Framework (CSF), Cybersecurity and Infrastructure Security Agency (CISA), Cyber Resilience Review (CRR), and Cybersecurity industry websites.

24-FT3: The Reduction of Auxiliaries Power Demand on Electric/Battery Operated Transit Buses

According to CALSTART's zero-emission buses (ZEBs) report, Zeroing in on ZEBs, the electric bus market in the U.S. has increased by 66% since 2021. For example, New York City's Metropolitan Transportation Authority, the country's largest transit network, has committed to an all-electric bus fleet by 2040. The adoption of electric buses has many benefits for the transit industry. It lowers emissions, improves air quality, reduces noise, increases comfort for passengers, and reduces maintenance costs. It also aligns with the U.S. DOT's strategic goals of Climate and Sustainability and Economic Strength and Global Competitiveness.

The major consumption of electrical energy in electric/battery-operated buses for public transport is from non-traction needs (auxiliaries), the main component of which is Heating Ventilation and Air Condition (HVAC). These auxiliary units consume about 50% of the overall energy in electric/battery buses. During extreme weather seasons, the auxiliary powers consume more energy, resulting in a shortened range and disruptions of services.

This SBIR topic seeks to help reduce auxiliary power demand on electric/battery-operated transit buses. It is very important to carefully analyze the energy distribution and reduce energy consumption, primarily for heating and cooling purposes. The issue of energy demand for non-traction purposes is a fundamental problem in the optimization of electric vehicles' energy consumption and creating an alternative power supply to supplement the battery usage.

This technology has the potential for commercialization opportunities, not only for transit buses but also for school buses and other heavy-duty electric trucks, as well as other transportation modes such as electric ferries.

Expected Phase I Outcomes

Phase I will serve as a feasibility-study of the potential solutions to reduce or supplement the energy consumption of non-traction units (auxiliaries) of transit buses. The process will include a literature review of any work conducted so far on auxiliary power units that could supplement energy demand for the available technological options to brainstorm possible solutions that can be used for transit buses. Following the literature review, a proof-of-concept report that addresses the problems stated in this topic will be created. The proof-of-concept report will clearly define the product's criteria for success and contain documentation of how the proof-of-concept report will be carried out. The proof-of-concept report should include the functionalities of the product, its features, benefits, and the problem it solves for end-users. Moreover, it should include the cost, timeline, and resources required for Phase II for prototype development.

Expected Phase II Outcomes

Phase II will focus on the development of a prototype that will reduce or supplement the energy consumption of non-traction units (auxiliaries) of transit buses. The applicant will develop and demonstrate a prototype which builds upon the proposed solution and recommendation of the Phase I proof-of-concept design. A design review should be conducted early in the development phase to help refine and iterate on the product design through testing and feedback, allowing for adjustments and improvements to be made before finalizing the design. The review should also evaluate the prototype's performance and functionality and identify any technical or usability issues that need to be addressed to improve the product.

Technical References

Boothe, Matt and Alexis Hedges, UTA Paratransit Vehicle Accessory Electrification Project: Eparc System Deployment and Validation Study, *FTA Report No. 0171*, August 2020, https://www.transit.dot.gov/sites/fta.dot.gov/files/2020-08/FTA_Report_No._0171.pdf.

Bartłomiejczyk, Mikołaj and Robert Kołacz, The reduction of auxiliaries power demand: The challenge for electromobility in public transportation, *The Journal of Cleaner Production*, Volume 252, 119776, April 10, 2020, https://www.sciencedirect.com/science/article/pii/S0959652619346463.

24-FT4: Reducing Visibility Impairments in Small Transit Vehicles

Visibility challenges are a major contributor to bus-to-pedestrian fatalities and injuries, particularly during left-hand turns. While research and development is underway to improve visibility in transit buses, other vehicles like cutaways, vans and other smaller transit service vehicles would also benefit from innovative solutions to improve driver visibility, thereby reducing collisions with pedestrians, personal vehicles, and others on the road.

This topic seeks to develop products and/or services that address visibility challenges. Solutions may aim to retrofit existing small transit vehicles to address visibility impairments inherent in the design of a vehicle and/or tackle visibility challenges that certain drivers experience based on their physical characteristics and abilities.

The solution must reduce or eliminate blind spots or zones, thereby improving the driver's ability to see pedestrians and other vehicles from their driving position in the transit vehicle, without reducing the safety of the transit vehicle. It must address a defined need or gap in existing solutions for transit vehicles or transit operators, based on stakeholder input. It must meet all relevant laws and regulations.
The solution must:

- Be applicable to one or more vehicles used by small or rural transit providers in transit service, such as cutaways or vans.
- Involve Section 5310 and/or Section 5311 transit providers as stakeholders for market research, piloting and/or testing. The prototype solution must be considered feasible (both from an implementation and cost perspective) by these stakeholders.

Commercialization potential includes all transit providers that operate the vehicle(s) addressed, or who have operators that have the physical characteristics or disabilities addressed. Commercialization potential also includes non-transit providers that operate those vehicles or have drivers with the addressed visibility challenges.

Expected Phase I Outcomes
The Phase I project is expected to result in a proof-of-concept report that describes the proposed prototype, how it will reduce or eliminate blind spots or zones, and how it will be integrated into existing transit vehicles without compromising safety. The report must also specify applicable vehicle(s) and/or driver characteristics. Stakeholder input regarding need and feasibility must be addressed in the report.

Expected Phase II Outcomes
The expected Phase II outcome is a demonstration of a working prototype, as well as a plan for piloting and testing with relevant stakeholders.

Technical References
None

National Highway Traffic Safety Administration (NHTSA)

About us: The National Highway Traffic Safety Administration's (NHSTA) mission is to save lives, prevent injuries and reduce economic costs due to road traffic crashes, through education, research, safety standards and enforcement activity. NHTSA's research offices are the Office of Vehicle Safety Research and the Office of Behavioral Safety Research. The Office of Vehicle Safety Research's mission is to strategize, plan, and implement research programs to continually further the agency's goals in reduction of crashes, fatalities, and injuries. Our research is prioritized based on potential for crash/fatality/injury reductions and is aligned with Congressional Mandates, along with DOT and NHTSA goals. The Office of Behavioral Safety Research studies behaviors and attitudes in highway safety, focusing on drivers, passengers, pedestrians, and motorcyclists, and uses that to develop and refine countermeasures to deter unsafe behaviors and promote safe alternatives.

24-NH1: Algorithms for computer vision inside and outside the vehicle

This SBIR project seeks to develop, or modify two open-source computer vision systems capable of:

1. Detection of one or more observable indicators of drowsiness, inattention, and/or incapacitation (e.g., gaze direction, percentage of eyelid closure (PERCLOS), holding a mobile phone). The algorithm may process data sources from either: (1) real-time data collected from proprietary or commercial-off-the-shelf (COTS) sensors selected at their discretion (e.g., Time-of-flight sensors, camera sensors, infrared camera sensors), or (2) pre-recorded data from proprietary or COTS sensors selected at their discretion.
2. Detection of surrounding traffic, vulnerable road users, and observable indicators of driving performance (e.g., standard deviation of lane position (SDLP)). The algorithm may process data sources from either: (1) real-time data collected from proprietary or COTS sensors selected at their discretion (e.g., Time-of-flight sensors, camera sensors, infrared camera sensors), or (2) pre-recorded data from proprietary or COTS sensors selected at their discretion.). The algorithm may process data sources from either: (1) real-time data collected from proprietary or commercial-off-the-shelf (COTS) sensors selected at their discretion (e.g., Time-of-flight sensors, camera sensors, infrared camera sensors), or (2) pre-recorded data from proprietary or COTS sensors selected at their discretion.

The proposed SBIR project aligns with two U.S DOT innovation principles: (1) providing opportunities to collaborate, and (2) being flexible and adapting as technology changes. The project will enable collaboration with small business researchers exploring computer vision and will assist NHTSA in understanding the state of the art and capabilities of computer vision.

The proposed SBIR project also aligns with NHTSA's FY 2023-2024 Annual Modal Research Plan (AMRP) program area of advanced safety technologies, and the programmatic effort of "expand[ing] research into the effectiveness of driver monitoring system strategies at mitigating driver distraction. This project will contribute to research, development, and technology (RD&T) activities outlined in the AMRP advanced safety technologies program area, including advanced driver assistance systems (ADAS) innovation deployment, and driver distraction from in-vehicle technology interfaces. Additionally, it will contribute to RD&T activities in the highway safety research program area, including encouraging positive traffic safety behaviors and exploring advanced technologies to address traffic safety issues. In particular, driver distraction will be addressed. Driver distraction is also a mandated topic of research in the Bipartisan Infrastructure Law (BIL). The AMRP also outlines RD&T activities on the topic of functional safety, specifically development of an interior driver monitoring system (DMS) to detect drowsiness, inattention, and incapacitation.

The solution shall detect inside the vehicle, with $P_d \geq 0.90$ and $P_{fa} \leq 0.10$,:

1. A driver's hand touching a mobile phone (or portable electronic device)
2. The direction of driver's gaze, with 95% confidence interval falling within ≤10 degrees of visual angle
3. PERCLOS, within ongoing 12 second epochs
4. An indicator of driver incapacitation, chosen at the respondent's discretion

The solution shall detect outside the vehicle, with $P_d \geq 0.90$ and $P_{fa} \leq 0.10$,:

1. Lane position, with a 95% confidence interval falling within 25 cm
2. Surrounding vehicles within 3.7 m to the left and right of the vehicle, and within 150 m ahead of and behind the vehicle
3. Vulnerable road users (VRUs, including pedestrians, cyclists, e-scooter users, and those using wheelchairs, walkers, or other mobility assistance devices)

NOTE: The above thresholds are *target* performance thresholds. The *requirement* is to demonstrate an ability to detect the above-mentioned items, to report the achieved level of sensitivity and specificity, and to provide documentation of factors limiting system performance (see Phase I Expected Outcomes).

The project team should demonstrate a knowledge of recent publications in computer vision, especially as applied to vehicle safety systems and DMS. Any software and hardware platforms are acceptable.

Finally, a computer vision system developed in this project may have the potential to be licensed to Tier-1 suppliers of DMS systems, vehicle Original Equipment Manufacturers (OEMs), and/or companies producing commercial augmented reality products.

Expected Phase I Outcomes

The Phase I proof-of-concept report should describe the intended design of a protype to be used for the collection of data that is sufficient to address the specifications listed above. This proof-of-concept report should describe the potential for, and any challenges with, integration with market-prevalent software and hardware platforms suitable for use in vehicles available to consumers.

Expected Phase II Outcomes

The expected outcomes for Phase II are:

1. A functioning prototype demonstrating the capability of correlating inside-the-vehicle (e.g., gaze direction) and outside-the-vehicle (e.g., surrounding traffic, time to collision (TTC)) data. For example, the capability for the algorithms to detect a lead vehicle with decreasing TTC and a driver gaze direction pattern suggesting the lead vehicle has not been seen by the driver.
2. Collection of data sufficient to address that Phase II outcome and a final report describing the potential for, and any challenges with, integration with market-prevalent software and hardware platforms suitable for use in vehicles available to consumers.

Technical References

None

24-NH2: Device for Automatic Seat Belt Use Detection, Data Collection, and Driver Feedback

This SBIR topic seeks to resolve two problems: First, over the last decade, the national seat belt use rate has stabilized at 90%[1], and the rate of unrestrained fatalities has stabilized at 50%[2]. NHTSA's goal is to increase seat belt use to 100%. However, this has proven difficult using traditionally effective approaches such as high-visibility enforcement. Consequently, NHTSA is pursuing the development of non-enforcement behavioral traffic safety countermeasures for belt use, including those that promote seat belt use by increasing its social desirability or perceived normativity and thereby inducing social pressure.

Second, NHTSA, the States, and others regularly conduct observational surveys of seat belt use that require substantial investments of money by sponsoring parties and the time of trained observers. Automating the process of collecting seat belt observational data could reduce associated costs and effort and help address persistent sampling issues in observational data collected by human observers.

The proposed solution to the two problems above is a device for the automatic detection of seat belt use by passenger vehicle occupants. The device should:

1. Determine if front-row occupants in approaching vehicles are wearing their seat belts and display that determination back to them in a manner similar to driver feedback signs for speed (i.e. "Your Speed" signs featuring radar speed detection). Driver feedback signs have been used as traffic calming devices for speed; the goal of this functionality is to achieve similar behavior modification mid-drive, albeit for seat belt use.
2. Conduct automatic collection of seat belt use observational data.

The device should be able to:

- Detect seat belt use under a variety of traffic, weather, and lighting conditions with over 99% accuracy. In optimal conditions, accuracy over 99.5% should be obtained. Drivers' trust in the feedback displayed and the veracity of observational data collected are paramount.
- Provide visual feedback to drivers regarding their seat belt use or non-use. The feedback should be provided quickly enough to be visible at highway speeds well before passing the device. It should be easily visible under a variety of lighting and weather conditions and at ranges similar to those of currently available driver feedback signs for speed. When the device cannot determine belt use with high confidence, no feedback should be displayed rather than a potentially false negative or positive.
- Operate in a "feedback" mode, in which it displays visual feedback to drivers on their observed seat belt use, and a "silent" mode, in which observations of seat belt use are collected but no feedback is displayed. Operating in the "feedback" mode should not preclude the collection of observational data; that is, the device should still be able to collect observational data on seat belt use while providing driver feedback. Operation in the "silent" mode should be visually distinct to drivers from receiving feedback either of seat belt use or non-use and from the device malfunctioning or being unable to determine belt use. This could be achieved through obscuring the portion of the device on which driver feedback is provided.
- Retrieve observational data in a commonly used and non-proprietary format, e.g., as a .csv file. Observational data should include, at minimum, the following elements: unique ID for each observation; unique ID for each device; year, month, day of month, day of week, and time of observation; location of observation; number and seating positions of vehicle occupants observed (e.g., driver, front passenger); seat belt status of each occupant observed (belted, unbelted); confidence rating of each seat belt status determination.

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[1] 2022 Traffic Safety Stats | National Highway Traffic Safety Administration

[2] Fatality Facts 2021 Yearly Snapshot | Insurance Institute for Highway Safety (IIHS)

Technical specifications of the solution include:

- The detection of seat belt use by the device may involve the capture of photo, video, LIDAR, or other sensor data, as well as AI, computer vision, deep learning, and other techniques. These techniques should not be used in any way that could compromise the privacy or security of vehicle occupants.
- Any photo, video, LIDAR, or other sensor data captured by the device should not be stored longer than the time required for the device to make a determination regarding the seat belt use of the vehicle occupants observed. These data should not be usable for purposes other than driver feedback and the collection of seat belt use observational data.
- Individuals with minimal training should be able to deploy the device at roadsides and retrieve collected observational data. Moving/redeploying the device by authorized parties should be straightforward, which should facilitate collection of observational data at multiple locations. Measures should be in place to prevent unauthorized parties from moving or tampering with the device, or from accessing data stored on the device.
- The device should operate once deployed without human supervision or intervention for extended periods of time (i.e. several days at minimum). Means of powering the device for extended periods (i.e. solar power, as used in driver feedback signs for speed) should be explored.
- The device should be reasonably weatherized, such that it will not be damaged or have its functioning negatively impacted by normal exposure to the elements.

Potential buyers may come from two categories: those who typically collect observational data regarding belt use (e.g., States, independent researchers, NHTSA, and other government contractors), and those interested in increasing belt use through driver feedback as they would manage speed (e.g., school districts, municipalities).

Expected Phase I Outcomes

The Phase I project is expected to result in a proof-of-concept report that describes a proposed prototype of the device, including: the physical form of the device; how it will detect vehicle occupant seat belt use, including what data will be collected and the specific algorithm(s) responsible for determining belt use; how feedback on seat belt use will be displayed to vehicle occupants; how seat belt use observational data will be aggregated, stored, and secured; and how vehicle occupant privacy will be maintained.

Specific reference should be made to:

- The accuracy of seat belt use detection under various traffic,
- Weather and lighting conditions,
- Data privacy concerns, and the
- Ability of the device to be deployed with minimal training and operate continuously without human supervision or intervention for extended periods.

Expected Phase II Outcomes

Phase II outcomes will include the development of a prototype for user testing and possible commercialization. A report should be provided detailing all aspects of the construction and workings of the device, as well as any preliminary field testing conducted during its development.

Technical References

Chen, Y., Tao, G., Ren, H., Lin, X., & Zhang, L. (2018). Accurate seat belt detection in road surveillance images based on CNN and SVM. *Neurocomputing, 274*, 80-87.

Feng, W., Yu, W. & Nan, R. (2022). Deep learning based vehicle seat belt detection algorithm for driver and passenger seat occupants. *7th International Conference on Intelligent Informatics and Biomedical Science (ICIIBMS), Nara, Japan*, 306-310. doi: 10.1109/ICIIBMS55689.2022.9971531.

Hosseini, S., & Fathi, A. (2023). Automatic detection of vehicle occupancy and driver's seat belt status using deep learning. *SIViP 17*, 491–499. https://doi.org/10.1007/s11760-022-02244-w

24-NH3: Evaluating the Performance of Driver Monitoring Systems: Human Surrogate Design

To support the Society of Automotive Engineers (SAE) Level 2 driving automation systems, driver monitoring systems (DMS) are increasingly being deployed in production vehicles to detect driver distraction and drowsiness and to provide real-time feedback to drivers. This proposed SBIR project will design a human surrogate to test and validate how accurately camera-based DMSs detect and classify driver inputs to the DMS.

This proposed SBIR project aligns with NHTSA's FY2024 Annual Modal Research Plan (AMRP) activities which include advanced vehicle safety technologies that help prevent crashes or mitigate the severity of a crash and automated driving systems. Further, the project supports U.S. DOT innovation principles by investing in private-public partnerships to arrive at purpose-driven innovative solutions to the Nation's most pressing transportation safety issues. Finally, this proposed project supports the functional safety activities prioritized in the AMRP, namely the development of an interior DMS to detect drowsiness, inattention, and incapacitation.

This SBIR project seeks to design a human surrogate to test and validate how accurately infrared-camera-based DMSs detect and classify driver inputs to the DMS including:

- Head pose
- Eye location
- Gaze direction
- Blink frequency
- PERCLOS

The surrogate design must support a wide variation of pupil and corneal reflectivity, eye shapes, and color. Additionally, it must incorporate flexibility to cover a range of driver characteristics including:

- Drivers: ethnicity, sex, age, height
- Appearances: glasses, hats and other head coverings, beards, makeup, piercings

For the proposed project, any software and hardware platforms are acceptable.

A human surrogate that is designed and developed as part of this SBIR project may have the potential to be licensed to Tier-1 suppliers of DMSs, vehicle original equipment manufacturers (OEMs), and/or military contractors.

Expected Phase I Outcomes

The expected outcome for Phase I is a proof-of-concept report which provides a prototype design of a human surrogate that is capable of simulating human eye activity over a range of adult ages, sizes, and ethnicities (described above).

Expected Phase II Outcomes

The expected outcomes for Phase II are:

- A functioning human surrogate prototype demonstrating the capability of simulating human eye and head activity
- Data collection and analysis that includes testing of at least three commercially available DSMs using the human surrogate
- Final report

Technical References

None

24-NH4: Lightweight Universal Docking Interface Geometry (UDIG) Manual Wheelchair Attachment

This research challenge aligns with the FY 2023 - 2024 Annual Modal Research Plan (AMRP) and U.S. DOT innovation priorities by directly addressing the U.S. DOT strategic goals of safety, equity, and accessibility. This research problem directly promotes safe transportation for motor vehicle occupants who ride in wheelchairs. A successful research outcome could benefit occupants who ride in wheelchairs in automated vehicles (AVs) and other forms of transportation.

NHTSA recently published a report[3] on the feasibility of a proof-of-concept automated wheelchair tiedown and occupant restraint system, or WTORS, however, the previously developed proof-of-concept wheelchair anchors and attachments were a demonstration and not thought to be suitable for production and implementation into the marketplace. The current research problem will build upon this effort and seeks to develop pre-production Universal Docking Interface Geometry (UDIG) attachments for manual wheelchairs. These UDIG attachments may be integrated into the design of the manual wheelchairs (i.e., modify an existing wheelchair member) or may be designed to be added/removed from existing wheelchair designs (i.e., develop a new member). A lightweight UDIG attachment may have the potential to improve UDIG acceptance for manual wheelchair users.

In the previous study, a novel set of UDIG attachments for manual and power wheelchairs were demonstrated. Add-on attachments were developed for five commercial wheelchairs. The current task seeks to improve upon these attachments. Consideration should be given to developing an integrated, lightweight UDIG attachment, or a readily detachable UDIG attachment. The aim is to improve acceptance for manual wheelchair users, who have demonstrated sensitivity to the overall wheelchair weight. These users may desire a UDIG attachment that minimizes weight or can be readily removed to minimize wheelchair weight in non-transportation usage.

The system must:

- Be compatible with American National Standards Institute (ANSI)/Rehabilitation Engineering and Assistive Technology Society of North America (RESNA) standards for connection geometry and location of wheelchair attachments, per ANSI/RESNA WC-4:2017, Section 19 - Wheelchairs Used as Seats in Motor Vehicles.
- Minimize the added weight of the UDIG attachment.
- Retain the wheelchair without deformation during frontal sled testing in accordance with ANSI/RESNA WC-4:2017, Section 18 – Wheelchair Tiedown and Occupant Restraint Systems for Use in Motor Vehicles.
- Meet crashworthy requirements for side impacts per Klinich et al., 2024.
- Consider the potential for a lightweight, integrated design.
- Consider methods for a quick disconnect to easily remove the attachment and minimize weight when the wheelchair is not being used for transportation.

The specifications shall be designed such that the attachment remains connected to the wheelchair and does not visually deform in the RESNA frontal impact test (RESNA WC 18). Phase I should utilize crash simulations to demonstrate the safety performance of the UDIG attachment. The prototype should be physically tested in Phase II using pre- and post-test measurements to demonstrate the attachment performance. Per RESNA WC18, a WTORS designed for use by a range of wheelchairs and wheelchair users must undergo two frontal impact test scenarios. The first frontal impact test is used to evaluate the complete WTORS, including the three-point occupant restraint system and the wheelchair

[3] Development of an Automated Wheelchair Tiedown and Occupant Restraint System: Initial Progress | UMTRI

docking/securement system. The second frontal impact test is used to evaluate the wheelchair docking/securement system using a surrogate lap and shoulder belt and surrogate wheelchair (the surrogate lap belt is anchored to the surrogate wheelchair). Both tests require a 48 kph (30 mph), 20g frontal impact and utilize a midsize male anthropomorphic test device (50M ATD) seated in the test wheelchair. Since this task involves only the development of the UDIG attachment, and not the occupant restraint system, only the second frontal impact test is to be completed. Additionally, because the attachment is designed for a specific wheelchair model (SWM), tests will be conducted with the SWM rather than the surrogate wheelchair. Surrogate belt geometry should be installed per RESNA WC18. If the offeror develops an attachment that is compatible with multiple manual wheelchair models, tests should be completed with a surrogate wheelchair in addition to any SWMs. If the offeror develops an attachment that is expected to be integrated with the occupant restraint system, the actual occupant lap and shoulder belt should be used instead of a surrogate lap and shoulder belt.

Performance criteria of the attachment must be met per RESNA WC18. Specifically, excursion requirements per RESNA WC18 state that the WTORS shall not allow horizontal excursions of point P of the test wheelchair to exceed specified values (wheelchair point P, X_p). Simulations must show that wheelchair and occupant kinematics are controlled per Klinich et al., 2022.

Additional post-test requirements include:

- The wheelchair must remain upright on the sled platform with the ATD seated in the wheelchair seat (ATD torso may not be leaning more than 45 degrees from vertical).
- Load carrying components of WTORS shall not completely fail (unless tear/failure is part of design and/or a backup component/structure does not show significant failure).
- WTORS shall not be detached/separated at anchorages or securement points.
- Deformation of securement points on attachments shall not prevent manual disengagement and removal of a wheelchair from securement device.
- Test wheelchair shall be removed from test platform without the use of tools.

The UDIG attachment system shall also be evaluated for performance in side impact crashes as outlined in Klinich et al., 2024. Similar to the frontal impact tests, side impact performance shall be demonstrated through simulations during Phase I. The prototype will be physically tested in Phase II. Per Klinich et al., 2024, WTORS performance in side impacts is to be evaluated during a 20.9 kph (13 mph), 10g lateral impact (left side, near), using a midsize male (50M) ATD. The specific wheelchair model that the UDIG attachment was designed for will be used during the side impact tests. The wheelchair station shall be rotated 80 degrees clockwise from the primary direction of travel. The test is to be performed with a wheelchair-anchored lap belt and lack of lateral wall to maximize loads applied to the attachment. If the offeror develops an attachment that is compatible with multiple wheelchair models, tests should be completed with a surrogate wheelchair in addition to any SWMs. Surrogate belt geometry should be installed per Klinich et al., 2024. If the offeror develops an attachment that is expected to be integrated with the occupant restraint system, the actual occupant lap and shoulder belt should be used instead of a surrogate lap and shoulder belt.

Simulations must show that wheelchair and occupant kinematics are controlled, per Klinich et al., 2024. Attachment performance criteria shall include the following post-test observations:

- The wheelchair shall remain upright with the ATD seated in the wheelchair seat (torso should not be leaning more than 45 degrees from vertical).
- Loaded components of WTORS shall not completely fail (unless there is a backup component or structural member without failure).
- Any WTORS components that may contact a vehicle occupant shall not fragment or separate such that sharp edges are produced (radius of less than 2mm or 0.08 inches).

- WTORS rigid components of 150 grams or greater shall not detach completely.
- The wheelchair and ATD must be able to be manually (without the use of tools) disengaged and removed from the securement system.
- The maximum angle of the wheelchair back support posts shall not exceed 12 degrees from vertical.
- The lateral excursion of the far edge of the wheelchair seatpan near point-P shall not exceed 275mm when measured perpendicular to the initial wheelchair centerline.

The attachment design must be compatible with the following:
- System must conform to UDIG geometry per ANSI/RESNA (2017) WC19: Wheelchairs Used as Seats in Motor Vehicles, American National Standards Institute (ANSI)/Rehabilitation Engineering Society of North America (RESNA).
- System must be compatible with RESNA frontal impact test procedures and performance requirements per ANSI/RESNA (2017) WC18: Wheelchair tiedown and occupant restraint systems for use in motor vehicles, American National Standards Institute (ANSI)/Rehabilitation Engineering Society of North America (RESNA).
- System must be compatible with recently developed side impact test procedures and performance requirements per Klinich, K. D., Manary, M. A., Orton, N. R., Boyle, K. J., & Hu, J. (2024, January). Development of side impact test procedures for improved wheelchair transportation safety (Report No. DOT HS 813 498). National Highway Traffic Safety Administration.

Recent developments in AVs have raised interest in the potential for the UDIG standard to enhance the transportation options available for vehicle occupants who ride in wheelchairs. Preliminary research has demonstrated the feasibility of automated wheelchair tiedown and restraint systems that have the potential for wheelchair users to utilize future AVs without the need for assistance. Pilot testing with these systems demonstrated significant concern among manual wheelchair users regarding the weight of the UDIG attachment. This research task is intended to address these concerns and improve the public acceptance for use of UDIG wheelchair tiedown systems.

Expected Phase I Outcomes

At the end of Phase I, the report should identify at least one candidate manual wheelchair design and provide design(s) for lightweight integrated or removable UDIG compliant attachment to use for prototype development for use by manual wheelchairs. Phase I should develop a preliminary attachment design that is intended to be commercially feasible. This will include a detailed pre-production design(s) that demonstrates how the attributes listed above will be addressed in the prototype(s). The design should aim to impact the widest target of RESNA approved wheelchairs to achieve the greatest market penetration (RESNA WC 19). The Phase I report shall include:
- Preliminary feasibility study that identifies the potential market demand for a UDIG manual wheelchair attachment to support increased independence of people who use wheelchairs in motor vehicles, particularly AVs.
- A discussion of design considerations and requirements.
- Rationale for attachment design should include explanation of features that allow independent use by motor vehicle occupants who ride in wheelchairs.
- Strength versus weight optimization.
- Engineering analysis and use of finite element models to demonstrate that the designs perform safely in frontal (RESNA WC18) and side (Klinich et al., 2024) impact scenarios.
- Crash simulations to demonstrate robust safety performance for the intended wheelchair and occupant combinations.

Expected Phase II Outcomes

At the end of Phase II, production-ready UDIG attachment prototype(s) shall be developed that are suitable for commercial sale. Safe performance of the attachment(s) will be demonstrated in frontal (RESNA WC18) and side (Klinich et al., 2024) impact sled tests. The Phase II final report shall include design specifications and drawings, all test results, cost, and weight estimates for the final design(s). The final report should also include an evaluation of the commercial readiness for the attachment design(s) and marketing plan. Possible user acceptance testing may be considered.

Technical References

ANSI/RESNA (2017). ANSI/RESNA WC19: Wheelchairs Used as Seats in Motor Vehicles, *American National Standards Institute (ANSI)/Rehabilitation Engineering Society of North America (RESNA)*. https://webstore.ansi.org/standards/resna/ansiresnawc4_2017s19

ANSI/RESNA (2017). ANSI/RESNA WC18: Wheelchair tiedown and occupant restraint systems for use in motor vehicles, *American National Standards Institute (ANSI)/Rehabilitation Engineering Society of North America (RESNA).* https://webstore.ansi.org/standards/resna/ansiresnawc4_2017s18

Klinich, K. D., Manary, M. A., Boyle, K. J., Orton, N. R., & Hu, J. (2022, October). Development of an automated wheelchair tiedown restraint system (Report No. DOT HS 813 275). *National Highway Traffic Safety Administration*, https://rosap.ntl.bts.gov/view/dot/64468/dot_64468_DS1.pdf.

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Klinich, K. D., Hu, J., Boyle, K. J., Manary, M. A., Orton, N. R. (2023). Finite Element Models of Wheelchairs and Associated Components to Support Wheelchair Transportation Research [Data set], University of Michigan - Deep Blue Data. https://doi.org/10.7302/xqqe-ef62

ISO (2012). ISO 10542-1:2012: Technical systems and aids for disabled or handicapped persons — Wheelchair tiedown and occupant-restraint systems — Part 1: Requirements and test methods for all systems, *International Organization for Standardization (ISO).* https://webstore.ansi.org/standards/iso/iso105422012

24-NH5: Prehospital Post-Crash Care Systems Improvement

It is important to ensure that motor vehicle crash (MVC) patients receive the most effective post-crash care in the prehospital setting immediately following a crash. Currently, there are no system-wide solutions for prehospital provision of blood to MVC patients suffering life-threatening blood loss. An innovative treatment for bleeding includes damage control resuscitation (DCR) treatments such as the administration of whole blood, blood products (e.g., red blood cells, fresh frozen plasma, platelets, and cryoprecipitate) and adjuvant therapies (e.g., Recombinant activated factor 7 (rFVIIa)). Small programmatic solutions have had success nationally in implementing and administering DCR treatments but have been small in scope and have required extensive and novel local resources and collaborative efforts to become effective.

Systems-based solutions that provide equitable prehospital Emergency Medical Services (EMS)administration of life-saving blood products to crash victims are needed as additional tools to reduce fatalities.[4] Improvements in post-crash care are integral to the National Roadway Safety Strategy and the Safe Systems, and the USDOT's Research, Development, and Technology Strategic Plan (RDT).

While evidence shows the benefits of providing blood to patients with life-threatening bleeding[5], few EMS clinicians have received the education and training required to provide blood products in the prehospital setting. Additionally, supply, distribution, and coordination of blood for prehospital use has required extensive local resources to implement such programs. In the United States, prehospital blood programs have in general been limited to pilot programs operating in well-resourced communities. A systems solution including coordination, supply, distribution, education, training, and equipment support would allow for all communities to implement a prehospital blood program. More specifically, a system is needed to support ground-based EMS clinicians in administering blood products to crash victims in the prehospital setting. The system must be designed for easy adoption and implementation by EMS agencies, personnel, and should include: coordination between blood suppliers and EMS agencies, products and services, devices, hardware, software, training, management, supply, storage, deployment, shipping, distribution, and post-crash care support of whole blood, blood products, and adjuvant therapies.

This SBIR topic seeks to develop a system that addresses the following parameters:

- Recommends and/or provides best practices in collection, storage, distribution, delivery by ground, air, and/or by drone, and which enables easy transfusion of blood products by EMS providers in prehospital settings
- Assists with distribution of blood products quickly and easily, especially to rural and frontier communities, and, if applicable, is compliant with drone airspace regulations
- Improves transfusion logistics and implementation
- Enhances the life cycle of blood products and prevents product wastes
- Reduces administrative, logistical, policy, and partnership hurdles

Local EMS agencies (private, public, non-profit, fire-based, and/or other types) would be end-users and potential consumers. Blood banks, EMS supply companies, and other blood and EMS related organizations are both potential suppliers and users of blood transfusion products and services. Ground,

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[4] Association of Prehospital Transfusion With Mortality in Pediatric Trauma | JAMA Pediatric. 2023 Jul 1;177(7):693-699

[5] Is prehospital blood transfusion effective and safe in hemorrhagic trauma patients? A systematic review and meta-analysis | Injury. 2019 May;50(5):1017-1027

air, and drone shipping companies may be partners. In Rwanda, for example, blood is already distributed successfully by drone.

Expected Phase I Outcomes

The proof-of-concept report should describe the proposed system prototype and provide a preliminary feasibility study that identifies the potential market demand for a prehospital blood transfusion system to support post-crash care. The report should include:

- The unique needs and capabilities of stakeholders.
- The intended plan for how the development and demonstration of a system used for post-crash care at the local and/or State level can be scalable and provide information for countermeasure development and deployment
- A description of hardware, software, delivery systems and related coordination, partnerships, agreements, and system parts to be used for a Phase II demonstration
- A summary description of Federal Aviation Administration (FAA) authorization procedures required to enable successful drone delivery of blood

Expected Phase II Outcomes

Phase II is expected to include the development and demonstration of a system prototype for testing, marketing, and commercialization. The prototype should be validated on a local and/or statewide basis, including at least one pilot EMS agency, municipality, region, or State. Template documents should be created including:

- Draft communications, letters, and agreements for suppliers, delivery organizations, EMS providers, and other necessary partners;
- Operations guidebook and systems specifications;
- Training package; and
- Draft submission package to the Federal Aviation Administration (FAA) to authorize successful drone delivery of blood.

Technical References

Prehospital hemorrhage control and treatment by clinicians: a joint position statement. American College of Surgeons Committee on Trauma, the American College of Emergency Physicians, and the National Association of EMS Physicians. Berry C, et al. Prehospital Emergency Care, March 2023. https://pubmed.ncbi.nlm.nih.gov/36961935/

Fluid resuscitation for hemorrhagic shock in tactical combat casualty care. TCCC guidelines change 14-0. June 2, 2014, JSOM, 2014. https://pubmed.ncbi.nlm.nih.gov/25344706/

THOR-AABB working party recommendations for a prehospital blood product transfusion program. Prehospital Emergency Care, November 2022. https://pubmed.ncbi.nlm.nih.gov/34669564/

MH Yazer, et al.. Prehospital Emergency Care, 2001.

Prehospital Blood Transfusion Initiative Coalition. (https://prehospitaltransfusion.org/)

Association for the Advancement of Blood & Biotherapies, Standards for Blood Banks and Transfusion Services. (https://www.aabb.org/)

Research indicating crash victim fatality reduction potential:

- Nationwide estimates of the need for prehospital blood products after injury. ZG Hashmi, et al. Transfusion, 2022. https://pubmed.ncbi.nlm.nih.gov/35753065/
- Prehospital plasma during medical transport in trauma patients at risk for hemorrhagic shock. JL Sperry, et al. New England Journal of Medicine, 2018. https://pubmed.ncbi.nlm.nih.gov/30044935/
- Association of prehospital blood product transfusion during medical evacuation of combat casualties in Afghanistan with acute and 30-day survival. SA Shackelford, MD, et. Al. Journal of the American Medical Association, 2017. https://pubmed.ncbi.nlm.nih.gov/29067429/

- Damage control resuscitation in patients with severe traumatic hemorrhage: a practice management guideline from the Eastern Association for the Surgery of Trauma. Journal of Trauma, 2017. https://pubmed.ncbi.nlm.nih.gov/28225743/
- Damage control resuscitation: Directly addressing the early coagulopathy of trauma. JB Holcomb, MD, et. Al. Journal of Trauma, 2007. https://pubmed.ncbi.nlm.nih.gov/17297317/
- Prospective Observational Multicenter Massive Transfusion study (PROMMT). JAMA Surgery, February 2013. https://pubmed.ncbi.nlm.nih.gov/23560283/
- Prospective Randomized Optimum Platelet and Plasma Ratios study (PROPPR). Injury, September 2014. https://pubmed.ncbi.nlm.nih.gov/24996573/

Partial/program solutions in development:

- Velico "FrontlineODP" spray dried plasma & plasma unit. Partial development funded by the Biomedical Advanced Research and Development Authority (BARDA), Office of the Assistant Secretary for Preparedness and Response, U.S. Department of Health and Human Services, contract HHS0100201200005C. https://www.veli.co/frontlineodp/

Limited scope & international programs:

- Texas Regional Advisory Council lead prehospital transfusion program: https://www.usfa.fema.gov/blog/ig-092222-2.html
- Pilot Agency Program cases (including Harris County ESD 48 Fire Department):- https://www.ems1.com/ems-products/medical-equipment/articles/2-texas-ems-agencies-first-in-us-to-deploy-whole-blood-2CoSwuKfzZXvFhqP/
- Connection to RDT's call for rural technology transfer of uncrewed Aircraft Systems for delivery of medical supplies and emergency medical equipment to improve emergency response and post-crash care in remote areas (RDT, p.74)
- Zipline drone delivery (flyzipline.com/)
- Blood delivery for most of Rwanda: https://www.aviationtoday.com/2022/12/15/zipline-partners-government-rwanda-autonomous-drone-delivery-services/
- FAA approval in US: https://www.faa.gov/newsroom/faa-authorizes-zipline-deliver- commercial-packages-beyond-line-sight
- US Marines Blood delivery: https://www.defenseone.com/technology/2019/10/us- marines-test-medical-delivery-drones/160746/

24-NH6: Anchor Design for Universal Docking Interface Geometry

This research challenge aligns with the FY 2023 - 2024 [Annual Modal Research Plan (AMRP)] and [U.S. DOT innovation priorities] by directly addressing the U.S. DOT strategic goals of safety, equity, and accessibility. This research problem directly promotes safe transportation for motor vehicle occupants who ride in wheelchairs. A successful research outcome could benefit occupants who ride in wheelchairs in automated vehicles (AVs) and other forms of transportation.

NHTSA recently published a report[6] on the feasibility of a proof-of-concept automated wheelchair tiedown and occupant restraint system, or WTORS, however, the previously developed proof-of-concept wheelchair anchors and attachments were a demonstration and not thought to be suitable for production and implementation into the marketplace. The current research problem will build upon this effort and seeks to develop a pre-production wheelchair anchor design that fulfills the Universal Docking Interface Geometry (UDIG) requirements and is compatible with various transportation modes (e.g., rail, surface, and air). Consideration will be given to understanding how a solution for motor vehicle application can promote accessibility in other modes of transportation. A successful research outcome could benefit occupants who ride in wheelchairs in motor vehicles, particularly AVs, and could have applications in other forms of transportation.

In the previous study, a novel set of UDIG anchors for manual and power wheelchairs were demonstrated. The solution to the current task should build upon this effort. Consideration should be given to developing a UDIG anchor system by contrasting the needs for safety, weight, size, stowability, and removability for other transportation modes. The overall solution desired is to develop a UDIG anchor system that has commercial applications for motor vehicles and other modes of transportation.

The system must:

- Be compatible with American National Standards Institute (ANSI)/Rehabilitation Engineering and Assistive Technology Society of North America (RESNA) standards for connection geometry and location of wheelchair attachments, per ANSI/RESNA WC-4:2017, Section 19 - Wheelchairs Used as Seats in Motor Vehicles.
- Retain the wheelchair without deformation during frontal sled testing in accordance with ANSI/RESNA WC-4:2017, Section 18 – Wheelchair Tiedown and Occupant Restraint Systems for Use in Motor Vehicles.
- Meet crashworthy requirements for side impacts per Klinich et al., 2024.
- Be compared to the crashworthy requirements for passenger seats in passenger trains, which are specified in American Public Transportation Association (APTA) PR-CS-S-016-99, Rev 3. Any conflicts between APTA or other modal specifications for passenger seating systems shall be clearly described.
- Be designed so the anchor system specifications work with both manual and power wheelchairs. Any combined weight limits for the wheelchairs and occupants should be clearly identified.

The specifications shall be designed to meet requirements in RESNA WC18 for frontal impact test performance. Phase I should utilize crash simulations to demonstrate the safety performance of the UDIG anchor. The prototype should be physically tested in Phase II using pre- and post-test measurements to demonstrate the anchor performance. Per RESNA WC18, a WTORS designed for use by a range of wheelchairs and wheelchair users must undergo two frontal impact test scenarios. The first frontal impact test is used to evaluate the complete WTORS, including the three-point occupant restraint system and the wheelchair docking/securement system. The second frontal impact test is used to evaluate the wheelchair docking/securement system using a surrogate lap and shoulder belt and surrogate wheelchair (the

[6] Development of an Automated Wheelchair Tiedown and Occupant Restraint System: Initial Progress | UMTRI

surrogate lap belt is anchored to the surrogate wheelchair). Both tests require a 48 kph (30 mph), 20g frontal impact and utilize a midsize male anthropomorphic test device (50M ATD) seated in the test wheelchair. Since this task involves only the development of the UDIG anchor, and not the occupant restraint system, only the second frontal impact test is to be completed. Surrogate belt geometry should be installed per RESNA WC18.

Performance criteria of the anchor must be met per RESNA WC18. Specifically, excursion requirements per RESNA WC18 state that the WTORS shall not allow horizontal excursion of point P of the test wheelchair to exceed a specified value (wheelchair point P, X_p). Simulations must show that wheelchair and occupant kinematics are controlled, per Klinich et al., 2022.

Additional post-test requirements include:

- The wheelchair must remain upright on the sled platform with the ATD seated in the wheelchair seat (ATD torso may not be leaning more than 45 degrees from vertical).
- Load carrying components of the anchor shall not completely fail (unless tear/failure is part of design and/or a backup component/structure does not show significant failure).
- WTORS shall not be detached/separated at anchorages or securement points.
- Deformation of securement points on anchor shall not prevent manual disengagement and removal of a wheelchair from securement device.
- Test wheelchair shall be removed from test platform without use of tools.

The UDIG attachment system shall also be evaluated for performance in side impact crashes as outlined in Klinich et al., 2024. Similar to the frontal impact tests, side impact performance shall be demonstrated through simulations during Phase I. The prototype will be physically tested in Phase II. Per Klinich et al., 2024, WTORS performance in side impacts is to be evaluated during a 20.9 kph (13 mph), 10g lateral impact (left side, near), using a midsize male (50M) ATD. Klinich et al., 2024 developed a surrogate wheelchair for side impact (SWCSI), which will be used to evaluate the anchor. The wheelchair station shall be rotated 80 degrees clockwise from the primary direction of travel. The test is to be performed with a wheelchair-anchored lap belt and lack of lateral wall to maximize loads applied to the anchor. Surrogate belt geometry should be installed per Klinich et al., 2024.

Simulations must show that wheelchair and occupant kinematics are controlled, per Klinich et al, 2024. Anchor performance criteria shall include the following post-test observations:

- The wheelchair shall remain upright with the ATD seated in the wheelchair seat (torso should not be leaning more than 45 degrees from vertical).
- Loaded components of the WTORS shall not completely fail (unless there is a backup component or structural member without failure).
- Any WTORS components that may contact a vehicle occupant shall not fragment or separate such that sharp edges are produced (radius of less than 2mm or 0.08 inches).
- WTORS rigid components of 150 grams or greater shall not detach completely.
- The wheelchair and ATD must be able to be manually (without use of tools) disengaged and removed from the securement system.
- The maximum angle of the wheelchair back support posts shall not exceed 12 degrees from vertical.
- The lateral excursion of the far edge of the wheelchair seatpan near point-P shall not exceed 275mm when measured perpendicular to the initial wheelchair centerline.

The attachment design must be compatible with the following:

- System must conform to UDIG geometry per ANSI/RESNA (2017) WC19: Wheelchairs Used as Seats in Motor Vehicles, American National Standards Institute (ANSI)/Rehabilitation Engineering Society of North America (RESNA).

- System must be compatible with RESNA frontal impact test procedures and performance requirements per ANSI/RESNA (2017) WC18: Wheelchair tiedown and occupant restraint systems for use in motor vehicles, American National Standards Institute (ANSI)/Rehabilitation Engineering Society of North America (RESNA).
- System must be compatible with recently developed side impact test procedures and performance requirements per Klinich, K. D., Manary, M. A., Orton, N. R., Boyle, K. J., & Hu, J. (2024, January). Development of side impact test procedures for improved wheelchair transportation safety (Report No. DOT HS 813 498). National Highway Traffic Safety Administration.

Recent developments in AVs have raised interest in the potential for the UDIG standard to enhance the transportation options available for vehicle occupants who ride in wheelchairs. Preliminary research has demonstrated the feasibility of automated WTORS that have the potential for wheelchair users to utilize future AVs without the need for assistance. An anchor system that can be used in multiple transportation modes may provide an attractive option for enhanced travel options and improved safety. Future AVs may provide travel options without the need for assistance. This research task is intended to develop a commercial product for this underserved transportation sector.

Expected Phase I Outcomes

At the end of Phase I, the report should include the selection of a UDIG anchor design to use for prototype development for use by manual and power wheelchairs. Phase I should develop a preliminary anchor design that is intended to be commercially feasible. This will include a detailed pre-production design that demonstrates how the attributes listed above will be addressed in the prototype. The Phase I report should:

- Identify the potential market demand for a UDIG anchor to support increased independence of people who use wheelchairs in motor vehicles, particularly AVs.
- Review and compare UDIG anchor requirements for the major transportation modes.
- Highlight any differences in requirements and develop design parameters for meeting motor vehicle requirements while addressing any unique requirements for other transportation modes where possible.
- Include a discussion of design considerations and requirements.
- Provide a rationale for anchor design and an explanation of features that allow independent use by motor vehicle occupants who ride in wheelchairs.
- Describe any combined weight limits for wheelchairs and occupants.
- Describe the engineering analysis and use of finite element models to demonstrate that the design performs safely in frontal (RESNA WC18) and side impact scenarios (Klinich et al., 2024).
- Describe desired deliverables for this technology including weight, cost, and safety estimates.

Expected Phase II Outcomes

At the end of Phase II, a production-ready UDIG anchor prototype shall be developed that is suitable for commercial sale. Safe performance of the anchor will be demonstrated in frontal (RESNA WC18) and side (Klinich et al., 2024) impact sled tests. The Phase II final report shall include design specifications and drawings, all test results, cost, weight estimates and refinement for the UDIG anchor design. The final report should also include an evaluation of the commercial readiness for the anchor design and marketing plan. Possible user acceptance testing may be considered.

Technical References

ANSI/RESNA (2017). ANSI/RESNA WC19: Wheelchairs Used as Seats in Motor Vehicles, *American National Standards Institute (ANSI)/Rehabilitation Engineering Society of North America (RESNA)*. https://webstore.ansi.org/standards/resna/ansiresnawc4_2017s19

ANSI/RESNA (2017). ANSI/RESNA WC18: Wheelchair tiedown and occupant restraint systems for use in motor vehicles, *American National Standards Institute (ANSI)/Rehabilitation Engineering Society of North America (RESNA).* https://webstore.ansi.org/standards/resna/ansiresnawc4_2017s18

APTA PR-CS-S-016-99 Revision 3, Passenger Seats in Passenger Rail Cars, *American Public Transportation Association*, October 26, 2023. https://www.apta.com/research-technical-resources/standards/passenger-rail-equipment-safety-standards/apta-pr-cs-s-016-99/

Klinich, K. D., Manary, M. A., Boyle, K. J., Orton, N. R., & Hu, J. (2022, October). Development of an automated wheelchair tiedown restraint system (Report No. DOT HS 813 275). *National Highway Traffic Safety Administration*. https://rosap.ntl.bts.gov/view/dot/64468/dot_64468_DS1.pdf.

Klinich, K. D., Manary, M. A., Orton, N. R., Boyle, K. J., & Hu, J. (2024, January). Development of side impact test procedures for improved wheelchair transportation safety (Report No. DOT HS 813 498). National Highway Traffic Safety Administration, https://dx.doi.org/10.7302/8070.

Klinich, K. D., Hu, J., Boyle, K. J., Manary, M. A., Orton, N. R. (2023). Finite Element Models of Wheelchairs and Associated Components to Support Wheelchair Transportation Research [Data set], University of Michigan - Deep Blue Data. https://doi.org/10.7302/xqqe-ef62

ISO (2012). ISO 10542-1:2012: Technical systems and aids for disabled or handicapped persons — Wheelchair tiedown and occupant-restraint systems — Part 1: Requirements and test methods for all systems, *International Organization for Standardization (ISO).* https://webstore.ansi.org/standards/iso/iso105422012

Pipeline and Hazardous Materials Safety Administration (PHMSA)

About Us: The Pipeline and Hazardous Materials Safety Administration (PHMSA) operates in a dynamic and challenging environment where advances in technology, manufacturing, and energy production impact transportation safety. PHMSA's mission is to protect people and the environment by advancing the safe transportation of energy and other hazardous materials that are essential to our daily lives. PHMSA's Pipeline Safety Research Program sponsors research and development projects focused on providing near-term solutions for the U.S.'s pipeline transportation system that will improve safety, reduce environmental impact, and enhance reliability. This includes ensuring that PHMSA's R&D program implements the Administration's priorities through R&D investments that promote safety and environmental protection, climate change, economic recovery and rebuilding, and transportation as an engine for equity.

Recent R&D projects are focused on leak detection; detection of mechanical damage; damage prevention; improved pipeline system controls, monitoring, and operations; and improvements in pipeline materials. These projects are addressing technological solutions that can quickly be implemented to improve pipeline safety and limit environmental impact of PHMSA-regulated infrastructure. PHMSA's Office of Hazardous Material Safety regulates the transportation of hazardous materials by air, rail, highway, and water. Over 1.3 million hazardous material products are transported daily over the various transportation modes. Because of the ubiquity of hazardous material movements, supporting the safe transport of these products will have a positive impact on safety and performance. The Office of Hazardous Material Safety seeks to improve the safety and reliability of hazardous material transportation.

24-PH1: Innovative Solutions for Internal Corrosion Control of Hazardous Liquid Pipelines

Corrosion of the internal surfaces of pipelines and pipeline components such as tanks continues to be a challenge for pipeline operators, especially in pipelines carrying products such as crude oil or operating with low flow rates. Current solutions such as cleaning pigs and biocides can be ineffective in some pipelines, and damage to internal pipe surfaces can be costly and difficult to detect.

This topic seeks innovative solutions to economically prevent, detect, and/or mitigate internal corrosion damage to hazardous liquid pipelines and pipeline components.

Expected Phase I Outcomes
The Phase I project is expected to develop a prototype or proof of concept experiment to demonstrate the technology's feasibility for preventing, detecting and/or mitigating internal corrosion on hazardous liquid pipelines.

Expected Phase II Outcomes
The Phase II project is expected to develop and test a refined prototype of the technology demonstrated during Phase I. The prototype should be further demonstrated in a field setting to demonstrate functionality as a field-ready solution.

Technical References
None

24-PH2: Survivability of Hazardous Materials Placards

Placards play a crucial role in safely transporting hazardous materials; Over 1.2 million hazardous materials are shipped daily, totaling 3.3 billion tons of hazardous materials shipped annually. Over 70 million tons of hazardous materials are transported on truck and rail. The Hazardous Materials Regulations states that each bulk packaging containing hazardous materials must be placarded.

Placards are an integral part of an internationally harmonized system of communicating the hazards of hazardous materials in transportation. They also play a critical role in communicating the presence of hazardous materials to emergency responders in the event of a hazardous materials incident. Damaged or lost placards increase the risk of emergency response crews not knowing what type of hazardous materials they are dealing with in an incident nor how to mitigate the chemicals involved. For example, the placards on the tank cars in the East Palestine, Ohio derailment melted in the heat, preventing first responders from quickly identifying what chemicals they were encountering. Placards reduce the disruptiveness of communicating hazardous materials information. Placards are often subjected to harsh conditions during transportation, including exposure to weather elements, chemical exposure, and physical damage. The degradation or loss of placards can result in safety hazards, regulatory non-compliance, and financial penalties. Therefore, there is a need to develop a solution that enhances the durability and security of placards on bulk packaging such as rail tank cars.

The overall solution should identify or propose a readily available tool, technology, or material to improve the survivability of placards on rail tank cars or other motor vehicles that were involved in a hazardous material incident or withstand environmental damage without compromising or degrading safety. The overall solution needs to meet the placard specification outlined in 49 CFR 172.519 and must be able to survive high excessive heat, due to fires in hazardous material incidents, and the placard must remain intact and legible for first responders and operators to read. The proposed solution should be easily deployed on multiple placards, does not add additional weight to the placards or alter the requirements, and kept the placard to the specifications outlined in 49 CFR 172.519. It must also demonstrate that the placard remains intact and can still be easily identifiable if excessive heat is applied.

There is widespread commercialization potential for this solution. There are 1.2 million HAZMAT shipments per day, which equals 3.3 billion tons of HAZMAT shipped annually. The requested solution could apply to many shipments of hazardous materials. Placards are a regulatory requirement on motor vehicles and bulk packing; operators could face penalties without proper placarding. The proposed solution could assist with ensuring the operators won't lose their placards on their packaging and reduce the risk of first responders not knowing the contents inside a bulk package.

Expected Phase I Outcomes
The expected deliverable for this solution would include a research report to demonstrate the technical feasibility of the proposed solution to increase the survivability of placards on bulk packing tank cars during Phase I, potentially an early-stage prototype and a pathway to towards a demonstration of the prototype in Phase II.

Expected Phase II Outcomes
The expected Phase II outcome would be a working demonstration of the solution that was identified in Phase I and to demonstrate how it will increase the survivability of the placards in a variety of environmental conditions.

Technical References

Code of Federal Regulations, 49 CFR 172.519, Hazardous Materials Table, Special Provisions, Hazardous Materials Communications, Emergency Response Information, Training Requirements, and Security Plans. https://www.ecfr.gov/current/title-49/subtitle-B/chapter-I/subchapter-C/part-172?toc=1

24-PH3: Non-Destructive Testing of High-Pressure Cylinders

Recertifying cylinders and tanks is a costly and time-consuming process that ensures a minimum level of safety for the transportation of hazardous materials. During operation and in-between re-certifications cylinders and tanks can encounter a variety of chemical and physical stresses that can accelerate package failure. The early identification of packages that have experienced excessive physical strain and are susceptible to rupture or chemical interaction that causes embrittlement may help prevent catastrophic failures from occurring in unsafe manners. With an emerging Hydrogen economy, having an effective, quick, and inexpensive way to ensure the tank's safety will be imperative.

This SBIR topic seeks to develop real-time and continuous monitoring, or rapid checkpoints, for inspection of pressure cylinders. Further information on these inspections can be found in the 49 CFR 180 Subpart C. The proposed solution is expected to use technology such as high frequency sound modulators or metrology in fiber optics coupled with software to rapidly identify defects. Ideally, this should provide an equivalent or greater level of safety than current inspection practices, while also reducing the need to pull packages out of circulation for inspections and recertification.

The solution should provide a nondestructive and relatively quick or continuous detection of defects in the cylinder's packaging. The solution should also aim to cost the same or less than current requalification methods. Proposals should show an understanding of current requalification methods and how their proposed technology will aid in this process. The proposed solution should be able to detect small defects in cylinders that would lead to a requalification failure of that specific packaging type. The focus should be on Hydrogen related cylinders which can be found in 49 CFR section 173.302 and 173.314.

To be commercialized, the technology must be accessible and capable of being directly integrated into new packaging or built to be compatible with existing form factors. Potential end users include customers transporting contents under pressure or bulk hazardous materials in tanks such as fuel, petrochemical, and specialized gas industries, or Hydrogen transportation.

Expected Phase I Outcomes

The Phase I proof-of-concept report should provide a detailed recommendation of the proposed characteristics of the solution, including: technology, ultrasound, fiber optics, or a combination with identified and recommended needs for checkpoint vs continuous monitoring.

Other outcomes include:

- Estimated cost savings,
- Incident reductions, and
- New methodologies for measuring packaging performance to establish new requirements and/or be in compliance with regulations.

Expected Phase II Outcomes

At the end of Phase II, the awardee should be able to demonstrate the fabrication of prototype devices or packaging. The Phase II report should provide data analysis on the data collected throughout the project that shows that the proposed solution is able to detect defects at a rate greater than or equal to the traditional requalification methodology.

Technical References

Code of Federal Regulations, 49 CFR Part 173, Shippers – General Requirements for Shipments and Packagings. https://www.ecfr.gov/current/title-49/subtitle-B/chapter-I/subchapter-C/part-173

Code of Federal Regulations, 49 CFR Part 178 subpart C, Specifications for Packagings. https://www.ecfr.gov/current/title-49/subtitle-B/chapter-I/subchapter-C/part-178.

Code of Federal Regulations, 49 CFR Part 180, Continuing Qualification and Maintenance of Packagings. https://www.ecfr.gov/current/title-49/part-180

24-PH4: Rail Car Coupling Monitoring

Hard coupling occurs when two rail cars are coupled at high speeds. Often the forces caused by hard coupling may lead to damage on either rail car. Hard coupling occurs within the switch yard when operators position cars within the train composition. Currently, there is no method of detecting if a tank car has sustained a hard coupling event. The risk of a hard coupling event on a tank car could lead to cracks in the tank shell and damage to the draft gear or the coupler.

In November 2016, the bottom of a rail tank car released denatured ethanol in a rail yard. The probable cause of the release occurred due to undetected cracks on the tank car that resulted from overspeed high-energy coupling events, which caused deformation in the tank shell and led to the initiation of several fatigue cracks. There have been other hazardous material incidents that were caused as a result of overspeed high energy coupling events.

The National Transportation Safety Board (NTSB) issued several safety recommendations based on their findings from the November 2016 incident.[7] One recommendation is to develop a method to identify tank cars that have sustained overspeed and high-energy coupling force events.

This SBIR project seeks a novel technology that can assist in identifying tank cars that have sustained overspeed and high-energy coupling force events. Currently, some proposed solutions are coupler monitoring systems that monitor the status of the train coupler or use a mechanical notification such as a flag near the bottom of the rail car if the coupler bolts are sheared off due to high forces between the couplers.

The overall solution being sought should be a self-powering sensor or mechanical notification that assists in identifying tank cars that have sustained a hard coupling event.

The system must be modular, lightweight, and easily deployable to tank cars or freight cars. The solution must be solar or battery-powered since no power sources are on a rail tank car. The solution, either sensor or mechanical notification, should not alter the coupler, draft gear, or stub stills or require the initial service to the tank car to deploy the solution. Additionally, it should withstand normal working train operations and environmental conditions such as dust, shocks, vibration, and weather conditions.

If the solution is mechanical, the notification must be visible in a switch yard, easily identifiable, and easily replaceable once the notification has gone off. The mechanical solution should have highly visible colors or shapes to notify train crew and yard operators; the solution should also be an easy replacement after the notification is deployed.

If it is a sensor-based solution, it should include a data acquisition component to send and store information back to the train crew, yard operators, and dispatch centers and the ability to notify them that a train has sustained a hard coupling event. The sensor should be able to report the location of the tank car, the time when a hard coupling event occurred, and the speed of the tank car.

Over 90 million tons of hazardous materials were moved by rail in 2017, out of that 90 million tons. In 2022, over 100,000 tank cars carried class 3 flammable liquids within the U.S.[8] There have been multiple tank car incidents caused by hard coupling or a tank car that has sustained a hard coupling event. This solution could assist train operators and yard switching crew to be notified if a tank car has sustained a hard coupling event before it continues to be used in service, which could lead to cracks or deformation in

[7] CSX Transportation, Inc. Tank Car Release of UN1987 | National Transportation Safety Board
[8] Fleet Composition of Rail Tank Cars Carrying Class 3 Flammable Liquids

the tank car. This solution could also be used on other rail cars beyond tank cars, such as freight or even passenger rail cars, to assist with notifications if there is a collision between rail cars or if a rail car's coupler has been involved in an overspeed and high-energy coupling force event.

Expected Phase I Outcomes

The expected deliverable for this solution is a research report demonstrating the technical feasibility of either a workable sensor or mechanical notification on tank cars in an overspeed and high-energy coupling force event. The Phase I effort can potentially include an early version of the prototype of the solution and show a path toward a demonstration of the prototype in Phase II.

Expected Phase II Outcomes

The expected Phase II outcome is a live demonstration of the proposed solution. This demonstration can be at a railroad equipment testing facility such as the Transportation Technology Center in Pueblo, CO, or potentially in a live rail yard. The proposed solution should be fixed on a DOT tank car near the coupler to record the hard coupling event. The demonstration must show the proposed solution can notify and determine which tank car and where on the tank car has sustained an overspeed and high-energy coupling force event.

Technical References

None

24-PH5 Biodegradable Casting for Fireworks

According to the American Pyrotechnics Association, over 416 million pounds of consumer fireworks were used in the U.S. in 2021[9], and over 12 million pounds of professional display fireworks were also consumed, totaling over 428 million pounds of fireworks.[10] With consumption, waste is generated, leaving tons of waste from fireworks.

The outer shell or casing is the exterior of the firework, usually made out of paper or cardboard; the casting contains all the other components that go into the firework. After a firework has been used, the casing is coated with gunpowder residue and other toxic chemicals. Because of this, fireworks cannot be recycled as they pose a safety concern with gunpowder and other chemical residue after the firework is discharged.

The overall solution is to develop a biodegradable material that can replace the non-biodegradable casings used in ground device and cake and combination device-type fireworks. The proposed casting solution should be consistent with: (1) the general requirements outlined in the APA 87-1A 2018 2.4 General Requirements for all consumer firework devices and novelties and (2) the requirements outlined in the two proposed fireworks APA 87-1A- 2018 section 3.3.2 ground device and APA 87-1A- 2018 section 3.2.4 cake and combination device. The solution should not affect the overall safety of the fireworks as well.

The solution should be a material capable of breaking down through the normal environmental processes. The material must be compatible with the chemical composition of the ground, cake, and combination device. The material used should maintain the existing level of safety. The proposed material of construction must be capable of passing all technical requirements found in APA87-1A-2018.
The material should comply with all of the technical requirements outlined in the APA-87-1A-2018 standard. The material should be easily sourced and useable with existing firework manufacturing processes and equipment.

Phase I Expected Outcomes
The expected Phase I deliverable for this solution is a research report demonstrating the technical feasibility of a material that is biodegradable and can replace the existing cardboard or plastic casing on a ground or cake or combination devices and a potentially early version of the prototype of the solution to show a path toward a demonstration of the prototype in Phase II.

Phase II Expected Outcomes
The expected Phase II outcome would be a continuation of the work from Phase I and a workable demonstration of how the proposed material can work in a ground or cake or combination devices as well as with different types of fireworks and different types of energetics beyond fireworks, such as flares, hobby rockets, propellants, or explosives.

Technical References
2018 APA Standard 87-1A, Standard For The Construction, Classification, Approval, And Transportation of Consumer Fireworks, *American Pyrotechnical Association*. https://www.americanpyro.com/assets/docs/APAStd871/APA%2087-1A%20Final%20Consumer%20Fireworks%20Std.%20_.pdf.

[9] U.S. Fireworks Consumption Figures 2000-2021 | American Pyrotechnics Association

[10] Data derived from the annual, cumulative reports of the U.S. Department of Commerce and the U.S. International Trade Commission, Imports for Consumption (3604101000 Class 1.3G fireworks, 3604109010 Class 1.4G Fireworks, and 360490 party poppers/pyrotechnic articles.) | U.S. Imports / Exports Dataweb