United States Department of Transportation
Annual Modal Research Plans FY 2023
Program Outlook FY 2024

Pipeline and Hazardous Materials Safety Administration

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Executive Summary

The Pipeline and Hazardous Materials Safety Administration's (PHMSA) mission is to protect people, property, and the environment by advancing the safe transportation of energy products and hazardous materials that are essential to our daily lives. The Agency operates in a dynamic and challenging environment in which changes in technology, manufacturing, and energy production affect transportation safety. PHMSA anticipates that the scope and complexity of our safety mission will continue to grow to protect the environment, serve environmental justice, and support the country's economic recovery from the COVID-19 pandemic.

America's pipeline infrastructure spans more than 3.3 million miles and is used to transport nearly all the natural gas and about two-thirds of the liquid petroleum energy products consumed domestically. According to the U.S. Energy Information Administration, oil furnishes 35 percent of our energy, natural gas 34 percent, coal 10 percent, nuclear 9 percent, and renewables make up 12 percent. (https://www.eia.gov/energyexplained/us-energy-facts/). Adaptation of the existing pipeline structure to support alternative energy sources and the need to serve underserved communities will drive the need for innovation in the coming decade. PHMSA also confronts safety challenges posed by the increased transportation of hazardous materials across all modes—more than 3.3 billion tons annually and more than 1.2 million shipments per day. The routes taken by these shipments must be chosen in an equitable and environmentally sustainable manner. Unexpected circumstances continue to arise, and the Agency must prepare for any emerging issues such as with COVID-19. Research and development (R&D) activities provide critical solutions to these ongoing challenges.

Due to the significant contribution of energy and hazardous materials to our economy and standard of living as well as their potential safety and environmental impacts, research projects promoting the safety, resilience, and performance of our transportation system are essential. PHMSA will fund research that improves safety to reduce potential human and environmental impacts. This kind of research will enhance the security of our infrastructure, our people, and our environment. In Fiscal Year (FY) 2023 PHMSA will pursue research, development, and technology (RD&T) goals through a variety of projects carried out by its Office of Pipeline Safety (OPS) and the Office of Hazardous Materials Safety (OHMS).

PHMSA supports evaluation and performance measurement efforts related to the Foundations for Evidence-Based Policymaking Act of 2018 (Pub. L. 115-435). In support of the U.S. Department of Transportation's (DOT or the Department) strategic objectives as identified in *Figure 1*, PHMSA's performance goals will be monitored for trends, reported DOT-wide and serve as a guide for both R&D and operational performance. *Figure 1* also identifies the performance goals for which PHMSA is the lead Agency and those agency-wide goals that PHMSA supports.

Figure 1 Performance Goals

Strategic Goal	Strategic Objective	Performance Goal
PHMSA Lead Agency		
Safety	Safe Public	Reduce Fatalities Caused by the Release of Hazardous Material Transported via Pipeline or Surface Transportation Conveyance (PHMSA)
Economic Strength & Global Competitiveness	High-Performing Core Assets	By 2036, Repair or Replace 1,000 Miles of High-Risk, Leak-Prone, Community-Owned Legacy Gas Distribution Pipeline Infrastructure, as Well as an Estimated Reduction of 1,000 Metric Tons of Methane Emissions and a Reduction in Fatalities/Serious Injuries (PHMSA) Key Performance Indicator (KPI), Bipartisan Infrastructure Law (BIL)
Economic Strength & Global Competitiveness	Resilient Supply Chains	Reduce the Number of Hazardous Materials Incidents that Resulted in a Road Closure of One Hour or More (PHMSA)
Equity	Power of Community	Increase the Percentage of Community Outreach Activities Directed Toward Underserved Communities to Increase Hazmat Transportation Awareness, Preparedness, and Response (PHMSA)
Climate & Sustainability	Path to Economy-Wide Net-Zero Emissions by 2054	Reduce the Gross Volume Spilled from Crude Oil and Refined Products' Pipeline Systems (PHMSA)
PHMSA Support of DOT-Wide Goals		
Equity	Proactive Interventions, Planning, and Capacity Building	By 2025, Increase by 5% the Number of U.S. DOT Discretionary Grant Applicants from Disadvantaged Communities who have Never Applied for U.S. DOT Funding Before (OST-P, All Operating Administrations) KPI, BIL
Climate & Sustainability	Path to Economy-Wide Net-Zero Emissions by 2054	Reduce Transportation Emissions in Support of Net-Zero Emissions Economy-Wide by 2050 (OST, All Operating Administrations) KPI
Climate & Sustainability	Climate Justice and Environmental Justice	Ensure that the Benefits of At Least 40% of U.S. DOT Investments in the Areas of Clean Energy and Energy Efficiency, Clean Transportation, and the Remediation and Reduction of Legacy Pollution Flow to Disadvantaged Communities (OST-P, All Operating Administrations) KPI
Transformation	Matching Research and Policy to Advance Breakthroughs	Double the Number of Research and Deployment Projects Centered on Breakthrough Discoveries that Introduce New Technologies or Approaches Not Currently Deployed in the Transportation System (OST-R, All Operating Administrations) KPI

PHMSA remains focused on collaboration with all stakeholders to leverage investment and successes to date. PHMSA makes continual efforts to remove unnecessary duplication while engaging a wide range of stakeholders, including advanced technology providers and academia, to fund and co-fund critical research that develops new technology, products, and knowledge. PHMSA's RD&T activities are non-duplicative with known prior or current projects within the Agency.

Figure 2 illustrates the contribution of PHMSA's research activities in support of the six DOT strategic goals. The table demonstrates how PHMSA-specific research activities, such as research in alternative fuels, liquefied natural gas (LNG) safety, and pipeline threat prevention, align with the Office of the Secretary, Research and Technology (OST-R) programmatic goals and working groups' (Transportation Research Working Group (TRG), Center for Climate Change, and Equity Task Force) objectives.

Figure 2 Strategic Goals

DOT Goal	OST-R Linkages: TRWG Center for Climate Change Equity Task Force	Alternative Fuels	LNG Safety	Underground Natural Gas Storage	Pipeline Anomaly Detection	Pipeline Threat Prevention	Pipeline Repair / Rehabilitation	Risk Management and Mitigation	Emerging Technology	Technical Analysis to Aid Risk Assessments
Safety	Automation				x			x	x	
	Systemic Safety Approach	x	x	x	x	x	x	x	x	x
Economic Strength & Global Competitiveness	State of Good Repair	x	x	x	x	x	x	x		
	Technology Transfer/Deployment	x	x	x			x	x	x	x
	Economic Competitiveness	x	x						x	
Equity	Equity Task Force	x	x					x	x	x
Climate and Sustainability	Environmental Stewardship (chair)	x	x	x	x			x	x	x
	Center for Climate Change	x					x	x	x	
Transformation	Emerging/Enabling Technologies	x	X	x	x	x	x	x	x	x
Organizational Excellence	Evaluation/Performance Measurement									x

In the FY 2023 Budget (see Table 2 below), PHMSA's funding by strategic goal is allocated solely to safety, however the impact of PHMSA's R&D activities will extend to all strategic goals (see Figure 2 above). While PHMSA's primary mission is safety, its research programs also support key Administration priorities such as *Climate and Sustainability* and *Equity*.

For instance, PHMSA plans significant investments in hydrogen research, methane emissions reductions, and the safety of lithium batteries. While the focus of these research activities will be on improving safety, the investments will also help to reduce the climate impacts of fossil fuels, stimulate innovative research and thereby improve economic strength and global competitiveness. Likewise, reductions in emissions from previously unregulated rural gathering lines will help to address equity disparity in exposure to hazardous liquids and gas. To further enhance PHMSA's ability to analyze equity impacts, PHMSA plans investments in a modeling framework to analyze equity implications for hazardous materials routing and exposure.

PHMSA's investment program is designed to improve equity and stimulate innovation by increasing stakeholder engagement with minority serving institutions (MSI) and small businesses to increase participation in upcoming grant and contract awards.

Table 1 - FY 2023 RD&T Program Funding Details

Budget Account	FY 2023 PRES. BUDGET	Applied	Tech Transfer	Facilities	Experimental Development	Major Equipment, R&D Equipment
Pipeline Safety	**$15,000**	**$15,000**				
Safety						
Liquefied Natural Gas (LNG)	2,500	2,500				
Underground Natural Gas Storage (UNGS) Safety Research	3,000	3,000				
Pipeline Anomaly Detection/ Characterization	1,500	1,500				
Pipeline Leak Detection	2,500	2,500				
Pipeline Threat Prevention	1,500	1,500				
Repair/Rehabilitation	1,500	1,500				
Competitive Academic Agreement Program*	-	-				
Climate Change Solutions/Hydrogen	2,500	2,500				
Infrastructure						
Pipeline Transportation Technology Center (TTC) Research**	-	-				
Hazardous Materials Safety	**$7,570**	**$7,570**				
Safety						
Risk Management	1,500	1,500				
Technical Analysis	1,000	1,000				
Package Integrity	2,500	2,500				
Innovation						
Emerging Technologies	2,570	2,570				
Administrative Expenses	**$2,209**					
Pipeline Safety	1,363					
Hazardous Materials Safety	846					
Total	**$24,779**					

*The Competitive Academic Agreement Program (CAAP) is a sub-program that funds research through universities in the safety areas listed in the table. The 2020 Protecting Our Infrastructure of Pipelines and Enhancing Safety (PIPES) Act requires a 20% cost share from non-federal sources for university research projects. Historically, PHMSA has awarded $2.0 million for CAAP projects annually but may choose to award in excess of $2.0 million in future years.

**As directed by Section 105 of the 2020 PIPES Act, PHMSA is currently conducting a study to determine the need for a national pipeline safety research and testing facility.

Table 2 - FY 2023 RD&T Program Budget Request by DOT Strategic Goal

DOT STRATEGIC GOALS							
ACCOUNT/ PROGRAM	FY 2023 President's Budget Request* ($000)	Safety ($000)	Economic Strength and Global Competit-iveness ($000)	Equity ($000)	Climate and Sustainability ($000)	Trans-forma-tion ($000)	Organiza-tional Excellence ($000)
Pipeline Safety	**$15,000**	**$15,000**					
Safety							
Liquefied Natural Gas	**2,500**	**2,500**					
Underground Natural Gas (UNGS) Safety Research	**3,000**	**3,000**					
Pipeline Anomaly Detection/ Characterization	**1,500**	**1,500**					
Pipeline Leak Detection	**2,500**	**2,500**					
Pipeline Threat Prevention	**1,500**	**1,500**					
Repair/ Rehabilitation	**1,500**	**1,500**					
Climate Change Solutions/ Hydrogen	**2,500**	**2,500**					
Infrastructure							
Pipeline Transportation Technology Center (TTC) Research**	**-**	**-**					
Hazardous Materials Safety	**$7,570**	**$7,570**					
Safety							

Risk Management	**1,500**	**1,500**					
Technical Analysis	**1,000**	**1,000**					
Package Integrity	**2,500**	**2,500**					
Innovation							
Emerging Technologies	**2,570**	**2,570**					
Administrative Expenses							
Pipeline Safety	**1,363**	**1,363**					
Hazardous Materials Safety	**846**	**846**					
Total	**$24,779**	**$24,779**					

The AMRP reflects funding as found in the FY 2023 President's budget request per 49 U.S.C. Chapter 65 Sec. 6501 Research Planning. The FY 2023 enacted numbers will be posted as part of the FY2024 President's budget request.

Chapter 1 – FY 2023 RD&T Programs

Pipeline Safety Research Program

$16,363,000

Program Description:

PHMSA's OPS RD&T Fiscal Year 2023 initiatives will continue to address ongoing safety and environmental risks and challenges while focusing specifically on transporting new energy products. New RD&T will also be required to transition to new energy sources that reduce greenhouse gas (GHG) emissions and transportation-related pollution. This process will include investments in research on hydrogen, carbon dioxide, and biofuels to ensure safe and effective regulation of the transport of new energy products—particularly as volumes scale up.

America's pipeline infrastructure spans more than 3.3 million miles, transporting nearly all the natural gas and about two-thirds of the liquid petroleum energy products consumed domestically. Research and development therefore provide critical solutions to ongoing and unexpected challenges.

In FY 2023, OPS' Pipeline Safety Research Program (PSRP) will continue to pursue its RD&T goals through four sub-programs: the Competitive Academic Agreement Program (CAAP), the Pipeline Core Research Program (Core), Small Business Innovative Research (SBIR), and Inter-Agency Agreements (IAAs). The PSRP is executed through competitive awards, cost-sharing agreements, grants, and IAAs. The sub-programs address different research requirements and are designed to develop concepts from their initial stages to industry or government adoption.

Major Program Objectives:

In FY 2023, the PSRP will remain focused on improving pipeline safety through research that provides engineering solutions, applications, and recommendations. The PSRP achieves its goals through Core program demonstrations, deployments, and commercialization; research partnerships with universities through CAAP; small business-focused innovation; and expertise from federal agencies and national labs through IAAs. The PSRP's main objectives are to:

- Help advance a safe and reliable pipeline transportation system for the American public by providing the scientific and engineering basis for improved industry standards and rulemaking;
- Promote emerging technologies for the pipeline industry implementation; and
- Identify and address pipeline safety challenges and research gaps and invest in research projects that address the Department's FY 2022 through FY 2026 strategic goals.

The PSRP achieves its objectives by establishing public-private RD&T partnerships with pipeline stakeholders. In addition, PHMSA sponsors RD&T projects focused on providing near-term solutions that will improve safety, reduce negative environmental impacts, and enhance the reliability of the Nation's pipeline transportation system. PHMSA avoids unnecessary research duplication through extensive public outreach, working closely with interagency partners from federal agencies, private research consortiums, academia, public advocacy groups, and other pipeline stakeholders. Together, these efforts aim to fund and share the cost of critical research to

develop new technologies, products, and knowledge while promoting stakeholder engagement and transparency.

PHMSA uses its own pipeline data and the information gained from Pipeline RD&T public forums to establish future fiscal year research funding agendas and solicitations. From November 30 to December 2, 2021, the PSRP hosted a virtual public meeting and forum to develop its research agenda and identify research gaps and topics for research in FY 2022 and FY 2023 to address DOT's strategic goals on *Safety* and *Climate and Sustainability* solutions. Over 300 participants attended the forum, including participants from Canada and the United Kingdom, and more than 60 presentations were given over three days.

The public meeting and forum helped identify over 25 research gaps on repair, rehabilitation, or replacement of leak prone, legacy cast iron pipelines; integrity of underground fuel storage, including hydrogen; utilization of inspection tools and network components on hydrogen pipeline facilities; integrity management of natural gas and hazardous liquid pipelines to include carbon dioxide lines; and methane mitigation from pipeline infrastructure. PHMSA reviewed these gaps and prioritized them for research in FY 2022 and FY 2023. The PSRP's planned investments in FY 2022 and 2023 will be based on received proposals and budget funding.

Anticipated Program Activities:

Research activities lead to the development of new or improved tools and technology to aid in the prevention and reduction of pipeline failures, damage, or incidents. Research investments also assist with the early identification of pipeline defects (before they lead to catastrophic ruptures) and the identification of issues related to the transportation of alternative fuels which may be used to reduce GHG emissions. Investments in these areas are aimed at preventing or lessening the release of hazardous materials into the environment. The PSRP is designed to be a collaborative program with stakeholders. Research funding is derived from pipeline operators through user fee assessments and from Oil Spill Liability Trust Fund contributions.

A comprehensive research strategy is developed systematically through RD&T forums, research gap ideas submitted by stakeholders, PHMSA initiatives, and collaborative partnerships with government and non-governmental organizations. OPS coordinates and collaborates on R&D topics through workgroups, conferences, and meetings with international partners and other federal and state agencies.

PHMSA will continue building research partnerships with universities, industry, and safety organizations that specialize in bringing safety technology to the market. An important programmatic component is PHMSA's funding of cooperative research projects through the CAAP with colleges and universities, which spurs innovation by enabling academic research. The CAAP is focused on theoretical and high-risk projects that have high promise of success to a wide range of pipeline safety challenges. Promising CAAP theoretical research results may be handed-off to the Core program for further development. CAAP also exposes students to both the pipeline industry and common pipeline safety challenges to show them how highly valued and needed their engineering and technical disciplines are in the pipeline field.

PHMSA will ensure CAAP becomes more inclusive by expanding outreach communication of funding opportunities and by ensuring all higher education institutions, including minority serving institutions (MSIs), such as Historically Black Colleges and Universities (HBCUs), Hispanic-Serving Institutions (HSIs), and Asian-American, Native American, and Pacific Island-Serving Institutions

(AANAPISIs) are notified of opportunities. On February 28, 2022, PHMSA issued its FY 2022 Notice of Funding Opportunity (NOFO) for the CAAP through the Grants.gov webpage: (https://www.grants.gov/web/grants/search-grants.html?keywords=Competitive%20Academic%20Agreement%20Program). PHMSA strongly encouraged universities to partner with MSIs in their grant proposals. PHMSA will continue to plan, assess, and execute strategies to increase research partnerships and collaboration with MSIs; increase awareness, capacity, and interest in pipeline safety research and careers; and introduce science, technology, engineering, and math (STEM) curricula and learning through CAAP research partnerships. In March 2022, PHMSA conducted two informational sessions with HBCUs and HSIs on the CAAP in order to encourage proposals for the FY 2022 CAAP NOFO.

For FY 2023, PHMSA plans to invest in the following pipeline safety focus areas:

Liquefied Natural Gas (LNG) Safety

The recent growth in the production and export of LNG has required PHMSA to provide clear regulatory guidance within the changing energy landscape. In addition, this has resulted in PHMSA initiating updates to its regulations for LNG facilities to address the mandates in the Protecting Our Infrastructure of Pipelines and Enhancing Safety (PIPES) Acts of 2016 and 2020 (Pub. L. 114-183 and Pub. L. 116-260, Division R). In addition, PHMSA will host an LNG R&D Public Meeting and Forum on November 15 and 16, 2022 with interactive working groups to assist PHMSA in developing upcoming research topics for funding consideration. The meeting will also include panel discussions in a general session among government, industry, research consortiums, and environmental advocacy stakeholders on the current state of the LNG industry, LNG infrastructure safety impacts, and LNG R&D activities. LNG research activities will address safety system testing, hazard mitigation models, and emerging technologies. The close coordination with LNG sector stakeholders will seek research solutions to address performance-based risk reduction at every type of LNG facility during site location, design, construction, operations, maintenance, and fire protection activities.

Underground Natural Gas Storage (UNGS) Facilities Safety

In October of 2015, a containment failure of stored natural gas from Aliso Canyon's Gas Storage Field resulted in an atmospheric release of 97,100 metric tons of methane (https://www.energy.gov/sites/prod/files/2016/10/f33/Ensuring%20Safe%20and%20Reliable%20Underground%20Natural%20Gas%20Storage%20-%20Final%20Report.pdf). This event prompted Congress to provide PHMSA with significant new statutory authorities to regulate underground natural gas storage. In 2018, PHMSA began funding research and building a portfolio of solutions to support the development of integrity management programs applicable to more than 17,000 wells associated with UNGS facilities in the United States. PHMSA will pursue additional Underground Natural Gas Storage (UNGS) research gaps in FY 2023 for risk assessments, well casing integrity investigations, subsurface safety valve testing, subsurface and facility-level equipment analysis, and knowledge generation on maintenance practices for UNGS wells. Furthermore, PHMSA will use lessons learned from facility inspections and audits conducted over the past few years to identify research gaps in UNGS.

Pipeline Anomaly Detection/Characterization

The detection and characterization of anomalies in pipeline systems require solutions that integrate people, processes, and technology into a comprehensive program. Detection capability must progress past simple corrosion to complex anomalies involving a mixture of dents, gouges, and corrosion. Incident data by cause continues to show corrosion as a leading cause of pipeline incidents. Therefore, corrosion as a threat will remain a focus of pipeline safety research investments. Research will develop new or improved tools, technology, and/or assessment processes to identify and locate critical pipeline defects and to improve the capability to characterize the severity of defects. This will support further research into detection and characterization solutions and develop technology and models that can improve the management of pipeline integrity threats.

Pipeline Leak Detection

Leak detection continues to present a challenge. Based on data from the 2022 Environmental Protection Agency (EPA) Inventory of U.S. Greenhouse Gas Emissions and Sinks (GHGI), natural gas transmission and distribution pipeline systems accounted for 28 percent of total U.S. methane emissions while LNG and UNGS facilities accounted for another 5 percent, which combines to comprise approximately one-third of total U.S. methane emissions from natural gas systems (2022 EPA GHGI https://www.epa.gov/system/files/documents/2022-04/us-ghg-inventory-2022-main-text.pdf Table 3-69 and annex 3.6, table 3.6-1).

In May 2021, PHMSA hosted a public meeting, which focused on pipeline leak detection and leak repair (https://primis.phmsa.dot.gov/meetings/MtgHome.mtg?mtg=152). Several technology providers participated and presented on advanced leak detection technologies. The anticipated goals of pipeline leak detection and repair research strongly support efforts to abate fugitive and operational methane releases. Input received from the public meeting, which included industry, government agencies, public advocacy groups, and concerned citizens, helped drive the specific research strategy funded in FY 2022 and will help guide research in FY 2023.

The PSRP expects to fund future research focused on operational and maintenance functions that cause the release of methane including:

- Development of new or improved tools and/or technology to prevent or reduce damage to pipelines, thereby preventing or mitigating releases into the environment;
- Further development and prove-out of continuous leak detection monitoring and identification systems for both gas and hazardous liquid pipelines;
- Development of sensing equipment to better detect, pinpoint, and prioritize small leaks (i.e., light detection and ranging (LIDAR) technology that can simultaneously focus on leak detection and pinpointing leak location); and
- Further development of economical leak detection systems for home monitoring of gas leaks, to reduce the device cost and to prioritize identification of ideal device placement within a home.

In FY 2023, PHMSA expects to address gaps in methane detection, concentration measurement, and flow rate estimation that are not part of FY 2022 methane leak detection research.

Pipeline Threat Prevention

As damage to pipelines by excavation and other outside forces continued to be a leading cause of pipeline failures (https://www.phmsa.dot.gov/data-and-statistics/pipeline/national-pipeline-performance-measures), preventing or reducing damage would dramatically improve pipeline safety and reduce methane emissions. PHMSA's research will help develop new or improved tools and technology to aid in the prevention and reduction of damage to pipelines, thereby enhancing safety and preventing or reducing releases into the environment. The PSRP will focus on locating subsurface utilities, applications for new failure-prevention machine learning methodologies, investigations into corrosion prevention techniques, and risk assessment modeling that addresses and/or remediates pipeline failure from these threats.

Repair/Rehabilitation

As damaged coatings and corrosion are major problems for pipelines, reliable methods of repairing pipelines to bring the systems back online are critical to safety. This focus area will concentrate on enhanced repair materials, techniques, processes, tools, and/or technology that support this objective. Research priorities may be identified to further support PHMSA efforts to help repair or replace 1,000 miles of aging, leak-prone, municipality and community-owned natural gas distribution pipeline infrastructure, supported by the Natural Gas Distribution Infrastructure Safety and Modernization Grant Program. The degrading nature of iron alloys, the age of the pipelines, and weak pipe joint designs will receive higher focus since these areas increase the risk of accidents and climate damaging methane emissions.

Climate Change Solutions/Hydrogen

The 2022 EPA GHGI data reports that natural gas systems accounted for 23 percent of total U.S. methane emissions in 2020. Transmission and storage (e.g., LNG and UNGS) facilities accounted for 24.6 percent of methane emissions from natural gas systems, gathering and boosting accounted for 22.7 percent, while distribution accounted for 8.4 percent. (https://www.epa.gov/system/files/documents/2022-04/us-ghg-inventory-2022-main-text.pdf ; Table 3-69).

Significant research investments at the federal and international level have been conducted on alternative renewable fuels such as hydrogen and/or hydrogen blends. PHMSA will address climate change by funding research projects that identify methods to reduce methane emissions on its regulated infrastructure, which will be done in coordination with its stakeholders and interagency partners. PHMSA plans to identify research gaps for hydrogen gas and/or various hydrogen blends in natural gas pipeline facilities. These include gas transmission or gas distribution systems, compressor stations, and gas storage facilities that reflect current projections for future pipeline systems and storage use. Furthermore, PHMSA plans to include a recommended prioritization of RD&T topic areas based on future usage projections.

Potential Program Outputs, Outcomes, and Impacts:

Research investments into pipeline-, LNG-, or UNGS-related challenges may result in published analytical outcomes, small-scale tests, and in some cases, full-scale demonstration projects that lead to new technology and scientific methods that improve pipeline safety. The results from each completed project are provided in final reports shared publicly on the PHMSA website and/or the

National Transportation Library. Researchers are required to disseminate their findings through presentations and publications at conferences or in peer-reviewed journals. Completed technology development projects may result in new patents or products for commercialized adoption. PHMSA plans to continue tracking each project's performance using metrics to monitor the progress of the research and the readiness of the technology for commercial or government adoption.

The PSRP has specific annual performance goals that support the priorities and objectives of the Department and PHMSA. These performance goals demonstrate the program's outputs, outcomes, and impacts across multiple research areas as described below in support of PHMSA's safety mission and the Department's strategic goals.

Liquefied Natural Gas Safety

PHMSA will continue to invest in LNG safety research to address the safety risks and operational challenges from LNG facilities, as well as foster development of new technologies and alternative designs for LNG storage and piping systems. As an example, there are currently no suitable industry standards that identify best practices or establish minimum acceptable inspection requirements for cryogenic storage tanks. Research outputs will yield recommendations on optimal inspection intervals and identify best practices to improve the inspection and testing of aboveground cryogenic LNG storage tanks. Outcomes from the research will lead to changes to federal regulations or industry standards, providing immediate benefit in terms of inspection standardization for LNG tanks to limit operational safety risks to employees and the public to acceptable levels. The impact of LNG research will provide a consistent and systematic methodology for improving the safety and integrity of LNG storage tanks.

Underground Natural Gas Storage Facility Safety

PHMSA will continue research to improve the safety of UNGS facilities over their full life cycle with a focus on design and reliability improvements to storage well equipment and maintenance practices. Research outputs from UNGS projects will provide reliability-based methodologies focused on well integrity management and corrosion protection practices while evaluating the effectiveness of real-time, continuous pressure monitoring systems for well surveillance and leak monitoring. PHMSA will consider incorporating research project outcomes into industry standards or best practices as minimum requirements and/or guidance for storage well casing integrity management. Furthermore, the research outcomes will provide operators with improved efficiency in managing casing corrosion, thereby potentially reducing delayed maintenance-driven well casing incidents. The impacts from UNGS research results will support new policy development on the safe operation of these facilities and reduce uncontrolled releases of gas into the atmosphere.

Pipeline Anomaly Detection/Characterization

PHMSA will continue to fund research to improve pipeline anomaly detection and characterization in steel and non-metallic or composite pipes. Research outputs in this area are designed to identify critical defects or anomalies within pipelines and provide PHMSA and pipeline operators with effective instrumentation and methodologies to find, assess, and evaluate manufacturing defects and in-service anomalies in pipe. Research outcomes will better inform PHMSA and pipeline operators to make integrity management decisions on steel and composite pipe systems to support safer operations and aid in determining a pipeline's fitness for service. Impacts from the research results will increase stakeholder confidence in pipeline technologies and the accuracy of improved

decision-making tools for integrity management. Furthermore, the research impacts will provide pipeline operators with effective instrumentation for detection, allowing for accurate remediation measures that reduce the likelihood of pipeline failures harming the public or environment.

Pipeline Leak Detection

PHMSA will continue investing in research projects to develop new or improved tools and technology solutions to locate, quantify, and repair liquid or natural gas pipeline leaks. Project outputs will develop, test, and deploy advanced leak detection platforms (ground-based, aerial, and satellite) and protocols under real-time field conditions to provide pipeline operators with critical knowledge on gas behavior and real-time data to help locate and quantify natural gas leaks. Research outcomes will provide the ability to quantify below ground leaks utilizing real-time data, which can reduce the risk of an incident caused by migrating gas to a residence or a prolonged release of methane into the environment. Impacts from the research findings will lead to further development of advanced leak detection monitoring, identification, and measurement systems for gas and hazardous liquid pipelines. This research will enable operators to expeditiously repair leaks thereby limiting the duration of methane emissions. Ultimately this safety improvement will also help to advance the Administration's strategic goal to tackle climate change by lowering the United States' cumulative methane emissions.

Pipeline Threat Prevention

Excavation damage and vehicular damage to pipelines continue to be the cause of serious and injury causing pipeline incidents. PHMSA will continue to invest in research to prevent pipeline threats and damage. Research outputs in this focus area will refine tools to develop sensing platforms to help operators map existing pipelines, make existing unlocatable plastic pipes locatable in advance of planned excavations, develop markers to locate new plastic pipes without the need for a separate tracer wire, or alert operators of possible excavation damage to pipelines. Research outcomes will allow operators to utilize technologies to mitigate excavation pipeline damage and allow operators to quickly detect and respond to damages and leaks to the pipeline system. Impacts from the research findings will help improve safety by developing better methods to detect underground pipelines and by helping to prevent excavation damage to buried pipelines. This will ensure an effective, efficient, and reliable underground utility network and reduce GHG emissions caused by excavation damage.

Repair/Rehabilitation

PHMSA will continue to invest in improving anomaly repair and pipe remediation and rehabilitation. Research outputs will provide reliable methods to repair damaged coatings and corrosion damage—a major cause of pipeline incidents, as well as develop testing protocols needed when using composite materials—which are the most common materials used for pipeline repairs. Research outcomes will provide the pipeline industry with validated and safe solutions to rapidly repair and return pipelines to service, reducing economic losses and customer inconvenience. Impacts from these research investments would advance technological solutions and have longstanding impacts on 1) safety, with the repair of aging pipelines; 2) equity, with the provision of better service to often underserved communities; and 3) climate change solutions, with pipeline rehabilitation or new pipeline installation that will minimize methane emissions.

Climate Change Solutions/Hydrogen

PHMSA will continue to invest in research initiatives to promote the Administration's strategic goals related to climate change solutions and decarbonization. Research outputs would provide solutions to safely store hydrogen gas and/or hydrogen gas blended with natural gas in underground storage facilities, as well as determine practical methods to optimize or repurpose existing pipeline networks to safely transport pure hydrogen or hydrogen-blends. Additional research outputs would provide knowledge on the impact of hydrogen and hydrogen-blend concentrations on inline inspection tools to characterize the integrity of an operator's pipeline system. Research outcomes in this focus area will work to remove technical and safety barriers to transporting emerging fuels such as hydrogen by pipelines. Hydrogen can serve as a sustainable power-generating fuel and could reduce GHG emissions by blending hydrogen into natural gas pipelines. Impacts from research investments in this focus area would expand the development and safe transportation by pipeline of gaseous hydrogen and supercritical carbon dioxide. Both are integral to increase the production of green hydrogen, which is developed from renewable fuels, and blue hydrogen, where the climate impact is decreased through carbon dioxide capture and storage or utilization.

Potential Economic or Societal Impacts:

The pipeline infrastructure in the U.S. is the primary means of transporting natural gas and the majority of hazardous liquids from production basins and ports to areas of consumption. The importance of energy pipelines to the U.S. economy and our standard of living—as well as the risk it poses to health, safety, and the environment—requires that these assets be maintained safely and reliably and, where appropriate, transitioned or expanded to meet our energy demands while contributing to the mitigation of global climate change.

Pipelines cross through thousands of communities in every state. Congress has entrusted PHMSA to protect the safety of millions of Americans who live and work around pipelines. It is anticipated that continued R&D investments will have a positive impact on communities by improving pipeline safety and environmental protection. To that end, continued investments in pipeline safety research will provide PHMSA with science-based solutions and resources to support the safe delivery of energy and other products via the more than 3.3 million miles of pipelines. This will protect the environment, help reduce GHG emissions, promote economic growth, and create jobs. PHMSA anticipates that the combination of improving existing infrastructure and continuing groundbreaking, evidence-based R&D will transform the pipeline industry and modernize this mode of delivery. The goal of this transformation is to spur the pipeline industry to pursue operational excellence that enhances safety, environmental and climate change management, and reduces harmful community impacts from pipeline accidents.

Pipeline safety RD&T supports DOT's strategic goal of *Transformation* and engenders innovations for national, regional, and local pipeline operational safety and reliability improvements, including identification of the best technology for commercialization. This enhances the protection of people, property, and the environment from pipeline failures, while allowing for uninterrupted operation of the U.S. energy sector. PHMSA and nonprofit institutions of higher education recognize the role research plays in innovation.

The PSRP will continue to play a significant role in finding solutions to national, regional, and local pipeline operational safety, reliability, and environmental challenges. The outcomes from pipeline

safety R&D investments will assist pipeline operators with finding the most suitable technology to efficiently and effectively meet or exceed federal and state pipeline safety and integrity regulatory requirements. Knowledge-based research investments will strengthen critical industry consensus standards with the latest scientific information and data to support the safe design, construction, operation, maintenance, and repair of pipelines.

The PSRP will continue to conduct outreach that increases awareness of research funding opportunities and build research partnerships, specifically with MSIs. These efforts will help advance the strategic goal for *Equity*, as well as diversity and inclusion, while encouraging young professionals in under-represented communities to consider careers in the pipeline workforce. In support of the strategic goals for *Safety* and *Economic Strength and Global Competitiveness*, student involvement would cultivate new talent in all aspects of the pipeline sector to continue the safe and reliable delivery of energy to support our economy while protecting the environment. Further, the PSRP will continue to focus on funding research in support of the strategic goal for *Climate and Sustainability* to advance technological solutions to rehabilitate aging cast iron pipelines, which are prone to leaks and are mostly located in disadvantaged areas of older cities and towns.

Potential Progress Made Toward Achieving Strategic Goals:

PHMSA will continue to advance the safe transportation of energy and other hazardous materials essential to our daily lives by conducting research that aligns with the Department's strategic goals. Results of the research findings will continue to address both national and local challenges in urban and rural communities. The PSRP remains focused on systemic, performance-based approaches to ensure pipeline transportation safety, protect the environment, and ensure the cost effectiveness of alternative energy transportation.

PHMSA's safety mission is paramount, and its programs provide tangible safety and operational benefits to the American public. PHMSA has three primary means of improving pipeline safety: a regulatory program, which establishes a set of minimum safety regulations while allowing for the use of new and proven technology through a special permit process; an inspection and investigation program to determine compliance with the minimum regulations; and a research program that provides financial support to advance technology and knowledge transfer. By conducting research to reduce the frequency of pipeline failures and minimize releases, the R&D program supports the safety mission and addresses climate and sustainability strategic goals. The risks from pipeline failures and releases are disproportionately among older, legacy pipeline systems (concentrated in urban areas) or in previously unregulated rural areas where gathering lines are prevalent. Improvement of the performance and safety of these systems thus also supports equity goals in reducing risk.

Research results and outputs provide scientific and engineering support for PHMSA's safety activities and regulatory rulemaking efforts. They also increase PHMSA's knowledge on inspections and enforcement proceedings, as well as facilitate decision-making and supports regulatory reform and policies to improve pipeline safety and reduce GHG emissions. Specifically, PHMSA's research investments provided support on developing rulemaking criteria to address anomaly detection and characterization (corrosion, seam cracking and pipe body cracking, denting, and fatigue) and integrity management on pipe assessment/reassessment inspection intervals. Additionally, PHMSA's research investments have supported leak and rupture detection criteria on the performance standards described below for the Valve Rule.

The research outputs, outcomes, and impacts from PHMSA's investments are not always directly quantifiable; however, R&D plays a foundational role in addressing pipeline transportation challenges facing the United States by developing innovative solutions and ensuring that the best available science and technology are the basis for PHMSA's safety regulatory actions, enforcement, and programs. PHMSA's research investments have resulted in safety impacts through industry utilization and adoption of technology, and specifically 35 technology transfers have been commercialized. Additionally, PHMSA is making significant progress in supporting the Administration's efforts to minimize methane emissions from pipelines by upgrading and expanding federal pipeline safety regulation. Research results in the focus areas of LNG safety and pipeline leak detection will inform PHMSA in its proposed rulemaking initiatives in these areas. Specifically, PHMSA expects that the LNG Facilities Rule would strengthen standards for LNG facilities, to help prevent large scale incidents and releases from storage tanks, which are a major source of methane emissions. The proposed rule would seek to prevent large-scale incidents like the 2014 LNG incident in Plymouth, Washington, which emitted 3,246 metric tons of methane. It also would reduce the risk of low probability/high consequence incidents, such as an LNG storage tank failure. Such tanks can contain as much as 69,000 metric tons of methane. PHMSA targets publication of a proposed rulemaking in this proceeding in mid-2023. Additionally, the Gas Pipeline Leak Detection Rule would establish standards for leak detection technologies and practices and require repair of all leaks on gas pipeline facilities. PHMSA estimates that these amendments could reduce methane emissions by as much as 800,000 to 1.6 million metric tons of methane each year. PHMSA targets publication of a proposed rulemaking in this proceeding in early 2023.

An example of PHMSA-funded research that supported the Department's strategic goal of *Safety* included five research projects totaling $4.5 million in the area of anomaly characterization (dent evaluation criteria). The research projects included Mechanical Damage at Welds, Structural Significance of Mechanical Damage, Dent Fatigue Life Assessment, Full Scale Testing of Interactive Features, and Improving Models to Consider Complex Loadings, Operational Considerations, and Interactive Threats. These projects were used to help form PHMSA's technical basis for dent assessments in its pipeline safety rules, as well as for American Petroleum Institute's Recommended Practice (RP) 1183 – Assessment and Management of Dents in Pipelines, published in November 2020. RP 1183 presents guidance to pipeline operators for developing a dent assessment and management program and provides the information and methodology to make informed integrity management decisions regarding the management of dents on their systems.

Several of PHMSA's regulations issued since 2019 were supported by R&D investments in leak detection, pipeline anomaly assessments, threat prevention, and non-destructive examination tools to measure pipe strength. These rules included the Gas Transmission Rule, Hazardous Liquid Rule, Gas Gathering Rule, and Valve Rule.

Gas Transmission Rule – In support of the *Safety* and *Climate and Sustainability* goals, PHMSA's research contributed to the Gas Transmission Rule. ("Pipeline Safety: Safety of Gas Transmission Pipelines: MAOP Reconfirmation, Expansion of Assessment Requirements and Other Related Amendments", 84 FR 52180, October 1, 2019). The Gas Transmission Rule requires operators of gas transmission pipelines constructed before 1970 to determine the material strength of their pipelines by reconfirming the pipeline's maximum allowable operating pressure (MAOP) it can safely withstand. (See PHMSA R&D Report: ''Final Summary Report and Recommendations for the Comprehensive Study to Understand Longitudinal ERW Seam Failures—Phase 1'' (Task 4.5); https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=390). In addition, the rule updates reporting and records retention standards for gas transmission pipelines. The rule was the result of a tragic September 9, 2010, Pacific Gas and Electric (PG&E) incident in San Bruno, CA, which

resulted in the deaths of eight people, injured 51, destroyed 38 homes, and damaged another 70 homes (See PHMSA R&D Report: ''Final Summary Report and Recommendations for the Comprehensive Study to Understand Longitudinal ERW Seam Failures—Phase 1'' (Task 4.5)). The National Transportation Safety Board issued several recommendations to PHMSA and other entities because of the PG&E incident. The rule went into effect on July 1, 2020.

Hazardous Liquid Rule – Hazardous liquids pipelines transport crude oil, gasoline, butane, propane, carbon dioxide, and other hazardous liquids that provide crucial domestic and international energy supplies. Hazardous liquid pipelines consisted of approximately 229,308 miles in calendar year 2020. Ensuring their safe operation supports the strategic goal of global *Economic Competitiveness*. The Hazardous Liquid Rule *(*"Pipeline Safety: Safety of Hazardous Liquid Pipelines", 84 FR 52260, October 1, 2019*)* requires operators to use available data to identify pipeline safety threats (See PHMSA Research and Development Report: Comprehensive Study to Understand Longitudinal ERW Seam Research & Development study task reports: Battelle Final Reports ("Battelle's Experience with ERW and Flash Weld Seam Failures: Causes and Implications" - Task 1.4), Report No. 13-002 ("Models for Predicting Failure Stress Levels for Defects Affecting ERW and Flash-Welded Seams" – Subtask 2.4), Report No. 13-021 ("Predicting Times to Failure for ERW Seam Defects that Grow by Pressure-Cycle-Induced Fatigue" – Subtask 2.5), and "Final Summary Report and Recommendations for the Comprehensive Study to Understand Longitudinal ERW Seam Failures – Phase 1" – Task 4.5), which can be found online at: https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=390) and to have a system for detecting leaks on all non-gathering hazardous liquid pipelines. See PHMSA Report commissioned and developed by: Kiefner & Associates, Inc.: "Leak Detection Study," Final Report No. 12-173, DTPH56-11-D-000001, December 10, 2012, which can be found online at: https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/docs/technical-resources/pipeline/16691/leak-detection-study.pdf. In addition, the rule requires operators to inspect and repair damaged pipelines following an extreme weather event or natural disaster.

Gas Gathering Rule – In recent years, gathering lines with diameters, operating pressures, and associated risk factors similar to larger interstate transmission lines have become more common. Gas gathering lines typically transport natural gas from production facilities to interstate gas transmission pipelines. Historically, gathering lines have been lower-pressure, lower risk, smaller-diameter lines, typically situated in lesser-populated, rural areas. Under the Gas Gathering Rule *(*"Pipeline Safety: Safety of Gas Gathering Pipelines: Extension of Reporting Requirements, Regulation of Large, High-Pressure Lines, and Other Related Amendments", 86 FR 63266, November 15, 2021), over 400,000 miles of gas gathering pipelines will be subject to PHMSA reporting requirements with a subset, approximately 90,000 miles, that will be required to meet certain pipeline safety requirements, including for design, construction, corrosion control, damage prevention, and leak surveys. Gas gathering pipelines can be composed of steel, plastic, or composite materials. PHMSA R&D reports will be used to help in future rule implementation including the: "Assessment of Nondestructive Examination (NDE) and Condition Monitoring Technologies for Defect Detection in Non-Metallic Pipe", https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=952, as well as the report on "Feasibility of Using Alternative-Steel and Composite Material in Gas and Hazardous Liquid Pipeline Systems", https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=951. The rule went into effect on May 16, 2022.

Valve Rule – PHMSA seeks to reduce pipeline failures and leaks as much as possible, but occasional pipeline failures still occur. The Valve Rule ("Pipeline Safety: Amendments to Parts 192

and 195 to Require Valve Installation and Minimum Rupture Detection Standards", 87 FR 20940, April 8, 2022) addresses both *Safety and Climate and Sustainability* goals by seeking to minimize product releases once they occur. The Valve Rule amends U.S. pipeline safety regulations to expand the use of automatic and remotely controlled shut-off valves and to enhance rupture identification and response actions by operators for all new natural gas, hazardous liquid, and carbon dioxide pipelines. The Valve Rule will apply to most hazardous liquid/carbon dioxide, natural gas transmission, and some gas gathering pipelines that are 6-inches or greater in diameter. The valve rule requires operators to identify a pipeline rupture and close the rupture-mitigation valves to prevent or mitigate the public safety and environmental consequences of pipeline ruptures. PHMSA expects this rule will significantly reduce the impact of natural gas, carbon dioxide, and hazardous liquid pipeline incidents. In addressing the Department's *Climate and Sustainability* strategic goal, PHMSA estimates the faster response times can reduce emissions up to 40 percent or more for pipelines up to 30-inches in diameter, when compared to historical incidents where rupture isolation may have taken more than 90 minutes. The rule went into effect on October 5, 2022.

In sum, PHMSA expects the safety enhancements included in these rules to improve public safety; reduce threats to the environment including, but not limited to, reduction of GHG emissions released during ruptures of natural gas pipelines and leaks of hazardous liquid pipelines, supporting the strategic goal of *Climate and Sustainability*; and improve *Equity* by promoting environmental justice for minority populations, low-income populations, or other underserved and disadvantaged communities.

Continued pipeline safety research is necessary due to continued expansion and aging of existing pipelines across the U.S. PHMSA plans to continue research investments focused on corrosion, material failure, and equipment failure which cause 55 percent of all PHMSA-jurisdictional pipeline incidents. These efforts and others to consider operational releases will also focus on containment of GHGs (such as methane); pipeline transportation of alternative fuels, including hydrogen and carbon dioxide; and improved leak detection and quantification.

Collaboration Partners:

The PSRP RD&T collaboration efforts include both federal and non-federal partners. Historically, OPS has reached interagency agreements with the Departments of Energy, Interior, and Commerce to conduct materials research. OPS partners with academic institutions through its CAAP. Under CAAP, PHMSA funds 80 percent of basic RD&T costs, leaving 20 percent to be funded by university partners. PHMSA may fund up to 100 percent of RD&T costs related to regulatory analysis or other purely governmental purposes. These levels are specified in and mandated by Section 22 of the PIPES Act of 2020.

In FY 2021 and FY 2022, PHMSA participated in the following interagency hydrogen and carbon dioxide pipeline initiatives:

- U.S. Dept of Energy (DOE)
    - Hydrogen and Fuel Cell Technologies Office
        - DOE's National Hydrogen Strategy and Roadmap
        - Clean Hydrogen Joint Undertaking Expert Workshop on Environmental Impacts of Hydrogen
    - Fossil Energy & Carbon Management
        - Division of Methane Mitigation Technologies

    - Division of Carbon Transport and Storage
- U.S. Dept of Commerce/U.S.-India Strategic Partnership Forum
- National Association of Pipeline Safety Representatives
    - Distribution Team, Hydrogen/Biofuels Working Group

External Partners

PHMSA's research program partners with a wide range of external partners who share the same objectives in developing technology or generating and promoting new knowledge among decision makers to advance pipeline and hazardous materials safety. Collaborative forums with academia, departmental, and federal partners help identify pertinent technology and knowledge gaps.

In March 2019, PHMSA OPS released a *Special Notice for "Identifying Pipeline Safety Research Ideas"* in the beta.SAM.gov portal. The ongoing *Special Notice* invites any interested stakeholder to submit ideas for future research. This notice is open year-round and is revised as needed to reflect initiatives coming from PHMSA or the Administration. PHMSA launched this measure to widen the participation in formulating its future research strategy. A web-based portal was created to support and manage this action which can be found at https://primis.phmsa.dot.gov/rd/gapsuggestions.htm.

Partnerships with government organizations (GO) and non-government organizations (NGO) provide clear opportunities to leverage ongoing successes, cost-share on mutual safety challenges, and remove duplication. Throughout the year, PHMSA briefs the pipeline industry and public interest groups on the research program and consults with them on individual projects that are within their sphere of expertise. Research collaboration partners—both GOs and NGOs—who cost-share research with PHMSA include federal agencies, associations, regulatory entities, and industry.

Hazardous Materials Safety Research Program

$8,416,000

Program Description

Every day there are over 1.2 million shipments of hazardous materials and over 3.3 billion tons are shipped annually in the United States. These products are critical for America's manufacturing, powering and agriculture industries and are essential to our daily lives. Changes to the types of hazardous materials, quantities, packages, and methods of transportation continue to occur. Research therefore provides critical solutions to ongoing and unexpected challenges.

PHMSA's Hazardous Materials Research & Development, Analysis & Technical Assessment Program (HMR-DATA) Fiscal Year 2023 initiatives will research ways to reduce the risks associated with the transportation of hazardous materials and to identify and evaluate new technologies to facilitate the safe, secure, and efficient transportation of hazardous materials. These goals are supported through four core areas of research in FY 2023: Risk Management and Mitigation, Package Integrity, Emerging Technologies, and Technical Analysis to Aid Risk Assessments. Each core area is described below.

Risk Management and Mitigation: Researching risk reduction strategies to lower transportation-related injuries and fatalities, increase packaging and operational safety, and improve system reliability.

Packaging Integrity: Researching innovative, novel packaging materials and ways to improve current packaging design and integrity.

Emerging Technology: Researching emerging materials, processes, transport operations, energy products and packaging technologies to keep pace with an ever-evolving transportation system. This research will leverage new technology to reduce and mitigate risks of hazmat transportation systems.

Technical Analysis to Aid Risk Assessment: Researching evaluation methods for hazardous material transportation activities, events, and incidents. This type of research will aid in understanding packaging failures and hazmat anomalies.

In FY 2023, HMR-DATA will continue to pursue its goals through its research solicitation programs: Broad Agency Announcement (BAA), Small Business Innovative Research (SBIR), and Inter-Agency Agreements (IAAs). HMR-DATA also self-initiates research projects with academia and industry, these self-initiated research projects are from stakeholder input from our research forum as well as HMR-DATA subject matter experts. These research solicitations enable HMR-DATA to engage with a variety of stakeholders, including modal partners and small businesses. They are designed to take innovative research ideas and incorporate them into new technologies with an eye toward collecting data that enables needed regulatory changes.

Major Program Objectives

HMR-DATA will continue to focus on the safe transportation of energy products and other hazardous materials by identifying risk management and mitigation tools, improving packaging technologies and designs, and identifying and developing new and emerging transportation technologies through our research projects.

HMR-DATA's main objectives are to:

- Reduce the number of injury and fatality-related incidents that involve hazardous material transportation.
- Engage and collaborate with our modal partners on joint research projects and review studies.
- Promote emerging technologies and innovative risk mitigation techniques, with a focus on small businesses and universities.
- Identify and address the research gaps in transporting hazardous materials and support projects that will advance the Department's strategic goals.

The program achieves these objectives through partnerships with stakeholders, small businesses, and intergovernmental agreements to execute research projects. To develop research proposals into potential technology transfers or regulatory outcomes, we announce solicitations through the Small Business Innovation Research (SBIR) program, Broad Agency Announcements (BAA), and Inter-Agency Agreements (IAAs). HMR-DATA will continue to engage with existing partners at the Transportation Research Board, the Interagency Advanced Power Group, and Naval Research Laboratory and build new relationships with other federal partners.

Anticipated Program Activities

In FY 2023, HMR-DATA will work with our stakeholders and modal partners to continue its activities within its four research areas with a focus on lithium-ion batteries, equity, and emerging technology. In FY 2023, HMR-DATA will continue to carry out the following program activities:

Risk Management and Mitigation

Research in risk management and mitigation is essential to reduce the number of injury and fatality-related incidents that involve hazardous material transportation. HMR-DATA's objective is to reduce and prevent incidents with research projects that identify and analyze safety gaps with high-consequence materials and rapidly developing industries. Two such research areas are Liquefied Natural Gas (LNG) transport by rail and evaluation of modal choice and hazardous materials routing.

PHMSA will collaborate with Federal Railroad Administration (FRA) on research efforts on LNG by Rail to address input received from the National Academies of Science study

concerning LNG by rail. The study looked to evaluate the current safety and regulations regarding the transport of LNG in the DOT 113 rail cars. The biggest unanswered question is related to the safety of the cars in various accident situations. These questions are helping direct future planned research. The results of these new research efforts will assist PHMSA in making decisions on LNG transport by rail.

Modal choice and routing are crucial to minimizing risks related to hazardous material transportation. As the annual number of shipments of hazardous materials continues to rise, new risks will emerge; technological developments in materials or packaging may not be sufficient to address new risks. However, there is currently no publicly available tool that can be used to assess the relative risk of different modal options for transporting hazardous materials or to enable scenario exploration to evaluate low-risk transportation modes and routes. In FY 2023, HMR-DATA will work with the Volpe National Transportation Systems Center (Volpe Center) to add risk as an optimization factor to Volpe's existing Freight and Fuel Transportation Optimization Tool (FTOT). Adding risk as an optimization factor will give shippers and carriers another tool to help manage risk when transporting hazardous materials. For more information on FTOT please see the Volpe Center’s website.

Emerging Technology

The DOT FY 2022-26 strategic goals task Operating Administrations (OA) to "invest in purpose-driven research and innovation to meet the challenges of the present and modernize a future transportation system that serves everyone today and, in the decades, to come." HMR-DATA has a well-established history of researching emerging technologies. HMR-DATA will continue to support and pilot projects to analyze new materials for innovative packaging and other emerging technologies to aid in the transportation of hazardous materials. The program will work with small businesses through the SBIR program; the program is a two “Phase” project. During Phase I, the small business researches the feasibility of their technologies with the hope of being awarded Phase II, which allows the small business to take their proof of concept to build a physical prototype. In FY 22, the program started two new Phase I projects: monitoring cylinders using carbon nanomaterial sensing networks and a compact leak detector for autonomous vehicles.

Monitoring cylinders using carbon nanomaterial sensing networks aim to develop the capability to help detect any deficiencies in cylinders in real time. The long-term goal for this project is to have the capabilities to attach the nanomaterial sensing networks around other larger pressure vessels.

The second SBIR Phase I project is the compact leak detector for autonomous vehicles. The project's goal is to create a leak detector to be affixed to a commercial drone and be compatible with other autonomous vehicles. In the next phase, the small business plans to work with the air carriers to implement the system onto an autonomous cargo delivery drone.

In FY 23, in addition to innovative packaging and leak detection, HMR-DATA plans to solicit SBIR topics in other critical emerging technology areas such as machine learning/artificial intelligence, novel sensor technologies and processes to leverage the "Internet of Things."

Packaging Integrity

Packaging Integrity research studies help inform standards that ensure hazardous materials remain within original packaging during transportation. HMR-DATA continues to research different packaging solutions. The fiber-reinforced plastic (FRP) portable tank is an innovative packaging type. HMR-DATA is collaborating with the Volpe Center to test the integrity of this new packaging material to understand its performance in the U.S. transportation system. The planned research in FY 2023 will implement a test plan that the Volpe Center and PHMSA completed in the initial Phase of the FRP portable tank research project.

Package integrity research will also explore how hazardous materials packages can be safely reused and recycled to reduce emissions associated with the manufacture of new packages. This research includes identifying strategies for reducing per- and polyfluoroalkyl substances (PFAS) and other harmful materials. This research will also address how the research program can help reduce climate change impacts.

Technical Analysis to Aid Risk Assessment

The DOT Hazardous Material Incident Reporting Program collects information about a hazmat-related incident. HMR-DATA will use incident data, including root cause, pattern, and anomaly analyses, to inform its research agenda with the longer-term goals of developing safer and more efficient inspection, testing, classification, and certification methods.

To minimize safety risks, it is essential to understand where hazmat accidents occur relative to where they are typically transported. Adding a yearly hazmat packaging commodity survey to the existing U.S. Census Bureau Commodity Flow Survey has been an ongoing research project within the program. The yearly hazmat survey provides:

- More granular data on shipping performance.
- Packaging performance.
- Quantity.
- Mode of transportation for each of the different hazmat packaging types.

This detailed packaging survey helps PHMSA determine new packaging requirements or the need for potential rulemaking for packaging standards.

Lithium-ion batteries

Ensuring the safe transportation of lithium batteries continues to be a priority for HMR-DATA and PHMSA. Recently, PHMSA has observed a significant increase in lithium battery fires in transportation and storage incidental to movement. This trend is likely to continue, based on increased lithium battery shipments due to advancements in personal electronic devices, micro-mobility, and electric vehicles.

Research in the safe transportation of batteries has been an ongoing project area for HMR-DATA since FY 2019. This research will continue in FY 2023 as the electrification of our transportation system continues to grow. To address the increase in battery-related incidents, HMR-DATA will continue researching strategies for lithium-ion battery risk management and mitigation. Such strategies include end-of-life battery management, lithium-ion battery alternatives and state of charge evaluation techniques.

In particular, HMR-DATA will continue its research collaboration with the United States Naval Research Laboratory (NRL) to develop strategies for de-energizing end-of-life lithium-ion batteries such as pouch packs and 18650s. This project is multi-year and wrapping up its first year of the project. NRL has been evaluating saltwater solutions as a possible method to de-energize end-of-life batteries. In FY 23, NRL will look at cost-effective ways to de-energize end-of-life batteries at consumer collection points (e.g., Home Depot) and determine if other ideal solutions provide a maximum discharge rate without corroding the cell.

HMR-DATA's second project with NRL tests sodium-ion batteries as a potential alternative or complement to lithium-ion batteries. HMR-DATA wants to understand sodium-ion battery properties and whether they act like lithium-ion batteries. NRL procured two different types of sodium-ion batteries to test and conducted thermal stability testing. In the future, NRL will conduct nail-penetration testing and toxicity and relative concentrations of off-gases from the two sodium-ion battery types. Going into FY 23, the goal is for NRL to document the test findings and provide recommendations on how PHMSA might incorporate sodium-ion batteries into regulations.

On March 6, 2019, PHMSA published an interim final rule, "Transportation of Lithium Batteries" (HM-224 I). This rule requires batteries from manufacturers to have a state of charge (SOC) of 30 percent if transported via aircraft. However, we do not know of any current methods to confirm state of charge. In FY 23, HMR-DATA will address this challenge in collaboration with the Federal Aviation Administration (FAA). The research will evaluate the state of charge of new 18650 and pouch cell lithium-ion batteries shipped by air. The evaluation of 30 percent SOC in lithium-ion batteries will determine if these batteries shipped by air are at or below 30 percent SOC. The research will also identify a potential method to determine if pouch packs and 18560 batteries are at 30 percent SOC and gather knowledge on the physical limits of lithium-ion batteries above 30 percent SOC before thermal runaway occurs.

HMR-DATA continues to plan and conduct packaging research to address the risk and issues with batteries that go into thermal runaway while they are in their packaging. Notably, HMR-DATA's first ever successfully funded SBIR Phase II project is developing an

intelligent packaging solution aiming to predict and contain the hazardous effects from batteries in a thermal runaway. Under Phase II, the small business will continue developing and refining intelligent packaging. HMR-DATA is planning to solicit proposals in FY 2023 for thermal insulating materials that meet the criteria to mitigate thermal runaway of medium format batteries.

Equity Measurement

One of the Department's goals is to reduce inequities across our transportation systems and the communities they affect. HMR-DATA, in collaboration with the Volpe Center, has developed an equity measurement case study that will look at PHMSA's activities. Volpe will use a logic model framework to analyze the equity implications for various HMR-DATA program activities. The models will trace inputs and activities to outputs, outcomes, and impacts. The program activities will be assessed to determine the degree to which outcomes and impacts are equitable, mindful of the possibility of existing inequities. Case studies will then be developed to demonstrate the practical application of the measures and metrics to PHMSA activities. The project will begin by researching many of PHMSA's activities and follow with development of a method for selecting the activities based on the importance of the particular activity for equity issues, the feasibility of developing specific equity measures; and the difficulty in implementing the measure.

The research will include identifying and reviewing data needed to understand PHMSA activities, evaluate baseline conditions, or develop equity measures and metrics. The resulting analysis will include actionable measures and metrics that can be applied to existing risk models or other decision-making activities. The analysis may also result in guidance and recommendations for data collection efforts to establish and implement proposed equity measures. This study will communicate information gaps but attempt to leverage the available information to provide practical and actionable measures and metrics.

Potential Program Outputs, Outcomes, and Impacts

Risk Management and Mitigation

The program will continue to invest in research to manage and mitigate the risks associated with transporting hazardous materials. For example, PHMSA will collaborate with FRA in FY 2023 on ongoing research to evaluate the risks and consequences of LNG by rail presented to public health, safety, and the environment. Research efforts include worst-case scenario models, modal conversions, train energy dynamics, and loading/unloading safety practices. The outcome of these research efforts on the risk and consequences of LNG by rail will assist PHMSA in updating the LNG companion rulemaking and help inform the regulation of LNG by rail.

Emerging Technology

The program has an immense interest in emerging technology. Partnering with small businesses has enabled the program to discover innovative and emerging technologies that

could assist in safely transporting hazardous materials. Through the SBIR program, HMR-DATA has seen many innovative projects. For example, several small businesses are currently researching the feasibility of cylinders using carbon nanomaterial sensing networks and leak detectors for autonomous vehicles. These feasibility studies will determine if there is a pathway to proof of concept. The outcome of these projects would be a physical technology for hazardous material users to use when transporting hazardous materials. The impact of emerging technology on the hazardous material transportation system would update safety standards and find non-traditional ways of safely transporting hazardous materials.

Packaging Integrity

Hazmat packaging failures pose a significant threat to public safety and continue to occur within our transportation system. Our research investigates ways to reduce packaging failures through non-traditional materials like fiber-reinforced plastics on portable tanks and cargo tank motor vehicles. These lightweight materials would reduce the overall weight of the packaging while keeping the hazardous material inside the packaging. The outcome of these research projects would be new packaging, promoting a safer transportation system, and enhancing economic strength and global competitiveness. The impact of the research should improve the safety of all hazmat transportation while informing future rulemaking

Technical Analysis to Aid Risk Assessment

Using incident data and identifying root causes, patterns, and anomalies to inform HMR-DATA's research agenda would set longer-term goals of developing safer and more efficient inspection, testing, classification, and certification methods. The output of the annual hazardous material commodity flow survey would allow timely data on the current shipping landscape of hazardous materials. The outcomes of this survey may also help inform the buildout of frameworks using geo-spatial mapping to determine the risk of hazmat incidents during the in-transit transportation phase. The impact of the commodity flow survey could establish frameworks that could help predict where routing might have a higher or lower risk to the public.

Lithium-ion batteries

As consumer demand for personal devices continues to grow, so does the use of lithium-ion batteries. HMR-DATA and PHMSA have recognized the need to continue researching lithium-ion batteries, their chemistry, their impact on transportation systems, and risk. The outputs include continued research collaboration projects with the Naval Research Laboratory (NRL), Federal Aviation Administration (FAA), Environmental Protection Agency (EPA), and Department of Energy (DOE) to study lithium-ion battery properties. The outcome of these collaborative research efforts would be better informing the lithium-ion battery users throughout the entire supply chain and reducing the risk these batteries pose. The additional outcome would be identifying other battery chemistries, such as sodium-ion batteries. The impact would provide more information and guidelines on how hazardous material carriers and shippers should handle, dispose of, and ship this kind of battery.

Equity Measurement
HMR-DATA will execute research to identify ways to reduce inequities across our transportation systems and the communities they affect. With the ongoing research efforts between HMR-DATA and the Volpe Center, the outputs would be identifying equity metrics and measurements that will support PHMSA's activities. While the outputs will identify the level at which PHMSA's activities are equitable, the outcome of this research will empower PHMSA with the necessary tools for program managers to adjust their programs and activities accordingly to ensure each activity is equitable. The impact of this research will ensure that any of PHMSA's internal or external activities will be fair and close the inequality gaps affecting our underserved communities and our transportation systems.

Potential Economic or Societal Impacts:

Hazardous materials are transported through thousands of communities in every state, every day. Congress has entrusted PHMSA to protect the safety of millions of Americans who live and work around hazardous materials transportation routes. It is anticipated that continued R&D investments will have a positive impact on communities and improve hazardous materials safety and environmental protection. To that end, continued investments in hazardous materials safety research will provide PHMSA with science-based solutions and resources to support the safe delivery of hazardous materials via highway, rail, vessel, or air. This will protect the environment, help reduce GHG emissions, promote economic growth, and create jobs. PHMSA anticipates that the combination of improving existing hazardous materials packages and continuing exploration of new materials and solutions through groundbreaking, evidence-based R&D will transform the hazardous materials industry and make hazardous materials transportation even safer. PHMSA believes this will enable a transformation within the hazardous materials industry that further enhances safety, environmental and climate change management, and reduces harmful community impacts from hazardous materials accidents.

HMR-DATA supports DOT's strategic goal of transformation and engenders innovations ever-improving hazardous materials safety and reliability, including identification of the best technology for commercialization. This enhances the protection of people, property, and the environment from hazardous materials incidents, while allowing for reliable transportation for industries relying on hazardous materials to manufacture goods.

HMR-DATA will continue to conduct outreach that increases awareness of research funding opportunities and build research partnerships. These efforts will help advance the strategic goal for Equity, as we evaluate PHMSA activities and develop tools and metrics to ensure PHMSA's activities are equitable. In support of the strategic goals for Safety and Economic Strength and Global Competitiveness, HMR-DATA will continue to promote topics under the SBIR program, work with our federal partners, and seek input from our stakeholders to address the research gaps within the hazardous material transportation community.

Potential Progress Made Toward Achieving Strategic Goals

HMR-DATA continues to make progress on research that aligns with the Department's strategic goals. *Safety* is the first and foremost goal, reducing the number of incidents involving fatalities and significant injuries from the transportation of hazardous materials. The program focus areas that address Safety include risk management and mitigation, technical aid to risk management, and packaging integrity. While the primary goal for the program is always *Safety*, HMR-DATA research activities also further departmental goals related to *Equity, Climate and Sustainability, Economic Strength and Global Competitiveness, and Innovation*.

As HMR-DATA continues to work with the Volpe Center on its equity measurement study, PHMSA will be able to apply equity measures and metrics to its activities. These tools will allow PHMSA program managers to test scenarios and outcomes, and program managers will be able to adjust their programs and activities accordingly.

Risk factors in choosing routes need to include the identification of routes that involve highly vulnerable areas and underserved communities. In FY 23, HMR-DATA will start to work with the Volpe Center to evaluate adding a risk assessment to Volpe's existing Freight and Fuel Optimization Tool when transporting hazardous materials. This is another tool that can be used to identify inequalities in hazardous materials routes.

To address *Climate and Sustainability* and air pollution/greenhouse gas emissions from transportation operations, the program will set a target to use 25 percent of its funds towards new sustainable energy sources. Through our research forum and other solicitations, the program will collect information on efforts pertaining to climate and generate topics for the next Broad Agency Announcement. Other potential planned research includes looking at reusing and processing plastics that carry hazmat into new plastic packaging for hazmat. This type of research would also assist in reducing carbon emissions and the number of used plastic packaging.

One objective outlined in the *Economic Strength and Global Competitiveness department* goal is to "improve incident and emergency response and recovery practices to reduce system disruption."

HMR-DATA has an ongoing research project with the Volpe Center to evaluate costs of delay in freight transportation incidents by rail and to develop methods to estimate and monetize delay costs specific to rail transportation incidents involving hazardous materials releases. Combining the results from this study with previous estimates of other costs (property damage costs, environmental remediation costs, value of lost lives and injuries, emergency response costs) will produce a more comprehensive view of the total costs associated with transportation incidents of hazardous materials by rail.

The research results will support and improve PHMSA's economic analyses of standards, regulations, and other policies that address safety issues.

Collaboration Partners

Hazardous materials are transported daily by all modes of transportation (air, rail, highway, and water), so HMR-DATA needs to take every opportunity to collaborate with our modal partners on joint work.

HMR-DATA has collaborated with the Federal Railroad Administration (FRA) on several current and past projects related to impact and fire testing on tank cars and portable tanks as well as the use of the Train Energy and Dynamics Simulator (TEDS) for different rail routes.

The program continues to partner with the Volpe Center on several projects, including the equity measurement case study, fiber-reinforced plastic portable tanks, costs of delay in freight transportation incidents by rail, and the Freight and Fuel Optimization Tool.

In FY 23, the program hopes to partner with the Federal Aviation Administration (FAA) on several lithium-ion battery projects, reviewing SOC on batteries shipped by air, and methods for classifying damaged, defected, and recycled batteries.

Like PHMSA, HMR-DATA and its projects also touch every aspect of air, rail, highway, and water. The program is always finding ways to collaborate with our federal partners.

External Partners

HMR-DATA collaborates with a broad range of external stakeholders and partners who want to engage and solve the same objectives HMR-DATA has identified. HMR-DATA collaborates with academia; small businesses; and other federal partners such as the National Labs, Department of Energy, the National Institute of Standards and Technology, the Environmental Protection Agency, the Naval Research Lab, the United States Coast Guard and the National Academy of Sciences. These partnerships help HMR-DATA identify knowledge gaps and innovative research topics and promote new knowledge to inform potential regulatory changes.

Chapter 2 – FY 2024 RD&T Programs

The AMRP FY 2024 outlook year chapter in the annual plan is not developed in alignment with the President's budget request of the same year due to the AMRP development schedule per 49 U.S.C. Chapter 65 Sec. 6501 Research Planning

Pipeline Safety Research Program

Program Description:

In FY 2024, PHMSA will continue to seek stakeholder input, review historical and current accident trends, and evaluate the progress on its current projects and completed research. This will identify any additional research gaps and research topics to be funded in FY 2024 and identify any follow-on research based on the research outputs from prior years. Based upon this analysis, PHMSA will continue to support all of the Department's strategic goals through research investments to develop a comprehensive research portfolio in FY 2024–while focused on pipeline safety solutions.

Major Program Objectives:

The PSRP's objectives for FY 2024 will address a comprehensive review of the research portfolio that was awarded in FY 2021-2023, focused on safety, transportation of alternative fuels, and climate change solutions. PHMSA plans to host an RD&T forum in FY 2023 that will build momentum from the FY 2021 RD&T forum and the FY 2023 LNG R&D Forum to determine strategic research needs and priorities for FY 2024 through collaboration with stakeholders, including academia, public advocacy groups, other DOT modes, federal agencies, and the pipeline industry. Research proposals would then be awarded to support addressing any safety gaps.

The PSRP will also support research that addresses PHMSA's priorities identified in the U.S. DOT Strategic Plan FY 2022-2026 on pipeline safety, infrastructure development for transporting alternative fuels, climate change mitigation, and environmental justice and equity.

Anticipated Program Activities:

Activities from FY 2023 are anticipated to extend into FY 2024, with PHMSA continuing to pursue research investments that align with the Department's strategic goals and its safety mission. PHMSA will continue to invest in pipeline safety research in the seven program areas described above. Program activities that advance the safe transportation of clean alternative fuels, as well as solutions to mitigate the effects of geohazards (land movement, landslides, heavy rains/floods) on pipelines may also come increasingly to the forefront as 2023 research identifies ways to connect research efforts to emerging safety risks and climate change objectives. PHMSA will publish research solicitations, review research proposals, and select prospective research projects to support the Department's and PHMSA's goals.

PHMSA will continue strengthening its research partnerships with universities, industry, and safety organizations, and continue implementation of its MSI outreach and engagement initiatives to address the equity and diversity challenges in the pipeline workforce. Increased collaboration with stakeholders and interagency partners will also continue to ensure research outcomes result in technology transfer and adoption of innovative concepts and methods that will enhance the safety and performance for pipeline-, LNG-, and UNGS-related facilities.

As part of its research activities, PHMSA will continue to implement project evaluation methodologies, conduct project evaluations, and optimize performance management metrics.

Furthermore, PHMSA will review the evaluation data to understand trends and establish new project success criteria.

Hazardous Materials Safety Research Program

Program Description:

In FY 2024 the HMSRP plans to combine the two core areas "Risk Management and Mitigation" and "Technical Analysis to Aid Risk Assessment," into a single core area. This core area will be titled Risk Analysis, Management, and Mitigation. However, the mission and strategy for hazardous materials research will remain unchanged, with a focus on efforts to improve the safe transport of hazardous materials across all modes. The HMSRP will execute research within the core areas of risk management and mitigation, package integrity, emerging technologies, and technical analysis to aid risk assessments, as discussed below:

Major Program Objectives:
Risk Analysis, Management, and Mitigation

Research will continue into FY 2024 under the Risk Analysis, Management, and Mitigation program to reduce the number of injury and fatality-related incidents that involve hazardous material transportation.

Ongoing projects that will continue into FY 2024 with Risk Analysis, Management, and Mitigation include the further development of the Commodity Flow Survey with the U.S. Census Bureau that will define the quantity and number of shipments of hazardous materials transported annually. The data, which will be subdivided by hazard class, will improve our transportation risk modeling and analysis capability that in turn will inform activities that can lower the risk of transport.

The HMSRP will continue working with the U.S. Naval Research Laboratory to develop strategies for de-energized, end of life lithium-ion batteries to assist in reducing the risk of transporting end of life batteries within the transportation system.

Projects from the 2021 BAA are in review with aims to begin in FY 2024. Topics that support Risk Analysis, Management, and Mitigation include the Hazard Comparison of Aerosols and Understanding the Hazards Posed by Dissolved Gases in Liquids.

With aerosols, the HMSRP is seeking data detailing the risks posed by different aerosols and measurements of the flammability posed by aerosols that follow the United Nations Model Regulations on the Transport of Dangerous Goods' definition in contrast to the flammability of comparable aerosols that follow the U.S. Hazardous Materials Regulations' definition.

There are also significant risks posed by combinations of gases and liquids (such as flammable liquid with flammable gas, flammable liquid with non-flammable gas, non-flammable liquid with flammable gas, etc.). Currently, there are no criteria that define the amount of a dissolved gas required to make the "material" (i.e., gas in liquid) regulated as a gas. Section173.115(f) of the Hazardous Materials Regulations defines a compressed gas in a solution, but there is no mention of when to use this definition or how much hazardous gas can be dissolved in a non-hazardous liquid and still have the mixture be classified as non-hazardous. Understanding the hazards posed by various types of gases dissolved in various types of liquids would aid in developing and issuing regulations that clearly delineate how to classify various mixtures. PHMSA is looking for the offeror to propose research that explores this issue and states what criteria might be best suited for inclusion in these regulatory areas.

The HMSRP also anticipates development of research topics in response to the increased number of battery incidents with increased electrification of scooters, bicycles, and cars. Ongoing crises such as the pandemic, Russia's invasion of Ukraine, and climate change will also require the HMSRP to be able to pivot and meet the rising needs.

Packaging Integrity

The HMSRP will continue to conduct research in FY 2024 under the Packaging Integrity program to address the issues pertaining to existing, new to market, and developing packaging technologies and testing methods.

Projects examining or developing packaging integrity that continue into FY 2024 include the Full-Scale Tank Car Side Impact, where the testing and evaluation of a new and aged LNG Tank Car will be conducted to evaluate the performance and crashworthiness of current and future DOT 113 specification tank cars. The work will also support the above, Risk Analysis, Management, and Mitigation objective through developing and verifying puncture models with the actual testing data.

The HMSRP aims to develop new projects under Packaging Integrity research in FY 2024 that have a range of technology readiness levels: high levels, technical demonstration (>TRL5) for implementation of new technologies, medium levels (TRL 2-5) to show feasibility and development, and low levels (TRL <2) to aid in identifying new materials or methodologies for packaging hazardous materials.

Emerging Technology

The HMSRP will continue research into FY 2024 under the Emerging Technology program that analyzes emerging materials, innovative packaging technologies, and new technology for transportation operations.

Areas of great interest in emerging technology center on small scale sensors and computers that can bring the analog shipping community into internet-connected commerce, new energy storage devices that exceed charge capacity and safety of lithium batteries, artificial intelligence to aid and assist in hazard classification and route selection, and new materials for packaging construction and performance. New projects in FY 2024 under Emerging Technology aim to leverage state of the art, off-the-shelf technologies to create new solutions to existing problems and identifying cutting edge technologies that present new risks or enable greater safety.

Anticipated Program Activities:

Hazardous materials research will continue to play an important role in advancing the safe transportation of hazardous materials and energy products essential to our daily lives. The core research areas in risk assessment, management, and mitigation, packaging integrity, and emerging technology will support the Department's strategic goals on *Safety*, *Economic Strength and Global Competitiveness*, *Equity*, and *Climate and Sustainability*. Projects in line for FY 2024 will help analyze risks and hazards associated with aerosols and dissolved gasses, help bring new technologies to market that reduce downtime in tank and cylinder inspections, characterize the effects of accidents on bulk packaging, and aid in risk mitigation through transportation route optimization.

Projects that will be brought online from efforts in FY 2024 will come from a new broad agency announcement that incorporates research needs as identified by stakeholders at meetings, conferences, and the HMSRP annual forum. This input will be collected and vetted by a newly established internal review board that ensures projects are in good alignment with Agency and Department goals. The same review board will also assist in vetting topics of high technology readiness levels for the next round of solicitations through the Small Business Innovative Research Program.

For More Information on DOT's Research see

https://researchhub.bts.gov/search