



U.S. Department of Transportation

**Pipeline and Hazardous Materials Safety Administration**



**Pipeline Safety Research and Development  
Five-Year Program Plan  
2023–2027**

**Updated August 2024**

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## Acronyms and Abbreviations

AANAPISI	Asian American, Native American, and Pacific Island-Serving Institution
AI	Artificial Intelligence
AO	Advocacy Organization
CAAP	Competitive Academic Agreement Program
CCUS	Carbon Capture and Underground Storage
CO <sub>2</sub>	Carbon Dioxide
Core	Core Research Program
DOC	U.S. Department of Commerce
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
DOT	U.S. Department of Transportation
EDF	Environmental Defense Fund
EIA	U.S. Energy Information Administration
FECM	Fossil Energy and Carbon Management
FY	Fiscal Year
GHG	Greenhouse Gas
GPI	Great Plains Institute
GO	Government Organization
H <sub>2</sub>	Hydrogen
HBCU	Historically Black College/University
HIT	H <sub>2</sub> Interagency Task Force
HSI	Hispanic-Serving Institution
IAA	Interagency Agreement
ICCOPR	Interagency Coordination Committee on Oil Pollution Research
IPSTF	Independent Pipeline Safety Testing Facility
LNG	Liquefied Natural Gas
ML	Machine Learning
MSI	Minority-Serving Institution
NAPSR	National Association of Pipeline Safety Representatives
NGO	Nongovernmental Organization
NIST	National Institute of Standards and Technology
NOFO	Notice of Funding Opportunity
OPS	Office of Pipeline Safety

PHMSA	Pipeline and Hazardous Materials Safety Administration
PIPES Act	Protecting our Infrastructure of Pipelines and Enhancing Safety Act (2016 and 2020)
PSIA	Pipeline Safety Improvement Act (2002)
PST	Pipeline Safety Trust
Pub. L.	Public Law
R&D	Research and Development
ROSA-P	DOT Repository & Open Science Access Portal
ROW	Right-of-Way
SBIR	Small Business Innovation Research
SDO	Standards Developing Organization
T2	Technology Transfer
TAP	Technical Advisory Panel
TRL	Technology Readiness Level
UNGS	Underground Natural Gas Storage

## Executive Summary

The mission of the U.S. Department of Transportation (DOT or Department) Pipeline and Hazardous Materials Safety Administration (PHMSA or Agency) is to protect people and the environment by advancing the safe transportation of energy and other hazardous materials that are essential to our daily lives. As part of its mission, PHMSA funds research to advance and improve pipeline safety, protect the environment, and support pipeline system reliability.

In accordance with Section 12 of the Pipeline Safety Improvement Act (PSIA) of 2002 [Public Law \(Pub. L.\) 107-355](#), as amended by Section 32 of the Pipeline Safety, Regulatory Certainty, and Job Creation Act of 2011, Pub. L. 112-90, Congress directed DOT to develop a Pipeline Safety Research and Development (R&D) Program Plan (Plan) every five years, after the initial plan was submitted to Congress in 2004. The Plan should be prepared in consultation with the Director of the National Institute of Standards and Technology (NIST), as appropriate. The Plan will guide PHMSA's pipeline safety R&D Program and include research, development, demonstration, and standardization activities related to:

- Materials inspection;
- Stress and fracture analysis; detection of cracks, corrosion, abrasion, and other abnormalities inside pipelines that lead to pipeline failure; and development of new equipment or technologies that are inserted into pipelines to detect anomalies;
- Internal inspection and leak detection technologies, including detection of leaks at very low volumes;
- Methods of analyzing content of pipeline throughput;
- Pipeline security—including improving real-time monitoring; conducting surveillance of pipeline rights-of-way (ROWs); developing tools for evaluating and enhancing pipeline security and infrastructure; reducing natural, technological, and terrorist threats; and protecting first response units and persons near an incident;
- Risk assessment methodology, including vulnerability assessment and reduction of third-party damage;
- Communication, control, and information systems surety;
- Fire safety of pipelines;
- Improved excavation, construction, and repair technologies; and
- Other appropriate elements.

While Section 12 of PSIA identified the above research focus areas, PHMSA's focus on those areas has evolved to meet the Agency's safety mission and the Administration's priorities. Therefore, PHMSA continues to update the Five-Year Plan to identify new, and further refine existing, focus areas that reflect the changing landscape of pipeline safety R&D needs. Section 32 also requires that a report be transmitted to Congress on the status and results-to-date of implementation of the Plan every two years. The biennial report shall include a summary of updated research needs and priorities identified in the Plan.

To fulfill the request in Congress' Joint Explanatory Statement accompanying Division L of the Consolidated Appropriations Act of 2021, DOT submitted a report to Congress in April 2023 that updated PHMSA's research and development program for Fiscal Years (FYs) 2021–2022. The report assessed the causes of pipeline failures and pipeline safety risks; identified specific short-term and long-term research and development objectives that address pipeline safety risks and vulnerabilities; identified specific research activities and how they relate to DOT and PHMSA's research goals, Agency objectives, and research programs; outlined the roles and responsibilities of PHMSA, industry, academia and other federal partners in advancing technological solutions that improve the overall safety and integrity of the nation's pipeline system through the execution of the proposed R&D activities; and reported on the implementation and execution of the prior year proposed annual research activities compared to the annual research plan and how such activities were co-funded with industry and/or academia consistent with subparagraph (b) of Section 22 of P. L. 114-183.

Since the April 2023 report updated PHMSA's R&D plan through FY 2022, this report will provide the Plan for 2023–2027. This Plan outlines detailed objectives and initiatives for each research focus area as well as specific research activities that will help move proven concepts into the market, drive innovation, and enhance safety.

## **1.0 Mission and Strategic Goals**

### **1.1 Mission**

PHMSA's mission is to protect people and the environment by advancing the safe transportation of energy and other hazardous materials that are essential to our daily lives. PHMSA establishes national policy, sets and enforces standards, educates, and conducts research to prevent incidents.

PHMSA operates in a dynamic and challenging environment in which changes in technology, manufacturing, and energy production affect transportation safety. The scope and complexity of PHMSA's safety mission continues to expand to advance safety, protect the environment, serve environmental justice, and prepare infrastructure for emerging and/or alternative fuel sources.

America's pipeline infrastructure includes more than 3.3 million miles subject to PHMSA's regulatory oversight. This complex pipeline infrastructure transports nearly all the natural gas and approximately two-thirds of the liquid petroleum energy products consumed domestically. According to the most recent data from the U.S. Energy Information Administration (EIA), in 2023 crude oil and natural gas liquids accounted for 34 percent of domestic energy production, natural gas 38 percent, coal 11 percent, nuclear 8 percent, and renewables 8 percent.<sup>1</sup>

Due to the significant contribution of energy and hazardous materials to our economy and standard of living, it is essential that PHMSA continues to fund research projects that enhance safety, address environmental impacts, and improve the resilience and performance of our energy transportation system to improve the security of our infrastructure, economy, and environment.

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<sup>1</sup> <https://www.eia.gov/energyexplained/us-energy-facts/>

PHMSA R&D goals—discussed in detail in this report—address four major subprograms:

- Competitive Academic Agreement Program (CAAP)
- Small Business Innovation Research (SBIR) Program
- Core Research (Core) Program
- Interagency Agreements (IAAs)

## 1.2 Strategic Goals

The PHMSA Office of Pipeline Safety (OPS) R&D Program seeks to advance knowledge and technology in-line with the requirements of Section 12 of the PSIA and to support the following in the [U.S. Department of Transportation's Strategic Plan for FY 2022–2026](#):

- *Safety.* Make our transportation system safer for all people. Advance a future without transportation-related serious injuries and fatalities.
- *Climate and Sustainability.* Tackle the climate crisis by ensuring that transportation plays a central role in the solution. Substantially reduce greenhouse gas (GHG) emissions and transportation-related pollution, and build more resilient and sustainable transportation systems to benefit and protect communities.
- *Equity.* Reduce inequities across our transportation systems and the communities they affect. Support and engage people and communities to promote safe, affordable, and multimodal access to opportunities and services while reducing transportation-related disparities, adverse community impacts, and adverse health effects.
- *Economic Strength and Global Competitiveness.* Grow an inclusive and sustainable economy. Invest in our transportation system to provide American workers and businesses reliable and efficient access to resources, markets, and good-paying jobs.
- *Transformation.* Design for the future. Invest in purpose-driven research and innovation to meet the challenge of the present and modernize a transportation system of the future that serves everyone today and decades to come.
- *Organizational Excellence.* Strengthen our world class organization. Advance the Department's mission by establishing policies, processes, and an inclusive and innovative culture to effectively serve communities and responsibly steward the public's resources.

The R&D Program supports PHMSA's mission by funding research that promotes the commercialization of cutting-edge pipeline safety technologies; the issuance of new U.S. patents; and solutions to complex issues that improve pipeline safety, including the transportation and storage of alternative fuels. In addition, the R&D Program will continue to provide scientific and engineering support for the Agency's safety enforcement and regulatory policy and rulemaking efforts. Results of the research findings will continue to address both national and local challenges in urban and rural communities.



## 1.3 Initiatives

OPS's R&D Program will continue using pipeline performance data to evaluate causes of pipeline failures and monitor emerging issues to inform research programmatic areas. PHMSA continues to bolster its stakeholder engagement program, increase commercialized technologies, and identify research challenges and limitations to using certain technologies in the field.

### 1.3.1 Stakeholder Engagement

PHMSA will continue to engage with stakeholders to identify and prioritize research projects—strengthening its research partnerships with universities, industry, public, government, and research organizations. PHMSA engages academia, industry, states, and other federal partners to fund and co-fund critical research that develops new technology, products, and knowledge to improve pipeline safety and protection of the environment. To improve data transparency and avoid research duplication, PHMSA will continue to engage with both government and nongovernmental stakeholder organizations.

To ensure PHMSA reaches a diverse set of stakeholders to continue improving the R&D Program, the Agency will publish and make available research results through various platforms, such as the National Transportation Library, DOT Research Hub, and DOT Repository & Open Science Access Portal (ROSA-P).

With the goal to advance technological solutions and knowledge that improve the overall safety and reliability of pipeline systems, PHMSA regularly communicates with stakeholders through public meetings, website publications, and conferences. Additionally, R&D projects that have successfully led to product commercialization are available to the public on PHMSA's [Technology Research & Development: Success Stories web page](#).

In March 2019, PHMSA issued a special notice, titled "Identifying Pipeline Safety Research Gaps," in the [beta.SAM.gov portal](#) to invite interested stakeholders to submit ideas for future research. This portal is open year-round. PHMSA also invites stakeholders and the public to submit research gap ideas throughout the year via the [gap submission portal](#). PHMSA invites the public to join PHMSA's [Distribution List](#) to stay informed of all R&D related projects and activities.

PHMSA held an R&D forum and public meeting from October 31 through November 1, 2023. Approximately 175 stakeholders attended in person, and an additional 406 attended virtually. Over the two days, there were 47 speakers between the main session and six specialized breakout working group sessions. The forum and public meeting provided an opportunity for stakeholders to discuss research gaps and challenges in the industry. Furthermore, the forum also served as a venue for PHMSA, public interest groups, industry, academia, intergovernmental partners, and the public to inform PHMSA's FYs 2024 and 2025 research and funding strategy.

Partnerships with government organizations (GOs) and nongovernmental organizations (NGOs) 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 R&D Program and consults on individual projects that are within these groups' sphere of expertise. NGO and GO research collaboration partners that

cost-share research with PHMSA include federal agencies, associations, regulatory entities, and industry.

The R&D Program's technology transfer (T2) successes depend highly on the strategic partnerships PHMSA forms with the pipeline sector. PHMSA uses the following best practices to drive its T2 program:

- Developing key strategies to deploy new technologies through direct technical and financial assistance, training, peer exchanges, and collaboration with industry groups to determine effectiveness, assess needed improvements, and document outcomes;
- Facilitating interactions with key stakeholders to understand their technology needs, then addressing those needs through public-private focused workshops, town hall meetings, and/or webinars;
- Partnering with organizations that promote technology development and commercialization; and
- Identifying entities to pilot new technologies and/or be early adopters of new technology. As the technology becomes more mature and ready for widespread use, training aids can be developed for delivery.

### **1.3.2 Academia**

OPS partners with academic institutions through the CAAP. Academia also participates in the Core, either as the main recipient of R&D awards or as part of the research team when other organizations are awarded. Under CAAP, PHMSA funds 80 percent of basic R&D costs and the remaining 20 percent is funded by university partners. PHMSA may fund up to 100 percent of R&D costs related to regulatory analysis or other purely governmental purposes. These funding levels are specified in and mandated by Section 22 of the Protecting our Infrastructure of Pipelines and Enhancing Safety Act (PIPES) Act of 2020, P.L. 116– 260, Division R.

To ensure awareness, PHMSA has expanded its communication of CAAP funding opportunities to 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). On April 3, 2024, PHMSA conducted an informational session on CAAP with MSIs to encourage proposals for CAAP. On March 18, 2024, the FY 2024 CAAP Notice of Funding Opportunity (NOFO) was issued on [Grants.gov](https://www.grants.gov).

Since 2013, PHMSA has received 15 proposals from MSIs. PHMSA strongly encouraged other universities to partner with MSIs in their grant proposals; in FY 2023, PHMSA awarded funding to Marquette University, an emerging HSI. PHMSA will continue to execute strategies for increasing research partnerships and collaboration with MSIs, as well as promoting pipeline safety research and careers in the pipeline sector through CAAP research partnerships.

### **1.3.3 Pipeline Industry**

PHMSA engages with a wide range of industry partners that share the objectives of (1) developing pipeline safety technology, and (2) generating and promoting new knowledge among decision makers to advance pipeline and hazardous materials safety. PHMSA regularly informs industry stakeholders of the Agency's ongoing pipeline safety research efforts to ensure

that information and data—particularly on research projects, potential technology, and potential knowledge that can be used to meet or exceed regulatory safety requirements—are shared in a timely manner. At the completion of projects, researchers present their results to pipeline stakeholders with the goal of disseminating applicable lessons and technologies for broader adoption in the industry and improving pipeline safety.

### 1.3.4 Government

PHMSA frequently enters into IAAs with the U.S. Department of Energy (DOE), the U.S. Department of Commerce (DOC), and the U.S. Department of the Interior (DOI) to conduct research. Beyond interaction within IAAs, periodic interagency coordination meetings are held to share information about interagency and other research activities. These meetings have directly led to increased interagency participation and collaboration for future IAAs.

In FY 2022, FY 2023, and FY 2024, PHMSA participated in the following interagency hydrogen (H<sub>2</sub>) and carbon dioxide (CO<sub>2</sub>) clean energy initiatives:

- DOE
  - H<sub>2</sub> and Fuel Cell Technologies Office
    - National H<sub>2</sub> Strategy and Roadmap
    - Regional Clean H<sub>2</sub> Hubs – Technology Special Purpose Review
    - Clean H<sub>2</sub> Joint Undertaking Expert Workshop on Environmental Impacts of H<sub>2</sub>
  - Office of Energy Efficiency and Renewable Energy H<sub>2</sub> Program
    - Annual Merit Review and Peer Evaluation Meeting
  - Fossil Energy and Carbon Management (FECM)
    - Workshop on Applied Research for CO<sub>2</sub> Transport
    - Carbon Capture, Usage, and Storage (CCUS) Interagency Field Training
    - Annual Carbon Management Project Review Meeting
    - Carbon Management Collegiate Competition Review Team
    - CCUS Interagency Working Group
    - CCUS Engagement Topic Team Working Group
    - CO<sub>2</sub> Transport Team Working Group (PHMSA is co-lead with FECM)
  - H<sub>2</sub> Interagency Task Force (HIT) – H<sub>2</sub> Infrastructure, Siting, and Permitting Working Group
- DOC/U.S.-India Strategic Partnership Forum
- PHMSA/National Association of Pipeline Safety Representatives (NAPSR) Gas Distribution Team and H<sub>2</sub>/Biofuels Working Group

PHMSA will continue to work with federal agencies to accomplish the following:

- Develop and implement a periodic notification practice and/or system to notify stakeholders of new public materials and research data, including T2 and knowledge metrics, as they become publicly available. Promoting research successes and project outcomes will not only encourage conversation and transparency among stakeholders but also create demand for pipeline research from the industry;
- Expand the publication of its reports beyond the PHMSA website and DOT Research Hub to the ROSA-P database, National Transportation Library, and Transportation Research Board's Transport Research International Documentation database; and
- Coordinate research efforts with DOE, NIST, and the Interagency Coordination Committee on Oil Pollution Research (ICCOPR)—particularly on emerging fuels and oil spill prevention—to co-sponsor and collaborate on mutual priorities, and to reduce duplicative research and maximize funding efficacy.

### **1.3.5 Other Stakeholders**

PHMSA continuously monitors the pipeline sector for emerging issues, including seeking input and data from state pipeline safety partners, NGO stakeholder organizations, pipeline technical committees, standards developing organizations (SDOs), and advocacy organizations (AOs). This information is vital for developing new or modifying current programs, research focus areas, and practices to increase R&D Program efficiency and effectiveness.

Pre-award research solicitations and post-award agreements contain requirements for researchers to include relevant SDOs on their technical advisory panels (TAPs) for research projects. This requirement facilitates knowledge transfer and integration of research results into standards. Several standards—some incorporated by reference in federal pipeline safety regulations—are directly informed by PHMSA's research results.

Ongoing coordination with AOs, such as the Pipeline Safety Trust (PST), the Great Plains Institute (GPI), and the Environmental Defense Fund (EDF), not only provides awareness of program and project activities but also assists PHMSA's development of research topics and funding strategies. Participation also occurs by AOs in the pre-award review of submitted research proposals, which supports integrating diverse perspectives into how safety and environmental research should be funded and executed.

### **1.3.6 Integration of Stakeholder Feedback**

PHMSA utilizes a multi-faceted approach to capture stakeholder input for its R&D Program planning. Biennial R&D forums serve as a platform for focused discussions with industry experts, researchers, and the public. These forums identify technical gaps and challenges through interactive working groups, allowing stakeholders to directly influence the direction of future research efforts. Additionally, PHMSA maintains an online portal for ongoing stakeholder submissions throughout the year. Submissions are reviewed and incorporated into upcoming research announcements, as exemplified by the FY 2023 CAAP NOFO topics derived from FY 2021 stakeholder input submitted through the portal. Beyond these formal channels, PHMSA staff actively participate in various interagency working groups and industry conferences. Feedback from state and federal pipeline safety inspectors, and PHMSA's own data analysis, also helps identify pressing safety challenges requiring research solutions.

## **1.4 Project Success Metrics and Evaluation Criteria**

PHMSA employs a multi-faceted approach to assess the success and impact of its R&D projects. The following subsections break down the key metrics used in this approach.

### **1.4.1 Developing Innovative Technology**

OPS's R&D Program aims to foster the creation of novel solutions for pipeline safety challenges. A key metric for this objective is technology transfer.

PHMSA recognizes the critical role of technology transfer in ensuring that advancements from its R&D Program translate into real-world benefits for pipeline safety. While research generates innovative solutions, successful commercialization can be a significant hurdle. Studies suggest that only a fraction of new technologies reach the market, highlighting the importance of a strategic approach.

PHMSA utilizes a technology readiness level (TRL) framework to track technology maturity. This framework defines seven stages, from basic research concepts to fully functional prototypes ready for field deployment. PHMSA focuses its program on the earlier stages (TRL 1-3) where proof-of-concept is established. Partnering with industry during these stages helps ensure that developed technologies are aligned with practical needs.

A critical step towards commercialization is validating the technology's effectiveness in real-world settings. PHMSA incorporates technology demonstrations into project scopes. These demonstrations progress from controlled test rigs to actual operational pipelines, allowing researchers to refine the technology and gather valuable field data.

To gauge the effectiveness of its technology transfer efforts, PHMSA monitors a range of metrics. These include tracking the number of patent applications filed and patents granted to protect intellectual property from promising research projects. Additionally, PHMSA monitors the success of technology demonstrations that validate a technology's functionality in realistic pipeline environments. Technology commercialization is tracked by monitoring the number of technology projects that successfully transition to market and practical application by end users. Approximately 30 percent of PHMSA funded technology projects are commercialized. Finally, PHMSA monitors special permits issued by the Agency, noting references to its funded research in permit applications. The special permit process allows, among other things, newly developed technologies to be used in active pipeline service following a safety review by PHMSA. The special permit and any associated conditions help mitigate the risks associated with new technologies while still allowing cutting edge technology to be deployed. This multifaceted approach provides a comprehensive picture of how OPS's R&D Program fosters innovation and facilitates the translation of research findings into real-world solutions.

### **1.4.2 Strengthening Consensus Standards**

A cornerstone of OPS's R&D Program is its focus on strengthening and expanding the applicability of industry standards. PHMSA tracks the contribution to consensus standards by monitoring how R&D projects directly impact industry codes and standards. This is achieved through active participation in standard development organizations and working groups. Incorporation into standards mitigates the risks of using new technology by subjecting it to expert review and developing best practices for safe use. For instance, a recent project on H<sub>2</sub>

pipeline weld qualification is intended to inform revisions to relevant standards, ensuring they address the unique properties of H<sub>2</sub> transportation.

### 1.4.3 Promoting Knowledge to Decision Makers

PHMSA actively disseminates research findings to inform decision-making by various stakeholders. This is measured through knowledge dissemination metrics. PHMSA tracks the number of publications in peer-reviewed journals and presentations at industry events. Additionally, the Agency monitors the number of Publicly Available Final Reports and the usage of OPS's R&D Program website. Metrics such as website visits and file downloads indicate the level of stakeholder interest in research findings. PHMSA also tracks the number of New Knowledge Promotion Projects as an indicator of successful knowledge transfer to relevant end users, including policymakers.

## 2.0 OPS's R&D Program

### 2.1 Overview

OPS funds innovative research to support PHMSA's mission to improve safety, protect the environment, and support reliable supplies of energy products and hazardous materials. The focus of the R&D Program is twofold: 1) partner with pipeline stakeholders to leverage private R&D investment that would enhance pipeline safety and protect the environment; and 2) fill the gaps in research not conducted by industry. PHMSA strives to promote stakeholder engagement and avoid duplicative research, and works closely with academia and pipeline stakeholders to fund and share the cost of critical research for developing new technologies, products, and knowledge. Additionally, the R&D Program seeks to advance knowledge and technology that addresses the following [Fiscal Year \(FY\) 2022 through FY 2026 Department strategic goals](#):

- Safety
- Economic Strength and Global Competitiveness
- Equity
- Climate and Sustainability
- Transformation
- Organizational Excellence

The R&D Program executes research funding through four major subprograms: the CAAP, the SBIR program, the Core program, and IAAs. Each subprogram is designed to advance research concepts throughout their lifecycles, from initial conceptual stages to industry or government adoption (Figure 1). All PHMSA research programs are funded through general revenue dollars and the Oil Spill Liability Trust Fund. In 2023, the total R&D budget was \$12.5 million— \$9.5 million from general revenue dollars and \$3 million from the Oil Spill Liability Trust Fund.

#### 2.1.1 CAAP

The CAAP funds research through competitive agreements with colleges and universities. The program is intended to spur innovation by enabling an academic research focus on high-risk,

high-reward solutions to address a wide range of pipeline safety challenges. Innovation developed by CAAP projects can lay the groundwork for further technology development and commercialization via other programs, such as Core or SBIR. This program also introduces students to the transportation of energy by pipelines to encourage interest in pipeline safety sector careers after graduation.

### 2.1.2 SBIR

OPS uses the SBIR program to identify innovative small businesses providing novel concepts and prototype technologies that can later lead to commercialization of pipeline safety technologies. Additionally, PHMSA's SBIR program collaborates with small businesses that can leverage successes in other economic sectors, such as medical or defense, to resolve pipeline safety challenges.

The SBIR program is structured in the following three phases:

- *Phase I.* The objectives of Phase I are to (1) establish the technical merit, feasibility, and commercial potential of the proposed research efforts; and (2) determine the quality of performance of the small business awardee organization prior to providing further federal support in Phase II. Phase I awards can be up to \$200,000 for six months. No Phase I awards were made in 2023.
- *Phase II.* The objective of Phase II is to continue the research efforts initiated in Phase I. Funding is based on the results achieved in Phase I, as well as the scientific and technical merit and commercial potential of the project proposed in Phase II. Only Phase I awardees are eligible for Phase II awards, which can be up to \$1.5 million for two years. In 2023 two Phase II awards were made for a total of \$2 million.
- *Phase IIb<sup>2</sup>.* The objective of Phase IIb is to serve as an extension of Phase II work when PHMSA determines additional time and funding is required to meet the project objectives. Phase IIb awards can be up to \$1.5 million for two years. In 2023, two Phase IIb awards were made for a total of \$2 million.

### 2.1.3 Core Research Program

OPS's R&D Program is primarily executed through the Core, the main activities of which focus on developing new technologies or products and conducting demonstrations to transfer technologies into commercialization. Additionally, the Core promotes the use of new knowledge for decision-makers. There is no mandated minimum funding amount for the Core. In 2023, 13 projects were awarded for a total of \$6.78 million.

### 2.1.4 IAAs

PHMSA partners with government research organizations through IAAs to conduct technical research. PHMSA currently has IAAs with the DOT Volpe National Transportation Systems Center, Oak Ridge National Laboratory, Sandia National Laboratories, NIST, and other federal

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<sup>2</sup> Phase III. The objective of Phase III is for the small business to pursue commercialization objectives resulting from Phases I and II research activities. (The DOT SBIR programs do not fund Phase III.) At some federal agencies, Phase III may involve follow-on, non-SBIR funded research or production contracts for products, processes, or services intended for use by the U.S. Government.

entities. OPS frequently enters into IAAs to utilize the expertise of federal laboratories to bring forward innovative solutions and provide critical data needed for standardization.

### **2.1.5 Funding Allocation**

PHMSA's primary mission is safety in its research program, as well as supporting DOT's strategic goals of economic strength and global competitiveness, equity, climate and sustainability, and transformation. The R&D Program will remain focused on improving pipeline safety through research that provides engineering solutions, applications, and recommendations for advancement of the safe transportation of energy products. The allocation of funds, research projects, and scope of activities may change from year-to-year to address emerging challenges based on data analysis and industry needs, and in response to congressional mandates and specific pipeline incidents.

## **3.0 The 2023–2027 Five Year Plan**

This Plan outlines the objectives and initiatives for research areas to match the requirements of Section 12 of the PSIA, as amended by Section 32 of the Pipeline Safety, Regulatory Certainty, and Job Creation Act of 2011. Further, while the PSIA identified certain research focus areas, OPS's R&D program has evolved to meet the Agency's safety and environmental protection mission. PHMSA continues to identify new, and further refine existing, focus areas that reflect R&D needs to help ensure the safety of the existing pipelines and prepare for the infrastructure of the future. OPS's pipeline research strategy continues to be informed by R&D forums, research gap ideas submitted by the public, PHMSA's own initiatives, and collaboration with government and nongovernment stakeholders.

The following sections detail OPS's R&D Plan through 2027.

### **3.1 Preventing Pipeline Threats/Damage**

#### **3.1.1 Agency Objectives**

Prioritizing research activities in this area supports developing new tools, technologies, and general knowledge/best practices that help address safety impacts to people and the environment by preventing damage to pipelines from threats, such as geohazard, excavation damage, other outside forces, and corrosion. Research outputs in this area will refine tools to identify and predict geohazards and other natural threats; make existing unlocatable plastic pipes locatable in advance of planned excavations at a reasonable cost; and improve corrosion control methods on pipelines and storage tanks. Impacts from the research findings will help enhance safety by improving detection of difficult-to-identify geological hazards; developing better methods to detect underground pipelines to prevent excavation damage to buried pipelines; and improving methods of corrosion control.

Analysis of incident data, public submission of research gaps, and workshop results from the 2023 PHMSA R&D Forum have informed the R&D Program to focus on the following list as priority research topics for PHMSA funding in the area of Preventing Pipeline Threats/Damage:

- *Geotechnical Threat Identification* – Develop tools to measure the strain state of pipe, improve understanding of strain capacity in vintage pipe, and validate scour monitoring technologies.



- *Climate Change* – Improve data integration of climate and geotechnical data to better understand, predict, and forestall the evolving threats to pipelines posed by climate change impacts and extreme weather events.
- *Corrosion Control* – Improve understanding of problematic corrosion mechanisms and develop tools/technology to combat corrosion.
- *Stress Corrosion Cracking* – Improve understanding of the role of thermal cycling in stress corrosion cracking.

### 3.1.2 Research Initiatives

Some examples of recently awarded projects under this focus area include:

- A fiber optic monitoring system that will help operators detect excavation or other hazardous activities near the pipeline in real time; and
- Four projects related to controlling corrosion on hazardous liquid tanks, including the use of vapor corrosion inhibitors to improve corrosion control.

There are currently 30 active multi-year threat prevention R&D projects with a total of \$20.1 million in PHMSA funding and \$8.3 million in funding through cost sharing.

## 3.2 Improving Pipeline Leak Detection Systems

### 3.2.1 Agency Objectives

PHMSA R&D investments in pipeline leak detection will assist with the early identification of leaks before they result in a pipeline failure. This will ensure that leaks do not remain undetected and cause safety and environmental damage; reduce GHG emissions released during ruptures or undetected leaks in natural gas and hazardous liquid pipelines; and ensure safe and reliable pipeline system infrastructure for all communities, including underserved and disadvantaged communities.

PHMSA will continue investing in R&D projects to develop new or improved tools and technology solutions to locate, quantify, and repair hazardous liquid or natural gas pipeline leaks. Project outputs will develop processes to predict leaks more accurately, as well as develop, test, and deploy advanced leak detection platforms (ground based, aerial, and satellite) and protocols under real-time field conditions. This will 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 operators with the capability to quantify leaks using real-time data. This capability can reduce the risk of an incident caused by migrating gas to a residence or a prolonged release of methane into the environment, and can help operators predict where leaks are likely to occur before they happen. 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.

Analysis of incident data, public submission of research gaps, and workshop results from the 2023 PHMSA R&D Forum have developed the following list as priority research topics for PHMSA funding in the area of Improving Pipeline Leak Detection Systems:

- *Improved Technology Selection Guidance* – A system or tool that helps operators select optimal leak detection technology for their system.
- *Pinpointing Leaks* – Development of tools to pinpoint the exact location of underground leaks to minimize excavation and repair time.
- *Improved Leak Detection Tools* – Improved sensors and other equipment to obtain more reliable data for more accurate leak detection.
- *Modeling* – Development of systems to integrate information about system composition, performance, and monitoring to more readily identify potential leaks and emissions.

### 3.2.2 Research Initiatives

Research in this area will help pipeline operators detect smaller leaks, detect leaks more quickly, and mitigate leaks more easily.

Some examples of recently awarded projects under this focus area include:

- Development of new algorithms and pattern detection methods to improve leak detection accuracy; and
- Field validation of existing pipeline leak detection systems under complex environments to identify possible enhancements.

There are currently six active multi-year leak detection projects with a total of \$2.6 million in PHMSA funding and \$2.0 million in funding through cost sharing.

## 3.3 Improving Anomaly Detection and Characterization

### 3.3.1 Agency Objectives

Research investments in anomaly detection and characterization will improve the ability to identify and locate critical pipeline defects, and characterize the severity or interacting nature of these defects. These investments will improve public safety; reduce environmental threats, such as GHG emissions released during leaks and/or ruptures of natural gas or hazardous liquid pipelines; and promote safer and more reliable pipeline infrastructure system for all communities, including underserved and disadvantaged communities.

PHMSA will continue to fund research to improve pipeline anomaly detection, characterization, prediction, and prioritization in metallic and non-metallic pipes. Research outputs are designed to more consistently and accurately identify critical defects within pipelines and provide PHMSA and pipeline operators with effective instrumentation, methodologies, and processes to locate, evaluate, and predict manufacturing defects and in-service anomalies in pipe.

Research outcomes will better inform PHMSA and pipeline operators to make integrity management decisions on metallic and non-metallic pipeline 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.

Analysis of incident data, public submission of research gaps, and workshop results from the 2023 PHMSA R&D Forum have developed the following list as priority research topics for PHMSA funding in the area of Anomaly Detection and Characterization:

- *Non-Metallic Pipe Inspection Tools* – Development of in-line tools to inspect nonmetallic pipe for anomalies and characterize damage.
- *Artificial Intelligence (AI)/Machine Learning (ML) Classification Technologies* – Advancements using AI and ML tools to more quickly classify features and signals from anomaly detection tools to allow quicker response.

### **3.3.2 Research Initiatives**

Research in this area will assist operators in detecting and characterizing anomalies on in-service pipelines, allowing quicker response and more accurate identification of potentially hazardous conditions.

Some examples of recently awarded projects under this focus area include:

- A dual-purpose tool for cleaning and assessing pipe integrity; and
- An assessment of non-destructive examination and condition monitoring technologies in non-metallic pipe.

There are currently seven active multi-year anomaly detection and characterization projects with a total of \$6.0 million in PHMSA funding and \$2.3 million in funding through cost sharing.

## **3.4 Improving Anomaly Repair and Pipe Remediation and Rehabilitation**

### **3.4.1 Agency Objectives**

Research investments in pipeline repair and methods for pipe remediation and rehabilitation for legacy pipelines, including the use of internal liner materials, will contribute to the continued safe operation of existing pipeline infrastructure. Research outputs will provide reliable methods to repair damaged pipe, coatings, manufacturing defects, and corrosion damage (a major cause of pipeline incidents), as well as develop testing protocols needed when using composite repair materials.

Impacts from these research investments will advance technological solutions and have longstanding impacts on the Agency's goals with the repair of aging pipelines; provisions for better service to often underserved communities; and the reduction in new pipeline installation or existing pipeline rehabilitation or replacement that will minimize methane emissions.

Analysis of incident data, public submission of research gaps, and workshop results from the 2023 PHMSA R&D Forum have developed the following list as priority research topics for PHMSA funding in the area of Anomaly Repair and Pipe Remediation and Rehabilitation:

- *Database of Vintage Pipe Characteristics* – A repository for information on historical pipeline steel.

- *Minimally Invasive Tools for Pipeline Repair* – Development of improved in-pipe installation methods, coatings, and liners, to repair pipe in a minimally invasive manner.

### 3.4.2 Research Initiatives

Research in this area will improve the ability of pipeline operators to quickly and safely repair hazardous conditions, particularly on aging pipe and in difficult to reach locations.

Some examples of recently awarded projects under this focus area include:

- An in-line tool to repair oil and gas pipelines with no excavation; and
- A study of the factors affecting degradation of existing liner materials and development of improved liner materials with consideration of these factors.

There are currently four active multi-year projects under this focus area with a total of \$3.3 million in PHMSA funding and \$1.3 million in funding through cost sharing.

## 3.5 Improving Design, Materials, and Welding/Joining

### 3.5.1 Agency Objectives

Research investments in improving design, materials, welding/joining of pipeline systems (including composites), and proper construction and maintenance of pipelines will aid in the prevention of incidents. Incident data has identified incidents often occur within the first few years following construction, many attributed to welding related issues. Effective welding/joining methods and materials support longer operational pipeline lifecycles, contribute to improved public safety, and reduce environmental threats, such as GHG emissions from natural gas and hazardous liquid pipelines.

Analysis of incident data, public submission of research gaps, and workshop results from the 2023 PHMSA R&D Forum have developed the following list as priority research topics for PHMSA funding in the area of Improving Design, Materials, and Welding/Joining:

- *Fracture Toughness Determination* – Tools and methods are needed to non-destructively obtain fracture toughness measurements on in-service pipe.
- *H<sub>2</sub> Embrittlement* – Develop surface treatments, coatings, and/or liners to prevent H<sub>2</sub> embrittlement of pipeline steel.
- Update existing welding standards for use in H<sub>2</sub> pipelines.

### 3.5.2 Research Initiatives

Research in this area will improve the materials used in pipeline construction, PHMSA's understanding of vintage materials still in service, and the ability to make safe and reliable welds and joints.

Some examples of recently awarded projects under this focus area include:

- Two projects to develop technology for measuring pipeline fracture toughness; and
- An investigation of the impacts of H<sub>2</sub> gas on composite/multilayered pipe.

There are currently nine active multi-year projects under this focus area with a total of \$8.1 million in PHMSA funding and \$0.9 million in funding through cost sharing.

## **3.6 Improving Safety Systems for Liquefied Natural Gas Facilities**

### **3.6.1 Agency Objectives**

Research investments in liquefied natural gas (LNG) safety will support the Department's strategic goals by improving the safety and global competitiveness of domestic LNG facilities, as well as help mitigate climate change impacts associated with LNG. These research investments will address safety risks and operational challenges from LNG facilities due to H<sub>2</sub>-blend products, as well as develop new technologies and alternative designs for LNG facilities to improve safety. Understanding the efficacy of mitigation measures will improve the protection of critical structures and reduce risks to the public. In addition, the results of the research will assist with improvement of PHMSA's policies relative to LNG safety.

Analysis of incident data, public submission of research gaps, and workshop results from the 2023 PHMSA R&D Forum and the 2022 LNG Forum have developed the following list as priority research topics for PHMSA funding in the area of Improving Safety Systems for LNG Facilities:

- *Impacts of H<sub>2</sub>* – How H<sub>2</sub>-blended products could affect the existing leak detection systems of LNG facilities.
- *Automated Leak Detection Drone* – Evaluation of an automated drone or robot equipped with leak detection equipment, and a study on the effectiveness of such technology in a congested area and on obscured equipment.

### **3.6.2 Research Initiatives**

Research in this area will improve the capability to safely operate LNG facilities and to prevent, detect, and repair leaks within facilities.

Some examples of recently awarded projects under this focus area include developing:

- Methodologies for cryogenic and fireproofing requirements;
- A passive fire mitigation system; and
- Periodic external and internal requirements to assess low temperature and cryogenic storage tanks.

There are currently eight active multi-year projects under this focus area with a total of \$3.1 million in PHMSA funding and \$1 million in funding through cost sharing.

## **3.7 Improving Safety Systems for Underground Natural Gas Storage Facilities**

### **3.7.1 Agency Objectives**

Energy supply via underground natural gas storage (UNGS) facilities is a critical component of domestic energy security. Research investments in improving operational integrity and effectiveness, preventing accidental releases, and maintaining storage well integrity will protect local populations and ensure the reliability of UNGS facilities. PHMSA continues to conduct

research in UNGS facilities, including evaluating the technical feasibility of converting existing facilities to store CO<sub>2</sub> and H<sub>2</sub>/H<sub>2</sub>-blends. These research investments will address safety risks, operations challenges, and environmental threats of UNGS facilities.

Analysis of incident data, public submission of research gaps, and workshop results from the 2023 PHMSA R&D Forum have developed the following list as priority research topics for PHMSA funding in the area of Improving Safety Systems for UNGS Facilities:

- *Improve Wellhead Seal Design* – Improved design of wellhead seals to prevent false indications of leaks, and allow operators to more quickly identify and remediate real leaks.
- *Improve Cathodic Protection of Well Tubulars* – Evaluation of cathodic protection practices and monitoring on well tubulars and casings.

### **3.7.2 Research Initiatives**

Research in this area will improve the safety of UNGS facilities and prevent, detect, and repair leaks within the facilities.

Some examples of recently awarded projects under this focus area include:

- Study into the use of engineering particles to more quickly and reliably plug leaks;
- Development of a fiber optic system for monitoring UNGS wells; and
- Study of potential leak paths and migration methods, including evaluating current technology for prevention and repair of leaks.

There are currently six active multi-year projects under this focus area with a total of \$4.7 million in PHMSA funding and \$1.5 million in funding through cost sharing.

## **3.8 Advancing Safety of Emerging Fuels: H<sub>2</sub>/CO<sub>2</sub>**

### **3.8.1 Agency Objectives**

Research investments in the safe transportation of gaseous CO<sub>2</sub>, blended H<sub>2</sub>, and biofuels will support important regulatory updates necessary for increased transportation of fuels that are critical to decarbonization and mitigation of climate change. Transportation infrastructure will likely include new, repurposed, and converted pipelines to aid in decarbonization.

Research in this area will help identify methods to reduce safety risks from regulated infrastructure, in coordination with pipeline stakeholders and interagency partners. Significant research investment into alternative renewable fuels, such as H<sub>2</sub> and/or H<sub>2</sub> blends and carbon capture and underground storage (CCUS), has been made at the federal and international levels. PHMSA continues to identify research gaps for H<sub>2</sub> and/or various H<sub>2</sub> blends in natural gas pipeline facilities and CO<sub>2</sub> transport and storage.

Public submission of research gaps and workshop results from the 2023 PHMSA R&D Forum have developed the following research topics for PHMSA funding in the area of Advancing Climate Change Solutions/H<sub>2</sub>/CO<sub>2</sub>:

- *Equations of State* – Study the potential effects of impurities, contaminants, and additives on CO<sub>2</sub> equations of state.
- *Fracture Control Model* – Develop fracture control models for pipeline steels for use in CO<sub>2</sub> service.

### 3.8.2 Research Initiatives

Research in this area will improve our capability to prevent GHG emissions and to safely transport alternative fuels and CO<sub>2</sub> from carbon capture operations.

Some examples of recently awarded projects under this focus area include:

- Study of technologies to limit methane emissions from compressor stations;
- Development of design and welding requirements for CO<sub>2</sub> pipeline construction; and
- Review of integrity threat characterization on H<sub>2</sub> pipelines.

There are currently 15 active multi-year projects under this focus area with a total of \$14.6 million in PHMSA funding and \$3.0 million in funding through cost sharing.

## 3.9 National Center of Excellence for LNG Safety

In FY 2023, Congress allocated up to \$8.4 million to PHMSA for the creation of a National Center of Excellence for LNG Safety (Center) aimed at positioning the U.S. as the leader and foremost expert in LNG operations. The Center offers a unique opportunity for all LNG stakeholders and will enable PHMSA to be an active collaborator with LNG sector stakeholders, as defined in Section 111 of the PIPES Act of 2020. The Center will define the research roadmap with the assistance and support of federal partners and stakeholders; shape its strategic research direction by monitoring emerging trends, industry developments, and stakeholder needs; and oversee the management of research results. As required by the PIPES Act, the Center will create an electronic repository for sharing information on best practices with LNG facility operators and other stakeholders.

## 3.10 Long-Term Vision

PHMSA recognizes the dynamic nature of pipeline safety challenges and environmental considerations. To ensure its R&D Program remains responsive, PHMSA employs several strategies:

- *Continuous Stakeholder Engagement* – PHMSA will continue its multi-pronged approach to stakeholder engagement, including R&D forums, online portals, and industry conference participation. This continuous dialogue with industry experts, government agencies, the public, and state and federal inspectors helps identify emerging risks and future challenges that can inform future research priorities.
- *Horizon Scanning* – To proactively identify potential future threats and opportunities, PHMSA will use horizon scanning techniques. These techniques will involve monitoring technological advancements, analyzing accident data for recurring patterns, and considering the evolving regulatory landscape.

- *Adaptable R&D Programs* – The R&D Program is flexible to accommodate new priorities. PHMSA has the ability to have short research cycles and reserve a portion of funding for rapid response to unforeseen safety challenges.
- *Collaboration and Knowledge Sharing* – Continued collaboration with other government agencies, international pipeline safety organizations, and research institutions will continue to provide valuable insights into global trends and best practices. Sharing knowledge and research findings fosters innovation, and accelerates the development of solutions for future pipeline safety and environmental challenges.
- *Independent Pipeline Safety Testing Facility (IPSTF)* – Section 105 of the PIPES Act 2020 required PHMSA to determine whether the establishment of a DOT IPSTF would benefit the overall R&D Program of the Agency. If directed and funded by Congress, an IPSTF could offer enhanced research opportunities identified through post-accident testing and allow real world testing of new research technologies to help further support commercialization of those technologies.

By remaining adaptable, fostering continuous communication with stakeholders, and employing forward-looking strategies, PHMSA can ensure that its R&D Program effectively addresses the evolving pipeline safety landscape beyond the 2023–2027 timeframe.

## 4.0 Conclusion

In the next five fiscal years, the OPS R&D Program will continue to invest in R&D projects to address critical pipeline safety challenges and help enhance safety and environmental protection. The Program will continue to consider input from diverse stakeholders and pipeline experts to fund projects not only to mitigate known risks affecting safety, but also explore solutions to unique challenges as new energy resources that could be transported by pipelines are explored to meet the country’s clean and sustainable energy needs.

Advancing pipeline safety and environmental protection requires PHMSA and the industry to be proactive and continuously gain a practical understanding of the transportation and storage characteristics of resources, such as H<sub>2</sub>, CO<sub>2</sub>, and other renewable fuels. PHMSA’s goal to mitigate and reduce methane releases from pipelines enhances safety and helps address environmental risks.