



U.S. Department
of Transportation
**Pipeline and Hazardous
Materials Safety
Administration**

Administrator

1200 New Jersey Avenue, SE
Washington, DC 20590

September 7, 2021

The Honorable Maria Cantwell
Chair, Committee on Commerce,
Science, and Transportation
United States Senate
Washington, DC 20510

Dear Chair Cantwell:

Enclosed please find the report entitled, "Fiscal Years 2019 and 2020 Update Report to Congress on the Pipeline Safety Research and Development Five-Year Program Plan." It is submitted in fulfillment of the mandate found in Section 12 of the Pipeline Safety Improvement Act of 2002, 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 (the Act). The Act requires the Secretary of Transportation to submit reports updating Congress on the progress and implementation of the Pipeline Safety Research and Development (R&D) Five-Year Program Plan. The current Pipeline Safety R&D Five-Year Program Plan covers Fiscal Years 2016-2020 and is publicly available from the Pipeline Safety R&D Program website.¹

I have sent similar letters to the Ranking Member of the Senate Committee on Commerce, Science, and Transportation; the Chair and the Ranking Member of the House Committee on Energy and Commerce; and the Chair and the Ranking Member of the House Committee on Transportation and Infrastructure.

Should you require further information or assistance, please feel free to call me or have your staff contact Patricia Klinger, PHMSA's Deputy Director of Governmental, International, and Public Affairs, by phone at (202) 366-6374 or by email at patricia.klinger@dot.gov. I hope this information is helpful.

Sincerely,

A handwritten signature in black ink that reads "Tristan H. Brown".

Tristan H. Brown
Acting Administrator

Enclosure

¹ https://primis.phmsa.dot.gov/rd/docspr/PHMSA_Pipeline_RD_5-Year_Plan.pdf



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1200 New Jersey Avenue, SE
Washington, DC 20590

September 7, 2021

The Honorable Roger Wicker
Ranking Member, Committee on Commerce,
Science, and Transportation
United States Senate
Washington, DC 20510

Dear Ranking Member Wicker:

Enclosed please find the report entitled, "Fiscal Years 2019 and 2020 Update Report to Congress on the Pipeline Safety Research and Development Five-Year Program Plan." It is submitted in fulfillment of the mandate found in Section 12 of the Pipeline Safety Improvement Act of 2002, 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 (the Act). The Act requires the Secretary of Transportation to submit reports updating Congress on the progress and implementation of the Pipeline Safety Research and Development (R&D) Five-Year Program Plan. The current Pipeline Safety R&D Five-Year Program Plan covers Fiscal Years 2016-2020 and is publicly available from the Pipeline Safety R&D Program website.¹

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1200 New Jersey Avenue, SE
Washington, DC 20590

September 7, 2021

The Honorable Peter A. DeFazio
Chair, Committee on Transportation and Infrastructure
U.S. House of Representatives
Washington, DC 20515

Dear Chair DeFazio:

Enclosed please find the report entitled, "Fiscal Years 2019 and 2020 Update Report to Congress on the Pipeline Safety Research and Development Five-Year Program Plan." It is submitted in fulfillment of the mandate found in Section 12 of the Pipeline Safety Improvement Act of 2002, 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 (the Act). The Act requires the Secretary of Transportation to submit reports updating Congress on the progress and implementation of the Pipeline Safety Research and Development (R&D) Five-Year Program Plan. The current Pipeline Safety R&D Five-Year Program Plan covers Fiscal Years 2016-2020 and is publicly available from the Pipeline Safety R&D Program website.¹

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1200 New Jersey Avenue, SE
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September 7, 2021

The Honorable Sam Graves
Ranking Member, Committee on Transportation and Infrastructure
U.S. House of Representatives
Washington, DC 20515

Dear Ranking Member Graves:

Enclosed please find the report entitled, "Fiscal Years 2019 and 2020 Update Report to Congress on the Pipeline Safety Research and Development Five-Year Program Plan." It is submitted in fulfillment of the mandate found in Section 12 of the Pipeline Safety Improvement Act of 2002, 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 (the Act). The Act requires the Secretary of Transportation to submit reports updating Congress on the progress and implementation of the Pipeline Safety Research and Development (R&D) Five-Year Program Plan. The current Pipeline Safety R&D Five-Year Program Plan covers Fiscal Years 2016-2020 and is publicly available from the Pipeline Safety R&D Program website.¹

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1200 New Jersey Avenue, SE
Washington, DC 20590

September 7, 2021

The Honorable Frank Pallone, Jr.
Chair, Committee on Energy and Commerce
U.S. House of Representatives
Washington, DC 20515

Dear Chair Pallone:

Enclosed please find the report entitled, "Fiscal Years 2019 and 2020 Update Report to Congress on the Pipeline Safety Research and Development Five-Year Program Plan." It is submitted in fulfillment of the mandate found in Section 12 of the Pipeline Safety Improvement Act of 2002, 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 (the Act). The Act requires the Secretary of Transportation to submit reports updating Congress on the progress and implementation of the Pipeline Safety Research and Development (R&D) Five-Year Program Plan. The current Pipeline Safety R&D Five-Year Program Plan covers Fiscal Years 2016-2020 and is publicly available from the Pipeline Safety R&D Program website.¹

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1200 New Jersey Avenue, SE
Washington, DC 20590

September 7, 2021

The Honorable Cathy McMorris Rodgers
Ranking Member, Committee on Energy and Commerce
U.S. House of Representatives
Washington, DC 20515

Dear Ranking Member McMorris Rodgers:

Enclosed please find the report entitled, "Fiscal Years 2019 and 2020 Update Report to Congress on the Pipeline Safety Research and Development Five-Year Program Plan." It is submitted in fulfillment of the mandate found in Section 12 of the Pipeline Safety Improvement Act of 2002, 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 (the Act). The Act requires the Secretary of Transportation to submit reports updating Congress on the progress and implementation of the Pipeline Safety Research and Development (R&D) Five-Year Program Plan. The current Pipeline Safety R&D Five-Year Program Plan covers Fiscal Years 2016-2020 and is publicly available from the Pipeline Safety R&D Program website.¹

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Pipeline and Hazardous Materials Safety Administration



A photograph of a pipeline system at sunset or sunrise. The pipes are arranged in a perspective that recedes into the distance, illuminated by the warm orange and yellow light of the sun. The sky is a gradient of yellow, orange, and blue. A dark blue diagonal band on the right side of the image contains the title text.

**Fiscal Years
2019 and 2020
Update Report
to Congress**

Pipeline Safety Research and Development

Five-Year Program Plan

R&D Update Report on FY 2019 and 2020 to the Five-Year Program Plan

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FOREWORD:

This report represents the second of two update reports on the progress of implementing the Pipeline Safety Research and Development Five-Year Program Plan. This plan is publicly available on the Pipeline Safety R&D Program website.¹ Additionally, the first update report covering Fiscal Years 2017 and 2018 is publicly available on the website.²

¹ https://primis.phmsa.dot.gov/rd/docspr/PHMSA_Pipeline_RD_5-Year_Plan.pdf

² <https://primis.phmsa.dot.gov/rd/docspr/Five%20Year%20Research%20Plan%20-%20Biennial%20Report%20FY%2017-18.pdf>

Abbreviations List

3D	Three-Dimensional
AC	Alternating Current
AGA	American Gas Association
AI	Artificial Intelligence
AOPL	Association of Oil Pipe Lines
API	American Petroleum Institute
APGA	American Public Gas Association
ASME	American Society of Mechanical Engineers
ASU	Arizona State University
ATDS	Automated Threat Detection System
BLEVE	Boiling Liquid Expanding Vapor Explosion
BSEE	Bureau of Safety and Environmental Enforcement
CAAP	Competitive Academic Agreement Program
CEC	California Energy Commission
CER	Canada Energy Regulator
CFD	Computational Fluid Dynamics
CFR	Code of Federal Regulations
CPM	Computational Pipeline Monitoring
CSU	Colorado State University
CT	Computed Tomography
DOC	Department of Commerce
DOE	Department of Energy
DOI	Department of the Interior
DOT	Department of Transportation
EMAT	Electromagnetic Acoustic Technology
EPA	Environmental Protection Agency

FAA	Federal Aviation Administration
FERC	Federal Energy Regulatory Commission
FFRDC	Federally Funded Research and Development Centers
FRA	Federal Railroad Administration
FY	Fiscal Year
GIS	Geographic Information System
G/L PAC	Gas/Liquid Pipeline Advisory Committee
GO	Government Organizations
GPR	Ground Penetrating Radar
GPS	Global Positioning System
GTI	Gas Technology Institute
GUI	Graphical User Interface
IAA	Inter-Agency Agreements
IAC	Interference Current
IFG	Industry Focus Group
ILI	In-Line Inspection
ILPP	Intrinsically-Locatable Plastic Pipe
INGAA	Interstate Natural Gas Association of America
IPC	International Pipeline Conference
ISC	Industry Stakeholder Committees
IWEX	Inverse Wave Field Extrapolation
LDC	Local Distribution Companies
LiDAR	Light Detection and Ranging
LNG	Liquefied Natural Gas
MATIPI	Multimodal Acoustic Tool for Inline Pipe Inspection
MD	Mechanical Damage
MEP	Model Evaluation Protocol
ML	Machine Learning

MSU	Michigan State University
MWM	Meandering Winding Magnetometer
NACE	National Association of Corrosion Engineers
NAPSR	National Association of Pipeline Safety Representatives
NDE	Non-Destructive Evaluation
NGA	Northeast Gas Association
NGO	Non-Governmental Organizations
NII	NACE International Institute
NIST	National Institute of Standards and Technology
NTL	National Transportation Library
OTA	Other Transaction Agreement
OTD	Operations Technology Development
PDCA	Plan, Do, Check, Act
PHMSA	Pipeline and Hazardous Materials Safety Administration
PRCI	Pipeline Research Council International
PSRP	Pipeline Safety Research Program
R&D	Research and Development
ROW	Right-Of-Way
SBIR	Small Business Innovative Research
SCC	Stress Corrosion Cracking
SP	Special Permit
T2	Technology Transfer
TAS	Test Assembly Stations
TTC	Transportation Technology Center
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
UGS	Underground Gas Storage
USDA	Department of Agriculture

UTA University of Texas at Arlington

WVU West Virginia University

1. Executive Summary

The Pipeline and Hazardous Materials Safety Administration's (PHMSA's) mission is to protect people and the environment by advancing the safe transportation of energy products and other hazardous materials that are essential to our daily lives. PHMSA oversees the transportation of hazardous materials, including energy products, through all modes of the transportation industry. PHMSA operates in a dynamic and challenging environment in which changes in technology, manufacturing, and energy production affect transportation safety. The agency anticipates that the scope and complexity of its safety mission will continue to grow, requiring it to continuously evaluate how it uses information and technology to achieve the Department of Transportation's (DOT's) safety goals. PHMSA partners with any stakeholder who shares the goal of developing new technology, products, and knowledge aimed at improving safety in all its research. The research agenda adapts to address existing and future safety threats.

Due to the importance of energy products and other hazardous materials to our economy and standard of living, it is essential that research projects promote safety and reliability, and ensure our transportation system's efficient and reliable performance. Therefore, PHMSA funds research that improves safety, ensures reliability, protects the environment, boosts business and government productivity, and enhances the security of infrastructure and people. In 2016, PHMSA developed a research plan in accordance with the Pipeline Safety Improvement Act of 2002 to fund innovative research. The Pipeline Safety Research and Development (R&D) Five-Year Program Plan (Plan) provides ways to promote transparency, and inter-agency and stakeholder input to effectively and efficiently manage R&D project activities.

The Plan focuses research on the following six program elements in response to stakeholder input and identified subject areas:

- Threat Prevention
- Leak Detection
- Anomaly Detection and Characterization
- Anomaly Remediation and Repair
- Liquefied Natural Gas (LNG) and Underground Natural Gas Storage
- Design, Materials, and Welding/Joining

PHMSA routinely consults with stakeholders to identify research gaps, develop research projects, and conduct independent peer-review of research results across the six program elements. This collaborative partnership with pipeline stakeholders has resulted in the development and transfer of more than 30 new commercialized technologies since 2002. This report includes a summary of updated research needs and priorities identified in the Pipeline Safety Improvement Act of 2002. This report also provides a general overview of the PHMSA

R&D program, highlights past success, and describes the Plan activities through fiscal years (FY) 2019 and 2020.

During FY 2019 and 2020, PHMSA invested in 15 projects to develop new technology and 44 projects to promote knowledge for decision-makers. The R&D in FY 2019 and 2020 included a greater focus on underground natural gas storage facilities, methane detection, and LNG facilities due to changes in regulatory landscape and energy supply/demand. PHMSA's Competitive Academic Agreement Program (CAAP) continues to engage students from higher education institutions in pipeline safety-related research, providing a potential career pathway into the industry. Such engagement also illustrates that R&D carried out in academia, particularly in science and technology, contributes to American innovation, competitiveness, and economic growth.

PHMSA's research results in scholarly publications and commercially viable products to improve pipeline safety. During FY 2019 and 2020, two patents and four commercialized technology improvements resulted from PHMSA's R&D investments.

PHMSA continued its R&D work in 2019 and 2020 and successfully met the primary objectives of the Pipeline Research, Development and Technology Program to develop new technologies or processes, and to generate and promote pipeline decision-makers' knowledge across all levels.

PHMSA will utilize a Plan, Do, Check, Act process to develop its next five-year (2021-2025) pipeline safety R&D priorities to ensure it is agile by analyzing emerging technologies capable of responding to critical gaps in pipeline safety. In addition, the 2021-2025 program will focus on the new Administration's goals of addressing climate change. For example, PHMSA is currently looking into hydrogen pipeline safety research, which can be used as a sustainable fuel for power generation and carbon-neutral energy alternatives.

PHMSA, as directed by Section 105 of the Protecting our Infrastructure of Pipelines and Enhancing Safety Act of 2020 (PIPS Act of 2020), will conduct an assessment and cost-benefit analysis of the need to develop an independent pipeline safety research and testing facility and submit a report to Congress.

2. Introduction

Section 12 of the Pipeline Safety Improvement Act of 2002, P.L. 107-355, as amended by Section 32 of the Pipeline Safety, Regulatory Certainty, and Job Creation Act of 2011, Pub. L. 112-90, requires the Secretary of the DOT to submit reports updating Congress on the progress and implementation of the Pipeline Safety Research and Development Five-Year Program Plan (Plan).

The current Plan covers FY 2016-2020 and is publicly available on the Pipeline Safety R&D Program Webpage.¹ This report provides a general overview of the PHMSA Pipeline RD&T Program, highlights past successes, and recounts Plan activities through FY 2019 and 2020. Initiation of the next five-year research plan covering FY 2021 through 2025, is underway, and covered in Section 13.

PHMSA oversees the transportation of hazardous materials, including energy products, through all modes of the transportation industry. 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 its safety mission will continue to grow, requiring the agency to continuously evaluate how it uses the data from the research and technology analysis conducted to achieve the DOT's safety goals.

3. PHMSA Pipeline Safety Research Program

PHMSA's Pipeline Safety Research Program (PSRP) funds innovative research that helps improve safety and the protection of the environment and supports reliable supplies of energy products and hazardous materials. The PSRP provides scientific and engineering support for PHMSA's safety enforcement and regulatory rulemaking efforts. It also identifies and develops emerging technologies for the pipeline industry to adopt voluntarily.

The focus of the PSRP is to fill the gaps in research not conducted by industry and to partner with pipeline stakeholders to leverage private R&D investment that would ensure public safety and protection of the environment. PHMSA strives to avoid duplicating research, and works closely with academia and pipeline stakeholders to fund and share the cost of critical research to develop new technology, products, knowledge, and promote stakeholder engagement. A comprehensive research strategy is developed systematically through research and development forums, research gap ideas submitted by the public, PHMSA initiatives, and collaboration partners, as shown in Figure 3-a.

Figure 3-a. Developing a Research Program Strategy



¹ [HTTPS://PRIMIS.PHMSA.DOT.GOV/RD/DOCSPR/PHMSA_PIPELINE_RD_5-YEAR_PLAN.PDF](https://PRIMIS.PHMSA.DOT.GOV/RD/DOCSPR/PHMSA_PIPELINE_RD_5-YEAR_PLAN.PDF)

4. Stakeholder Involvement in the R&D Program Research Agenda

The FY 2019 research strategy was derived in part from a Pipeline R&D Forum attended by approximately 200 stakeholders in Baltimore, Maryland, on September 11-12, 2018.² The forum provided an opportunity to discuss research gaps and have five working groups finalize research recommendations on the following topic areas:

1. Improving Assessment Methods for Dents & Cracks
2. Remote Sensing/Leak Detection-Mitigation
3. Locating & Preventing Damage to Distribution Pipelines
4. Expanding In-Line Inspection (ILI) Capabilities & Application
5. LNG

PHMSA utilized the recommendations to establish its FY 2019 research funding agenda that was competitively solicited in Research Announcement #693JK3191RA01.

In March 2019, PHMSA 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.³

Partnerships with government organizations (GO) and non-government organizations (NGO) provide clear opportunities to leverage ongoing successes, cost share on research on mutual safety challenges, and remove duplication. Throughout the year, PHMSA briefs trade associations and the pipeline industry on the research programs 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, but are not limited to, the following as shown in Table 4-a below:

² [HTTPS://PRIMIS.PHMSA.DOT.GOV/RD/MTG_091118.HTM](https://PRIMIS.PHMSA.DOT.GOV/RD/MTG_091118.HTM)

³ [HTTPS://PRIMIS.PHMSA.DOT.GOV/RD/GAPSUGGESTIONS.HTM](https://PRIMIS.PHMSA.DOT.GOV/RD/GAPSUGGESTIONS.HTM)

Table 4-a. Research Collaboration Partners

Organization Name	GO	NGO
American Gas Association (AGA)		X
American Petroleum Institute (API)		X
American Public Gas Association (APGA)		X
American Society of Mechanical Engineers (ASME)		X
Association of Oil Pipe Lines (AOPL)		X
California Energy Commission (CEC)	X	
Canada Energy Regulator (CER)	X	
Department of Agriculture (USDA)	X	
Department of Commerce (DOC): National Institute of Standards and Technology (NIST)	X	
Department of Energy (DOE)	X	
Department of the Interior (DOI): Bureau of Safety and Environmental Enforcement (BSEE)	X	
Environmental Protection Agency (EPA)	X	
Interstate Natural Gas Association of America (INGAA)		X
NACE International Institute (NII)		X
National Association of Pipeline Safety Representatives (NAPSR)	X	
Northeast Gas Association (NGA)/NYSEARCH		X
Operations Technology Development (OTD)		X
Pipeline Research Council International (PRCI)		X

The FY 2020 research strategy was derived in part from a Pipeline R&D Forum attended by approximately 240 stakeholders in Arlington, Virginia, on February 19-20, 2020.⁴ The forum provided an opportunity to discuss research gaps and have five working groups finalize research recommendations on the following topic areas:

1. Gas Gathering Pipelines
2. Preventing & Mitigating Geo-Forces on Pipelines & Facilities
3. Automation Solutions for Integrity Management Challenges
4. Underground Gas Storage Facilities
5. LNG

⁴ [HTTPS://PRIMIS.PHMSA.DOT.GOV/RD/MTG_021920.HTM](https://PRIMIS.PHMSA.DOT.GOV/RD/MTG_021920.HTM)

PHMSA plans to utilize the recommendations to establish its FY 2021 research funding agenda that will be competitively solicited in a research announcement.

4.1 Stakeholder Initiatives: Transportation Technology Center (TTC) Initiatives

Based on approximately 20 years of experience in R&D activities, PHMSA has concluded that privately managed pipeline research facilities in the U.S. have primarily focused on extending the service life of existing infrastructure and reducing costs associated with the physical “dig and inspect” requirements for certain pipeline anomalies. In addition, while there are several testing facilities available in the U.S., none can provide testbeds where a new technology can be tested in full-scale, real-world conditions (accelerated or normal time).

Even when new and worthy technologies are developed, technology transfer is a difficult hurdle. The technology must be developed, demonstrated, and commercialized before government provides the regulatory framework that permits its use. PHMSA’s special permits require credible data on the performance of new technologies to ensure pipeline safety is maintained, which can be a long and arduous process.

One comprehensive solution to address this gap is to create a robust pipeline research and testing facility that catalyzes innovation from the private sector, universities, or other research organizations.

As a result, in FY 2020, PHMSA pursued the development of a Research, Development, and Testing program at the Federal Railroad Administration’s (FRA’s) Transportation Technology Center (TTC) in Pueblo, Colorado by awarding an engineering services other transaction agreement (OTA) (Engineering OTA). The Engineering OTA initiated work for engineering, design, and development of PHMSA’s Research, Development, and Testing program at TTC. Also, PHMSA awarded an OTA to the incumbent operator at TTC for two short-term projects identifying pipe fatigue damage occurring during transportation on railroad flat cars and analyzing stress and load effects on uncased pipelines installed under railroad tracks to determine if casings are required.

PHMSA, as directed by Section 105 of the Protecting our Infrastructure of Pipelines and Enhancing Safety Act of 2020 (PIPES Act of 2020), will conduct an assessment and cost-benefit analysis of the need to develop an independent pipeline safety research and testing facility and submit a report to Congress to be completed by 2022. PHMSA will also address in the report the costs and benefits of colocating an independent pipeline safety testing facility at an existing training center of the Administration. Below are the specific requirements of Section 105 of the PIPES Act of 2020:

- (1) The research and development capabilities of the Administration, in accordance with section 12 of the Pipeline Safety Improvement Act of 2002;

- (2) The development of additional testing and research capabilities through the establishment of an independent pipeline safety testing facility under the Department of Transportation; and
 - i. whether an independent pipeline safety testing facility would be critical to the work of the Administration;
 - ii. the costs and benefits of developing an independent pipeline safety testing facility under the Department of Transportation; and
 - iii. the costs and benefits of colocating an independent pipeline safety testing facility at an existing training center of the Administration.
- (3) The ability of the Administration to use the testing facilities of the Department of Transportation, other Federal agencies, or federally funded research and development centers.

5. Inter-Agency Engagement

Inter-agency coordination meetings are periodically held between PHMSA and any federal agency having a mutual research interest. These meetings are utilized to share information on any notable recent successes, to summarize any pipeline, LNG, and gas storage research subjects that each agency is currently working on, to share pre-award information on what subjects are being considered for research solicitation, and to identify any opportunities for inter-agency collaboration and co-funding. These meetings reduce duplication, leverage resources, and result in collaborative research through inter-agency agreements.

In July of 2020, PHMSA kicked off two short-term research projects at TTC. The projects focused on the testing of fatigue on pipelines transported by rail and stress on pipelines subject to railroad loading. There was a high value in initiating this project at TTC to foster relationships with the FRA and rail stakeholders, and to engage the pipeline industry in cross-modal research. The projects quickly yielded dividends by establishing an industry focus group (IFG); which has highlighted inter-modal research areas that should be prioritized in PHMSA's research plan.

Table 5-a describes the various inter-agency engagement that occurred in FY 2019 and 2020.

Table 5-a. Inter-Agency Engagement Summary

Federal Agency Name	Subject Engagement	Pre-award Merit Review Panels	Agency Resource Sharing	Post-award Peer-review Panels	Inter-agency Meetings
DOC: NIST	FY 2019 DOT/DOC inter-		X		X

Federal Agency Name	Subject Engagement	Pre-award Merit Review Panels	Agency Resource Sharing	Post-award Peer-review Panels	Inter-agency Meetings
	agency agreement and inter-agency coordination meetings.				
DOE: National Energy Technology Laboratory, Oak Ridge National Laboratory; Sandia National Laboratories; Advanced Research Projects Agency – Energy; and Biomass Program	PHMSA pre-award participation on DOE Funding Opportunity Announcement DE-FOA-0002289 entitled Rapid Encapsulation of Pipelines Avoiding Intensive Replacement and inter-agency coordination meetings.	X			X
DOI: BSEE	DOI post-award peer review participation with DOT and inter-agency coordination meetings.			X	X
DOT: FRA	Inter-agency meetings between PHMSA/FRA to develop new research funded at the Transportation Technology Center.				X
Federal Energy Regulatory Commission (FERC)	FERC pre-award merit review panel and post-award peer review participation with DOT.	X		X	
State Agencies					
Various State Public Utility Commissions	State PUC pre-award participation on DOT research announcements and notices of funding opportunities.	X			

6. Programmatic Objectives

Based upon stakeholder input and historical and current accident trends, a set of high-value programmatic objectives have been identified as the focal point of PHMSA's research. The specific research projects and scope of activities may change from year to year to address emerging problems based on data analysis and industry needs, and in response to

Congressional mandates and specific pipeline incidents. Based upon the agency's analysis and stakeholder input, this Plan focuses on the following six program elements:

Preventing Pipeline Threats/Damage

Activities in this topic area include examining tools to alert operators of possible intrusions to pipelines (e.g., excavation damage), helping operators map existing pipelines, making new plastic pipes locatable without the need for a separate tracer wire, or making existing unlocatable plastic pipes locatable in advance of planned excavations. Additional opportunities in this topic area include advancements in high-altitude imaging, machine learning (ML), and predictive analytics to mitigate external threats to pipeline infrastructure.

Improving Pipeline Leak Detection Systems

Activities in this topic area include new or improved tools and technology solutions for locating, quantifying, and reducing the volume of pipeline leaks and ruptures into the environment. Additional opportunities in this topic area include using ML to identify small leaks before they lead to catastrophic ruptures.

Improving Anomaly Detection and Characterization

Activities in this topic area are designed to support the pipeline industry in making integrity management decisions and finding and removing critical defects in the pipeline system. This area of research will support efforts to identify threats within pipelines and will provide operators with effective instrumentation allowing for accurate remediation measures.

Improving Anomaly Remediation and Repair

Activities in this topic area will address reliable methods for repairing damaged coatings and corrosion damage—major problems for pipelines. Research activities will address ways to improve the pipeline repair processes and to improve standards or best practices for operators and contractors. Testing is needed for composite materials—the most common materials used for pipeline repairs—to understand its integrity under complex loading and over the long term. Research activities will also enhance repair materials, techniques, processes, tools, and/or technology designed to quickly bring pipeline systems back on line.

Improving Safety Systems for Liquefied Natural Gas Facilities

Activities in this topic area will address various LNG industry challenges related to LNG hazards, as well as foster development of new technologies and alternative designs for LNG storage and piping systems. Additional activities in this research topic will address performance-based risk reduction for design, construction, operations, maintenance, and fire protection of LNG facilities.

Improving Design, Materials, and Welding/Joining

Activities in this topic area will address improved pipeline materials and design, which can mitigate or minimize integrity threats to both transmission and distribution piping. The

welding and joining of transmission and distribution systems will require automation and inspection capabilities that can safely improve the efficiency of construction activities. The development of quality management system guidelines to improve construction-related quality issues can reduce the likelihood of girth weld failures shortly after welding, during lowering-in, during hydrostatic testing, and when in service. Research activities will improve industry's ability to design and construct safe, long-lasting pipelines using the most appropriate materials and welding/joining procedures for a given operating environment.

Improving Safety Systems for Underground Gas Storage

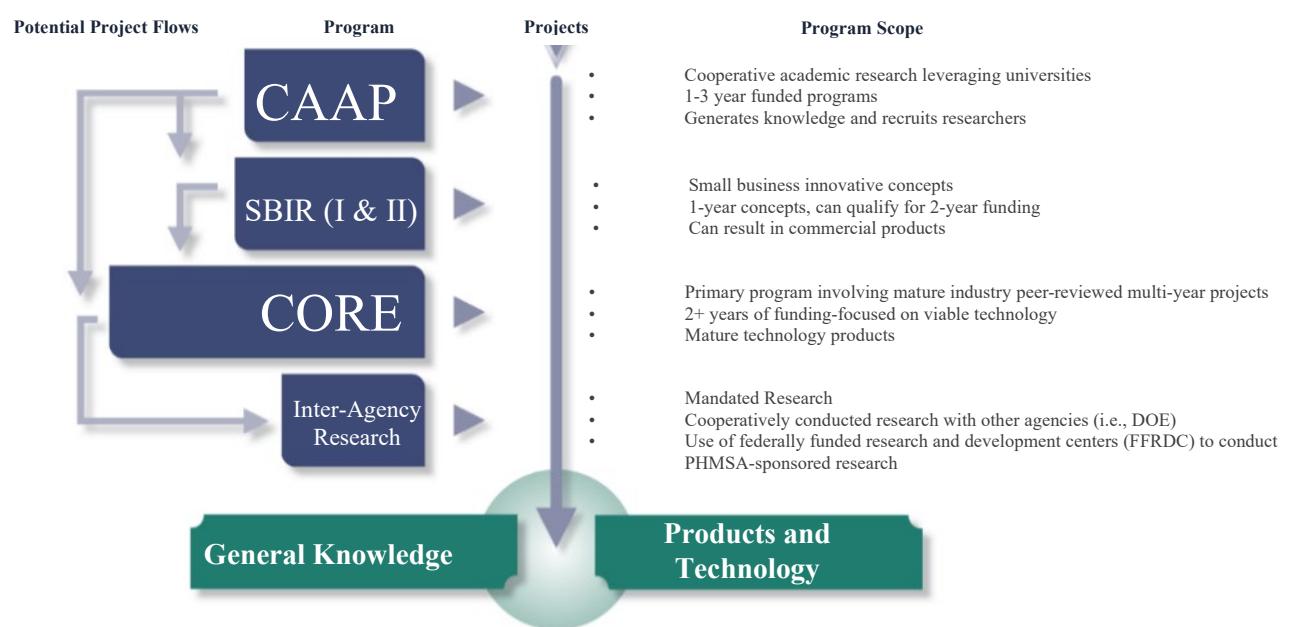
Activities in this topic area include research to improve the safety of underground gas storage (UGS) facilities for their full life-cycle. Research activities will focus on reducing risks to the public and UGS worker safety. Specific research areas include design and reliability improvements to UGS equipment, such as tubing, packers, and subsurface safety valves, as well as knowledge enhancement on associated maintenance practices for UGS wells.

7. Program Structure

PHMSA uses public-private partnerships with stakeholders, academic institutions, small businesses and intergovernmental agreements to conduct the PSRP. The program is executed through competitive awards, cost-sharing agreements, grants and inter-agency agreements. These four approaches address different research requirements and are designed to develop research concepts from initial conceptual stages to industry or government adoption.

Below, in Figure 7-a, is a demonstration of the four different research requirements.

Figure 7-a. Comprehensive Research Execution Strategy



7.1 Program Structure Funding Summary (FY 2019 and 2020)

PHMSA's PSRP includes four sub-program categories (see Figure 7-a):

Core Research Program – (\$17,349,958)

PHMSA's PSRP is primarily executed through the Core Research Program (Core). Under Core, the main activities focus on developing new technologies or products and conducting demonstrations, and on transfer of technology for commercialization. In addition, Core promotes the use of new knowledge by decision makers.

- FY 2019 Awarded Projects: \$9,717,593
- FY 2020 Awarded Projects: \$7,632,365

Competitive Academic Agreement Program – \$3,956,722

PHMSA developed and launched the Competitive Academic Agreement Program (CAAP) in 2013, funding research awards to conduct innovative research made through competitive bidding to colleges and universities. The CAAP is intended to spur innovation by enabling academic research focused on high-risk, high-reward solutions to a wide range of pipeline safety challenges.

- FY 2019 Awarded Projects: \$1,956,810
- FY 2020 Awarded Projects: \$1,999,912

Small Business Innovative Research Program – \$4,862,942

The Small Business Innovative Research (SBIR) program was established under Executive Order 13329 in February 2004 to encourage innovation in manufacturing. The executive order assigns duties to the Small Business Administration, defines the duties of the agencies and departments that participate in the SBIR program, and states that continued technological innovation is critical to the strength of the United States economy's manufacturing sector.

- FY 2019 Awarded Projects: \$2,987,903
- FY 2020 Awarded Projects: \$1,875,039

Inter-Agency and PHMSA-conducted Research – \$14,201,298

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

- FY 2019 Awarded Projects: \$705,000
- FY 2020 Awarded Projects: \$13,496,298

8. Communication of Program and Project Activities

In FY 2019 and 2020, PHMSA communicated its programs and project funding opportunities/activities through the following forms of media outlets:

beta.SAM.gov

- Core Research Announcement #693JK3191RA01 in FY 2019
- Special Notice 693JK319SN0001 welcoming submitted research gap ideas
- Core Research Announcement # 693JK320RA0001 in FY 2020
- TTC Research Announcement #693JK320NF0011 in FY 2020

SBIR.gov/solicitations

- SBIR 6913G620QSBIR1 in FY 2020

Grants.gov

- CAAP Notice of Funding Opportunity #693JK319NF0005 in FY 2019
- CAAP Notice of Funding Opportunity #693JK320NF0001 in FY 2020

Website Post

- New research project pages posted in FY 2019
- New research project pages posted in FY 2020
- Special Notice for research gap ideas in FY 2019

When announcing public events such as R&D forums, PHMSA posts information in the Federal Register, Twitter, LinkedIn, and social media. Other key R&D presentations are made at Gas/Liquid Pipeline Advisory Committee (G/L PAC) meetings, and research portfolios are commonly presented at industry conferences, such as the API Pipeline Conference, Control Room and Cybernetics Conference, Association of Materials Protection and Performance (AMPP, formerly National Association of Corrosion Engineers (NACE)) Corrosion Conference and Expo, and the International Pipeline Conference (IPC).

When announcing information about research funding opportunities and newly awarded research projects, PHMSA has a roll out plan which includes the following components:

Research Funding Opportunities

- Core and TTC opportunities are posted here: <https://beta.sam.gov/>
- SBIR opportunities are posted by the DOT here: <https://www.sbir.gov/solicitations/open>
- CAAP opportunities are posted here: <https://www.grants.gov/>

In each contract or agreement, PHMSA requires several deliverables that the researcher must provide to promote project results, such as commercialization of the product at the end of the

contract. In some cases, this knowledge or technology transfer occurs long after the end of the contract, limiting PHMSA's ability to observe and track it. PHMSA ensures that awarded research promotes general knowledge to decision-makers by requiring awardees to:

- Submit results at public conferences, forums, symposiums, workshops, or trade journals;
- Report any application for a U.S. patent;
- Conduct an output-focused final meeting with invited decision makers and stakeholders;
- Collaborate at public events where ongoing work or results are discussed, such as Research, Development, and Technology forums and workshops; and
- Participate in PHMSA's annual PSRP Peer Reviews, where knowledge from research is reviewed and shared.

Information about research projects awarded by PHMSA is made publicly-available on the USDOT Research Hub, the National Transportation Library (NTL) Digital Library, and PHMSA's website.⁵

9. 2019-2020 Research Objectives and Outputs

9.1 FY 2019

The next sections identify PHMSA's goals to address various programmatic elements, describe objectives to meet those goals, and list representative R&D projects undertaken to provide solutions and to improve pipeline safety and the protection of the environment. The funding total in FY 2019 was \$15,367,306.

Goal

Preventing Pipeline Threats/Damage (\$7,453,114)

Objective 1a: Subsurface Multi-Utility Asset Location Detection (Core: \$1,028,122)

To mitigate excavation damage to underground pipelines by installing a marker at early stages of production for plastic pipe. A marker attached by the plastic pipe manufacturer at the time of production obviates most of the risks associated with current methods of locating plastic pipe. The goals are to define/test the marker capability, the attachment design, and the manufacturing qualifications; and to complete installation/ testing with two major gas utilities.

⁵ INFORMATION FOR BOTH PROGRAMS IS AVAILABLE AT [HTTPS://WWW.PHMSA.DOT.GOV/RESEARCH-AND-DEVELOPMENT/PHMSA-RESEARCH-AND-DEVELOPMENT.](https://www.phmsa.dot.gov/research-and-development/phmsa-research-and-development)

Objective 1b: Procedures for Selecting Locating and Excavation Technologies (Core: \$495,000)

To investigate underground utility locating and excavating technologies and practices, and new systems for pipeline encroachment notification. The project will develop a web-based program and database to identify and proactively address high-risk excavations. The project will also develop a situational awareness framework intended to provide important information on underground utilities, site characteristics, and high-risk features of the excavation sites.

Objective 1c: Review the Intent and Safety Impact of Hoop Stress and Percentage of Specified Minimum Yield Stress Boundaries on Natural Gas Transmission and Distribution Pipelines (Core: \$431,902)

To provide pipeline operators with a simple set of criteria to be used when a system is governed by either Title 49 Code of Federal Regulations (CFR) Part 192 Subpart O – Gas Transmission Pipeline Integrity Management or Subpart P – Gas Distribution Pipeline Integrity Management requirements that are risk consistent. The criteria must be realistic, simple, and accurate (i.e., physics-based).

Objective 1d: Data Collection, Normalization and Integration Methods to Enhance Risk Assessment Tools for Decision-Making (Core: \$1,161,597)

To develop decision-making tools that would help pipeline integrity managers select the most cost-effective additions to sensor networks to reduce expected risk for risk management. The researcher will apply ML and science-based methods to develop decision tools for pipeline operators.

Objective 1e: Develop and Demonstrate a Remote Multi-Sensor Platform for Right-of-Way Defense (Core: \$439,000)

To improve and deploy a pipeline right-of-way (ROW) monitoring system based on stationary sensors mounted on/near the pipeline. Sensor data from multiple locations along the pipe is wirelessly transferred to a central location for processing, and analytics correlate the data from multiple sensors to rapidly alert operators to events occurring in the ROW. The project will deploy improved field hardware—sensors that will be located along the ROW—with ML analytics.

Objective 1f: Improving Subsurface Non-Metallic Utility Locating Using Self-Aligning Robotic Ground Penetrating Radar

To develop a pre-commercial prototype robotic system that will improve locating underground utilities. This will be achieved by improving the quality of image and location data using self-adapting antenna configurations that increase the probability of detection. Two robotic carts will autonomously align themselves to each other and to the buried utilities to locate both metallic and non-metallic pipelines.

Objective 1g: Mapping Indication Severity Using Bayesian Machine Learning from Indirect Inspection Data into Corrosion Severity for Decision-Making in Pipeline Maintenance (Core: \$310,000)

To provide industry with a fast, reliable, and accurate tool that determines corrosion severity and real corrosion rates by adapting current direct assessment practices to supplement the survey technologies with a slightly broader database of environmental data.

Objective 1h: Fundamental Understanding of Pipeline Material Degradation under Interactive Threats of Dents and Corrosion (CAAP: \$250,000)

To learn more about evaluating interactive threats—the coincidence of two or more threats in a pipeline segment—of external mechanical dents and secondary features. The evaluation will be done through an integrated lab-scale experimental and numerical framework that would characterize and better predict the remaining safe life and operating pressures of the pipeline, while also forecasting the need for mitigation measures.

Objective 1i: An Unmanned Aerial System of Visible Light, Infrared and Hyperspectral Cameras with Novel Signal Processing and Data Analytics (CAAP: \$250,000)

To develop and integrate an Unmanned Aerial System (UAS) with multiple sensors for multi-purpose pipeline safety data collection. The researchers will explore data processing techniques and ultimately evaluate and validate the field performance of the UAS for pipeline safety inspections.

Objective 1j: Combined Cleaning and Guided Wave Inspection System for Hazardous Liquid Pipelines (SBIR: \$993,938)

To develop a low-cost, lightweight inspection and cleaning prototype (dual-purpose) pigging tool—a pipeline inspection gauge that performs maintenance operations—that can be used in current hazardous liquid pipe cleaning applications. The final deliverable is a prototype tool that has been tested at a pilot facility.

Objective 1k: Multimodal Acoustic Tool for Inline Pipe Inspection (SBIR: \$994,865)

To develop a hybrid Multimodal Acoustic Tool for Inline Pipe Inspection (MATIPI)—combination of complementary techniques. A MATIPI determines material characteristics through two independent techniques measuring two separate properties, which significantly increases the accuracy of the overall approach. The solution will ultimately be demonstrated and verified at an actual pipeline dig site.

Objective 1l: Mechanical Metallurgy on Vintage X100 Experimental Pipe (IAA: \$750,000)

The NIST will conduct metallurgical testing on Columbia Gas X100 experimental pipe to provide valuable information on property changes due to degradation and property differences due to microstructure. The project will provide insight on vintage versus modern high-strength steels.

Below is a list of some of the major outputs associated with the objectives listed above.

Table 9-a. Research Project Outputs (Objective 1)

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Objective 1a: Subsurface Multi-Utility Asset Location Detection							
Output 1: Analysis of currently available optimized electronic pipeline markers.	Gas Technology Institute (GTI)		X				
Output 2: Manufacturing of prototype pipeline samples with pre-installed markers known as intrinsically locatable plastic pipe (ILPP).	GTI		X				
Output 3: Data from testing of prototype samples at GTI facilities.	GTI		X				
Output 4: Development of operator training for installation of ILPP pipeline.	GTI		X				
Output 5: Testing of installed ILPP pipeline samples at field sites in the US.	GTI		X				
Output 6: Deliver final report and conference presentation on ILPP value to pipeline safety.	GTI			X			
Objective 1b: Procedures for Selecting Locating and Excavation Technologies							
Output 1: Summary report of investigation of utilities locating and excavating technologies and practices.	OTD			X			
Output 2: Summary report of investigation of current and new systems for encroachment notification.	OTD			X			

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Output 3: Summary report of current federal and state requirements for excavation procedures and requirements.	OTD			X			
Output 4: Development of a web-based program and database to identify and proactively address high-risk excavations.	OTD				X		
Output 5: Development of a situational awareness framework to facilitate future collaborative planning of emergency responses in cases of excavation incidents. Framework will be accessible through a web-based access and user interface.	OTD				X		
Output 6: Deliver final report and conference presentation on projects value to pipeline safety.	OTD				X		
Objective 1c: Review the Intent and Safety Impact of Hoop Stress and Percentage of Specified Minimum Yield Stress Boundaries on Natural Gas Transmission and Distribution Pipelines							
Output 1: Prepare interim reports covering regulatory definition reviews, in-depth literature reviews; and incident history analysis.	GTI		X				
Output 2: Develop a sensitivity study of pipeline features and parameters.	GTI		X				

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Output 3: Development of a technically justifiable framework to assist with establishing the safety considerations required to allow pipeline segments to be properly and safely defined as either transmission or distribution pipelines.	GTI		X				
Output 4: Prepare a final report summarizing research. Prepare and present a paper at a public event or public paper in a journal/magazine.	GTI			X			
Objective 1d: Data Collection, Normalization and Integration Methods to Enhance Risk Assessment Tools for Decision-Making							
Output 1: Guidance on how to incorporate integrity information into a Bayesian Network.	GTI		X				
Output 2: A validated Bayesian model utilizing integrity management information.	GTI			X			
Output 3: A technical summary of how to use an intelligent decision-making tool to support a pipeline integrity manager's risk assessment estimate on their pipeline system.	GTI				X		
Objective 1e: Develop and Demonstrate a Remote Multi-Sensor Platform for Right-of-Way Defense							

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Output 1: Production of prototype ROW monitoring equipment and dashboard that can monitor data outputs from field equipment.	OTD		X				
Output 2: Report on the initial testing of improved ROW monitoring equipment.	OTD			X			
Output 3: Summary of the performance of the researcher's developed Geographic Information System (GIS) environment utilizing ML to visualize data from improved ROW monitoring equipment.	OTD			X			
Output 4: Develop final report on the functionality of a remote multi-sensor platform for ROW defense.	OTD			X			
Objective 1f: Improving Subsurface Non-Metallic Utility Locating Using Self-Aligning Robotic Ground Penetrating Radar							
Output 1: Complete a study on the optimal configuration of ground penetrating radar (GPR) equipment utilized to sense subsurface pipelines. Researcher will develop an algorithm to be utilized with GPR equipment.	ULC Robotics		X				
Output 2: Complete detailed design of self-aligning robotic system.	ULC Robotics		X				
Output 3: Complete fabrication and testing of robotic system.	ULC Robotics		X				

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Output 4: Researcher will conduct outdoor validation of the self-aligning robotic GPR system. The researcher will complete a product demonstration for the pipeline industry.	ULC Robotics		X				
Objective 1g: Mapping Indication Severity Using Bayesian Machine Learning from Indirect Inspection Data into Corrosion Severity for Decision-Making in Pipeline Maintenance							
Output 1: Establish database of results from inspections, moisture data, and corrosivity metrics. Identify gaps in previous corrosion severity tools.	Texas A&M University	X					
Output 2: Develop and evaluate/validate new decision-making tool for corrosion severity utilizing Bayesian ML. The tool will be tested on several real-world pipeline sections in different environmental conditions.	Texas A&M University		X				
Output 3: Final report on the decision-making tool. The report will include a comprehensive section guiding operators' use of the deliverable.	Texas A&M University		X				
Objective 1h: Fundamental Understanding of Pipeline Material Degradation Under Interactive Threats of Dents and Corrosion							

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Output 1: A technical summary and fundamental understanding of threat prevention actions to assist operators in determining the remaining safe life and operating pressures of the pipeline.	Iowa State University				X		
Output 2: Student exposure and training through research and exposing them for a possible future career in the pipeline industry.	Iowa State University				X		
Objective 1i: An Unmanned Aerial System of Visible Light, Infrared and Hyperspectral Cameras with Novel Signal Processing and Data Analytics							
Output 1: Develop and integrate a robust and stable, semi or fully automated UAS with multiple sensors for multi-purpose pipeline safety data collection.	University of Missouri			X			
Output 2: Explore and develop novel signal and image processing techniques for data analytics, damage assessment, and condition classification.	University of Missouri				X		
Output 3: Report on the field performance of the integrated UAS for pipeline safety inspection.	University of Missouri				X		
Output 4: Student exposure and training through research and exposing them for a possible future career in pipeline industry.	University of Missouri				X		

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Objective 1j: Combined Cleaning and Guided Wave Inspection System for Hazardous Liquid Pipelines							
Output 1: Testing and evaluation of inspection module for utilization in a combined tool.	ULC Robotics		X				
Output 3: Fabrication and testing of the prototype dual-purpose tool.	ULC Robotics			X			
Output 4: Final report on the prototype combined cleaning and guided wave inspection system.	ULC Robotics			X			
Objective 1k: Multimodal Acoustic Tool for Inline Pipe Inspection							
Output 1: Develop prototype multimodal inspection tool to enhance the accuracy of nondestructive examinations. Evaluate tool in pilot study.	Creare, LLC			X			
Output 2: Develop graphical user interface (GUI) for use with the multimodal tool.	Creare, LLC			X			
Output 3: Demonstrate device operation in field studies.	Creare, LLC			X			
Output 4: Pursue commercialization of prototype device and prepare final report.	Creare, LLC			X			
Objective 1l: Mechanical Metallurgy on Vintage X100 Experimental Pipe							

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Output 1: An interim report documenting the microstructure and chemistry characterization along with the Charpy testing and hardness mapping results of vintage and modern X100 pipe.	NIST			X			
Output 2: An interim report documenting the small-scale fracture testing and multiscale indentation mechanics results of vintage and modern X100 pipe.	NIST					X	
Output 3: Final report providing a full summary of the completed work and recommendations on the degradation assessment.	NIST					X	

Goal

Improving Pipeline Leak Detection Systems (\$1,442,482)

Objective 2a: Validation of Remote Sensing and Leak Detection Technologies Under Realistic and Differing Conditions (Core: \$500,000)

To develop and implement a sensor validation framework focused on actual pipeline leaks verified through ground-truthing measurement—performing surface observations and measurements of various properties of the ground—and simulated integrity threats. The framework will incorporate field settings with different infrastructure, terrain, and land cover challenges, from rural to suburban to urban.

Objective 2b: Improving the Reliability, Detection, and Accuracy Capabilities of Existing Leak Detection Systems Using Machine Learning (Core: \$177,717)

To develop a ML-based system capable of detecting hazardous liquid leaks shown in pipeline Computational Pipeline Monitoring (CPM) data. Such a system will improve leak detection below the detection threshold of current CPM data assessment.

Objective 2c: Develop Remote Sensing and Leak Detection Platform that Can Deploy Multiple Sensor Types (Core: \$307,881)

To validate the performance of a complete end-to-end system, operating on a long-range, long-endurance unmanned aircraft that operates over hundreds of miles of pipeline ROW. The result will provide automated, multi-threat ROW monitoring and surveillance through remote sensing systems.

Objective 2d: Unmanned Aerial Systems for Pipeline Inspection, Monitoring, and Landscape Analysis (CAAP: \$206,920)

To determine the most cost-effective combination of UAS sensors to monitor and evaluate pipeline conditions. The resulting knowledge will aid in further sensor development and field testing.

Objective 2e: An Autonomous Unmanned Aerial System Inspection Platform for High-Efficiency 3D Pipeline/Route Modeling/Change-Detection and Gas Leak Detection-Localization (CAAP: \$249,964)

To enhance the quality and efficiency of UAS pipeline and ROW inspections, and to evaluate and enhance the performance of pipeline leak detection localization. The resulting knowledge will aid in further sensor development and field testing.

Below is a list of some of the major outputs associated with the objectives listed above.

Table 9-b. Research Project Outputs (Objective 2)

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Objective 2a: Validation of Remote Sensing and Leak Detection Technologies Under Realistic and Differing Conditions							
Output 1: Researcher and industry partners will establish test specifications for ROW integrity threat monitoring.	OTD		X				
Output 2: Drone system integration; researcher will integrate UAS with sensors capable of leak detection and integrity threat monitoring.	OTD		X				

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Output 3: Field testing of the UAS mounted leak detection and integrity threat sensors.	OTD			X			
Output 4: Development of data analysis tools for UAS mounted sensing systems.	OTD			X			
Output 5: Final report on the validation of the integrated UAS system for remote sensing and leak detection.	OTD			X			
Objective 2b: Improving the Reliability, Detection, and Accuracy Capabilities of Existing Leak Detection Systems Using Machine Learning							
Output 1: Researcher will acquire operational datasets from pipeline operators for utilization in algorithm development.	PRCI		X				
Output 2: Development and validation of ML algorithm. The ML algorithm will be integrated into a pipeline operators' system for validation of improved leak detection.	PRCI			X			
Output 3: Researcher will submit to PHMSA documentation and final report on developed leak detection ML algorithm.	PRCI			X			
Objective 2c: Develop Remote Sensing and Leak Detection Platform that Can Deploy Multiple Sensor Types							
Output 1: Drone system integration; researcher will integrate a long range UAS with PRCI's Automated	PRCI		X				

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Threat Detection System (ATDS).							
Output 2: Develop application for FAA approval, including developing a safety case for long-range UAS usage in the pipeline safety enterprise.	PRCI			X			
Output 3: Researcher will test their ATDS system mounted to Unmanned Aerial Vehicles (UAVs) and manned aircraft in the field with simulated threats.	PRCI			X			
Output 4: Researcher will compare data from its ATDS-mounted system to ground truth and reports from aerial patrol pilots.	PRCI			X			
Output 5: Researcher will submit to PHMSA a final report summarizing their research efforts on remote sensing and leak detection.	PRCI			X			
Objective 2d: Unmanned Aerial Systems for Pipeline Inspection, Monitoring, and Landscape Analysis							
Output 1: Researcher will test their UAS systems along two different one-mile pipeline corridors during each season of the year. The UAS will include multiple sensors including Light Detection and Ranging (LiDAR), thermal, and hyperspectral to capture different phenology and witness conditions.	West Virginia University (WVU)			X			

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Output 2: Researcher will process and calibrate imagery captured in year 1 from mounted sensor systems.	WVU			X			
Output 3: Determine the most cost-effective combination of UAS sensors that focus on pipeline safety.	WVU				X		
Output 4: Student exposure and training through research and preparing them for a possible future career in the pipeline industry.	WVU				X		
Objective 2e: An Autonomous Unmanned Aerial System (UAS) Inspection Platform for High-Efficiency 3D Pipeline/Route Modeling/Change-Detection and Gas Leak Detection-Localization							
Output 1: Develop a three-dimensional (3D) inspection data management application that enables interactive inspection data visualization on 3D pipe/tank models.	University of Nebraska		X				
Output 2: Develop a 3D coverage path planning algorithm to balance UAS inspection efficiency with photogrammetry model quality.	University of Nebraska			X			
Output 3: Develop modules to identify leaks as well as topographic changes which can include land movement, third-party excavation, pipe displacement, scour erosion, etc.	University of Nebraska				X		

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Output 4: Final report and full-scale field validation and performance evaluation of the developed modules.	University of Nebraska				X		
Output 5: Student exposure and training through research and preparing them for a possible future career in the pipeline industry.	University of Nebraska				X		

Goal

Improving Anomaly Detection/Characterization (\$5,368,615)

Objective 3a: Improve Dent/Cracking Assessment Methods (Core: \$353,084)

To enhance previously developed industry assessment methods to improve the industry's ability to support pipeline mechanical damage integrity assessment and management. This project will also consider the variability of the assessment tool validation to define appropriate fatigue life safety factors.

Objective 3b: Systematize 20 Years of Mechanical Damage Research (Core: \$393,783)

To summarize work supporting what is currently known about mechanical damage with a focus on formation and behavior, detection and characterization, assessment and management, remediation and repair, and recommended practices and standards. The summary will provide a consolidated review of previous research over the past 20 years, including requisite bibliographic references, and will characterize the achievements made as well as opportunities for improvement.

Objective 3c: Program to Advance Computed Tomography for the Development of Reference Standards for Pipeline Anomaly Detection and Characterization (Core: \$500,000)

To validate data and develop a process confirming the use of Computed Tomography (CT) as a non-destructive evaluation (NDE) technology system that can be used for measuring crack and seam anomalies in pipe steels. NDE is the process of evaluating the component or system without causing damage. Validating the CT Technology System will enable the pipeline industry to establish a set of reference standards that can be used for a wide range of purposes, including technology development and qualification, personnel training, and competency testing.

Objective 3d: Improve In-Line Inspection Sizing Accuracy (Core: \$725,000)

To investigate the probability of detection by the current state of the art in-line inspection (ILI) for immediate conditions where the industry strives for 100% detection of critical integrity conditions. Understanding the probability of identification is key to minimizing the number of missed defects without increasing the number of false indications; optimizing the number of excavations needed for a safe operation of the pipelines; and ultimately a better utilization of resources to remedy threats with the highest risk to the safe operation of the pipeline systems.

Objective 3e: Validate In-Line Inspection Capabilities to Detect/Characterize Mechanical Damage (Core: \$1,397,722)

To expand what is known about ILI system performance in order to detect and characterize corrosion, welds, gouges, and crack/crack field features interacting with dents. Understanding current performance of ILI systems will support technology enhancements and identify requirements for new technologies.

Objective 3f: Artificial Intelligence-Enabled Interactive Threat Detection Using a Multi-Camera Stereo Vision System (CAAP: \$250,000)

To develop a vision-based inspection tool using stereo vision and Artificial Intelligence (AI)-enabled computer vision algorithms to detect and characterize pipeline threats. If successful, the project would transition into additional research to further develop and validate through field demonstration.

Objective 3g: Improved Non-Destructive Testing Detection and Probabilistic Failure Prediction for Interacting Pipeline Anomalies (CAAP: \$250,000)

To develop a method for better ultrasonic measurement of interacting anomalies and to develop an accurate model for failure load prediction. If successful, the project would transition into additional research to further develop and validate through field demonstration.

Objective 3h: Multi-Modal Non-Destructive Evaluation Assisted Probabilistic Pipeline Performance Evaluation Under Interactive Anomalies (CAAP: \$249,926)

To develop a probabilistic, pipeline performance evaluation framework based on multi-modal NDE under interactive anomalies. If successful, the project would transition into additional research to further develop and validate through field demonstration.

Objective 3i: Distributed Fiber Optic Sensor Network for Real-Time Monitoring of Pipeline Interactive Anomalies (CAAP: \$250,000)

To develop a distributed fiber optic sensor network that will provide real-time monitoring of pipeline interactive threats. If successful, the project would transition into additional research to further develop and validate through field demonstration.

Objective 3j: Non-Destructive Coercimetry Fracture Toughness Assessment for Steel Pipelines (SBIR: \$999,100)

To establish a robust correlation model between coercivity and fracture toughness on real-life samples in order to develop the first prototype of a coercimetry-based fracture toughness assessment solution. Such a solution will provide operators with new tools to quantify steel toughness.

Below is a list of some of the major outputs associated with the objectives listed above.

Table 9-c. Research Project Outputs (Objective 3)

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Objective 3a: Improve Dent/Cracking Assessment Methods							
Output 1: Assessment of dent strain evaluation criteria and potential modifications, if required, for indentation crack formation estimates.	PRCI		X				
Output 2: Enhancement for mechanical damage (MD) cracking criteria as well as providing feedback for setting performance requirements of ILI systems.	PRCI			X			
Output 3: Development and testing of new data and analytical tools enhancing the performance of MD fatigue and indentation cracking assessments.	PRCI			X			
Output 4: Final report and one-day seminar where results of this project and previous work will be discussed with pipeline safety stakeholders to brief them on the state of knowledge on MD assessment and management.	PRCI			X			
Objective 3b: Systematize 20 Years of Mechanical Damage Research							
Output 1: Report summarizing the past 20 years of research on	PRCI			X			

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
mechanical damage knowledge considering: formation and behavior, detection and characterization, assessment and management, and remediation and repair.							
Output 2: Report summarizing areas for improvement in mechanical damage knowledge and standards.	PRCI			X			
Output 3: Final project presentation and workshops describing the results of the project.	PRCI			X			
Objective 3c: Program to Advance Computed Tomography for the Development of Reference Standards for Pipeline Anomaly Detection and Characterization							
Output 1: Anomaly matrix which will serve as the basis for synthetic flaws to be studied in this project.	PRCI		X				
Output 2: Inspection via CT and NDE of pipelines with synthetic and real-world crack-like features.	PRCI		X				
Output 3: Crack profiles will be developed utilizing careful measurements of the synthetic and real-world crack-like features. The crack profiles will serve as a reference against which the CT and NDE inspection results will be measured.	PRCI			X			
Output 4: Final report including a framework for developing an industry-accepted master reference set of crack-like features.	PRCI			X			
Objective 3d: Improve In-Line Inspection (ILI) Sizing Accuracy							
Output 1: Literature review of root cause analysis reports;	PRCI		X				

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
providing a data-and-fact based understanding of the defect profiles that cause leaks and ruptures.							
Output 2: Following a testing process of existing commercial ILI systems, researcher will develop a data-driven ILI system evaluation identifying areas for improvement, peer reviewed by the project team prior to completing feedback loop to ILI technology providers.	PRCI			X			
Output 3: Researcher will develop an improved ILI system and retest the system. The researcher will produce an assessment of the ILI system improvement based on a data-driven evaluation of the ILI performance metrics.	PRCI				X		
Output 4: Researcher will prepare a report summarizing the findings, conclusions and recommendations. PRCI will work towards knowledge transfer by publishing technical papers and present the results at appropriate industry meetings and conferences (PRCI, IPC, API, AMPP, etc.)	PRCI				X		
Objective 3e: Validate In-Line Inspection Capabilities to Detect/Characterize Mechanical Damage							
Output 1: PRCI will develop three reports defining pipe specimens, specimen characterization and test protocol to evaluate ILI performance.	PRCI		X				

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Output 2: PRCI will collect and prepare test specimens, as well as characterize specimen material.	PRCI			X			
Output 3: PRCI will complete ILI tool pull tests to support technology and evaluation.	PRCI			X			
Output 4: Researcher will analyze ILI performance evaluation data; detailed ILI performance metrics will be developed for mechanical damage features.	PRCI				X		
Output 5: Final report will be developed describing project work and results.	PRCI				X		
Objective 3f: Artificial Intelligence-Enabled Interactive Threats Detection using a Multi-Camera Stereo Vision System							
Output 1: Researcher will prototype a novel multi-camera stereo vision system for pipeline ILI utilizing existing hardware.	Arizona State University (ASU)				X		
Output 2: Researcher will develop software for its prototype ILI tool using AI-enabled computer vision algorithms that will be able to accurately and efficiently identify the type, location, and size of pipeline anomalies.	ASU				X		
Output 3: Final report will be developed describing project work and results.	ASU				X		
Output 4: Student exposure and training through research and preparing them for a possible future career in the pipeline industry.	ASU				X		
Objective 3g: Improved Non-Destructive Testing Detection and Probabilistic Failure Prediction for Interacting Pipeline Anomalies							

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Output 1: A technical summary describing how an automated methodology can be used to significantly reduce uncertainties in the NDT flaw detection tools.	Brown University				X		
Output 2: Student exposure and training through research and preparing them for a possible future career in the pipeline industry.	Brown University				X		
Objective 3h: Multi-Modal Non-Destructive Evaluation (NDE) Assisted Probabilistic Pipeline Performance Evaluation under Interactive Anomalies							
Output 1: A technical summary about how NDE of interacting anomalies can be assisted through probabilistic methods.	University of Akron				X		
Output 2: Student exposure and training through research and preparing them for a possible future career in pipeline industry.	University of Akron				X		
Objective 3i: Distributed Fiber Optic Sensor Network for Real-time Monitoring of Pipeline Interactive Anomalies							
Output 1: Development, calibration, and validation of an innovative distributed fiber optic sensor network for detection, localization, characterization, and quantification of cracking, deformation (dent), material degradation (corrosion), and excavation along the pipelines.	Stevens Institute of Technology			X			
Output 2: Development and validation of data processing programs for real-time sensor data analysis to identify interactions between different anomalies.	Stevens Institute of Technology				X		

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Output 3: Final report outlining the development of a distributed fiber optic sensor network for real-time monitoring of pipeline interactive anomalies. Researcher will give presentations of the research findings at international and national conferences.	Stevens Institute of Technology				X		
Output 4: Student exposure and training through research and preparing them for a possible future career in the pipeline industry.	Stevens Institute of Technology				X		
Objective 3j: Non-Destructive Coercimetry Fracture Toughness Assessment for Steel Pipelines							
Output 1: Develop a robust correlation model between coercivity and fracture toughness utilizing data collected from pipeline samples.	Innerspec Technologies, Inc.		X				
Output 2: Develop a prototype system and software that calculates fracture toughness based on coercivity and other magnetic readings.	Innerspec Technologies, Inc.			X			
Output 3: Field validation of prototype system on pipeline samples, and final technical report.	Innerspec Technologies, Inc.			X			

Goal

Improving Safety Systems for Liquefied Natural Gas Facilities (\$1,103,095)

Objective 4a: Evaluation of the Efficacy and Treatment of Hazard Mitigation Measures for LNG Facilities (Core: \$319,707)

To develop a standardized, consistent, robust, and detailed methodology that uses the thermal radiation and vapor dispersion computational models currently approved by PHMSA, and calculate thermal radiation and vapor dispersion distances arising from the use of hazard mitigation measures that are commonly employed at LNG facilities but are not currently recognized under 49 CFR 193.

**Objective 4b: Develop a Risk-Based Approach and Criteria for Hazard Detection Layout
(Core: \$310,544)**

To develop a risk-based approach and criteria for hazard detection layouts at LNG facilities. The types of detectors best suited to serve different areas common to most LNG facilities will be identified and guidance will be provided on optimizing detector locations.

**Objective 4c: Develop an Evaluation Protocol for Non-LNG Release Hazards - Modeling
(Core: \$472,844)**

To develop a protocol for the review and approval of models to quantify the different types of hazards associated with LNG facilities. The protocol will include a set of requirements that a model needs to meet to be approved for use under 49 CFR 193, including validation against a set of relevant and well-defined empirical data.

Below is a list of some of the major outputs associated with the objectives listed above.

Table 9-d. Research Project Outputs (Objective 4)

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Objective 4a: Evaluation of the Efficacy and Treatment of Hazard Mitigation Measures for LNG Facilities							
Output 1: Identify certain mitigation measures commonly used at LNG facilities. Measure the effectiveness of the mitigation measures and quantify their uncertainties.	GTI		X				
Output 2: Develop recommended methods to implement mitigation measures in thermal radiation and vapor dispersion computational models. Provide example	GTI			X			

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
modeling to illustrate reductions in exclusion zone distances.							
Output 3: Develop recommendations for follow-up research.	GTI			X			
Output 4: Prepare final report summarizing and documenting the project activities.	GTI			X			
Objective 4b: Develop a Risk-Based Approach and Criteria for Hazard Detection Layout							
Output 1: Researcher will perform a risk-based analysis to determine which hazard scenarios will drive the detector layout.	Blue Engineering and Consulting Company		X				
Output 2: Consequence modeling will be performed to optimize hazard detection layout.	Blue Engineering and Consulting Company		X				
Output 3: Perform a case study on a small-scale LNG liquefaction plant utilizing the optimized hazard detection layout. Demonstrate how the optimized approach can be coordinated for an effective overall plant hazard detection layout.	Blue Engineering and Consulting Company			X			
Output 4: Final report outlining a risk-based approach and criteria for hazard detection layout at LNG facilities.	Blue Engineering and Consulting Company			X			
Objective 4c: Develop an Evaluation Protocol for Non-LNG Release Hazards Modeling							

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Output 1: Develop common methodology to review and evaluate modeling tools for any of the hazards required to be evaluated.	Blue Engineering and Consulting Company		X				
Output 2: Develop and publish Model Evaluation Protocols (MEP) for each type of hazard: non-LNG flammable vapor dispersion, toxic gas and vapor dispersion, vapor cloud explosions, and boiling liquid expanding vapor explosions.	Blue Engineering and Consulting Company			X			
Output 3: Develop recommendations on how the model reviews should be conducted.	Blue Engineering and Consulting Company			X			
Output 4: Final report summarizing and documenting project activities as well as potential future research needs.	Blue Engineering and Consulting Company			X			

9.2 FY 2020

The next sections identify the representative R&D projects for each goal and objective depicted below that comprise PHMSA's PSRP. The funding total in FY 2020 was \$25,003,614.

Goal

Preventing Pipeline Threats/Damage (\$4,727,621)

Objective 1a: Forced Resonance Imaging for 3D Mapping of Buried Gas Pipes (CORE: \$1,519,094)

Developing and demonstrating a system that can detect subsurface natural gas pipes, collect 3D location information with increased accuracy, and provide additional information on pipe diameter and type (plastic or metallic) by 3D mapping.

Objective 1b: Procedures for Retrofitting Indoor Gas Service Regulators (CORE: \$290,000)

Provide natural gas Local Distribution Companies (LDCs) with best practices and guidelines for the retrofitting of inside gas service regulators and associated piping to maintain the same level of safety as a regulator installed outside. Furthermore, the project will establish best practices for the inspection, recording, and maintenance of gas regulators and utility-owned indoor piping systems.

Objective 1c: Validating Models for Predicting Gas Migration and Mitigating its Occurrence/Consequence (CORE: \$1,134,646)

Advance the understanding of gas migration behavior and provide guidance to stakeholders such as first responders. The researcher will directly measure gas migration speed and extent at the surface and subsurface. The measurements will be paired with existing models to extend current knowledge of gas migration behavior.

Objective 1d: Distributed Strain Sensing for Pipeline Safety Against Fault Moving and Landslide (CAAP: \$250,000)

Develop a fiber optic strain-sensing system for long-term monitoring of pipelines subject to ground movements at fault crossing and landslide sites. The system will be tested and verified on a pipeline at a fault crossing site.

Objective 1e: Probabilistic Performance Evaluation of Cathodically Protected Pipeline Considering AC Corrosion (CAAP: \$250,000)

Provide tools and solutions to pipeline operators so they can better characterize, detect, and predict alternating current (AC) corrosion and increase the effectiveness of cathodic protection. Such assistance may help pipeline operators make more informed decisions while also saving them assessment time and maintenance costs.

Objective 1f: Non-Destructive Testing of Fracture Toughness for Pipeline Steels (SBIR: \$990,470)

Develop, verify, and deliver a nonlinear guided wave system for NDE of fracture toughness in pipeline steels to estimate the size, shape, and location of defects in the pipe. The industry standard (API Recommended Practice 579-1) to assess fitness-for-service requires knowledge of the fracture toughness in order to determine the critical flaw size.

Objective 1g: Managing Geohazards Quantitative Risk Assessment for Pipelines (SBIR: \$143,412)

Conduct a robust review of existing approaches to geohazard risk assessment for pipelines and similar infrastructure and assess existing software tools. The review and assessment will ultimately be utilized to develop a concept of operations for a risk assessment tool.

Objective 1h: Fiber Optic Sensors for Direct Pipeline Monitoring Under Geohazard Conditions (SBIR: \$149,999)

Demonstrate that distributed fiber optic sensing is a viable and cost-effective means to monitor natural gas pipelines. The researcher will use fiber optic sensing equipment to monitor sections of natural gas pipelines in geohazard prone locations. Data collected will be used to gain insights into improving risk modeling and monitoring solutions.

Below is a list of some of the major outputs associated with the objectives listed above.

Table 9-e. Research Project Outputs (Objective 1)

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Objective 1a: Forced Resonance Imaging for 3-D Mapping of Buried Gas Pipes							
Output 1: A technical summary of all completed work including the data from field testing.	Bakhtar Research and Engineering, LLC				X		
Output 2: If successful, a commercial technology for use in the pipeline industry.	Bakhtar Research and Engineering, LLC				X		
Objective 1b: Procedures for Retrofitting Indoor Gas Service Regulators							
Output 1: Report summarizing a review of current practices and technologies associated with the evaluation.	GTI			X			
Output 2: Report summarizing the evaluation of inspection activities and the retrofitting of indoor regulators.	GTI			X			
Output 3: A final report summarizing	GTI				X		

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
the resulting best practices and guidelines for retrofitting indoor regulators.							
Objective 1c: Validating Models for Predicting Gas Migration and Mitigating its Occurrence/Consequence							
Output 1: Report summarizing the design, operation and monitoring of natural gas soil venting systems.	Colorado State University (CSU)			X			
Output 2: Report summarizing the degree to which parameters affect the subsurface natural gas migration with significant flow rates.	CSU			X			
Output 3: Report understanding how gas composition and environmental variability affects the subsurface natural gas migration with significant flow rates.	CSU				X		
Output 4: Comprehensive experimental data sets from all field testing.	CSU				X		
Output 5: Report summarizing the gas migration rate to inform first	CSU					X	

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
responders' protocol - Urban/rural differences.							
Output 6: Final report with recommendations for incorporation into the relevant consensus guides, standards, and recommended practices manuals.	CSU					X	
Objective 1d: Distributed Strain Sensing for Pipeline Safety Against Fault Moving and Landslide							
Output 1: A technical summary describing the fiber optic system design and potential performance; field testing data; and a commercialization plan for the pipeline monitoring system.	University of California, Berkeley					X	
Output 2: Student exposure and training through research and preparing them for a possible future career in the pipeline industry.	University of California, Berkeley					X	
Objective 1e: Probabilistic Performance Evaluation of Cathodically Protected Pipeline Considering Alternating Current Corrosion							
Output 1: A technical summary of the resulting probabilistic methodology to evaluate the performance of	Rutgers University					X	

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
cathodically protected pipelines under AC-induced corrosion.							
Output 2: Student exposure and training through research and preparing them for a possible future career in pipeline industry.	Rutgers University					X	
Objective 1f: Non-Destructive Testing of Fracture Toughness for Pipeline Steels							
Output 1: A technical summary report of the work accomplished in this SBIR Phase 2 development project including all testing data.	FBS, Inc.			X			
Output 2: If successful, a commercial technology for use in the pipeline industry.	FBS, Inc.			X			
Objective 1g: Managing Geohazards Quantitative Risk Assessment for Pipelines							
Output 1: A technical summary report of the work and model accomplished in this SBIR Phase 1 feasibility project including all testing data. A Phase 2 award would continue model development.	Applied Engineering Management Corporation			X			
Objective 1h: Fiber Optic Sensors for Direct Pipeline Monitoring Under Geohazard Conditions							

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Output 1: A technical summary report of the work accomplished in this SBIR Phase 1 feasibility project including all testing data. A Phase 2 award would continue tool development.	Paulsson, Inc			X			

Goal

Improving Pipeline Leak Detection Systems (\$1,237,052)

Objective 2a: Pre-Commercial Development and Field Testing of a Portable Mercaptan Sensing Device for Gas Industry Applications (Core: \$427,052)

To develop and validate portable technology that measures the concentration of mercaptans—organic components of hydrocarbons with sulfur, in gas industry field applications. The device will provide the gas industry with additional tools to detect and locate leaks.

Objective 2b: Improve Pipeline Leak Rate Estimation (Core: \$560,000)

To improve existing leak rate estimation models by developing tools that can correlate through wall defect size and expected leak rates. These enhanced tools will support consequence evaluation and event simulation, as well as serve as a key linkage between inspection capability and leak detection technology specifications.

Objective 2c: Improving Pipeline Safety During Gas Leakage Events Using Near Real-Time Data Networks and Optimal Decision-Making Tools (CAAP: \$250,000)

To develop, test, and deploy a novel natural gas sensing protocol that provides operators with key critical knowledge on gas behavior over time and to ensure that these protocols are widely applicable and accessible to end users.

Below is a list of some of the major outputs associated with the objectives listed above.

Table 9-f. Research Project Outputs (Objective 2)

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Objective 2a: Pre-Commercial Development and Field Testing of a Portable Mercaptan Sensing Device for Gas Industry Applications							
Output 1: Field testing of refined device with industry partner to validate optimized parameters in field conditions.	NYSEARCH			X			
Output 2: Final technical report summarizing all project work including associated testing data.	NYSEARCH				X		
Output 3: If successful, a commercial technology capable of sensing mercaptans within the industry desired parameters.	NYSEARCH				X		
Objective 2b: Improve Pipeline Leak Rate Estimation							
Output 1: A series of leak testing to investigate the following defect type: dent axial cracks; corrosion pin holes; axially oriented cracks; circumferentially oriented cracks; and stress corrosion cracking.	BMT Fleet Technology Limited			X			
Output 2: Corrosion pin hole leak rate model.	BMT Fleet Technology Limited			X			
Output 3: Crack leak rate model(s).	BMT Fleet Technology Limited				X		

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Output 4: Final technical report summarizing all project work including associated testing data.	BMT Fleet Technology Limited				X		
Objective 2c: Improving Pipeline Safety During Gas Leakage Events Using Near Real-Time Data Networks and Optimal Decision-Making Tools							
Output 1: A technical summary of how to use real-time data networks and optimal decision making tools for improving pipeline safety.	University of Texas at Arlington (UTA)					X	
Output 2: Student exposure and training through research and preparing them for a possible future career in pipeline industry.	UTA					X	

Goal

Improving Anomaly Detection/Characterization (\$2,634,669)

Objective 3a: Feasibility Study for a Robotic Platform and Suite of Sensors to Identify Degradation in Non-Conforming Driscopipe 8000 (Core: \$801,000)

To conduct a systematic study of the performance of delamination detection technologies for such pipes and strategies for integrating these into a robotic inspection platform. In a future research phase, a robotic platform will be tested for launch operation and retrieval under live conditions and travel in natural gas plastic pipes over long distances without an attached tether.

Objective 3b: Stress Corrosion Cracking Prioritization and Decision Making Using a Bayesian Network Approach (Core: \$884,349)

To develop and validate a holistic, flexible ML model that captures stress corrosion cracking (SCC) knowledge and enables pipeline operators to prioritize inspections effectively.

Objective 3c: Artificial Intelligence-Enabled Inline-Inspection Robot with Integrated Structured Light Nondestructive Evaluation for Distribution Pipelines (CAAP: \$250,000)

To develop and demonstrate a field test-ready structured light tool integrated with a highly flexible snake robot, which can adapt to the complex environment inside distribution pipelines. The AI-enabled smart scanning tool will be able to reconstruct and characterize the pipe's 3D internal profile and detect damages like deformations and material losses. If successful, the project would transition into additional research to further develop and validate through field demonstration.

Objective 3d: Probabilistic Performance Modeling and Optimum Maintenance Planning of Plastic Pipeline with Piezoelectric Based NDE Updating (CAAP: \$249,912)

To develop an NDE probabilistic modeling and decision-making framework for plastic pipeline crack detection. Probabilistic modeling deals with the theory of probability or the fact that randomness plays a role in predicting future events. If successful, the project would transition into additional research to further develop and validate through field demonstration.

Objective 3e: ILI for Both Circumferential Cracking and Axial Stress Using Electromagnetic Acoustic Technology Guided Wave (SBIR: \$149,566)

A proof of concept project to evaluate the use of guided wave electromagnetic acoustic technology (EMAT) to detect circumferential cracks and measure axial stress. A successful output from this project will support transition into a second phase of this work.

Objective 3f: Meandering Winding Magnetometer Array Bending Stress and Crack Detection ILI Module (SBIR: \$149,944)

To confirm a proof of concept to establish the feasibility and methodology for using meandering winding magnetometer (MWM) arrays formatted for ILI to characterize circumferential anomalies and bending stresses. A successful output from this project will support transition into a second phase of this work.

Objective 3g: Magneto-Acoustic Bending Stress and Anomaly Detection ILI tool (SBIR: \$149,898)

To confirm a proof of concept to develop and demonstrate a robust, field-ready ILI tool for the accurate detection of cracks, other anomalies, and quantification of bending stress. A successful output from this project will support transition into a second phase of this work.

Below is a list of some of the major outputs associated with the objectives listed above.

Table 9-g. Research Project Outputs (Objective 3)

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Objective 3a: Feasibility Study for a Robotic Platform and Suite of Sensors to Identify Degradation in Non-Conforming Driscopipe 8000							
Output 1: Review sensor system requirements and select the technologies that will be reviewed in depth in this work.	NGA			X			
Output 2: Review robotic platform system requirements and select the technologies that will be reviewed in depth in this work.	NGA			X			
Output 3: A final report identifying the specifications for sensor and robotic delivery and select those technologies that promise to deliver solution to the problem.	NGA				X		
Objective 3b: Stress Corrosion Cracking Prioritization and Decision Making Using a Bayesian Network Approach							
Output 1: Develop a SCC Bayesian model which incorporates industry inputs from integrity management programs.	DNV GL USA, Inc.			X			
Output 2: Validate the model through a series of collected field data.	DNV GL USA, Inc.			X			
Output 3: A final technical report summarizing the inspection prioritization	DNV GL USA, Inc.				X		

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
methodology for pipeline operators.							
Objective 3c: AI-Enabled ILI Robot with Integrated Structured Light Nondestructive Evaluation for Distribution Pipelines							
Output 1: A technical summary of how to enable a ILI robot with integrated structured NDE for distribution pipelines.	Michigan State University (MSU)					X	
Output 2: Student exposure and training through research and preparing them for a possible future career in pipeline industry.	MSU					X	
Objective 3d: Probabilistic Performance Modeling and Optimum Maintenance Planning of Plastic Pipeline with Piezoelectric Based NDE Updating							
Output 1: A technical summary of how to use probabilistic modeling to achieve optimum maintenance of plastic pipe through using piezoelectric based NDE.	Rutgers, University					X	
Output 2: Student exposure and training through research and preparing them for a possible future career in the pipeline industry.	Rutgers, University					X	
Objective 3e: ILI for Both Circumferential Cracking and Axial Stress Using Electromagnetic Acoustic Technology Guided Wave							
Output 1: A technical summary report of the work accomplished in this SBIR Phase 1 feasibility project including all testing data. A Phase 2 award would continue tool development.	ULC Robotics			X			

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Objective 3f: Meandering Winding Magnetometer Array Bending Stress and Crack Detection ILI Module							
Output 1: A technical summary report of the work accomplished in this SBIR Phase 1 feasibility project including all testing data. A Phase 2 award would continue tool development.	JENTEK Sensors, Inc.			X			
Objective 3g: Magneto-Acoustic Bending Stress and Anomaly Detection ILI tool							
Output 1: A technical summary report of the work accomplished in this SBIR Phase 1 feasibility project including all testing data. A Phase 2 award would continue tool development.	Creare, LLC			X			

Goal

Improving Anomaly Repair & Pipe Remediation & Rehabilitation (\$141,750)

Objective 4a: No-Dig Point Repair Technology for Steel Oil & Gas Pipelines (SBIR: \$141,750)

A proof of concept project to develop repair solutions that expand the capability of rehabilitating larger diameter steel transmission oil and gas pipelines. A successful output from this project will support transition into a second phase of this work.

Below is a list of some of the major outputs associated with the objectives listed above.

Table 9-h. Research Project Outputs (Objective 4)

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Objective 4a: No-Dig Point Repair Technology for Steel Oil & Gas Pipelines							
Output 1: A technical summary report of the work accomplished in this SBIR Phase 1 feasibility project including all testing data. A Phase 2 award would continue tool development.	QuakeWrap, Inc		X				

Goal

Improving Safety Systems for Liquefied Natural Gas (LNG) Facilities (\$3,249,141)

Objective 5a: Vapor Cloud Explosion at Nil Wind (Core: \$134,704)

To develop criteria to define “nil wind”—low or no wind—conditions and to determine whether such conditions should be included in the siting requirements for LNG facilities. The researcher will use the newly defined conditions to quantify the potential increase in the severity of consequences from accidental releases under nil wind conditions as compared with the current regulatory requirements. The consequence modeling will be used to inform recommendations on whether nil wind conditions should be included in facility siting requirements.

Objective 5b: Development of Guidance on Potential Cascading Effects from Flammable Vapor Cloud Explosions (Core: \$1,231,520)

To provide guidance on the potential cascading effects from flammable vapor cloud explosions and projectiles regarding structural damage at LNG facilities. Understanding the potential for cascading effects on LNG facilities can inherently improve safety, protecting both people and key energy infrastructure.

Objective 5c: PHMSA Support for Safety, Regulation, Production, Distribution, and use of Liquefied Natural Gas (Inter-Agency: \$1,882,917)

Sandia National Laboratories will engage in analytical studies, computational modeling, quantitative risk assessments, advanced technology assessments, and systems engineering

research, development, and demonstrations in support of PHMSA's objective to enhance the safety, regulation, production, distribution, and use of LNG.

Below is a list of some of the major outputs associated with the objectives listed above.

Table 9-i. Research Project Outputs (Objective 5)

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Objective 5a: Vapor Cloud Explosion at Nil Wind							
Output 1: Establishing a definition of "nil wind" conditions.	Blue Engineering and Consulting Company			X			
Output 2: A statistical analysis of weather data (wind speed) at multiple locations across the United States.	Blue Engineering and Consulting Company			X			
Output 3: Review international reporting and discuss relevance to LNG facilities designed and built to PHMSA regulations.	Blue Engineering and Consulting Company			X			
Output 4: Utilize approved computational fluid dynamics models to perform consequence modeling (vapor dispersion and vapor cloud explosion) for specified set of scenarios and wind speeds, to compare the consequences under low wind and nil wind conditions.	Blue Engineering and Consulting Company			X			
Output 5: Perform a risk assessment, including the modeled scenarios, to compare risk with and	Blue Engineering and Consulting Company			X			

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
without the inclusion of nil wind conditions.							
Output 6: A final report quantifying the potential increase in the severity of consequences from accidental releases under nil wind conditions as compared with the current regulatory requirements.	Blue Engineering and Consulting Company			X			
Objective 5b: Development of Guidance on Potential Cascading Effects from Flammable Vapor Cloud Explosions							
Output 1: Report on review of types of LNG facilities and equipment for evaluation.	DNV GL USA, Inc.			X			
Output 2: Report on the initial blast capacity assessment.	DNV GL USA, Inc.			X			
Output 3: Report on the screening of explosion sources and targets.	DNV GL USA, Inc.			X			
Output 4: Report on the detailed computational fluid dynamics (CFD) explosion modeling.	DNV GL USA, Inc.			X			
Output 5: Report on the detailed structural response modeling.	DNV GL USA, Inc.				X		
Output 6: A final technical report with guidance on quantifying the potential cascading effects from flammable vapor cloud explosions.	DNV GL USA, Inc.				X		
Objective 5c: PHMSA Support for Safety, Regulation, Production, Distribution, and use of Liquefied Natural Gas							

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Output 1: Researcher will produce models (open source code as well as graphical user interface) that characterize natural gas releases from pressurized systems.	Sandia			X			
Output 2: Review of hazard modeling software to comply with the 49 CFR 193 as well as development of final decision letters for the federal docket.	Sandia				X		
Output 3: Develop a model evaluation protocol (MEP) to evaluate the suitability of the software models proposed to calculate the radiant heat effects from both LNG fires and non-LNG fires.	Sandia			X			

Goal

Improving Design, Materials and Welding/Joining (\$1,400,000)

Objective 6a: Hydrostatic Retesting Optimization for Older Liquid Pipelines (Core: \$650,000)

To investigate the relationship between post-hydrotest pressure cycles and crack growth rate to understand whether any surviving surface cracks will rupture.

Objective 6b: Modeling Slow Crack Growth Under Thermal and Chemical Effects and Accurate Nondestructive Testing of Cracks for Fitness Predictions of Polyethylene Pipes (CAAP: \$250,000)

To develop a slow crack growth model for polyethylene pipe failure under chemical and thermal environments and develop a method for accurate crack size measurements for reliable fitness for service assessment. If successful, the project would transition into additional research to further develop and validate through field demonstration.

Objective 6c: Holistic Electromagnetic and Ultrasonic Nondestructive Evaluation Techniques for Plastic Pipeline Aging and Degradation Characterization (CAAP: \$250,000)

To design an integrated near-field flexible microwave and non-linear ultrasonic probing tool to detect the extent of plastic pipeline degradation. If successful, the project would transition into additional research to further develop and validate through field demonstration.

Objective 6d: Nondestructive Diagnosis and Probabilistic Prognosis of Aging Plastic Pipe (CAAP: \$250,000)

To develop an NDE method for degradation assessment of in-situ plastic pipe and then make decisions based on probabilistic modeling. If successful, the project would transition into additional research to further develop and validate through field demonstration.

Below is a list of some of the major outputs associated with the objectives listed above.

Table 9-j. Research Project Outputs (Objective 6)

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Objective 6a: Hydrostatic Retesting Optimization for Older Liquid Pipelines							
Output 1: Validation of an analytical crack-driving force model previously developed by PRCI.	Engineering Mechanics Corporation of Columbus			X			
Output 2: Small-scale lab testing and full-scale burst test for developing crack retardation data after hydrotest overloads.	Engineering Mechanics Corporation of Columbus			X			
Output 3: Validation of crack retardation model and automated hydrotest optimization software.	Engineering Mechanics Corporation of Columbus				X		
Output 4: A final technical report summarizing the relationship between post hydrotest pressure cycles and crack growth rate to understand whether any	Engineering Mechanics Corporation of Columbus				X		

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
surviving surface cracks will rupture.							
Objective 6b: Modeling Slow Crack Growth Under Thermal and Chemical Effects and Accurate Non-Destructive Testing of Cracks for Fitness Predictions of Polyethylene Pipes							
Output 1: A technical summary of how to use modeling and NDE to estimate the impact from slow crack growth of plastic pipelines.	Brown University					X	
Output 2: Student exposure and training through research and preparing them for a possible future career in the pipeline industry.	Brown University					X	
Objective 6c: Holistic Electromagnetic and Ultrasonic Nondestructive Testing Techniques for Plastic Pipeline Aging and Degradation Characterization							
Output 1: A technical summary of how to use holistic electromagnetic and ultrasonic NDE techniques for estimating plastic pipeline aging and degradation characterization.	MSU					X	
Output 2: Student exposure and training through research and preparing them for a future possible career in the pipeline industry.	MSU					X	
Objective 6d: Nondestructive Diagnosis and Probabilistic Prognosis of Aging Plastic Pipe							
Output 1: A technical summary of how to use NDE diagnosis and probabilistic prognosis to understand the impacts of aging plastic pipe.	University of Nebraska					X	

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Output 2: Student exposure and training through research and preparing them for a possible future career in the pipeline industry.	University of Nebraska					X	

Goal

Identifying Pipe Fatigue Damage During Rail Transportation (Inter-Agency: \$789,325)

Objective 7a: To show through testing and analysis the influence of rail transportation on the fatigue damage for the pipe. Fatigue damage will be estimated through computer simulation as well as experimental testing utilizing TTC facilities and railroad tracks on site.

Below is a list of some of the major outputs associated with the objective listed above.

Table 9-k. Research Project Outputs (Objective 7)

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Objective 7a: Identifying Pipe Fatigue Damage during Rail Transportation							
Output 1: Convene industry focus group (IFG) to determine the testing plan for pipe fatigue damage by rail.	Transportation Technology Center, Inc. (TTCI)		X				
Output 2: IFG will submit finalized testing plan to PHMSA for review and approval.	TTCI			X			

Goal

Analyzing Loads on Pipelines Installed Under Railroad Tracks (Inter-Agency: \$119,056)

Objective 8a: To build upon prior research in the area of cased crossings and railroad loading, evaluate best practices and other guidance in use today, perform additional testing to determine stresses that can occur on pipe under rail in a variety of conditions and methods to mitigate such stresses, and determine if casings are needed in every pipeline/railroad crossing.

Below is a list of some of the major outputs associated with the objective listed above.

Table 9-I. Research Project Outputs (Objective 8)

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Objective 8a: Analyzing Loads on Pipelines Installed under Railroad Tracks							
Output 1: Convene IFG to determine the testing plan for pipe subjected to railroad loading.	TTCI		X				
Output 2: IFG will submit finalized testing plan to PHMSA for review and approval.	TTCI			X			

Goal

Developing Pipeline Research, Development, and Testing (RDT) Facility (Inter-Agency: \$10,000,000)⁶

Objective 9a: To design and develop a PHMSA Program for Pipeline Safety Research Projects at TTC.

⁶ PHMSA's expenditures were paused in February 2021 after spending approximately \$831,000. Based on current authorities and pending completion of the requisite study and report, PHMSA has paused all work activities until further notice.

Below is a list of some of the major outputs associated with the objective listed above.

Table 9-m. Research Project Outputs (Objective 9)

Output	Collaborator	Fiscal Year					
		2019	2020	2021	2022	2023	2024
Objective 9a: Developing Pipeline RDT Facility							
Output 1: Convene an industry stakeholder committees (ISC) to determine existing gaps in pipeline safety R&D and potential opportunities to fill those gaps at TTC.	Universal Pegasus International		X				
Output 2: Detailed Design Report for PHMSA RDT. This report includes a breakdown of proposed Test Assembly Stations (TASs) to meet the gaps determined by the ISC.	Universal Pegasus International			X			

10. Performance Management

PHMSA manages the planning, implementation, and reporting of the research, development, and testing projects through internal systems implemented by program staff. PHMSA maintains close relationships with research partners throughout a project to ensure the project remains on track and is on-pace to achieve its intended results. PHMSA uses project management best practices to track and evaluate project progress in meeting defined objectives, to ensure milestones and commitments are on track, to monitor and control project risks, and to monitor funds to ensure they are expended properly and in a timely manner. PHMSA tracks projects through performance metrics such as technology demonstrations, patent applications, commercialized technologies, and technology transfer (T2) success rate (i.e., the frequency of each completed research project resulting in commercialization). PHMSA's research program

closely aligns with DOT's strategic goals of safety, economic recovery and rebuilding, and climate change, as well as PHMSA's *Annual Performance Plan*.

PHMSA uses the following metrics to measure the development of new technologies during a reporting period:

Table 10-a. Technology Development Metrics

Technology Metric	Performance Definition
New Technology Development Projects	PHMSA tracks the number of new technology research projects that may yield future safety solutions into the market. This metric represents the total number of newly awarded technology projects.
Technology Demonstrations	PHMSA tracks the number of technology demonstrations occurring within research projects. This metric tracks the exposure PHMSA funded new technology projects receive; which could increase the likelihood new technology will be commercialized.
Patents Granted (US or Other)	PHMSA tracks the level of patent activity that resulted from awarded projects both via patent applications and patents granted. This metric indicates the level of activity to protect intellectual property and growth of innovation from PHMSA's program.
Other Technology Notifications	PHMSA reviews the 'granted with no objection' Other Technology Notifications ⁷ to document if PHMSA funded T2 is being used by the regulated community to demonstrate compliance.
Commercialized Technology	PHMSA tracks the number of projects bringing new technology to market. PHMSA uses this metric as an overall success rate for T2.
Net Safety Improvement due to T2	PHMSA documents the net safety improvement of T2 on a project-by-project basis. This information is publicly available from project pages where T2 has occurred.

⁷ AS CODIFIED IN 49 CFR PART 195.452(c)(1)(D) AND 192.921(A)(7)

PHMSA uses the following metrics to measure knowledge generated and promoted by its R&D activities during a reporting period:

Table 10-b. Knowledge Metrics

Knowledge Metric	Performance Definition
New Knowledge Promotion Projects	PHMSA tracks the number of knowledge generation research projects that can be promoted to relevant end users.
Publicly Available Final Reports	PHMSA tracks the number of new final reports made available to the public for utilization in pipeline safety efforts.
Special Permits	PHMSA reviews approved Special Permit (SP) ⁸ applications to document if PHMSA funded research results were used by the applicant as part of their application request and if PHMSA staff have used research results to develop conditions included in the SP approval.
Conference/Journal Papers	PHMSA tracks the publication/presentation of research results in peer reviewed conferences, journals, and magazines. Publication provides an additional form of peer review and disseminates knowledge out to a wide audience.
Public Events Held	PHMSA tracks the number of public events held that facilitate dissemination of research project information and results out to a wide audience. This metric is an indication of the level of stakeholder communication.
Stakeholders Reached at Events	PHMSA tracks the number of stakeholders attending all public events held. This metric is an indication of the level of stakeholder communication and interest in this program.
Website Visits	PHMSA tracks the number of visits to its research program portal and project pages. This metric is an indication of the level of stakeholder interaction and interest in this program.
Files Downloaded	PHMSA tracks the number of files downloaded from its research program and project pages. This metric is an indication of the level of stakeholder interaction and interest and level of use of research results.

⁸ As codified in 49 CFR Part 190.341

11. Performance Metrics: FY 2019

The following tables highlight the collected performance metrics data in FY 2019.

Table 11-a. FY 2019 Performance Metrics: Technology

Technology Metric	FY 2019 Performance
New Technology Development Projects	12
Technology Demonstrations	3
Patents Granted (US or Other)	1 applied/0 granted
Other Technology Notifications	0*
Commercialized Technology	See table 11-c.
Net Safety Improvement due to T2	See table 11-c.

Table 11-b. FY 2019 Performance Metrics: Knowledge

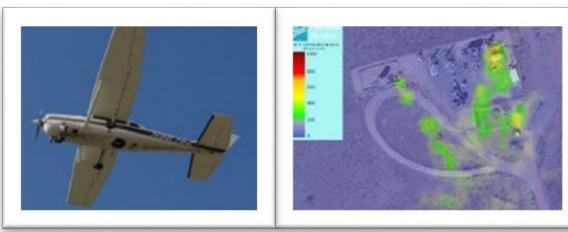
Knowledge Metric	FY 2019 Performance
New Knowledge Promotion Projects	18
Publicly Available Final Reports	8
Special Permits	2*
Conference/Journal Papers	5
Public Events Held	2
Stakeholders Reached at Events	372
Website Visits	766,654
Files Downloaded	136,853

* First reporting year of metric data capture.

Technology Transfer

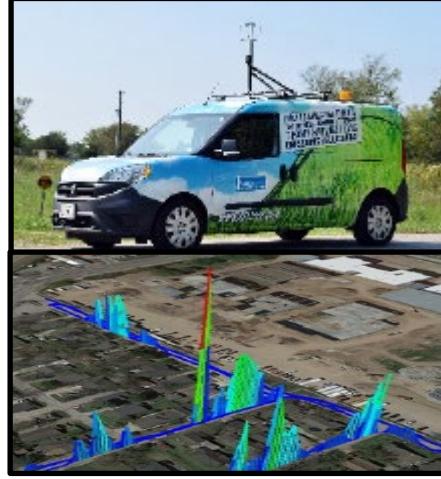
Table 11-c highlights the technologies through PHMSA funded research that were commercialized in FY 2019:

Table 11-c. Highlights of FY 2019 Technology Transfer Activities

Programmatic Element	Project Title	Technology Transfer Outcome
FY 2019		
Preventing Pipeline Threats/Damage	GPS-Based Excavation Encroachment Notification⁹	 <p><i>Pictures Courtesy of Gas Technology Institute</i></p> <p>The project demonstrations validated that data collection during active construction activities could be used to reduce or eliminate damage from excavation activities. The commercialized solution was licensed to HydromaxUSA under the product name UtilAlert. This data collection provides benefits that minimize the cost of damages, avoids delays to completion schedules, enhances safety for workers and the general public; and allows all stakeholders to benefit from enhancing situational awareness and reducing risk.</p>
Improving Pipeline Leak Detection Systems	Rapid Aerial Small Methane Leak Survey¹⁰	 <p><i>Pictures Courtesy of Ball Aerospace and Technologies, Corp.</i></p> <p>The research investment resulted in technology that enables rapid leak survey of natural gas transmission pipelines from low-cost, single engine aircraft, with plume imagery to</p>

⁹ [HTTPS://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=249](https://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=249)

¹⁰ [HTTPS://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=651](https://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=651)

Programmatic Element	Project Title	Technology Transfer Outcome
		<p>differentiate blow-over sources from off-system facilities. The wider-swath sensor also enables cost effective area mapping of methane emissions, including from oil and gas production basins. The improvements in mapping methane emissions will enable entities to more expeditiously locate and stop the release. The expeditious response to methane leaks will help advance the Administration's executive action to tackle climate change by ultimately lowering the United States' cumulative methane emissions.</p>
<p><i>Improving Pipeline Leak Detection Systems</i></p>	<p>Natural Gas Pipeline Leak Rate Measurement System¹¹</p>	 <p><i>Pictures courtesy of Heath Consultants, Inc.</i></p> <p>The project supported development of the Heath MobileGuard™ gas leak detection system, which consists of a methane/ethane analyzer, GPS, sonic anemometer, and proprietary leak detection software that presents real-time geospatial maps of multiple gas concentrations. The software's sophisticated leak detection algorithm combines the system's measurements of gas concentrations (CH₄, C₂H₆), local coordinates (GPS), and local wind velocity (sonic anemometer) to estimate the leak location. Readings are stored in the device and can be transmitted in real-time to the Cloud for centralized monitoring. The MobileGuard laser-based sensor sensitivity and precision is more than 3,000 times greater than legacy methods, enabling identification of leaks several hundred feet away from the source. The</p>

¹¹ [HTTPS://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=650](https://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=650)

Programmatic Element	Project Title	Technology Transfer Outcome
		systems improvement in identifying leaks and their location will enable entities to more expeditiously repair the leak source; limiting the duration of methane emissions. Limiting the duration of unintentional methane releases will help advance the Administration's executive action to tackle climate change by ultimately lowering the U.S.'s cumulative methane emissions.

Knowledge Transfer

Table 11-d summarizes the knowledge transfer activities registered during FY 2019:

Table 11-d. Highlights of Knowledge Transferred Activities in FY 2019

Programmatic Element Goal	Project Title	Knowledge Transfer Outcome
FY 2019		
Preventing Pipeline Threats/Damage	<u>Human Centric Approach to Improve Pipeline Non-Destructive Evaluation Performance and Reliability¹²</u>	A new approach to solve high-impact gaps with human and technology interventions. The summary presentation file is available from the public project page.
Improving Pipeline Leak Detection Systems	<u>Framework for Verifying and Validating the Performance and Viability of External Leak Detection Systems for Liquid and Natural Gas Pipelines¹³</u>	A leak detection evaluation framework has been developed for use by pipeline operators to identify and evaluate leak detection systems intended for transmission pipelines and to assist operators in making an informed technology selection. The summary presentation file is

¹² [HTTPS://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=644](https://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=644)

¹³ [HTTPS://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=657](https://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=657)

Programmatic Element Goal	Project Title	Knowledge Transfer Outcome
		available from the public project page.
<i>Improving Design, Materials & Welding/Joining</i>	<u>Glass-Polymer Composite High Pressure Pipes and Joints Design, Mfg & Characterize¹⁴</u>	Use of carbon fabric or aluminum foil on the surface of non-metallic pipes significantly improves detectability of the buried pipes using Ground Penetrating Radar. The summary presentation file is available from the public project page.
<i>Improving Design, Materials & Welding/Joining</i>	<u>An Inorganic Composite Coating for Pipeline Rehabilitation and Corrosion Protection¹⁵</u>	The analysis findings show that the patch repair can be used for composite repair of pipeline defects due to corrosion-induced thickness loss in the pipe wall. In addition, the bonding condition between carbon fiber reinforced polymer and pipe wall is critical to reduce the maximum stresses in the patch repair. The summary presentation file is available from the public project page.

¹⁴ [HTTPS://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=721](https://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=721)

¹⁵ [HTTPS://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=635](https://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=635)

12. Performance Metrics: FY 2020

The following tables highlight the collected performance metrics data in FY 2020:

Table 12-a. Highlights of FY 2020 Performance Metrics: Technology

Technology Metric	FY 2020 Performance
Technology Development Projects	3
Technology Demonstrations	7
Patents Granted (U.S. or Other)	2 applied/2 granted
Other Technology Notifications	*0
Commercialized Technology	See table 12-c.
Net Safety Improvement due to T2	See table 12-c.

Table 12-b. Highlights of FY 2020 Performance Metrics: Knowledge

Knowledge Metric	FY 2020 Performance
Knowledge Promotion Projects	26
Publicly Available Final Reports	3
Special Permits	*2
Conference/Journal Papers	14
Public Events Held	1
Stakeholders Reached at Events	240
Website Visits	**18,249,120
Files Downloaded	193,281

* First reporting years of metric data capture.

** Significant increase attributed to holding an R&D Forum in FY 2020, announcements on TTC and several project de-brief presentations held in FY 2020 than in the prior reporting year.

Technology Transfer

The following table highlights the T2 that occurred during FY 2020.

Table 12-c. Highlights of FY 2020 Technology Transfer Activities

Programmatic Element	Project Title	Technology Transfer Outcome
FY 2020		
<i>Improving Anomaly Detection/Characterization</i>	<u>In-Ditch Validation Methodology for Determination of Defect Sizing¹⁶</u>	 <p><i>Picture Courtesy: Applus</i></p> <p>The research development and validation success supported incorporating Inverse Wave Field Extrapolation (IWEX) technology onto calibration tools, seam weld inspections, and magnetic crawlers for Stress Corrosion Cracking inspections at Applus. IWEX is a next-generation ultrasonic inspection technique with the ability display flaws as a 2-dimensional (2D) cross-section or as a 3D image, allowing users to get a better look at flaws to determine if they are true defects or benign.</p>

¹⁶ [HTTPS://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=503](https://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=503)

Knowledge Transfer

The Table 12-d summarizes the knowledge transfer activity registered during FY 2020:

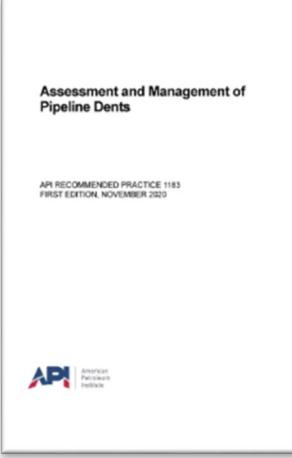
Table 12-d. Highlights of FY 2020 Knowledge Transfer Activities

Programmatic Element	Project Title	Knowledge Transfer Outcome
FY 2020		
Preventing Pipeline Threats/Damage	<u>Understanding and Mitigating the Threat of AC Induced Corrosion on Buried Pipelines</u>¹⁷	<p>The effect of AC on the corrosion of steel depends on both the magnitude of interference current (iAC) and on the Direct Current potential of the steel. Greater iAC leads to increased corrosion rates. At or below the commonly cited thresholds of AC density, cathodically protected samples show small or negligible increased corrosion rates. The summary presentation file is available from the public project page.</p>
Improving Anomaly Detection/Characterization	<u>Electromagnetic acoustic transducer (EMAT) Sensor for Small Diameter and Unpigable Pipes; Prototype and Testing</u>¹⁸	<p>The project developed built and tested an EMAT tool prototype to detect and quantify longitudinal cracks in metallic pipes. The summary presentation file is available from the public project page.</p>
Improving Safety Systems for LNG Facilities	<u>Performance Gap Comparison of Process Safety Management Consensus Standards and Regulatory Requirements for LNG Facilities</u>¹⁹	<p>Some key findings targeted changes to PHMSA regulations and to related standards, including expanding requirements related to Process Hazard Analyses; establishing “Management of Change” as a defined term; and expanding</p>

¹⁷ [HTTPS://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=636](https://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=636)

¹⁸ [HTTPS://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=653](https://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=653)

¹⁹ [HTTPS://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=732](https://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=732)

Programmatic Element	Project Title	Knowledge Transfer Outcome
		<p>requirements related to emergency planning and response, such as periodic tabletop exercises, field exercises, and emergency response notification tests. The summary presentation file is available from the public project page.</p>
Improving Anomaly Detection/ Characterization	<ol style="list-style-type: none"> 1. Mechanical Damage at Welds²⁰ 2. Structural Significance of Mechanical Damage²¹ 3. Dent Fatigue Life Assessment - Development of Tools for Assessing the Severity and Life of Dent Features²² 4. Consolidated Project Full Scale Testing of Interactive Features for Improved Models²³ 5. Improving Models to Consider Complex Loadings, Operational Considerations, and Interactive Threats²⁴ 	 <p>Portions of research knowledge resulting from these 5 projects were utilized by the API in the development of Recommended Practice 1183 <i>Assessment and Management of Dents in Pipelines</i>, 1st Edition.</p>

²⁰ [HTTPS://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=146](https://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=146)

²¹ [HTTPS://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=238](https://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=238)

²² [HTTPS://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=358](https://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=358)

²³ [HTTPS://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=555](https://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=555)

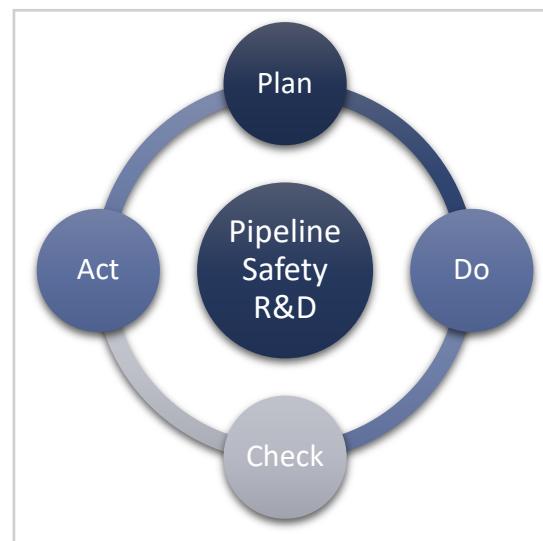
²⁴ [HTTPS://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=557](https://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=557)

13. Developing the Next Five-Year Research Program Plan

PHMSA's R&D programs must be administered effectively to address the pipeline safety challenges of both today and tomorrow. PHMSA has adopted a Safety Management System model of Plan, Do, Check, Act (PDCA) for its next five-year research program plan. PHMSA uses the PDCA process to ensure the pipeline safety R&D program is agile by funding research in emerging technologies capable of addressing critical gaps in pipeline safety.

- **Plan:** The Plan phase includes reviewing historical pipeline safety data to determine significant safety gaps in pipeline safety. Furthermore, the Plan phase includes a robust coordination process with partners in Federal, State, and local agencies, as well as industry and public safety stakeholders. The goal is to gain an understanding of the perceived safety gaps across the pipeline safety enterprise. PHMSA then develops short and long-term R&D priorities using the historical data and identified critical safety gaps.
- **Do:** The Do phase includes reviewing the short and long-term priorities and developing solicitations and making awards for projects that align with PHMSA's R&D goals.
- **Check:** The Check phase includes a rigorous review of technology and knowledge developed through PHMSA's R&D initiatives. PHMSA's review analyzes the outputs to determine each program's ability to advance pipeline safety and the protection of the environment, specifically in the areas of the short/long-term priorities.
- **Act:** The Act phase encompasses activities to encourage the implementation of research findings through commercialization on the part of industry partners, as well as direct government actions in the regulatory process. In the Act phase, PHMSA will continue to reassess future R&D priorities and make necessary changes to PHMSA's R&D plan.

Figure 13-a. PDCA



While PHMSA will use the PDCA process to develop the broad 2021-2025 Five-Year Research Program Plan, the agency will also use the framework on an annual basis to reassess short-term research goals. These annual plans will be captured in the Annual Modal Research Plan. The Five-Year Research Program Plan will reflect longer-range goals for stakeholder involvement, research infrastructure improvement, and inter-agency cooperation to address systemic issues, such as climate change initiatives. Modifications will be made to the plan on

an annual basis to enhance the effectiveness of the R&D program based upon Congressional and stakeholder feedback and analysis of system-wide risk.

The 2021-2025 Five-Year Research Program Plan will consider decarbonization and climate change initiatives by the Administration. One potential climate change initiative is a focus on hydrogen research; hydrogen can serve as a sustainable power generation fuel and may reduce greenhouse gas emissions by blending hydrogen into natural gas pipelines. Research in technology solutions in leak detection and leak repair of pipeline systems will also continue to be conducted to locate, quantify, and reduce the volume of pipeline leaks and ruptures into the environment.

Another important initiative to be addressed in the upcoming years is how to improve safety systems for LNG facilities. Activities in this topic area will address various LNG industry challenges related to LNG hazards, as well as foster development of new technologies and alternative designs for LNG storage and piping systems. Additional opportunities in this research topic will address performance-based risk reduction for design, construction, operations, maintenance, and fire protection of LNG facilities. PHMSA, as directed by Section 111(c) of the PIPES Act of 2020, plans to conduct a study to be completed in 2022 on the costs and benefits of establishing a Center of Excellence for LNG.

Development of two research projects at TTC will continue into FY 2022 through collaboration between PHMSA, FRA, and private industry. Additionally, PHMSA will provide a detailed research plan to the House and Senate Committees on Appropriations as directed in the FY 2021 appropriations bill and report language. PHMSA will conduct an assessment and cost-benefit analysis of the need to develop an independent pipeline safety research and testing facility and submit a report to Congress to be completed by 2022, as directed by Section 105 of the PIPES Act of 2020.

The PSRP will continue to play an important role in advancing the safe transportation of energy and other hazardous materials essential to our daily lives by conducting research supporting safety and infrastructure strategic goals. Results of this work 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, preserve the environment, and ensure the cost effectiveness of alternative transportation energy.

14. Program Website and Contacts

Program website: <https://www.phmsa.dot.gov/research-and-development/pipeline/about-pipeline-research-development>

Alan Mayberry, Associate Administrator for Pipeline Safety
Pipeline & Hazardous Materials Safety Administration
Office of Pipeline Safety
Phone: (202) 366-4595
Email: alan.mayberry@dot.gov

Sentho White, Director—Engineering & Research
Pipeline & Hazardous Materials Safety Administration
Office of Pipeline Safety
Phone: (202) 366-2415
Email: sentho.white@dot.gov