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

1200 New Jersey Avenue, SE
Washington, DC 20590

November 18, 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, "Pipeline Safety Research and Development Biennial Update Report, Fiscal Years 2019 and 2020," in fulfillment of the requirement in Section 22 of the Pipeline Safety Improvement Act of 2016, Pub. L. 114-183, (the Act). The Act requires the Secretary of Transportation (DOT) to submit a biennial update report to Congress that summarizes each of the research and development (R&D) projects awarded by the Pipeline and Hazardous Materials Safety Administration (PHMSA) to federal and non-federal stakeholders, and reviews of how each project affects pipeline safety. The most recent previous biennial update report covered fiscal years 2017 and 2018 and is publicly available on the Pipeline Safety R&D Program website: https://primis.phmsa.dot.gov/rd/docspr/PSA%202016%20Biennial%20Report%20FY%2017-18.pdf.

It is important to note that past update reports referenced herein were finalized in previous years under a previous administration, and may not fully reflect the most recent priorities and goals of the current administration and recent authorities granted by Congress, for example in the Protecting our Infrastructure of Pipelines and Enhancing Safety Act of 2020.

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.

A similar response has been sent 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.

Sincerely,

Tristan H. Brown
Deputy Administrator

Enclosure

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

1200 New Jersey Avenue, SE
Washington, DC 20590

November 18, 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, "Pipeline Safety Research and Development Biennial Update Report, Fiscal Years 2019 and 2020," in fulfillment of the requirement in Section 22 of the Pipeline Safety Improvement Act of 2016, Pub. L. 114-183, (the Act). The Act requires the Secretary of Transportation (DOT) to submit a biennial update report to Congress that summarizes each of the research and development (R&D) projects awarded by the Pipeline and Hazardous Materials Safety Administration (PHMSA) to federal and non-federal stakeholders, and reviews of how each project affects pipeline safety. The most recent previous biennial update report covered fiscal years 2017 and 2018 and is publicly available on the Pipeline Safety R&D Program website: https://primis.phmsa.dot.gov/rd/docspr/PSA%202016%20Biennial%20Report%20FY%2017-18.pdf.

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1200 New Jersey Avenue, SE
Washington, DC 20590

November 18, 2021

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

Dear Chair DeFazio:

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Sincerely,

Tristan H. Brown
Deputy Administrator

Enclosure

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

1200 New Jersey Avenue, SE
Washington, DC 20590

November 18, 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, "Pipeline Safety Research and Development Biennial Update Report, Fiscal Years 2019 and 2020," in fulfillment of the requirement in Section 22 of the Pipeline Safety Improvement Act of 2016, Pub. L. 114-183, (the Act). The Act requires the Secretary of Transportation (DOT) to submit a biennial update report to Congress that summarizes each of the research and development (R&D) projects awarded by the Pipeline and Hazardous Materials Safety Administration (PHMSA) to federal and non-federal stakeholders, and reviews of how each project affects pipeline safety. The most recent previous biennial update report covered fiscal years 2017 and 2018 and is publicly available on the Pipeline Safety R&D Program website: https://primis.phmsa.dot.gov/rd/docspr/PSA%202016%20Biennial%20Report%20FY%2017-18.pdf.

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Sincerely,

Tristan H. Brown
Deputy Administrator

Enclosure

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

1200 New Jersey Avenue, SE
Washington, DC 20590

November 18, 2021

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

Dear Chairman Pallone:

Enclosed please find the report entitled, "Pipeline Safety Research and Development Biennial Update Report, Fiscal Years 2019 and 2020," in fulfillment of the requirement in Section 22 of the Pipeline Safety Improvement Act of 2016, Pub. L. 114-183, (the Act). The Act requires the Secretary of Transportation (DOT) to submit a biennial update report to Congress that summarizes each of the research and development (R&D) projects awarded by the Pipeline and Hazardous Materials Safety Administration (PHMSA) to federal and non-federal stakeholders, and reviews of how each project affects pipeline safety. The most recent previous biennial update report covered fiscal years 2017 and 2018 and is publicly available on the Pipeline Safety R&D Program website: https://primis.phmsa.dot.gov/rd/docspr/PSA%202016%20Biennial%20Report%20FY%2017-18.pdf.

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Sincerely,

Tristan H. Brown
Deputy Administrator

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U.S. Department
of Transportation
**Pipeline and Hazardous
Materials Safety
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1200 New Jersey Avenue, SE
Washington, DC 20590

November 18, 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, "Pipeline Safety Research and Development Biennial Update Report, Fiscal Years 2019 and 2020," in fulfillment of the requirement in Section 22 of the Pipeline Safety Improvement Act of 2016, Pub. L. 114-183, (the Act). The Act requires the Secretary of Transportation (DOT) to submit a biennial update report to Congress that summarizes each of the research and development (R&D) projects awarded by the Pipeline and Hazardous Materials Safety Administration (PHMSA) to federal and non-federal stakeholders, and reviews of how each project affects pipeline safety. The most recent previous biennial update report covered fiscal years 2017 and 2018 and is publicly available on the Pipeline Safety R&D Program website: https://primis.phmsa.dot.gov/rd/docspr/PSA%202016%20Biennial%20Report%20FY%2017-18.pdf.

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Tristan H. Brown
Deputy Administrator

Enclosure

U.S. Department of Transportation

Pipeline and Hazardous Materials Safety Administration

Pipeline Safety Research and Development Biennial Update Report Fiscal Years 2019 and 2020

Pipeline Safety Research and Development Biennial Update Report Fiscal Years 2019 and 2020

Contents

Abbreviation List

2D	2-Dimentional
3D	3-Dimentional
AC	Alternating Current
AGA	American Gas Association
AI	Artificial Intelligence
AOPL	Association of Oil Pipe Lines
APGA	American Public Gas Association
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
CAAP	Competitive Academic Agreement Program
CEC	California Energy Commission
CER	Canada Energy Regulator
CP	Cathodic Protection
CPM	Computational Pipeline Monitoring
CT	Computed Tomography
DOC	Department of Commerce
DOE	Department of Energy
DOT	Department of Transportation
ECDA	External Corrosion Direct Assessment
EMAT	Electromagnetic Acoustic Technology
EPA	Environmental Protection Agency
FBO	Federal Business Opportunities
FAA	Federal Aviation Administration
FEA	Finite Element Analysis
FERC	Federal Energy Regulatory Commission
FRA	Federal Railroad Administration
FY	Fiscal Year
GIS	Geographic Information System
GO	Government Organization
GPS	Global Positioning System
IAA	Inter-Agency Agreement
IFG	Industry Focus Group
ILI	In-Line Inspection
ILPP	Intrinsically Locatable Plastic Pipe
INGAA	Interstate Natural Gas Association of America
IWEX	Inverse Wave Field Extrapolation
LDC	Local Distribution Company
LNG	Liquefied Natural Gas
MATIPI	Multimodal Acoustic Tool for Inline Pipe Inspection
MEP	Model Evaluation Protocols
MWM	Meandering Winding Magnetometer
NACE	National Association of Corrosion Engineers
NDE	Non-Destructive Evaluation
NDT	Non-Destructive Testing
NFPA	National Fire Protection Association
NGA	Northeast Gas Association
NII	NACE International Institute
NAPSR	National Association of Pipeline Safety Representatives

NIST	National Institute of Standards and Technology
NGO	Non-Government Organization
NTSB	National Transportation Safety Board
OTA	Other Transaction Agreement
OTD	Operations Technology Development
PE	Polyethylene
PG&E	Pacific Gas and Electric
PHMSA	Pipeline and Hazardous Materials Safety Administration
PIPES Act of 2016	Protecting our Infrastructure of Pipelines and Enhancing Safety Act of 2016
PRCI	Pipeline Research Council International
PSI	Pound-Force Per Square Inch
PSIA of 2002	Pipeline Safety Improvement Act of 2002
PSRP	Pipeline Safety Research Program
R&D	Research and Development
ROW	Right-of-Way
RP	Recommended Practice
SBA	Small Business Administration
SBIR	Small Business Innovative Research
SCC	Stress Corrosion Cracking
SNL	Sandia National Laboratories
TAS	Test Assembly Stations
TTC	Transportation Technology Center
UAS	Unmanned Aerial System
USDA	Department of Agriculture
UT	Ultrasonic Test
VCE	Vapor Cloud Explosion

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 increased growth in the scope and complexity of its safety mission, which requires continuous evaluation of how it uses information and technology to achieve the Department of Transportation's (DOT's) safety goals. PHMSA partners with any stakeholders that share the goal of developing new technologies, products, and knowledge aimed at improving safety in all areas of its research agenda focused on addressing 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 the Nation's transportation system's efficient and reliable performance. Therefore, PHMSA funds research that improves pipeline safety, reliability, and environmental protection, while simultaneously enhancing business and government performance. In 2016, PHMSA developed a research plan in accordance with the Pipeline Safety Improvement Act (PSIA) of 2002 to fund innovative research. To that end, PHMSA's Pipeline Safety Research and Development (R&D) Five-Year Program Plan (Plan) promotes transparency, as well as inter-agency and stakeholder input to effectively and efficiently manage R&D project activities.

This report describes how PHMSA's research program consults with stakeholders to develop and fund a research agenda that is relevant to its mission. This consultation on research with stakeholders goes as far back as 2002.

In compliance with the Protecting our Infrastructure of Pipelines and Enhancing Safety (PIPES) Act of 2016 mandate in section 22, PHMSA is reporting on the R&D investments for Fiscal Years (FYs) 2019 and 2020 by summarizing the anticipated results and potential impact on pipeline safety. PHMSA funded 59 R&D projects with $39,665,920 in federal funds for this reporting period. In FY 2019, PHMSA funded 30 R&D projects totaling $15,367,306, whereas in FY 2020, it funded 29 R&D projects totaling $24,298,614. The potential impact of these projects on safety can be significant. The safety benefits of the technologies and knowledge created from these projects can only be realized in the future after adoption by the pipeline industry at large. These solutions will impact safety on all pipeline types and liquefied natural gas (LNG) facilities by providing operators of these facilities with the tools and state-of-the-art knowledge to better prevent accidents.

1. Introduction

1.1 PHMSA's Pipeline Safety Research Program

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

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 protect 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 technologies, products and knowledge, and to promote stakeholder engagement.

1.2 Stakeholder and Inter-Agency Engagement in the Research and Development Program 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.[1] The forum, which had five working groups, provided an opportunity for stakeholders to discuss research gaps and to finalize research recommendations on the following topics:

1. Improving Assessment Methods for Dents and Cracks: Included for supporting efforts to develop an industry standard on assessment and management of dents in pipelines.
2. Remote Sensing/Leak Detection-Mitigation: Included for supporting the expansion of drones and machine learning (ML) used in safety operations.
3. Locating and Preventing Damage to Distribution Pipelines: Included for reducing one of the most frequent areas of reported damage and supporting a mandated study by Congress on improving damage prevention technology.
4. Expanding In-Line Inspection (ILI) Capabilities and Application: Included for supporting the National Transportation Safety Board (NTSB) focus and industry focus on expanding ILI capabilities to better detect and characterize defects in all pipeline types including those that cannot accommodate traditional ILI.
5. LNG: Included for supporting efforts to address the safety risks and operational challenges from LNG facilities, including export, import, peakshaving, and small-scale.

PHMSA utilized the recommendations from the working groups to plan its FY 2019 research 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 Federal Business Opportunities (FBO) portal. The ongoing Special Notice, open year-round and now posted in betaSAM, invites stakeholders to submit ideas for future

1 HTTPS://PRIMIS.PHMSA.DOT.GOV/RD/MTG_091118.HTM

research. The notice is revised, as needed, to reflect new safety initiatives from PHMSA or the Administration. A web-based portal was also created to support and manage this effort.[2]

Partnerships with government organizations (GOs) and non-government organizations (NGOs) provide clear opportunities to leverage ongoing successes, cost-share on research that addresses mutual safety challenges, and remove duplication. Throughout the year, PHMSA briefs trade associations, pipeline safety regulators, public interest groups, academic institutions, and the pipeline industry on these research programs and consults with pipeline representatives on individual projects that are within their sphere of expertise. Research collaboration partners are shown in Table 1.a. The table identifies both GOs and NGOs who cost-share research with PHMSA.

Table 1.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
National Association of Corrosion Engineers (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

In 2020, PHMSA began intermodal research efforts with the Federal Railroad Administration (FRA) at their Transportation Technology Center (TTC) in Pueblo, Colorado. The intermodal research efforts included an Industry Focus Group (IFG) in which FRA served as a railroad

2 HTTPS://PRIMIS.PHMSA.DOT.GOV/RD/GAPSUGGESTIONS.HTM

safety subject matter expert. The two projects conducted as part of the intermodal effort were: [1] Fatigue testing on pipe transported by rail; and [2] Technical testing of pipe subjected to railroad loading. There is a high value in initiating these projects at TTC, such as to foster relationships with FRA and rail stakeholders, and to engage the pipeline industry in cross-modal research.

1.3 Program Structure Funding Summary (FY 2019 and FY 2020)

PHMSA's PSRP includes four sub-program categories:

Core Research Program – $17,349,958

PHMSA's PSRP is primarily executed through the Core Research Program (Core) that focuses on developing new technologies or products, conducting demonstrations, and transferring 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 awards to conduct innovative research through competitive bidding among colleges and universities. The CAAP is intended to spur innovation by enabling academic research focused on high-risk, high-reward solutions to 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 in February 2004 under Executive Order 13329 to encourage innovation in manufacturing. The executive order assigns duties to the Small Business Administration (SBA), 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 U.S. 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 (SNL), NIST, and other Federal entities.

- FY 2019 Awarded Projects: $705,000

- FY 2020 Awarded Projects: $13,496,298[3]

2. Programmatic Elements and Objectives

PHMSA identified a set of high-value programmatic objectives as the focal point for its research based on stakeholder input from R&D forums, submissions on research gaps, and accident trends. The specific research projects and scope of activities may change from year to year to address emerging safety issues based on data analysis, and in response to Congressional mandates and specific pipeline incidents. Based upon the Agency's analysis and stakeholder input, the program elements in the following Section were funded during this reporting period.

3. Research Project Awards

In this Section, a summary of the R&D projects related to each of the Program Elements and how the projects affect safety is provided.

3.1 Preventing Pipeline Threats/Damage

Description: The funding total for this Program Element is $12,180,735.

Activities include examining tools to alert operator 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, and predictive analytics to mitigate external threats to pipeline infrastructure. As shown in Table 3.a below, the following are the funded projects in FY 2019.

The following information documents the projects funded during FY 2019 for this programmatic element.

Table 3.a - FY 2019 Funded Projects – Preventing Pipeline Threats/Damage

	Project Title	PHMSA Funding Total	Recipient	City	State
1.	Subsurface Multi-Utility Asset Location Detection	$1,028,122 (Core)	Gas Technology Institute	Des Plaines	IL
2.	Procedures for Selecting Locating and Excavation Technologies	$495,000 (Core)	Operations Technology Development	Des Plaines	IL

[3] FY 2020 includes funding for the Research, Development, and Testing Program at the Transportation Technology Center.

	Project Title	PHMSA Funding Total	Recipient	City	State
3.	Review the Intent and Safety Impact of Hoop Stress and Percentage of Specified Minimum Yield Stress Boundaries on Natural Gas Transmission and Distribution Pipelines	$431,902 (Core)	Gas Technology Institute	Des Plaines	IL
4.	Data Collection, Normalization and Integration Methods to Enhance Risk Assessment Tools for Decision-Making	$1,161,597 (Core)	Gas Technology Institute	Des Plaines	IL
5.	Develop and Demonstrate a Remote Multi-Sensor Platform for Right-of-Way Defense	$439,000 (Core)	Operations Technology Development	Des Plaines	IL
6.	Improving Subsurface Utility Locating Using Self-Aligning Robotic Ground Penetrating Radar	$393,690 (Core)	ULC Robotics	Hauppauge	NY
7.	Mapping Indication Severity Using Bayesian Machine Learning from Indirect Inspection Data into Corrosion Severity for Decision-Making in Pipeline Maintenance	$310,000 (Core)	Texas A&M University	College Station	TX
8.	Fundamental Understanding of Pipeline Material Degradation under Interactive Threats of Dents and Corrosion	$250,000 (CAAP)	Iowa State University	Ames	IA
9.	An Unmanned Aerial System of Visible Light, Infrared and Hyperspectral Cameras with Novel Signal Processing and Data Analytics	$250,000 (CAAP)	University of Missouri	Rolla	MO
10.	Combined Cleaning and Guided Wave Inspection System for Hazardous Liquid Pipelines	$993,938 (SBIR)	ULC Robotics	Hauppauge	NY
11.	Multimodal Acoustic Tool for Inline Pipe Inspection	$994,865 (SBIR)	Creare, LLC	Hanover	NH
12.	Mechanical Metallurgy on Vintage X100 Experimental Pipe	$705,000 (IAA)	National Institute of Standards and Technology	Boulder	CO
	FY 2019 Total: $7,453,114				

Project 1

Title: Subsurface Multi-Utility Asset Location Detection

Recipient: Gas Technology Institute

Project Description: The intention of this research project is 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 anticipated goals with this project are to define/test the capability, attachment design, and manufacturing qualifications of the marker; and to complete installation/testing with two major gas pipeline operators.

Anticipated Results: The project is expected to result in the manufacturing of a plastic pipe that can easily be located either by taping or fusing an electronic marker to the plastic pipe. The researcher will record the global positioning system (GPS) coordinates of characteristic locations along the pipe, such as nodes and specific markers; the GPS coordinates will serve as a backup to the plastic pipe markers. The gas utility operators participating in the research project will select various locations along the sample pipe utilizing the markers under a variety of conditions to evaluate the longevity of the pipe marker.

Potential Impact on Safety: This research project is expected to mitigate excavation pipeline damage through the completion and commercialization of innovative intrinsically locatable plastic pipe (ILPP). Currently, more than 90% of the gas distribution pipe installed is polyethylene pipe. A copper tracer wire installed with the pipe is used for locating the buried pipe. However, tracer wires are susceptible to breakage or corrosion, rendering the buried pipe undetectable. The ILPP system being developed can easily be located; therefore, the technology is anticipated to substantially reduce the risk of excavation damage, thereby enhancing safety and reducing methane emissions.

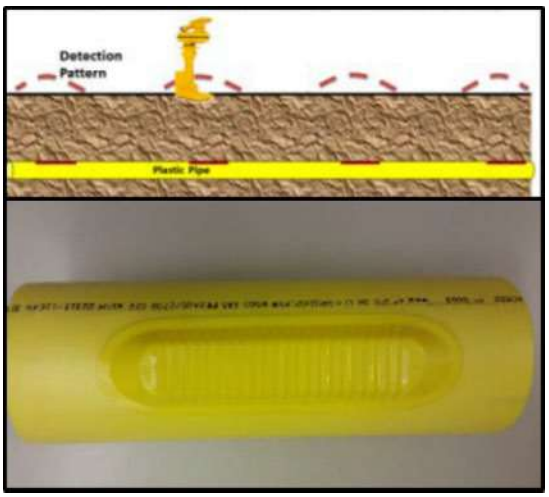

Figure 1 Field testing improved sensors to detect pipes from the surface. Courtesy Gas Technology Institute

Project 2

Title: Procedures for Selecting Locating and Excavation Technologies

Recipient: Operations Technology Development

Project Description: The purpose of this research project is to develop a web-based program to provide decision-making tools to assist pipeline operators identify risks and to provide situational awareness of excavation damage. The web-based program will include a database of existing locating and excavating technologies, an encroachment notification system, Federal/State excavation requirements, as well as GIS utility data when available.

Anticipated Results: The project is anticipated to produce a web-based program and database of relevant technologies, regulations, and best practices to improve locating of buried pipelines and practices to help prevent excavation damage. The dashboard interface will provide end-users with data management to integrate, visualize the output, and efficiently select locating tools and excavation technologies/practices based on their specific needs, operation resources, and site characteristics.

Potential Impact on Safety: Excavator companies and the public will be more informed from the results of the project by understanding the relevant regulations, practices, selections of locating technologies, and excavating practices through a web-based program. The web-based program will advance pipeline safety by providing decision-making tools to pipeline operators and excavator companies, thereby, ultimately minimizing the probability and consequences of excavation damage. Furthermore, the inclusion of GIS utility data may facilitate increased situational awareness for emergency responders in the event of an excavation incident.

Project 3

Title: Review the Intent and Safety Impact of Hoop Stress and Percentage of Specified Minimum Yield Stress Boundaries on Natural Gas Transmission and Distribution Pipelines

Recipient: Gas Technology Institute

Project Description: The purpose of this research project is to investigate the current definitions in Part 192 for natural gas transmission and distribution lines, identify safety/integrity implications from reclassifying a pipeline from transmission to distribution, and to provide pipeline operators with a new approach to pipeline integrity management. An emphasis will be placed on the current operating pressure/hoop stress as a percentage of minimum yield strength stress boundaries that differentiate a transmission line from a distribution line and will include leak versus rupture considerations. The project will include a simple set of criteria to be used when a system is regulated under

either Gas Transmission Pipeline Integrity Management or Gas Distribution Pipeline Integrity Management regulations.

Anticipated Results: This project is expected to provide a new method to categorize natural gas pipelines for integrity management. The developed framework will consider factors such as failure mode, pipe vintage, preventative and mitigation measures, limitations to pipe wall anomalies, and a combination of operating conditions, pipe attributes, and defect type and geometry. The framework will be summarized in a flowchart and will include a gap analysis, highlighting differences between this new framework and the current integrity management regulations for natural gas pipelines.

Potential Impact on Safety: This research project is expected take a purely scientific approach to pipeline integrity management. This approach could impact pipeline safety by potentially better reflecting real world conditions, and could result in a more accurate and useful categorization of the pipelines. This framework may be used as a basis to revise the current regulations used to categorize pipelines, both gas distribution and gas transmission.

Project 4

Title: Data Collection, Normalization and Integration Methods to Enhance Risk Assessment Tools for Decision-Making

Recipient: Gas Technology Institute

Project Description: The purpose of this project is 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-making tools for pipeline operators.

Anticipated Results: The results include developing a data repository with a diverse set of data sources that impact pipeline system risk assessment. A multi-model database will be structured and deployed that can house the input and output data. Decision-making tools that can integrate, normalize, and assess uncertainties of the diverse data sources will be developed and demonstrated at an industry workshop.

Potential Impact on Safety: The development of new decision-making tools can greatly assist decision makers to prioritize addressing critical safety gaps. The ability to focus on critical safety gaps may minimize pipeline incidents that arise due to delayed maintenance.

Project 5

Title: Develop and Demonstrate a Remote Multi-Sensor Platform for Right-of-Way Defense

Recipient: Operations Technology Development

Project Description: The purpose of this research project is 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.

Anticipated Results: This project is anticipated to result in the development and demonstration of a sensing platform permanently deployed at discrete locations in the right of way (ROW) to detect damage and leaks. Sensor data from multiple locations along the pipeline is wirelessly forwarded to a central location for processing and analytics that will correlate the data to rapidly alert operators to events occurring in the ROW.

Potential Impact on Safety: The project will help improve safety by advancing sensing platforms and data analysis to allow operators to quickly detect and respond to damages and leaks to the pipeline system.

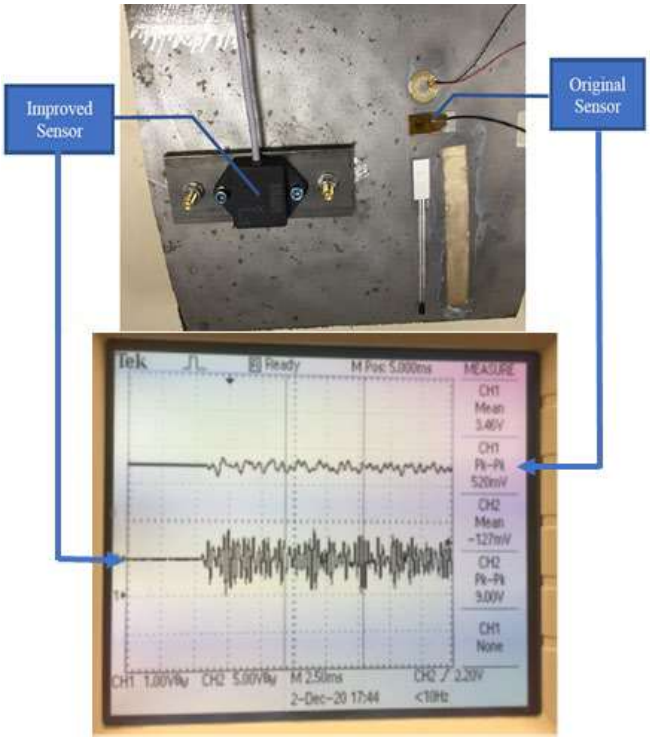

Figure 2 Testing new sensors to enable higher signal response.
Courtesy Operations Technology Development

Project 6

Title: Improving Subsurface Utility Locating Using Self-Aligning Robotic Ground Penetrating Radar

Recipient: ULC Robotics

Project Description: The purpose of this research project is to develop a pre-commercial prototype robotic system that will improve locating underground pipelines.

This goal 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 pipelines, to locate both metallic and non-metallic facilities.

Anticipated Results: The project is anticipated to develop a pre-commercial prototype robotic locating system that will reduce excavation damage to buried pipelines. The results will be achieved by improving the quality of image and location data using self-adapting antenna configurations that increase the probability of detection, enhance data quality, and automate the classification of detected targets. Two robotic carts will autonomously align themselves to each other and to the buried pipelines to obtain the best Signal to Noise Ratio.

Potential Impact on Safety: The project will help improve safety by improving methods to detect underground pipelines and by helping to prevent excavation damage to buried pipelines. Detection of non-metallic pipelines is particularly challenging.

Project 7

Title: Mapping Indication Severity Using Bayesian Machine Learning from Indirect Inspection Data into Corrosion Severity for Decision-Making in Pipeline Maintenance

Recipient: Texas A&M University

Project Description: The purpose of this research project is 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 broader database of environmental data.

Anticipated Results: The project is expected to develop a fast, fundamentally sound, reliable and accurate software tool to assess corrosion growth rate and severity by integrating local conditions which affect pipeline external corrosion. The tool will support operators by helping them optimize the numbers and locations of excavations to repair corrosion related issues. The desired outcome of this project is to prioritize threat severity and support the development of maintenance plans to address the pipelines with higher integrity risk and schedule these facilities for repair and mitigation.

Potential Impact on Safety: The impact will be promoting a deeper understanding of the uncertainty of the external corrosion indirect inspection data through utilizing Bayesian ML techniques. The outcome of this research project could be adapted to the existing industry standards (e.g., NACE Recommended Practice [RP] 0502) for external corrosion direct assessment (ECDA). The implementation of the developed software tool for real-world underground pipeline inspection could reduce the likelihood of pipeline failures due to external corrosion and improve the safety and reliability of pipeline systems.

Project 8

Title: Fundamental Understanding of Pipeline Material Degradation under Interactive Threats of Dents and Corrosion

Recipient: Iowa State University

Project Description: The project will help 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 will characterize and better predict the remaining safe life and operating pressures of the pipeline, while also forecasting the need for mitigation measures.

Anticipated Results: The submission of a report will include new, research-based metrics that consider external dents with cracking and corrosion, as they interact on a pipeline. The goal is to reduce the variability in the risk assessments of these interactive threats.

Potential Impact on Safety: Project metrics will be provided that potentially could be used to better predict the lifespan of the pipeline, characterize the interacting threats of dents and corrosion, and support statistically sound integrity management decisions. These could result in improved pipeline safety through regulatory updates. This could also enhance pipeline safety by improving assessment models to address the interacting threats and related integrity management decisions.

Project 9

Title: An Unmanned Aerial System of Visible Light, Infrared and Hyperspectral Cameras with Novel Signal Processing and Data Analytics

Recipient: University of Missouri (MU)

Project Description: The purpose of this research project is 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.

Anticipated Results: This project will enhance routine aerial patrol inspections of pipelines for critical data collection, processing, and application towards condition and risk assessments for pipeline operators. An integrated UAS of infrared and hyperspectral cameras with signal processing and data analytics will be developed.

Potential Impact on Safety: Pipeline operators will utilize the methodology developed from this project to perform aerial patrols using UASs, and be able to identify more potential threats to the pipeline. These UASs would use sensors to follow the pipeline automatically and would inspect the pipeline at much lower elevations than fixed wing aircraft.

Project 10

Title: Combined Cleaning and Guided Wave Inspection System for Hazardous Liquid Pipelines

Recipient: ULC Robotics

Project Description: The purpose of this research project is to develop a low-cost and lightweight inspection and cleaning prototype dual-purpose ILI tool 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.

Anticipated Results: The anticipated result with this research project is the detailed design and fabrication of supporting electronics, defect reporting automation software, and the operator data visualization software. Validation testing of the dual-purpose tool is planned for summer 2021.

Potential Impact on Safety: Cleaning tools will be developed that may improve product throughput, inhibit corrosion, and prepare pipelines for ILI. Accurate defect detection can prevent future incidents from occurring.

Project 11

Title: Multimodal Acoustic Tool for Inline Pipe Inspection

Recipient: Creare, LLC

Project Description: The purpose of this research project is to develop a hybrid Multimodal Acoustic Tool for Inline Pipe Inspection (MATIPI). The MATIPI will determine material characteristics through two independent techniques measuring two separate properties, which should significantly increase the accuracy of the overall approach. The solution will ultimately be demonstrated and verified at an actual pipeline dig site.

Anticipated Results: The development of a commercialized hybrid tool will enable pipeline operators to determine true material toughness through the cross-correlation of independent measurement techniques. Validation testing will occur by summer 2021.

Potential Impact on Safety: This research project will develop the MATIPI tool, which will provide pipeline operators with a validated non-destructive inspection technique capable of detecting material defects and corrosion. This tool can prevent incidents by accurately detecting these defects before failure.

Project 12

Title: Mechanical Metallurgy on Vintage X100 Experimental Pipe

Recipient: National Institute of Standards and Technology (NIST)

Project Description: The purpose of this project is for NIST to conduct metallurgical testing on Columbia Gas X100 experimental pipe to provide valuable information on property changes because of degradation and property differences due to microstructure. The project will provide insight on vintage versus modern high strength steels.

Anticipated Results: This project is experiencing delays due to the impacts from the COVID-19 pandemic. The NIST protocols have only supported limited lab testing to date. The portion of the project addressing the literary search is largely complete. That portion of the project supports the goal of obtaining other historical information about how vintage X100 steels were made so they can be compared to the modern approach.

Potential Impact on Safety: This project will provide results that support a qualitative understanding of how modern X100 steel may deteriorate over time as compared to the earlier vintage. These results will improve metallurgical-based science within integrity programs so that pipeline operators can better manage material-based deterioration threats. This will potentially prevent and mitigate such safety threats coming from material degradation.

Table 3.b highlights one technology in the area of pipeline threat and damage prevention that was commercialized in FY 2019.

Table 3.b - Highlights of FY 2019 Technology Transfer Activities

Programmatic Element	**Project Title**	**Technology Transfer Outcome**
Preventing Pipeline Threats/Damage	Global Positioning System-Based Excavation Encroachment Notification[4]	 *Pictures Courtesy of GTI* 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.

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The following information documents the projects funded during FY 2020 for this programmatic element.

Table 3.c - FY 2020 Funded Projects – Preventing Pipeline Threats/Damage

	Project Title	PHMSA Funding Total	Recipient	City	State
1.	Forced Resonance Imaging for 3-Dimentional Mapping of Buried Gas Pipes	$1,519,094 (Core)	Bakhtar Research and Engineering, LLC	Irvine	CA
2.	Procedures for Retrofitting Indoor Gas Service Regulators	$290,000 (Core)	Gas Technology Institute	Des Plaines	IL
3.	Validating Models for Predicting Gas Migration and Mitigating its Occurrence/ Consequence	$1,134,646 (Core)	Colorado State University	Fort Collins	CO
4.	Distributed Strain Sensing for Pipeline Safety Against Fault Moving and Landslide	$250,000 (CAAP)	The Regents of the University of California Berkeley	Berkeley	CA
5.	Probabilistic Performance Evaluation of Cathodically Protected Pipeline Considering Alternating Current Corrosion	$250,000 (CAAP)	The University of Akron	Akron	OH
6.	Non-Destructive Testing of Fracture Toughness for Pipeline Steels	$990,470 (SBIR)	FBS, Inc.	State College	PA
7.	Managing Geohazards Quantitative Risk Assessment for Pipelines	$143,412 (SBIR)	Applied Engineering Management Corporation	Herndon	VA
8.	Fiber Optic Sensors for Direct Pipeline Monitoring under Geohazard Conditions	$149,999 (SBIR)	Paulsson, Inc	Van Nuys	CA
	FY 2020 Total: $4,727,621				

Project 1

Title: Forced Resonance Imaging for 3-Dimentional Mapping of Buried Gas Pipes

Recipient: Bakhtar Research and Engineering, LLC

Project Description: The purpose of this research project is to develop and demonstrate a system that can detect subsurface natural gas pipes, to collect three-dimensional (3D) location information with increased accuracy, and to provide additional information on pipe diameter and type (plastic or metallic) by 3D mapping.

Anticipated Results: The project will develop a prototype utilizing forced resonance imaging systems from existing equipment. Testing will be conducted, and software algorithms will be upgraded to allow for near real-time detection of buried pipes. The capability will be further developed to allow for dimensional details, to differentiate between metallic and plastic pipes, and to determine depth of buried pipe. The capability will be field demonstrated at a site owned by pipeline operator Pacific Gas and Electric (PG&E) to verify the system's capability to 3D map buried pipelines.

Potential Impact on Safety: This project will provide the ability to more accurately map underground pipelines and may change the paradigm on the threat of excavation damage. The capability may reduce the number of incidents that result from an unintentional strike on a pipeline during routine maintenance or during installation of other underground utilities; and ultimately reduce the risk to the public, as well as to the environment from such incidents.

Project 2

Title: Procedures for Retrofitting Indoor Gas Service Regulators

Recipient: Gas Technology Institute (GTI)

Project Description: The purpose of this research project is to 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.

Anticipated Results: The project will establish best practices for the inspection, recording, and maintenance of gas regulators and operator-owned indoor piping systems. The project will also aid gas service regulator manufacturers with potential design changes to better accommodate the installation of regulators outside of buildings with limited space.

Potential Impact on Safety: This research project is expected to potentially provide information regarding the safety impacts of indoor service meters and regulators as compared to those located outdoors. This information could help operators to better manage those differences, and make decisions regarding their replacement, retrofit, or relocation, which may result in enhancing pipeline safety. This information may also be used to help respond to NTSB recommendations on the subject.

Project 3

Title: Validating Models for Predicting Gas Migration and Mitigating its Occurrence/ Consequence

Recipient: Colorado State University (CSU)

Project Description: The purpose of this research project is to 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 knowledge of gas migration behavior.

Anticipated Results: The project may result in additional field testing of natural gas leakage and migration patterns, particularly in scenarios involving moderate to high flow rates that can produce explosive concentrations within nearby substructures. A critical knowledge gap is how environmental conditions affect gas migration behavior in these scenarios. CSU and the University of Texas at Arlington (UTA) will collaborate with industry and first responder partners, who will be members on a technical advisory panel, provide access to their response protocols, and, in some cases, participate in field testing. Controlled field testing will be performed at CSU's Methane Emission Technology Evaluation Center (METEC).

Potential Impact on Safety: The project will help advance understanding of gas migration behavior and provide decision guidance for stakeholders (e.g., first responders) by: (a) taking direct measurements of gas migration speed and extent at the surface and subsurface in a range of environmental conditions; (b) pairing measurements with models to extend knowledge beyond measurable scenarios, and (c) linking gas concentration measurements with observations of environmental conditions to estimate extent and speed of gas migration.

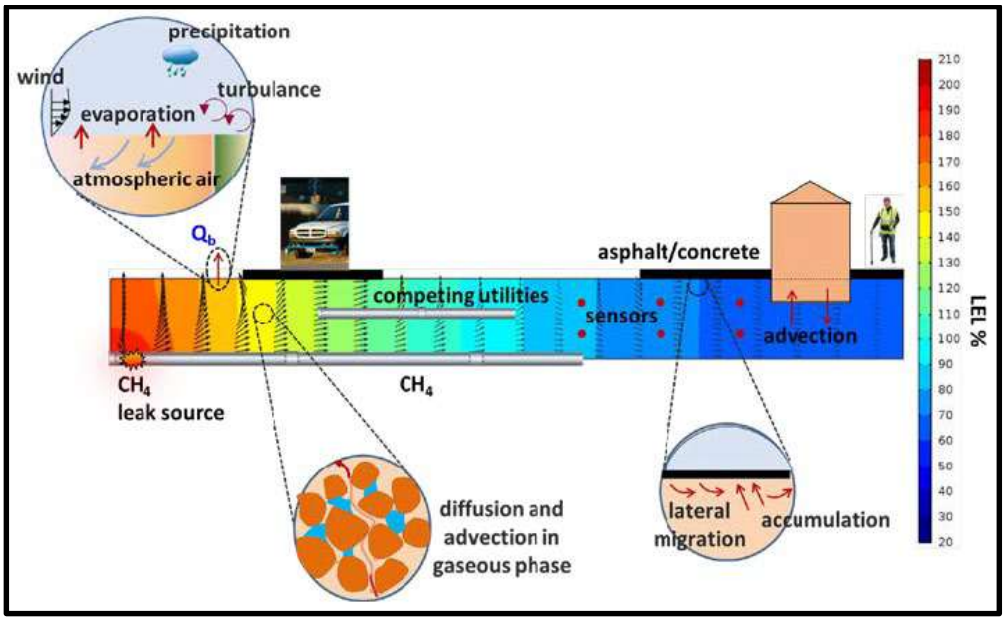


Figure 3 Gas migration field testing to validate prediction modeling.
Courtesy Colorado State University

Project 4

Title: Distributed Strain Sensing for Pipeline Safety Against Fault Moving and Landslide

Recipient: The Regents of the University of California Berkeley

Project Description: This project's goal is to 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.

Anticipated Results: This project will result in a field-tested, fiber optic strain-sensing system that can be utilized to monitor structural performance of oil and natural gas pipelines subjected to ground movements at fault crossing and landslide sites. Furthermore, the university will develop a commercialization plan for the strain-sensing system.

Potential Impact on Safety: This project will support the development of a long-term modeling system that can greatly enhance the pipeline operator's ability to determine potential integrity threats to pipeline systems due to ground movement. The ability to detect such integrity threat and take corrective actions prior to an incident will enhance pipeline safety and the protection of the environment.

Project 5

Title: Probabilistic Performance Evaluation of Cathodically Protected Pipeline Considering Alternating Current Corrosion

Recipient: The University of Akron

Project Description: The project aims to 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 (CP). Such assistance may help pipeline operators make more informed decisions and save them assessment time and maintenance costs.

Anticipated Results: This research will develop a better understanding of AC-induced corrosion on cathodically protected pipelines and provide a probabilistic model for AC corrosion. This project will also implement many aspects of AC corrosion characterization, profiling, diagnosis, and prognosis, with specific design considerations to improve the effectiveness of CP programs.

Potential Impact on Safety: The research will provide an improved understanding of AC-induced corrosion on pipelines with CP. AC-induced corrosion poses an increasing threat to pipelines as more pipelines are constructed in shared corridors with AC powerlines and other sources that cause AC-induced corrosion. Operators have been able to mitigate some of the threats, but the problem persists. An increased understanding of how the corrosion occurs and how CP might be used to mitigate the threat could lead to fewer failures and enhanced pipeline safety.

Project 6

Title: Non-Destructive Testing of Fracture Toughness for Pipeline Steels

Recipient: FBS, Inc.

Project Description: The project aims to develop, verify, and deliver a nonlinear, guided wave system for non-destructive testing (NDT) of fracture toughness in pipeline steels to estimate the size, shape, and location of defects in the pipe. The industry recommended practice (API Standard RP 579-1) to assess fitness-for-service requires knowledge of the fracture toughness to determine the critical flaw size.

Anticipated Results: The development of this research project is ongoing and new sensor types are being applied in nonlinear, guided wave systems for NDT of fracture toughness in pipeline steels. Validation testing will occur by summer 2021 on the prototype nonlinear, guided wave system for determining the fracture toughness in pipeline steels.

Potential Impact on Safety: A commercialized tool will provide operators with a system to measure the fracture toughness and determine critical flaw size of the pipeline. Pipeline operators can then utilize industry standards such as API Standard RP 579-1 to accurately assess the pipeline's fitness for service and operational safety.

Project 7

Title: Managing Geohazards Quantitative Risk Assessment for Pipelines

Recipient: Applied Engineering Management Corporation

Project Description: The project aims to 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 be utilized to develop a concept of operations for a risk assessment tool.

Anticipated Results: The project reviewed the current state of practice to determine the requirements in building the software tool. Conceptual models were also developed for three representative threat-asset pairs: earthquake-landslide, precipitation-landslide, and flood-scour (pipeline stream crossing).

Potential Impact on Safety: This project will provide models that can accurately assess the level of risk coming from various geohazard threats thereby reducing the number of leaks and ruptures resulting from such events.

Project 8

Title: Fiber Optic Sensors for Direct Pipeline Monitoring Under Geohazard Conditions

Recipient: Paulsson, Inc.

Project Description: The purpose of this research project is to 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 be utilized to develop a concept of operations for a risk assessment tool.

Anticipated Results: The project demonstrated that distributed fiber optic sensing is a viable, robust, and cost-effective means to monitor pipelines. In addition, machine learning techniques can be used to analyze collected data to effectively identify geohazard events.

Potential Impact on Safety: This project provides a distributed fiber optic sensing which offers a cost-effective, long-term monitoring solution for pipeline operators that can prevent incidents due to ground movements such as soil creep.

3.2 Improving Pipeline Leak Detection Systems

Description: The funding total for this Program Element is $2,679,534.

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.

The following information documents the projects funded during FY 2019 for this programmatic element.

Table 3.d - FY 2019 Funded Projects – Improving Pipeline Leak Detection Systems

	Project Title	PHMSA Funding Total	Recipient	City	State
1.	Validation of Remote Sensing and Leak Detection Technologies under Realistic and Differing Conditions	$500,000 (Core)	Operations Technology Development	Des Plaines	IL
2.	Improving the Reliability, Detection, and Accuracy Capabilities of Existing Leak Detection Systems Using Machine Learning	$177,717 (Core)	Pipeline Research Council International	Chantilly	VA
3.	Develop Remote Sensing and Leak Detection Platform that Can Deploy Multiple Sensor Types	$307,881 (Core)	Pipeline Research Council International	Chantilly	VA
4.	Unmanned Aerial Systems for Pipeline Inspection, Monitoring, and Landscape Analysis	$206,920 (CAAP	West Virginia University	Morgantown	WV
5.	An Autonomous Unmanned Aerial Systems Inspection Platform for High-Efficiency 3-Dimentional Pipeline/Route Modeling/Change-	$249,964 (CAAP)	University of Nebraska	Lincoln	NE

	Project Title	PHMSA Funding Total	Recipient	City	State
	Detection and Gas Leak Detection-Localization				
FY 2020 Total: $1,442,482					

Project 1

Title: Validation of Remote Sensing and Leak Detection Technologies Under Realistic and Differing Conditions

Recipient: Operations Technology Development

Project Description: The project aims at developing and implementing a sensor validation framework focused on actual pipeline leaks verified through field measurements and simulated integrity threats. The framework will incorporate field results with different infrastructure, terrain, and land cover challenges, from rural to suburban to urban.

Anticipated Results: The project seeks to develop and implement a sensor validation framework to help advance UASs, or drone-mounted, remote sensing technologies. The sensing technologies are used for identifying ROW integrity threats and detecting natural gas leaks under operational conditions within natural gas transmission and distribution pipeline systems across urban to rural sites. Deliverables will include a validation test framework for real-world, operational drone-mounted technologies; field-validated, drone-mounted integrity threat monitoring and methane detection instruments; and a probabilistic understanding of instrument performance under real-world field scenarios.

Potential Impact on Safety: The findings will strengthen industry consensus on the value of newly developed leak detection sensors, integrity threat monitoring methods, unmanned aerial monitoring platforms, and survey methods using multiple sensors.

Project 2

Title: Improving the Reliability, Detection, and Accuracy Capabilities of Existing Leak Detection Systems Using Machine Learning

Recipient: Pipeline Research Council International

Project Description: A machine learning-based system will be developed capable of detecting hazardous liquid leaks shown in computational pipeline monitoring (CPM) data. Such a system will improve leak detection below the detection threshold of current CPM data assessment.

Anticipated Results: The project is anticipated to result in a framework and ML model that will address three primary leak detection systems gaps capable of: [1] finding smaller leaks, [2] finding leaks faster, and [3] finding leaks more reliably (higher

confidence, lower false alarms) than is possible with conventional CPM systems. The data being used to train the ML models is the same data currently being used to detect leaks in CPM systems. A guidance document will also be developed explaining the framework and model input and outputs.

Potential Impact on Safety: Operators will be provided with additional guidance and resources to detect smaller leaks more quickly, efficiently, and reliably. Detecting and being able to respond to smaller leaks more quickly continues to be a challenge in the industry.

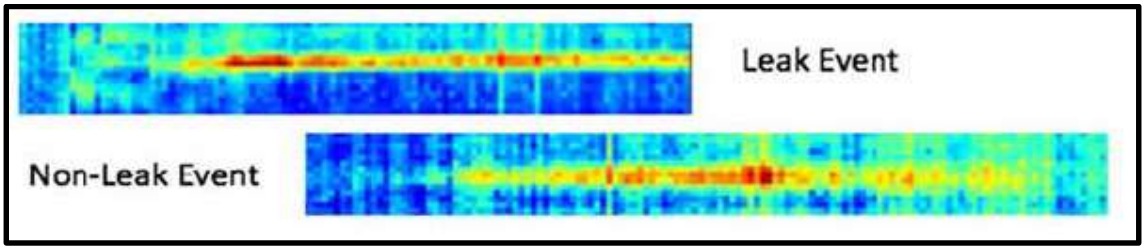


Figure 4 Machine Learning review of pipeline pressure/volume data to find small/missed leaks. Courtesy Pipeline Research Council International

Project 3

Title: Develop Remote Sensing and Leak Detection Platform that can Deploy Multiple Sensor Types

Recipient: Pipeline Research Council International

Project Description: The project seeks 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.

Anticipated Results: This project will include system and deployment platform development design actions, which are completed with the project focused on locating suitable validation sites for field testing through 2021. The project will also generate data from multiple sensors deployed on aerial patrol in supporting pipeline performance and safety improvement programs.

Potential Impact on Safety: This project provides a validated system for aerial patrol in supporting pipeline performance and safety improvement programs and will expand usage of such systems. It will also provide valuable data to the Federal Aviation Administration (FAA) with respect to the integration of long-range unmanned systems into the National Airspace System.

Project 4

Title: Unmanned Aerial Systems for Pipeline Inspection, Monitoring, and Landscape Analysis

Recipient: West Virginia University

Project Description: The project focuses on determining the most cost-effective combination of UAS sensors to monitor and evaluate pipeline conditions. The resulting knowledge will aid in sensor development and field testing.

Anticipated Results: The findings will result in a report detailing the most cost-effective combination of UAS sensors to monitor and evaluate pipeline conditions, as determined through the researcher's work on this project.

Potential Impact on Safety: The research will provide valuable information regarding the use of UASs to monitor pipelines. Increased and improved knowledge with respect to remote monitoring technologies may lead to safer pipelines since monitoring of pipeline corridors is important in identifying potential threats to the pipeline and threat avoidance or mitigation. Improved and more economical monitoring technologies would help increase the effectiveness of pipeline monitoring, and ultimately result in enhanced pipeline safety.

Project 5

Title: An Autonomous Unmanned Aerial Systems Inspection Platform for High-Efficiency 3D Pipeline/Route Modeling/Change-Detection and Gas Leak Detection-Localization

Recipient: University of Nebraska

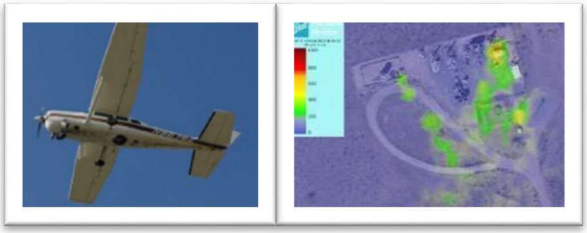
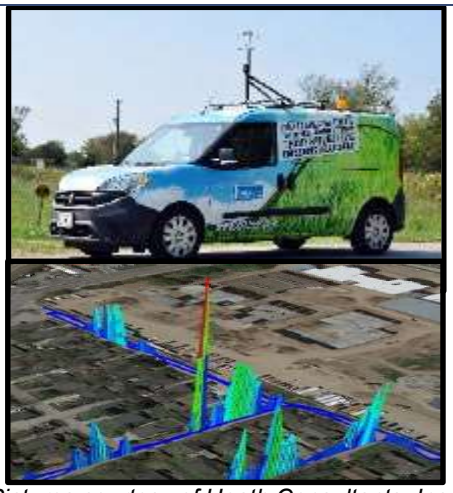
Project Description: The project's aim is to enhance the quality and efficiency of UAS pipeline and ROW inspections, and to evaluate and enhance the performance of pipeline leak detection-localization. This will aid in sensor development and field testing.

Anticipated Results: This project will substantially enhance the quality and efficiency of UAS pipeline/tank inspections so that it can be widely adopted for routine inspection tasks. Various sensors will be investigated to add leak detection capability onto the UAS during aerial inspections.

Potential Impact on Safety: This project seeks to provide a methodology for UASs to perform aerial patrolling of a pipeline using commercial software such as Google Maps, as well as cameras and sensors to keep the UAS over the pipeline. Having leak detection capability on a UAS located near the pipeline may provide early indication of leaks, leading to faster response, which would enhance public safety and protect the environment.

Table 3.e highlights technologies in the area of pipeline leak detection systems that were commercialized in FY 2019.

Table 3.e - Highlights of FY 2019 Technology Transfer Activities

Programmatic Element	Project Title	Technology Transfer Outcome
Improving Pipeline Leak Detection Systems	Rapid Aerial Small Methane Leak Survey[5]	 *Pictures Courtesy of Ball Aerospace and Technologies, Corp.* 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 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.
Improving Pipeline Leak Detection Systems	Natural Gas Pipeline Leak Rate Measurement System[6]	 *Pictures courtesy of Heath Consultants, Inc.* The project supported development of the Heath MobileGuard™ gas leak detection system, which consists of a methane/ethane analyzer, global positioning system (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

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

The following information documents the projects funded during FY 2020 for this programmatic element.

Table 3.f - FY 2020 Funded Projects – Improving Pipeline Leak Detection Systems

	Project Title	PHMSA Funding Total	Recipient	City	State
1.	Pre-Commercial Development and Field Testing of a Portable Mercaptan Sensing Device for Gas Industry Applications	$427,052 (Core)	Northeast Gas Association	Parsippany	NJ
2.	Improve Pipeline Leak Rate Estimation	$560,000 (Core)	BMT Fleet Technology Limited	Kanata	Canada
3.	Improving Pipeline Safety During Gas Leakage Events Using Near Real-Time Data Networks and Optimal Decision-Making Tools	$250,000 (CAAP)	The University of Texas at Arlington	Arlington	TX
FY 2020 Total: $1,237,052					

Project 1

Title: Pre-Commercial Development and Field Testing of a Portable Mercaptan Sensing Device for Gas Industry Applications

Recipient: Northeast Gas Association

Project Description: The goal of this research project is 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.

Anticipated Results: This research project is expected to result in pre-commercial development of a mobile mercaptan sensing device that can detect and quantify mercaptan concentrations in the single parts per billion range. Another anticipated result is completion of additional field testing of several of the redesigned systems with the non-radioactive ionizer to demonstrate commercial readiness.

Potential Impact on Safety: This research project will enhance safety by detecting leaks and preventing incidents. Mercaptans are an essential chemical additive to natural gas that allow humans to smell natural gas, should there be a leak. This research is developing and validating portable technology that measures the concentration of mercaptans in gas industry field applications comparable to the human nose that can detect mercaptans at concentrations as low as single parts per billion.

Project 2

Title: Improve Pipeline Leak Rate Estimation

Recipient: BMT Fleet Technology Limited

Project Description: The goal of this research project is to improve existing leak rate estimation models by developing tools that can correlate a 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.

Anticipated Results: This research project is expected to result in improving leak rate estimation models by developing tools that relate pipeline wall defect size and expected leak rates. Further anticipated results include focusing on experimental measurements and updating previously developed models to enhance leak rate estimation for pipelines with through-wall cracks of various orientations and morphologies and corrosion features of various sizes considering a range of pipe sizes and internal pressures.

Potential Impact on Safety: This research project is expected to enhance safety and prevent pipeline failures involving the release of product by estimating the leakage rate (based on defect sizes) and total release volume for various pipelines. These factors are important in evaluating the consequence of developing a through-wall crack, operational responses when incidents occur, and remedial action strategies and timelines. The testing expected to be completed in this project will support future testing (calibration) of in-leak detection sensors and liquid hydrocarbon product migration assessment.

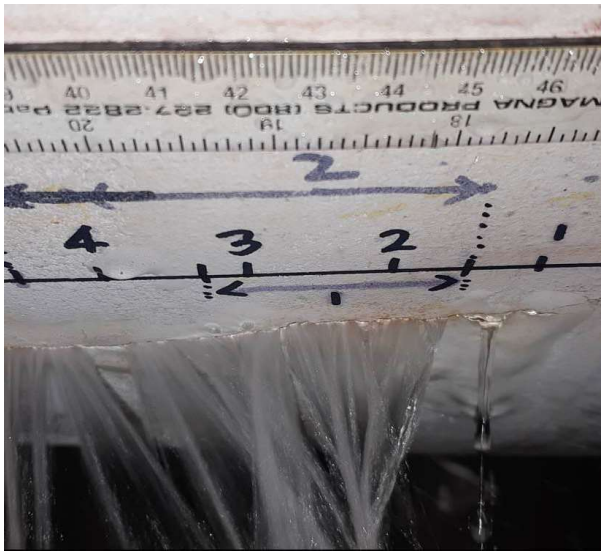

Figure 5 Leak volume/rate testing through real defects to validate models. Courtesy BMT Fleet Technology Limited.

Project 3

Title: Improving Pipeline Safety During Gas Leakage Events Using Near Real-Time Data Networks and Optimal Decision-Making Tools

Recipient: The University of Texas at Arlington

Project Description: The research project's goal is to develop, test, and deploy a novel natural gas sensing protocol that provides operators with critical knowledge on gas behavior over time, and to ensure that this protocol is widely applicable and accessible to end-users.

Anticipated Results: The project will commence with the development of a project guidance committee formed of LDCs, upstream operators, and regulatory agencies. The researcher will develop a low-cost, near real-time, wireless, natural gas detector network as well as a control-optimization algorithm for gas leakage detector network. The network and algorithm will then be field tested at the CSU METEC facility. Additional field tests will be conducted at various industry partner sites. The researcher will prepare a final guidance document on how to deploy the gas sensing protocol.

Potential Impact on Safety: This project will provide the ability to quantify below ground leaks utilizing real-time data, which can reduce the risk of an incident caused by migrating gas to a residence or a prolonged release of methane into the environment. The ultimate development of the natural gas sensing protocol will greatly enhance safety of the public and environment.

3.3 Improving Anomaly Detection and Characterization

Description: The funding total for this Program Element is $8,003,284.

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

The following information documents the projects funded during FY 2019 for this programmatic element.

Table 3.g - FY 2019 Funded Projects – Improving Anomaly Detection and Characterization

	Project Title	PHMSA Funding Total	Recipient	City	State
1.	Improve Dent/Cracking Assessment Methods	$353,084 (Core)	Pipeline Research Council International	Chantilly	VA
2.	Systematize 20 Years of Mechanical Damage Research	$393,783 (Core)	Pipeline Research Council International	Chantilly	VA
3.	Program to Advance Computed Tomography for the Development of Reference Standards for Pipeline Anomaly Detection and Characterization	$500,000 (Core)	Pipeline Research Council International	Chantilly	VA
4.	Improve In-Line Inspection Sizing Accuracy	$725,000 (Core)	Pipeline Research Council International	Chantilly	VA
5.	Validate In-Line Inspection Capabilities to Detect/Characterize Mechanical Damage	$1,397,722 (Core)	Pipeline Research Council International	Chantilly	VA
6.	Artificial Intelligence-Enabled Interactive Threats Detection Using a Multi-Camera Stereo Vision System	$250,000 (CAAP)	Arizona State University	Tempe	AZ
7.	Improved Non-Destructive Testing Detection and Probabilistic Failure Prediction for Interacting Pipeline Anomalies	$250,000 (CAAP)	Brown University	Providence	RI
8.	Multi-Modal Non-Destructive Evaluation Assisted Probabilistic Pipeline Performance Evaluation Under Interactive Anomalies	$249,926 (CAAP)	University of Akron	Akron	OH

	Project Title	PHMSA Funding Total	Recipient	City	State
9.	Distributed Fiber Optic Sensor Network for Real-Time Monitoring of Pipeline Interactive Anomalies	$250,000 (CAAP)	Stevens Institute of Technology	Hoboken	NJ
10.	Non-Destructive Coercimetry Fracture Toughness Assessment for Steel Pipelines	$999,100 (SBIR)	Innerspec Technologies, Inc	Forest	VA
	FY 2019 Total: $5,368,615				

Project 1

Title: Improve Dent/Cracking Assessment Methods

Recipient: Pipeline Research Council International

Project Description: The project aims 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.

Anticipated Results: The project is expected to further enhance previously developed tools that have been adopted in an industry RP for pipeline mechanical damage integrity assessment and management. The results will also enhance the indentation crack formation strain estimates, produce a better understanding of the impact of ILI measurement accuracy on dent integrity assessment, and support defining the appropriate safety factor to be used in design and dent assessment.

Potential Impact on Safety:

Federal regulatory standards require the repair of dents that exceed certain prescriptive thresholds based on the dent depth and the presence of coincident secondary features, including corrosion and cracks. However, leaks have been known to occur at dents with depths less than the regulatory thresholds. This research will provide further guidance to pipeline operators on their assessments of mechanical damage; ultimately determining a particular pipeline segment's fitness for service. The project will advance pipeline safety by reducing the likelihood of a pipeline failure caused by a dent or other form of mechanical damage.

Project 2

Title: Systematize 20 Years of Mechanical Damage Research

Recipient: Pipeline Research Council International

Project Description: The research project's purpose is 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 RPs and standards. The summary will provide a consolidated review of research over the past 20 years, including requisite bibliographic references, and will characterize the achievements made, as well as opportunities for improvement.

Anticipated Results: The project has completed a vast literary search accurately identifying the 20 years' worth of mechanical damage, knowledge, and know-how applied within the pipeline industry. The final report outline, now established, will effectively promote how this knowledge can assist pipeline operators in managing mechanical damage integrity threats.

Potential Impact on Safety: The project's final report will provide a summary of mechanical damage related knowledge, technology, and standards utilized to prevent and mitigate such threats. It will also effectively allow pipeline operators to quickly find the best consensus information on how to address the numerous integrity threats involved within mechanical damage. The project output will allow operators to apply the latest know-how and support safer operations.

Project 3

Title: Program to Advance Computed Tomography for the Development of Reference Standards for Pipeline Anomaly Detection and Characterization

Recipient: Pipeline Research Council International

Project Description: The goal of this research project is 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.

Anticipated Results: This research project is expected to further advance a new CT system to support pipeline inspection and generate new knowledge and data that can be used to validate both ILI and in-the-ditch inspection technologies. A proof of concept for the application of CT was demonstrated through previously-conducted research by PRCI. This project will validate the full-scale CT system for the inspection of pipe with cracks and crack-like features.

Potential Impact on Safety: This research project will support recent advances in CT technology that represent an improved method of NDE that delivers greater accuracy than conventional NDE techniques on cracks and crack-like features. This research project is aimed at reducing the uncertainty in pipeline assessment methods by generating a set of "truth data" that can be used to validate both ILI and in-the-ditch

inspection technologies. The project will provide a basis for establishing industry calibration and reference standards against which both ILI and NDE technologies can be evaluated to improve the reliability and operator confidence in pipeline inspection technologies. The accurate sizing of cracks will assist pipeline engineers in evaluating pipeline service conditions and in making decisions on integrity management and maintenance plans to improve pipeline safety.

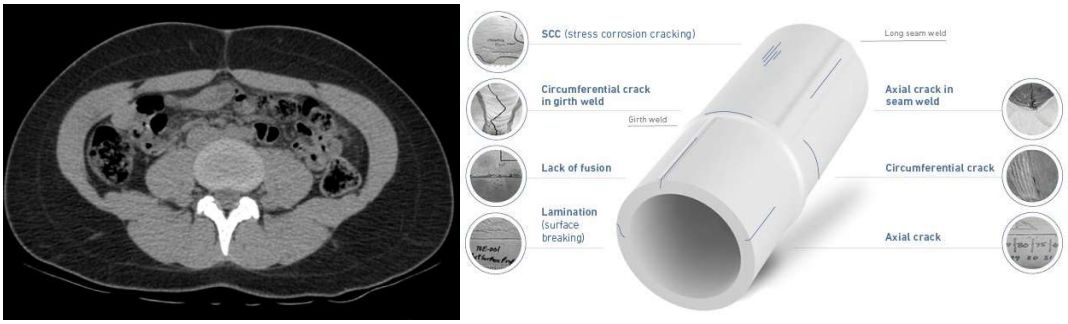

Figure 6 Testing medical grade Computed Tomography on pipeline defects to improve detection/characterization.
Courtesy radiopaedia.org and ROSEN.

Project 4

Title: Improve In-Line Inspection Sizing Accuracy

Recipient: Pipeline Research Council International

Project Description: The research project aims to investigate the probability of detection by the current state-of-the-art 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; to optimizing the number of excavations needed for safe operation of the pipelines; and, ultimately, to better utilizing resources to remedy threats with the highest risk to the safe operation of the pipeline systems.

Anticipated Results: The focus of the research project is to address improvements in ILI system's sizing accuracy for corrosion and cracks. A summary of the defect profiles that cause leaks and ruptures will be provided at the completion of a literature review and survey of existing pipe samples with defects. The project will also gather the "truth data" for evaluating ILI systems and interpreting ILI results, and identify areas for ILI system redesign and improvement. The improved ILI system will be re-tested and re-evaluated with statistically-based performance metrics. The achieved improvement of ILI systems will be documented at the completion of the project.

Potential Impact on Safety: This project will improve pipeline safety by improving the accuracy of detection and sizing capability of ILI systems, reducing the chance of a missed defect. Furthermore, the project will seek to limit any increase in false indications which could result in extraneous expenditures on unnecessary excavations. Ultimately, the proposed improved ILI system will provide pipeline operators with the

tools to locate critical safety threats on their system and remediate them, thereby avoiding an incident.

Project 5

Title: Validate In-Line Inspection Capabilities to Detect/Characterize Mechanical Damage

Recipient: Pipeline Research Council International

Project Description: The purpose of this research project is 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.

Anticipated Results: The project work is progressing to support results including standardized testing protocols, characterized test specimens, opportunities for ILI technology improvement, and an increased understanding of current technology performance. Significant ILI pull-testing is now commencing; the final validation goals of the project will be provided.

Potential Impact on Safety: The validation efforts within this project will support pipeline operator and regulator confidence in the ILI industry tools' ability to accurately detect and characterize mechanical damage features. It will also provide the ILI industry with a list of tool improvements and possible software improvements that will further future tool development. Overall outputs from this research will lessen the likelihood that mechanical damage features will be missed by commercial tools, therefore preventing related incidents.

Project 6

Title: Artificial Intelligence-Enabled Interactive Threats Detection Using a Multi-Camera Stereo Vision System

Recipient: Arizona State University

Project Description: The goal of this research project is 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 be further developed and validated through field demonstration.

Anticipated Results: The objective of this research project is to develop a vision-based inspection tool using stereo vision and AI-enabled computer vision algorithms for pipeline threat detection and characterization. This project is focusing on hardware prototyping and software development. The hardware prototyping is aimed at designing, calibrating, and demonstrating the inspection tool for pipeline ILI. The software designed will utilize algorithms that can be integrated with the developed hardware prototype to

automatically detect pipeline anomalies faster and more accurately. Potential technology transfer and commercialization of the developed system is planned for this project.

Potential Impact on Safety: This project demonstrates that pipeline anomalies, such as fatigue cracks, stress corrosion cracking, corrosion pits and seam weld defects, are major threats to the integrity of pipeline systems. If such pipeline defects are not detected and mitigated in a timely manner, these anomalies could grow to a critical condition resulting in pipeline failures, such as leak and ruptures. The expected AI-enabled, vision-based inspection tool that is developed in this project is aimed at providing pipeline operators a fast and automated anomaly detection tool, which allows accurate evaluation of the interactive threats. The developed tool will improve the detection accuracy on the defects that are difficult to accurately assess by traditional tools and evaluation methodologies, thereby reducing the likelihood of harm to the public or environment caused by a pipeline failure.

Project 7

Title: Improved Non-Destructive Testing Detection and Probabilistic Failure Prediction for Interacting Pipeline Anomalies

Recipient: Brown University

Project Description: The research project is designed 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 be developed and validated through field demonstration.

Anticipated Results: The objective of this research project is to develop a methodology utilizing ultrasonic techniques to measure interacting anomalies in pipelines, and develop a neural network model to predict failure load for the interacting anomalies. The anticipated results from this research project include an improved flaw characterization method utilizing non-destructive, ultrasonic test (UT) inspection methods. The results also include an analytical model to calculate probabilistic failure loads for interacting anomalies using the UT inspection results, as well as the results using the other NDT technologies, such as magnetic flux measurements.

Potential Impact on Safety: The current methods for predicting the failure load and remaining service life for pipelines are not able to accurately predict failures when there are interacting anomalies, such as crack-like flaws in dents and crack-like flaws with corrosion anomalies. It is critical for pipeline operators to understand the uncertainty in the NDT flaw detection methods and accurately quantify failure risk by utilizing the modernized analytical models that can improve the accuracy of the predicted remaining service life. This project is focusing on two critical interacting anomaly cases of crack-like flaws in dents, and crack-like flaws with corrosion wall loss. The developed flaw characterization method and the analytical model will significantly improve the accuracy of remaining service life predictions for pipeline integrity management.

Project 8

Title: Multi-Modal Non-Destructive Evaluation Assisted Probabilistic Pipeline Performance Evaluation Under Interactive Anomalies

Recipient: University of Akron

Project Description: The goal of this research project is 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 be further developed and validated through field demonstration.

Anticipated Results: The project is anticipated to result in a probabilistic pipeline performance evaluation framework based on multi-modal NDE of different interactive defects (anomalies) in pipelines. The project will use experimental testing and numerical analysis to generate more realistic defect shapes, which will be used to better characterize and validate the defects through NDE

Potential Impact on Safety: The project will help improve pipeline safety by providing a better understanding of how different defects interact with each other, how best to characterize and validate the defects in the field, and ultimately, how to better evaluate the impacts of multiple interactive defects on the integrity of the pipeline.

Project 9

Title: Distributed Fiber Optic Sensor Network for Real-Time Monitoring of Pipeline Interactive Anomalies

Recipient: Stevens Institute of Technology

Project Description: This research project will 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 be further developed and validated through field demonstration.

Anticipated Results: The expectation is that the research project will result in the 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, and their interactions in between these different anomalies. Another anticipated result will be the development and validation of a data processing program for real-time sensor data analysis to identify interactions between different anomalies for effective and efficient pipeline management. Training will be offered to graduate and undergraduate students through the research on pipeline anomaly detection to prepare them for future careers in the pipeline industry.

Potential Impact on Safety: This research project is expected to improve the safety and management of pipelines by providing pipeline operators with real-time information of the locations, types, and severity of the anomalies by transforming the current pipeline

anomaly detection technologies into a distributed fiber optic sensor network for real-time detection, localization, and quantification of interactive anomalies of pipelines.

Project 10

Title: Non-Destructive Coercimetry Fracture Toughness Assessment for Steel Pipelines

Recipient: Innerspec Technologies, Inc.

Project Description: The purpose of this research project is to establish a robust correlation model between coercivity and fracture toughness on real-life samples 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.

Anticipated Results: Non-destructive tests on actual pipe samples provided by the pipeline industry have been completed. Development continues on a field-deployable prototype and further validation tests are planned by summer 2021.

Potential Impact on Safety: This project validates that a commercial tool to quantify steel toughness will reduce pipeline operator errors in material paperwork and support improved risk assessment and integrity management safety programs.

The following information documents the projects funded during FY 2020 for this programmatic element.

Table 3.h - FY 2020 Funded Projects – Improving Anomaly Detection and Characterization

	Project Title	PHMSA Funding Total	Recipient	City	State
1.	Feasibility Study for a Robotic Platform and Suite of Sensors to Identify Degradation in Non-Conforming Driscopipe 8000	$801,000 (Core)	Northeast Gas Association	Parsippany	NJ
2.	Stress Corrosion Cracking Prioritization and Decision Making Using a Bayesian Network Approach	$884,349 (Core)	DNV GL USA, Inc.	Dublin	OH
3.	Artificial Intelligence-Enabled Inline-Inspection Robot with Integrated Structured Light Non-Destructive Evaluation for Distribution Pipelines	$250,000 (CAAP)	Michigan State University	East Lansing	MI
4.	Probabilistic Performance Modeling and Optimum Maintenance Planning of Plastic Pipeline with Piezoelectric Based Non-Destructive Evaluation Updating	$249,912 (CAAP)	Rutgers, The State University	New Brunswick	NJ
5.	In-Line Inspection for Both Circumferential Cracking and Axial	$149,566 (SBIR)	ULC Robotics	Hauppauge	NY

	Project Title	PHMSA Funding Total	Recipient	City	State
	Stress Using Electromagnetic Acoustic Technology Guided Wave				
6.	Meandering Winding Magnetometer Array Bending Stress and Crack Detection In-Line Inspection Module	$149,944 (SBIR)	JENTEK Sensors, Inc.	Marlborough	MA
7.	Magneto-Acoustic Bending Stress and Anomaly Detection In-Line Inspection tool	$149,898 (SBIR)	Creare, LLC	Hanover	NH
FY 2020 Total: $2,634,669					

Project 1

Title: Feasibility Study for a Robotic Platform and Suite of Sensors to Identify Degradation in Non-Conforming Driscopipe 8000

Recipient: Northeast Gas Association

Project Description: This research project aims to conduct a systematic study of the performance of delamination detection technologies for Driscopipe 8000 pipe and strategies for integrating these into a robotic inspection platform. In a future research phase, a robotic platform will be tested for deployment, operation, and retrieval under live conditions and travel in natural gas plastic pipes over long distances without an attached tether.

Anticipated Results: This research project is expected to develop appropriate specifications for an ILI system for non-conforming Driscopipe 8000 pipes. In addition, this research will result in identifying and evaluating robotic platforms able to carry sensing systems inside natural gas plastic pipes. Upon successful completion of this research, additional phases may be needed to implement a commercial product.

Potential Impact on Safety: This research project will allow the systematic inspection of potentially compromised pipes, and the detection of cracking and delamination before gas leaks and potential incidents may occur. In addition, the sensory technologies will be able to not only detect these kinds of pipeline defects, but will also be installed on a robotic platform within a very limited space within a gas distribution pipe.

Project 2

Title: Stress Corrosion Cracking Prioritization and Decision-Making Using a Bayesian Network Approach

Recipient: DNV GL USA, Inc.

Project Description: The research project's goal is to develop and validate a holistic, flexible ML model that captures stress corrosion cracking (SCC) defects and enables pipeline operators to prioritize inspections effectively.

Anticipated Results: This research project is expected to result in a unified SCC model to predict the location and severity using Bayesian modeling. This model will be validated using SCC data from operator and industry partners before being published as a newly created model in a free online tool to predict SCC probability and SCC severity.

Potential Impact on Safety: This project seeks to provide a methodology for operators to determine the location and severity of SCC on their pipeline systems. This methodology would provide operators with information on when to perform inspections and repairs for SCC which could reduce the number of SCC failures that occur in pipeline systems.

Project 3

Title: Artificial Intelligence-Enabled Inline-Inspection Robot with Integrated Structured Light Non-destructive Evaluation for Distribution Pipelines

Recipient: Michigan State University

Project Description: The goal of this research project is 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 be further developed and validated through field demonstration.

Anticipated Results: This research project is expected to result in developing and demonstrating a field test-ready, structured light tool integrated with a highly flexible snake robot for scanning medium density polyethylene (MDPE) pipes used in natural gas distribution systems.

Potential Impact on Safety: This research project will improve safety by providing operators with an AI-enabled smart scanning tool that can deliver precise 3D information about the condition of the pipe's internal surface, which increases the probability of damage detection and leads to better damage evaluation capabilities. The AI-enabled shared control method combines autonomous decision support and high-level human commands to improve safety and usability of robotic control.

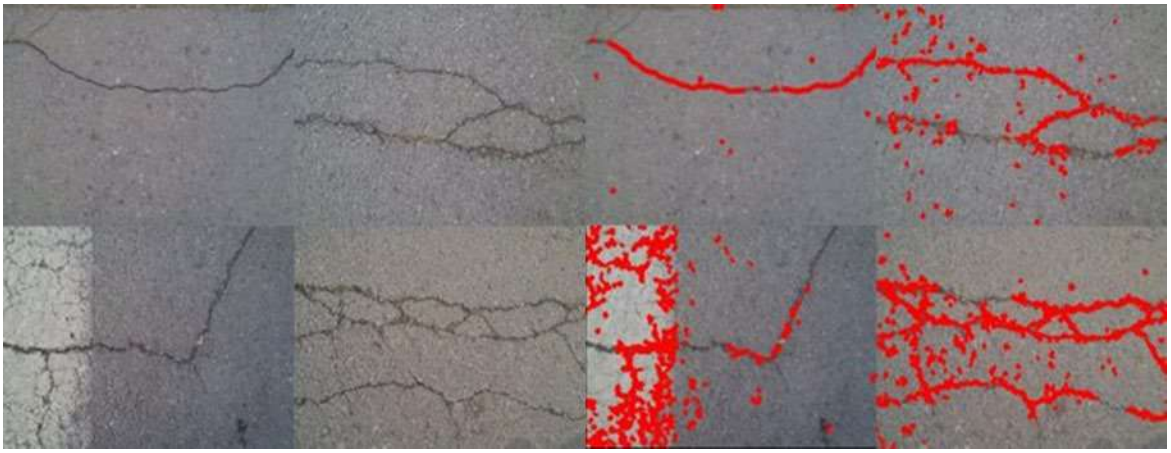

Figure 7 Testing with artificial intelligence analysis (shown in RED) of structured light sensors to improve defect detection.
Courtesy Michigan State University.

Project 4

Title: Probabilistic Performance Modeling and Optimum Maintenance Planning of Plastic Pipeline with Piezoelectric Based Non-Destructive Evaluation Updating

Recipient: Rutgers, The State University

Project Description: This research project aims to develop an NDE probabilistic modeling and decision-making framework for plastic pipeline crack detection. Probabilistic modeling entails 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.

Anticipated Results: This research project is expected to develop an NDE-updated probabilistic modeling and decision-making framework for plastic pipelines, which integrates a novel NDE method for crack detection, probabilistic deterioration modeling, and risk-based optimization of maintenance planning.

Potential Impact on Safety: This project seeks to improve the NDE of plastic pipes, which is currently much more limited than NDE for steel pipe. This lack of NDE techniques may allow defects to be undetected thereby leading to accidents/incidents. More effective NDE for plastic pipelines should lead to enhanced pipeline safety.

Project 5

Title: In-line Inspection for Both Circumferential Cracking and Axial Stress Using Electromagnetic Acoustic Technology Guided Wave

Recipient: ULC Robotics

Project Description: This research project is expected to produce a proof of concept 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.

Anticipated Results: In the first phase of this project, the researcher evaluated and tested an EMAT-guided wave technique for the detection of circumferential cracking and the measurement of axial stress within the pipe. This was completed within a laboratory setting.

Potential Impact on Safety: This research project proves that a commercial tool capable of measuring bending loads and detecting cracks for steel pipelines will support operator detection of integrity threats before failures, and support continued safe operations. A second phase of this work is required to further validate and commercialize the tool.

Project 6

Title: Meandering Winding Magnetometer Array Bending Stress and Crack Detection In-Line Inspection Module

Recipient: JENTEK Sensors Inc.

Project Description: The goal of this research project is 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.

Anticipated Results: In the first phase of this project, the researcher demonstrated sensor crack detection capability through hand-scans of pipe samples. The project also performed several load ramp tests and demonstrated a permeability-to-strain correlation for the steel bending test article with sensors placed on the inside and outside of the pipe.

Potential Impact on Safety: This research project shows that a commercial tool capable of measuring bending loads and detecting cracks for steel pipelines will support operator detection of integrity threats before failure and support continued safe operations. A second phase of this work is required to further validate and commercialize the tool.

Project 7

Title: Magneto-Acoustic Bending Stress and Anomaly Detection In-line Inspection Tool

Recipient: Creare, LLC

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

Anticipated Results: In the first phase of this project, the researcher identified sensor specifications through fabrication and laboratory-level feasibility demonstration of the proposed sensing approaches.

Potential Impact on Safety: This project determined that a commercial tool capable of measuring bending loads and detecting cracks for steel pipelines will support operator detection of integrity threats before failures and will support continued safe operations. A second phase of this work is required to further validate and commercialize the tool.

Tables 3.i and 3.j highlight technology that was commercialized and knowledge transferred, respectively, in the area of pipeline anomaly and characterization improvements in FY 2020.

Table 3.i - Highlights of FY 2020 Technology Transfer Activities

Programmatic Element	*Project Title*	*Technology Transfer Outcome*
Improving Anomaly Detection/ Characterization	In-Ditch Validation Methodology for Determination of Defect Sizing[7]	 *Picture Courtesy: Applus* 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 to display flaws as a 2-dimentional (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.

7 HTTPS://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=503

Table 3.j - Highlights of FY 2020 Knowledge Transfer Activities

Programmatic Element	Project Title	Knowledge Transfer Outcome
Improving Anomaly Detection/ Characterization	1. Mechanical Damage at Welds[8] 2. Structural Significance of Mechanical Damage[9] 3. Dent Fatigue Life Assessment - Development of Tools for Assessing the Severity and Life of Dent Features[10] 4. Consolidated Project Full Scale Testing of Interactive Features for Improved Models[11] 5. Improving Models to Consider Complex Loadings, Operational	 Portions of research knowledge resulting from these five projects were utilized by the API in the development of RP 1183 *Assessment and Management of Dents in Pipelines*, 1st Edition.

8 https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=146
9 https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=238
10 https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=358
11 https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=555

Programmatic Element	Project Title	Knowledge Transfer Outcome
	Considerations, and Interactive Threats[12]	

3.4 Improving Anomaly Repair and Pipe Remediation and Rehabilitation

Description: The funding total for this Program Element is $141,750.

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 repairs—to understand 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.

The following information documents the projects funded during FY 2020 for this programmatic element.

Table 3.k - FY 2020 Funded Projects
Improving Anomaly Repair & Pipe Remediation & Rehabilitation

	Project Title	PHMSA Funding Total	Recipient	City	State
1.	No-Dig Point Repair Technology for Steel Oil and Gas Pipelines	$141,750 (SBIR)	QuakeWrap, Inc.	Tucson	AZ
FY 2020 Total: $141,750					

Project 1

Title: No-Dig Point Repair Technology for Steel Oil & Gas Pipelines

Recipient: QuakeWrap, Inc.

Project Description: The aim of this research project is to conduct 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.

12 HTTPS://PRIMIS.PHMSA.DOT.GOV/MATRIX/PRJHOME.RDM?PRJ=557

Anticipated Results: In the first phase of this project, the researcher applied the composite repair system to a 24-inch diameter steel pipe sample having a deep corrosion defect (25 percent through-wall). The repaired defect with the composite material was pressurized up to 660 pound-force per square inch (psi) with no apparent failure observed.

Potential Impact on Safety: This project shows that a commercial tool capable of internal application of composite repairs will provide the pipeline industry with a validated and safe solution to rapidly repair and return pipelines to service. A second phase of this work is required to further validate and commercialize the tool.

3.5 Improving Safety Systems for Liquefied Natural Gas Facilities

Description: The funding total for this Program Element is $4,352,236.

Activities in this topic area will address various challenges related to LNG hazards, and 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.

The following information documents the projects funded during FY 2019 for this programmatic element.

Table 3.I - FY 2019 Funded Projects – Improving Liquefied Natural Gas Facilities

	Project Title	PHMSA Funding Total	Recipient	City	State
1.	Evaluation of the Efficacy and Treatment of Hazard Mitigation Measures for Liquefied Natural Gas Facilities	$319,707 (Core)	Gas Technology Institute	Des Plaines	IL
2.	Develop a Risk-Based Approach and Criteria for Hazard Detection Layout	$310,544 (Core)	Blue Engineering and Consulting Company	Ellicott City	MD
3.	Develop an Evaluation Protocol for Non-Liquefied Natural Gas Release Hazards - Modeling	$472,844 (Core)	Blue Engineering and Consulting Company	Ellicott City	MD
	FY 2019 Total: $1,103,095				

Project 1

Title: Evaluation of the Efficacy and Treatment of Hazard Mitigation Measures for Liquefied Natural Gas Facilities

Recipient: Gas Technology Institute

Project Description: This research project is designed to develop a standardized, consistent, robust, and detailed methodology that uses the thermal radiation and vapor dispersion computational models currently approved by PHMSA. The project will also 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 Code of Federal Regulations (CFR) Part 193.

Anticipated Results. The goal of the methodology used in this project is to evaluate the effectiveness of hazard mitigation measures commonly employed at LNG facilities, but not recognized under 49 CFR Part 193. The hazard mitigation measures discussed in this research project are: water curtains, high expansion foam, insulating polymer concrete, insulating floating foam blocks, minimizing hazardous release duration, and vapor barriers. The project also utilized unapproved computational fluid dynamic models for comparative purpose, or for circumstances when the approved models do not have the ability to model the presence of a certain mitigation measure.

Impact on Safety: The research project proposes a standardized and acceptable methodology for PHMSA, as well as LNG operators, to evaluate mitigation measures used in siting applications. It also supports PHMSA's strategy to update regulatory requirements for application of common hazard mitigation measures. Other end-users of the project include: the Federal Energy Regulatory Commission (FERC), if the agency allows the use of various hazard mitigation measures for siting applications; the National Fire Protection Association (NFPA) 59A Technical Committee for the revision of NFPA 59A; and State agencies or authorities having jurisdiction over LNG facilities not regulated by FERC or PHMSA. In addition, the research also recommends potential computational models to be considered for PHMSA's approval as additional tools to accurately evaluate vapor dispersion and thermal radiations.

Figure 8 Evaluating various LNG safety measures such as water curtains to determine efficacy. Courtesy VFP Fire Systems.

Project 2

Title: Develop a Risk-Based Approach and Criteria for Hazard Detection Layout

Recipient: Blue Engineering and Consulting Company

Project Description: Developing a risk-based approach and criteria for hazard detection layouts at LNG facilities is this research project's goal. 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.

Anticipated Results: The research project's objectives include: establishing a methodology to optimize hazard detection layouts; identifying the types of detector best suited to serve different common areas at an LNG facility; recommending voting logic of detection systems; and providing guidance on the type of hazard modeling software required (2D using Phast versus 3D using FLACS) at LNG facilities.

Potential Impact on Safety: This research project demonstrates that the NFPA standard 59A requires LNG facilities to be outfitted with equipment to detect and control fires, leaks, and spills of hazardous materials. However, it does not provide any guidance or requirements for the locations of hazard detection devices. In addition, for PHMSA siting studies, applicants may use a 10-minute spill duration if the engineering design includes acceptable detection, isolation, and shutdown. However, the LNG industry is lacking the guidance on how to achieve "acceptable detection" or a consistent approach to developing hazard detection layouts. There is no systematic method for regulators to evaluate these designs. This research project will provide LNG operators with a clear methodology to develop hazard detection layouts, a way to quantify hazard detector performance and optimize design, and a clear objective to satisfy regulatory requirements. It will also provide a systematic approach for PHMSA, FERC, and authorities having jurisdiction over LNG facilities, to evaluate the design and safety of the hazard detection layouts at LNG facilities.

Project 3

Title: Develop an Evaluation Protocol for Non-Liquefied Natural Gas Release Hazards-Modeling

Recipient: Blue Engineering and Consulting Company

Project Description: This research project is designed 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 must meet to be approved for use under 49 CFR Part 193, including validation against a set of relevant and well-defined empirical data.

Anticipated Results: This research project is expected to produce five model evaluation protocols (MEPs), which will be used for evaluating hazard modeling software that calculates the following hazards: source term, flammable vapor dispersion, toxic vapor dispersion, vapor cloud explosion, and boiling liquid expansion vapor explosion. Each MEP consists of an evaluation protocol, validation database report, and database spreadsheet. The evaluation protocol provides a general methodology for the evaluation

of models. The validation database report will describe the test series, and the database spreadsheet will include the data sets.

Potential Impact on Safety: This research project validates that 49 CFR § 193.2057 and § 193.2059 prescribe regulations for flammable vapor and thermal radiation exclusion zones. These regulations require that alternate models, besides those prescribed in Part 193, used to calculate the exclusion zones must be subject to the Administrator's approval. Potential incidents at LNG export plants would result in hazards to the surrounding public from flammable vapor dispersion, and boiling liquid expansion vapor explosion. The MEPs will provide a consistent and systematic methodology for evaluating new hazard modeling software that calculate these hazards.

The following information documents the projects funded during FY 2020 for this programmatic element.

Table 3.m - FY 2020 Funded Projects – Improving Liquefied Natural Gas Facilities

	Project Title	PHMSA Funding Total	Recipient	City	State
1.	Vapor Cloud Explosion at Nil Wind	$134,704 (Core)	Blue Engineering and Consulting Company	Ellicott City	MD
2.	Development of Guidance on Potential Cascading Effects from Flammable Vapor Cloud Explosions	$1,231,520 (Core)	DNV GL USA, Inc.	Katy	TX
3.	PHMSA Support for Safety, Regulation, Production, Distribution, and use of Liquefied Natural Gas	$1,882,917 (IAA)	Sandia National Laboratory	Albuquerque	NM
	FY 2020 Total: $3,249,141				

Project 1

Title: Vapor Cloud Explosion at Nil Wind

Recipient: Blue Engineering and Consulting Company

Project Description: This research project's aim is 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 to 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.

Anticipated Results: This research project is expected to result in a recommendation on whether nil wind conditions should be included in the siting requirements for LNG facilities. The project will define "nil wind" and determine historical frequency of occurrence. Computational fluid dynamics modeling will quantify the potential increase in severity of flammable vapor dispersion and overpressure consequences from accidental releases under nil wind conditions as compared with the current regulatory requirements.

Potential Impact on Safety: This project illustrates that if it is determined that there is a significant increase in hazards that accompany nil wind conditions, combined with a reasonable frequency in which the conditions occur, PHMSA may need to consider updating 49 CFR § 193.2059 to include nil wind in the consequence modeling of facilities. The additional nil wind models may indicate that more precautions are warranted to ensure the safety of the surrounding public.

Project 2

Title: Development of Guidance on Potential Cascading Effects from Flammable Vapor Cloud Explosions

Recipient: DNV GL USA, Inc.

Project Description: This project will 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.

Anticipated Results: This research project is expected to provide guidance on the potential cascading effects from flammable vapor cloud explosions and projectiles regarding structural damage at LNG facilities through identifying the range of LNG facility types and configurations. Emphasis will be placed on defining the explosion sources; flammable inventories and the characteristics of targets; assessing the blast capacities of the targets; defining the vapor cloud explosion (VCE) potential of the explosion sources and how this interacts with the targets; and developing guidance on the cascade potential that is sensitive to the characteristics of the type of LNG facility.

Potential Impact on Safety: The research project proposes standardized and acceptable guidance for PHMSA, as well as LNG operators, to assess the cascading effects from flammable VCEs. NFPA 59A (2001) Section 5.3.2.14 requires analysis of impacts from VCEs and fires that may cause major structural damage to a LNG storage container, LNG marine carrier, refrigerant storage vessel, buildings, or equipment required for the safe shutdown and control of the hazard. However, NFPA 59A (2001) does not provide guidance on how to assess the effects of VCEs regarding structural damage, as well as projectile impacts from an explosion. The project's results will not only provide guidance to LNG operators to comply with siting requirements, but also will assist PHMSA, FERC, and authorities having jurisdiction over LNG facilities to evaluate design and safety regarding LNG facility siting.

Figure 9 Modeling cascading effects from vapor cloud explosions to improve safety guidance. Courtesy DNV GL.

Project 3

Title: PHMSA Support for Safety, Regulation, Production, Distribution, and use of Liquefied Natural Gas

Recipient: Sandia National Laboratory

Project Description: The purpose of this research project is to engage in analytical studies, computational modeling, quantitative risk assessments, advanced technology assessments, systems engineering research, and development and demonstrations. This research will support PHMSA's objective to enhance the safety, regulation, production, distribution, and use of LNG.

Anticipated Results: This project is expected to produce an open-source code that calculates the unignited jet plume extent and concentration, as well as ignited jet flame heat flux and temperature from natural gas and LNG releases. Sandia also is assisting with reviews of hazard modeling software (including Phast v8.4, FLACS v10.9, exploCFD, and KFX) and will produce a MEP for fire models. The MEP will be used to evaluate the suitability of the software models proposed to calculate the radiant heat effects from both LNG fires and non-LNG fires.

Potential Impact on Safety: This project will develop an open-source code that provides another option for regulators and LNG stakeholders to quickly estimate the hazards of flammable vapor dispersion and radiant heat from hazardous releases. The evaluation of new software models allows the most up-to-date hazard modeling software to be used for calculating the exclusion zones in accordance with 49 CFR § 193.2057 and § 193.2059. The MEP for fire models will enhance the safety of LNG production, distribution, and use, and will increase the public's confidence in the regulatory review process of LNG facilities.

3.6 Improving Design, Materials, and Welding/Joining

Description: The funding total for this Program Element is $1,400,000.

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 pipelines will require automation and inspection capabilities to 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.

The following information documents the projects funded during FY 2020 for this programmatic element.

Table 3.n - FY 2020 Funded Projects –Improving Design, Materials, and Welding/Joining

	Project Title	PHMSA Funding Total	Recipient	City	State
1.	Hydrostatic Retesting Optimization for Older Liquid Pipelines	$650,000 (Core)	Engineering Mechanics Corporation of Columbus	Columbus	OH
2.	Modeling Slow Crack Growth Under Thermal and Chemical Effects and Accurate Nondestructive Testing of Cracks for Fitness Predictions of Polyethylene Pipes	$250,000 (CAAP)	Brown University	Providence	RI
3.	Holistic Electromagnetic and Ultrasonic Nondestructive Evaluation Techniques for Plastic Pipeline Aging and Degradation Characterization	$250,000 (CAAP)	Michigan State University	East Lansing	MI
4.	Nondestructive Diagnosis and Probabilistic Prognosis of Aging Plastic Pipe	$250,000 (CAAP)	Board of Regents of the University of Nebraska for the University of Nebraska-Lincoln	Lincoln	NE
	FY 2020 Total: $1,400,000				

Project 1

Title: Hydrostatic Retesting Optimization for Older Liquid Pipelines

Recipient: Engineering Mechanics Corporation of Columbus

Project Description: The aim of this research project is to investigate the relationship between post hydrotest pressure cycles and crack growth rate to understand whether any surviving surface cracks will rupture.

Anticipated Results: This research project's objective is to investigate and identify hydrostatic pressure test levels that may cause unnecessary leaks and blowouts (ruptures) during the hydrostatic pressure testing of older hazardous liquid (liquid) pipelines. The research findings will be used to develop an optimal test pressure range. For an older liquid pipeline where hydrotest pressures are too high, the hydrostatic pressure test could induce leaks or limited ruptures. Liquid pipelines have significant pressure cycles (higher to lower operating pressure) during their operating life. The pipe fatigue caused by pressure cycling during operations can have an effect on the pipe, limiting the use of higher hydrostatic test pressures.

Potential Impact on Safety: This research effort should improve liquid pipeline safety through the elimination of injurious pipe flaws that may be left in a pipeline after a hydrostatic pressure test and that may later be missed by ILI assessments according to 49 CFR § 195.2. Another potential safety impact would be to provide an accurate operating life (rupture free) for older liquid pipelines based upon the successful hydrostatic test pressure and the pressure cycling level.

Project 2

Title: Modeling Slow Crack Growth Under Thermal and Chemical Effects and Accurate Nondestructive Testing of Cracks for Fitness Predictions of Polyethylene Pipes

Recipient: Brown University

Project Description: The goal of this research project is to develop a slow crack growth model for polyethylene pipes (PE) 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.

Anticipated Results: This research project is expected to result in a slow crack growth model for PE pipe failure under chemical and thermal environments and a method for accurate crack size measurements for reliable fitness for service assessments.

Potential Impact on Safety: This project seeks to provide a methodology for operators of plastic pipe to perform fitness for service assessments on PE pipes. Similar models exist for steel pipe which allow operators to know when repairs or replacements need to

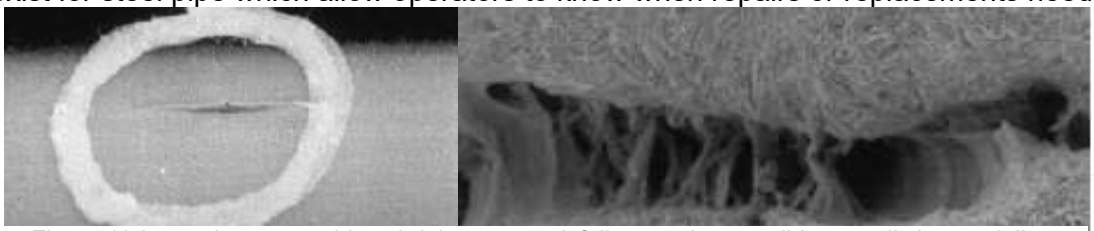

Figure 10 Internal pressure driven brittle type crack failure testing to validate prediction modeling. Courtesy Brown University.

be conducted on the pipeline. This project will enhance pipeline safety by providing pipeline operators with a methodology to know when in-service PE pipe should be repaired before a potential accident occurs.

Project 3

Title: Holistic Electromagnetic and Ultrasonic Nondestructive Evaluation Techniques for Plastic Pipeline Aging and Degradation Characterization

Recipient: Michigan State University

Project Description: This research project's aim is 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 be further developed and validated through field demonstration.

Anticipated Results: This research project is expected to develop a low-cost, non-contact and rapid scanning system based on near-field microwave and nonlinear ultrasonics to understand the plasticizer loss problem. The proposed research would offer fast NDE techniques for imaging of pipes made of polymetric materials. The proposed method presented in this research will involve the development of flexible microwave probe that can conform to any curvature and gauge the extent of plasticizer loss.

Potential Impact on Safety: This research project is expected to confirm that the detection of plasticizer loss in pipes is crucial for assessing the condition of the pipe and make the necessary predictions for its further service. In addition, the capabilities of the early detection will direct the operator to further diagnose the degradation.

Project 4

Title: Nondestructive Diagnosis and Probabilistic Prognosis of Aging Plastic Pipe

Recipient: Board of Regents of the University of Nebraska for the University of Nebraska-Lincoln

Project Description: The purpose of this research project is to develop a 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 be further developed and validated through field demonstration.

Anticipated Results: This research project will provide a probabilistic model that will be developed for prognosis of remaining service life of plastic pipe based on the NDE measurements. The model will be based on the collected data from testing results and from an assessment of the technology for implementation.

Potential Impact on Safety: The Plastic Pipe Database Committee has recognized a number of failures involving the pipe types to be tested in this project. An effective

modeling of pipe degradation will support end-of-life assessment, allowing pipeline operators to repair or replace pipe before failure. This approach will improve safety of such systems and lessen the methane released into the environment.

3.7 Identifying Pipe Fatigue Damage During Rail Transportation

Description: The funding total for this Program Element is $789,325.

The following information documents the projects funded during FY 2020 for this programmatic element.

Table 3.o - FY 2020 Funded Projects
Identifying Pipe Fatigue Damage During Rail Transportation

	Project Title	PHMSA Funding Total	Recipient	City	State
1.	Identifying Pipe Fatigue Damage during Rail Transportation	$789,325 (IAA)	Transportation Technology Center, Inc.	Pueblo	CO
FY 2020 Total: $789,325					

Project 1

Title: Identifying Pipe Fatigue Damage During Rail Transportation

Recipient: Transportation Technology Center, Inc.

Project Description: The goal of the project is to test fatigue on pipe transported by rail. The project will use the TTC's Vibration Test Unit (VTU) and other research methods to identify pipe fatigue damage occurring during transportation on railroad flatcars. These tests will help determine what improvements to applicable load bracing and blocking standards can be made to help reduce this risk to pipeline integrity caused by damage in transportation.

Fatigue damage will be estimated through computer simulation, as well as experimental testing utilizing TTC's facilities and railroad tracks on site.

Anticipated Results: The project kicked off with the development of an Industry Focus Group (IFG). The first phase of the project will culminate with the delivery of a comprehensive test plan based upon gaps identified by the IFG. The eventual full-scale testing of pipelines transported by rail will be funded in a subsequent award.

Potential Impact on Safety: This project can provide a valuable insight to the pipeline industry on potential integrity threats generated by rail transportation of pipeline segments. The knowledge gained can lead to better practices for pipeline transportation by rail, reduce potential fatigue damage to pipelines, and prevent possible related incidents.

3.8 Analyzing Loads on Pipelines Installed Under Railroad Tracks

Description: The funding total for this Program Element is $119,056.

Table 3.p - Analyzing Loads on Pipelines Installed Under Railroad Tracks

	Project Title	PHMSA Funding Total	Recipient	City	State
1.	Analyzing Loads on Pipelines Installed Under Railroad Tracks	$119,056 (IAA)	Transportation Technology Center, Inc.	Pueblo	CO
	FY 2020 Total: $119,056				

Project 1

Title: Analyzing Loads on Pipelines Installed Under Railroad Tracks

Recipient: Transportation Technology Center, Inc.

Project Description: The purpose of this research project is 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.

Anticipated Results: The project's initial phase includes the formation of an IFG, a literature review of prior research work, and a research plan for the eventual full-scale testing of pipelines subjected to stresses under rail. The eventual full-scale testing of pipelines under rail is included in a subsequent not yet funded phase of the project.

Potential Impact on Safety: The project's primary goal is to mitigate the risk of a pipeline failure due to railroad loading. An incident resulting from railroad loading could have significant multimodal safety impacts, and may lead to loss of life and damage to the environment.

3.9 Developing a Pipeline Research, Development, and Testing Program

Description: The funding total for this Program Element is $10,000,000.

Table 3.q - Developing a Pipeline Research, Development, and Testing Program

	Project Title	PHMSA Funding Total	Recipient	City	State
1.	Developing a Pipeline Research, Development, and Testing Program	$10,000,000 (OTA)	Universal Pegasus International	Houston	TX
FY 2020 Total: $10,000,000					

Project 1

Title: Developing a Pipeline Research, Development, and Testing Program

Recipient: Universal Pegasus International

Project Description: The goal of this project is to design and develop a world class program for pipeline safety research at the FRA's TTC. In line with DOT's goal of safety, PHMSA is exploring a new approach to develop comprehensive solutions to augment current pipeline research programs by hosting pipeline research projects at the TTC facility to more efficiently facilitate and encourage innovation and enhance pipeline safety. PHMSA's goal is to create a path for pipeline safety innovation to move more quickly from concept to testing to application, stimulate research, and promote the use of new technologies with the intent to increase knowledge and improve pipeline safety, reduce methane emissions from pipelines, and protect the environment.

Anticipated Results: This project has two main phases: the first is a conceptual/detailed design, and the second is the development/commissioning of the Research, Development, and Testing Program.

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 address in the report the costs and benefits of colocating an independent pipeline safety testing facility at an existing training center of the Administration versus at the FRA TTC facility. The study will also further examine the potential use of Federally Funded Research and Development Centers (FFRDCs) to carry out pipeline safety R&D projects.

The RDT Program at TTC is currently on hold pending results from the study.

4. Program Website and Contacts

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

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