



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

Administrator

1200 New Jersey Ave., S.E.  
Washington, DC 20590

May 21, 2020

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

Dear Mr. Chairman:

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

The current Pipeline Safety R&D Five Year Plan covers Fiscal Years 2016-2020 and is publicly available on the Pipeline Safety R&D Program website:

[https://primis.phmsa.dot.gov/rd/docspr/PHMSA\\_Pipeline\\_RD\\_5-Year\\_Plan.pdf](https://primis.phmsa.dot.gov/rd/docspr/PHMSA_Pipeline_RD_5-Year_Plan.pdf)

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

Sincerely,

Howard R. Elliott

Enclosure



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

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1200 New Jersey Ave., S.E.  
Washington, DC 20590

May 21, 2020

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

Dear Senator Cantwell:

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

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

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May 21, 2020

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

Dear Mr. Chairman:

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

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1200 New Jersey Ave., S.E.  
Washington, DC 20590

May 21, 2020

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

Dear Congressman Graves:

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

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1200 New Jersey Ave., S.E.  
Washington, DC 20590

May 21, 2020

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

Dear Mr. Chairman:

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1200 New Jersey Ave., S.E.  
Washington, DC 20590

May 21, 2020

The Honorable Greg Walden  
Ranking Member, Committee on Energy and Commerce  
U.S. House of Representatives  
Washington, DC 20515

Dear Congressman Walden:

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

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

Sincerely,

Howard R. Elliott

Enclosure

# **Pipeline Safety Research and Development Five-Year Program Plan**

## **Update Report**

**Fiscal Years  
2017 & 2018**

**Department of Transportation**

**Pipeline and Hazardous Materials Safety Administration**

**May 2020**

## Outline

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**Department of Transportation**  
**Pipeline and Hazardous Materials Safety Administration**  
**Pipeline Safety Research & Development Five-Year Program Plan**  
**Update Report**  
**Fiscal Years 2017 & 2018**

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

The current Pipeline Safety R&D Five Year Plan covers Fiscal Years 2016-2020 and is publicly available on the Pipeline Safety R&D Program Webpage.<sup>1</sup>

### **Executive Summary**

Due to the importance of energy and hazardous materials to our economy and standard of living, research projects promoting safety, reliability, and performance of our transportation system are essential. Therefore, PHMSA funds research that improves safety, ensures reliability of supply, boosts business and government productivity, and enhances the security of our infrastructure, our people, and our environment. In 2016, PHMSA developed a Plan to fund innovative research. The Plan also provides ways to promote transparency and stakeholder input to effectively and efficiently manage R&D project activities.

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

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

PHMSA consulted with stakeholders to identify research gaps, design research projects, and conduct an independent peer-review of research results of the aforementioned six programs elements. This collaborative partnership has resulted in the development and transfer of more than 30 new technologies since 2002.

This report includes a summary of updated research needs and priorities identified through the Section 12, Paragraph (2) consultation requirements of the Pipeline Safety Improvement Act of 2002. This report also

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<sup>1</sup> [https://primis.phmsa.dot.gov/rd/docspr/PHMSA\\_Pipeline\\_RD\\_5-Year\\_Plan.pdf](https://primis.phmsa.dot.gov/rd/docspr/PHMSA_Pipeline_RD_5-Year_Plan.pdf)

provides a general overview of the PHMSA R&D program, highlights past success, and recounts Plan activities through Fiscal Years 2017 and 2018. During this reporting period PHMSA-sponsored research developed seven new technologies and conducted demonstrations of four. Six patent applications were filed of which one was granted and one technology was commercialized.<sup>2</sup> Appendix A summarizes PHMSA's R&D program performance metrics, an itemized list of each R&D project pursued with Federal and non-Federal entities, and a review of how each project potentially improves safety. Program and project-related information is updated in real-time via our program website.<sup>3</sup>

## PHMSA R&D Program Overview and History

PHMSA partners with private industry, academia, and small businesses in its research projects. These public-private partnerships result in improved pipeline safety and respond to congressional requirements to promote pipeline safety through the use of technology. Moreover, the partnerships in research optimize investment in innovation, thereby maximizing human and financial resources. For example, university partnerships can create future opportunities for students to pursue careers in the pipeline industry. PHMSA also utilizes pipeline operator expertise and works with operators to make available pipeline samples to support research.

These partnerships have resulted in the development and transfer of more than 30 new technologies since 2002. As an example, the R&D program's success is illustrated in the further development of Guided Wave Ultrasonic Testing (GWUT) technology, which has recently been integrated into the pipeline safety regulations. GWUT is used in assessing and identifying defects in pipelines. PHMSA funded three research projects<sup>4</sup> that improved GWUT technology, thereby leading to consistent inspection standards and procedures. The GWUT improvements in hardware and software achieved through research demonstrations enabled the wider use of GWUT under PHMSA's Gas Transmission Integrity Management (IM) regulations.<sup>5</sup> This regulation allows a pipeline operator to use an alternative technology pipeline assessment method if the operator can demonstrate that the method provides an equivalent understanding of the pipe's condition. Such requests for using alternative technology were reviewed on a case-by-case basis by PHMSA. Years of industry GWUT usage through this regulatory process has led PHMSA to gain sufficient confidence in the technology to allow usage directly by operators without PHMSA review. This change was codified in PHMSA's *Safety of Gas Transmission Pipelines* rule issued on October 1, 2019



Figure 1: Guided Wave Ultrasonic Testing In-Situ Inspection  
(Courtesy of Gas Technology Institute)

<sup>2</sup> See Table 3

<sup>3</sup> <https://www.phmsa.dot.gov/research-and-development/pipeline/about-pipeline-research-development>

<sup>4</sup> <https://primis.phmsa.dot.gov/rd/success.htm>

<sup>5</sup> 49 C.F.R. §192.937(c)(4)

(Docket No. PHMSA-2011-0023) (84 FR 52180). The regulations no longer require PHMSA's prior approval for this assessment method, saving PHMSA and operators time and resources. The GWUT technology R&D efforts and the collaborative approach with industry to standardize the procedures to use GWUT as a pipeline integrity assessment method serves as one of the many examples of PHMSA's success stories to improve the safety and reliability of the Nation's pipeline systems.

### **Formulating the Research Strategy for Fiscal Years 2017 & 2018**

HMSA's R&D program consults with pipeline safety stakeholders to identify research needs and priorities by sponsoring biennial R&D forums. These forums with academia, departmental, and federal partners help identify pertinent technology and knowledge gaps. Using the inputs from these forums, PHMSA forms a national research agenda designed to improve pipeline safety and performance. To maximize stakeholder input, PHMSA announces the forum in the Federal Register and on social media in advance of the meeting. Forums are structured so that attendees gain a national perspective on key challenges from Federal and State regulators, as well as the different sectors of the pipeline industry. Forums also include discussions about current industry research projects and the challenges with transferring solutions into the marketplace.

PHMSA partners with a wide range of external stakeholders who share the same objectives in developing technology or generating and promoting new knowledge among decision makers. The forums promote collaboration within the pipeline research community in leveraging resources and broadening synergies. The collaborative nature of the forums further reduce duplication of federally- and industry-funded research programs by creating a venue for pipeline safety researchers to communicate on current research projects. The national research agenda and resulting programs make use of the best available knowledge and expertise in the pipeline industry and reflects stakeholder priorities.

PHMSA organized an R&D forum in Cleveland, Ohio, on November 16-17, 2016, with 330 stakeholders in attendance. The forum held working group sessions in the following five subject-focused areas:

1. Threat/Damage Prevention
2. Leak Detection/Mitigation
3. Anomaly Detection/Characterization
4. Natural Gas Underground Storage
5. Liquefied Natural Gas (LNG)

These five working groups identified technical gaps and challenges for future research while considering existing research efforts, such that identified research topics would address the gaps effectively. Each group identified both short- and long-term research objectives for hazardous liquid/natural gas transmission and distribution pipelines, as well as for underground gas storage and LNG. Appendix B provides more information on the subject areas.

The forum successfully identified key pipeline technical challenges facing industry and government, disseminated information on current research efforts, identified new research topics to help meet known pipeline safety challenges, and reached agreement on several additional topics that could be used by other stakeholder groups, such as academia and small businesses. The forum summary report and all presentation material is available for download from the event website.<sup>6</sup> The 2016 R&D forum set PHMSA's funding strategy for research projects for Fiscal Years 2017 and 2018 by identifying and prioritizing the research topics PHMSA should solicit. The recommendations collected at this event guided the program until the next biennial R&D forum was held in 2018.

PHMSA conducted a review of the 2016 R&D Forum outputs to determine how best to secure new research projects for the identified topics. PHMSA matched the generated topics with one or more of the following research programs:

- PHMSA's Competitive Academic Agreement Program (CAAP) – focuses on academia to research high risk and high pay-off solutions for pipeline safety challenges.
- PHMSA's Core Program of Research – focuses on the development, demonstration, and deployment activities to support technology transfer.
- DOT's Small Business Innovative Research (SBIR) Program – focuses on small businesses to explore their technological potential and provide the incentive to profit from its commercialization.

Both the CAAP and SBIR research programs are designed to provide innovation, from either academia or from small business sectors of the economy, for further investigation in the PHMSA Core Program of Research leading to demonstration and deployment.

For PHMSA's Core Program of Research, the 2016 R&D Forum identified several topics for research that were competitively solicited and publicly announced via the Pipeline Safety Research Announcement DTPH5617RA00002 in the Federal Business Opportunities website.

For PHMSA's CAAP, the 2016 R&D Forum identified topics that were most suitable for academic research due to their highly technical nature. These topics, listed below, were competitively solicited and publicly announced on March 5, 2018, via the Pipeline Safety Research Notice of Funding Opportunity # 693JK31852A01.<sup>7</sup>

- Detecting, Mitigating, and/or Locating Internal Pipeline Corrosion
  - Corrosion was responsible for 18 percent of pipeline accidents/incidents between 1998 and 2017, making corrosion mitigation a critical research topic for PHMSA.<sup>8</sup>
- Engineering Improvements to Pipeline Computational Models to Reduce Variance
  - Models have different computational methods and assumptions or factors of safety, which potentially may result in over-conservatism for pipeline integrity management decision makers. This topic was identified to leverage the latest data management systems available to pipeline

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<sup>6</sup> [https://primis.phmsa.dot.gov/rd/mtg\\_111616.htm](https://primis.phmsa.dot.gov/rd/mtg_111616.htm)

<sup>7</sup> <https://www.grants.gov/web/grants/search-grants.html?keywords=693JK31852A01>

<sup>8</sup> <https://primis.phmsa.dot.gov/comm/FactSheets/FSCorrosion.htm?nocache=9090>

integrity management decision makers and utilize computational based decision making to improve pipeline assessment methods and models to reduce conservatism.

#### Developing Advanced Knowledge Base Models from Root Cause Failure Analysis of Past Pipeline Incidents

- This research topic will develop a model and risk profile for pipeline failure probability based upon reported pipeline incident data.

For DOT's SBIR Program, the 2016 R&D Forum identified suitable topics in the following areas due to the need for near-term solutions that could be commercialized. The topics were competitively solicited and publicly announced on January 18, 2018, via the DOT Volpe Center SBIR Program Solicitation.<sup>9</sup>

- Innovative Technologies for Non-Destructive Determination of Fracture Toughness for Pipeline Steels in Transportation Infrastructure
  - This topic supported the Integrity Verification Plan portion of PHMSA's *Safety of Gas Transmission Pipelines: MAOP Reconfirmation, Expansion of Assessment Requirements, and Other Related Amendments* final rule issued on October 1, 2019 (Docket No. PHMSA-2011-0023).
- Dual Purpose Internal Integrity Assessment and Cleaning Tool for Hazardous Liquid Pipelines
  - Integrity assessment for pipelines emphasizes the use of inline inspection tools that must have a cleaning device first passed through the pipeline before the inspection instrument may be utilized. This was to decrease pipeline operational downtime due to inspection time and reduce the economic burden on energy end-users.

#### Pipeline Safety R&D Performance Metrics

PHMSA's R&D program has two main objectives: (1) fostering the development of new technologies, and (2) generating and promoting knowledge for decision makers. The performance metrics are designed to measure the actions that support program success within these two objectives.

PHMSA uses the following metrics to measure **fostering the development of new technologies**:

- The number of projects developing new technology,
- The number of projects demonstrating new technology,
- United States and other patent activities,
- The number of commercialized technologies for pipeline safety improvements, and
- The net safety improvement due to successfully commercialized technology.

PHMSA uses the following metrics to measure **generating and promoting knowledge for decision makers**:

- The number of projects promoting knowledge to decision makers,
- The number of publicly available final reports,

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<sup>9</sup> <https://www.sbir.gov/node/1413255>

- The number of conference/journal papers presented,
- The number of public events held,
- The number of stakeholders reached via public events,
- The number of website visits, and
- The number of files downloaded from the program website.

## Report on Fiscal Year 2017

In Fiscal Year 2017:

- PHMSA participated in the “Department of Energy (DOE) Workshop-Research Strategies to Address Oil & Gas Sector Methane Emission” held on October 13-14, 2016, in Alexandria, Virginia.
- PHMSA participated in an Interagency Research Meeting held on May 5, 2017, to share program updates, coordinate participation on agency research solicitation merit review panels, discuss the PHMSA Five-Year R&D Plan for Fiscal Years 2016-2020, and coordinate participation on agency public events. Research program representatives from DOE, the National Institute of Standards and Technology (NIST), and the Bureau of Safety and Environmental Enforcement (BSEE) also attended this meeting.
- PHMSA participated on a merit review panel for the California Energy Commission (CEC) Grant Funding Opportunity (GFO-16-508). This GFO sought applications for research to address Natural Gas Storage Infrastructure Safety and Integrity Risk Modeling where PHMSA participation assisted in selecting the best researchers to address CEC topics and ensure national research can be coordinated, leveraged, and not duplicated.
- As part of the coordination leading up to the 2016 R&D Forum, PHMSA invited participation from the several federal and state agencies as identified in Table 4 of the Plan.

**Table 1: Report of Fiscal Year 2017 Program Performance Metrics**

Performance Metric	Amount
<i>Fostering the Development of New Technologies</i>	
Projects developing new technology	*0
Projects demonstrating new technology	3
United States and other patent activity (applied/granted)	(4/0)
Commercialized technology improvements	0
<i>Generating/Promoting Knowledge for Decision Makers</i>	
Projects promoting knowledge to decision makers	*0
Publicly available final reports	11
Conference/journal papers presented	25
Public events	1
Stakeholders reached via public events	330
Website visits	1,685,564
Files downloaded from the program website	223,661

\*No new research projects were awarded in Fiscal Year 2017. Awards for new research were initiated in FY 2018.

Commercialized Technology Improvements

No technology transfer was reported for Fiscal Year 2017.

Interagency Coordination, Collaboration, and Resource Sharing

In any given Fiscal Year, PHMSA’s R&D program staff routinely share information with its interagency partners, as described in the Plan.<sup>10</sup> Since 2002, PHMSA continues to demonstrate its commitment to interagency coordination, collaboration, and resource sharing with a multitude of Federal and State agencies on various matters of research.

**Report on Fiscal Year 2018**

In Fiscal Year 2018:

- PHMSA’s R&D Program staff attended and participated in the “DOE Natural Gas Midstream Infrastructure Research and Development Workshop” held on February 15, 2018, in Houston, Texas.
- A coordination meeting was held between PHMSA and the CEC on March 2, 2018, to discuss common activities with developing inspection training technology and tools.
- A formal Interagency Research Meeting was virtually held on March 29, 2018, to share program updates, coordinate participation on agency research solicitations as merit review panel members, discuss the Plan for Fiscal Years 2016-2020, and further coordinate participation on agency public events. Research program representatives attended from PHMSA, DOE, NIST, and BSEE.

**Table 2: Report of Fiscal Year 2018 Program Performance Metrics**

<b>Performance Metric</b>	<b>Amount</b>
<i>Fostering the Development of New Technologies</i>	
Projects developing new technology	7
Projects demonstrating new technology	1
United States and other patent activity (applied/granted)	(2/1)
Commercialized technology improvements	1
<i>Generating/Promoting Knowledge for Decision Makers</i>	
Projects promoting knowledge to decision makers	27
Publicly available final reports	6
Conference/journal papers presented	11
Public events	1
Stakeholders reached via public events	200
Website visits	1,192,789
Files downloaded from the program website	54,032

<sup>10</sup>[https://primis.phmsa.dot.gov/rd/docspr/PHMSA\\_Pipeline\\_RD\\_5-Year\\_Plan.pdf](https://primis.phmsa.dot.gov/rd/docspr/PHMSA_Pipeline_RD_5-Year_Plan.pdf)

### Commercialized Technology Improvements

Technology transfer was reported on PHMSA's Comprehensive Study to Understand Longitudinal ERW Seam Failures.<sup>11</sup> The project investigations supported the deployment of Battelle's PipeAssess PITM Axial Crack Software, which enables evidence-based repair and replacement decisions that can reduce costs through optimization of re-inspection intervals and hydrotesting. The software was recognized as a 2017 R&D 100 Award Winner.<sup>12</sup>

### Interagency Coordination, Collaboration, and Resource Sharing

PHMSA's R&D Program staff routinely share information with its interagency partners, as described in the Plan. Since 2002, PHMSA continues to demonstrate its commitment to interagency coordination, collaboration, and resource sharing with a multitude of Federal and State agencies on various matters of research.

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<sup>11</sup> <https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=390>

<sup>12</sup> <https://www.rd100conference.com/awards/winners-finalists/year/2017/>

## **Program Website and Contacts**

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

**Alan Mayberry**, Associate Administrator for Pipeline Safety  
Pipeline & Hazardous Materials Safety Administration  
Office of Pipeline Safety  
Phone: (202) 366-4595

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Pipeline & Hazardous Materials Safety Administration  
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## Appendix A

### Combined Summary of Fiscal Years 2017 & 2018

**Table 3: Combined R&D Program Performance Metrics Summary**

Performance Metric	Fiscal Year 2017	Fiscal Year 2018	Since 2002
<i>Fostering the Development of New Technologies</i>			
Projects developing new technology	0	7	100
Projects demonstrating new technology	3	1	57
United States / Other patent activity (applied/granted)	(4/0)	(2/1)	(21/13)
Commercialized technology improvements	0	1	28
<i>Promoting Knowledge for Decision Makers</i>			
Projects promoting knowledge to decision makers	0	27	222
Publicly available final reports	11	6	231
Conference/journal papers presented	25	11	173
Public events	1	1	40
Stakeholders reached via public events	330	200	4081
Website visits	1,685,564	1,192,789	21,533,525
Files downloaded from program website	223,661	54,032	1,572,640

## Appendix B

### Programmatic Elements

PHMSA defines a program element as a technical area that is relevant to pipeline integrity. PHMSA funding can address such elements by focusing on the development of new or improved technology and the generation and promotion of new knowledge for decision makers. LNG and underground natural gas storage are two emerging threats for which such funding could be used on both a program and a project level.

**Table 4: Program Elements and Goals**

Program Element	Program Element Goal
Threat Prevention	Research in this area will develop new or improved tools and/or technology to prevent or reduce damage to pipelines, thereby preventing or mitigating releases into the environment.
Leak Detection	Research in this area will develop new or improved tools and/or technology solutions to identify leaks before they lead to catastrophic ruptures and to reduce the volume of product released into the environment.
Anomaly Detection and Characterization	Research in this area will develop new or improved tools, technology, and/or assessment processes to identify and locate critical pipeline defects and to improve the capability to characterize the severity of such defects.
Anomaly Remediation and Repair	Research in this area will enhance repair materials, techniques, processes, tools, and/or technology designed to quickly bring pipeline systems back online.
Design, Materials, and Welding/Joining	Research in this area 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.
LNG and Underground Natural Gas Storage	Research in this area will support a wide range of LNG safety system testing, quantitative risk assessments, and/or various hazard mitigation models. For gas storage, it will support foci on risk assessments, well casing strength evaluations, subsurface safety valve testing, and both subsurface and facility-level equipment analysis and monitoring.

The following subsections further describe the six program elements shown in Table 4.

#### *Threat Prevention*

Damage to pipe sustained during transportation or construction due to excavation and/or outside forces continues to be a leading cause of pipeline failure; preventing or reducing these threats and the resulting damage to pipelines would dramatically improve pipeline safety. Mechanical damage can result from a number of causes, including, but not limited to, contact with mechanized equipment (mechanical contact), fabrication and handling mishaps (fabrication damage), and pipeline settlement on a rock (rock dents).

Research in this area will develop new or improved tools and/or technology designed to reduce damage to pipelines, thereby preventing or mitigating releases into the environment.

#### *Leak Detection*

Ecological and drinking water resources can be impacted by small hazardous liquid pipeline leaks that are not quickly detected. Potential improvements for leak detection include monitoring systems capable of detecting small releases, small-leak detection sensors, aerial surveillance technologies for airborne chemicals, improvements in the cost and effectiveness of current leak-detection systems, and satellite imaging.

Leak detection, particularly for small leaks, continues to present a challenge. Research in this area will develop new or improved tools and/or technology solutions designed to reduce the volume of product released into the environment.

#### *Anomaly Detection & Characterization*

The detection and characterization of anomalies in pipelines requires a comprehensive program that integrates people, processes, and technology into any proposed solutions. The ability to detect anomalies must go beyond simple corrosion wall loss defect identification to the detection of complex anomalies with dent, gouge, and corrosion characteristics. A key goal of this program element is to find solutions for complex defects that come from a variety of threats. Another emerging concern is the ability of assessment algorithms to correctly calculate the remaining strength of areas with larger anomalies in lower-grade steels (under X70) and areas with various anomalies in higher-strength steels (above X70).

Research in this area will develop new or improved tools, technology, and assessment processes to identify and locate critical pipeline defects and to improve characterization of the severity of such defects.

#### *Anomaly Remediation & Repair*

Damaged coatings and corrosion damage can be major problems for pipelines; as such, reliable methods for repairing these issues and bringing pipeline systems back online are of paramount importance. Research in this area will address ways to improve the repair process by bringing automation to market and by improving standards or best practices for operators and contractors. Testing is needed for composite materials, which are now the most common materials used for pipeline repairs, to understand their integrity under complex loading and over the long term.

Research in this area will enhance repair materials, techniques, processes, tools, and/or technology designed to quickly bring pipeline systems back online.

*Design, Materials, & Welding/Joining*

Improved pipeline materials and design can mitigate or minimize integrity threats to both transmission and distribution piping. The welding and joining of transmission and distribution systems will require automation and inspection capabilities that can safely improve the efficiency of construction activities. The development of quality management system guidelines and use of these 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 in subsequent service.

Research in this area 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.

*LNG and Underground Natural Gas Storage*

Over the past several years, the LNG industry in the United States transitioned from a net importer to a net exporter, recognizing PHMSA's authority to prescribe and enforce the minimum safety standards for LNG pipeline facilities. Research in this area will support a wide range of safety system improvements, quantitative risk assessments, and various hazard mitigation models for both large and small LNG pipeline facilities.

As a result of the 2015 Aliso Canyon Gas Storage Field leak, Congress provided PHMSA with significant new statutory authorities in the area of underground natural gas storage. For example, a full Federal regulatory program is now required to set a minimum standard for more than 17,000 wells across 400 interstate and intrastate underground natural gas storage facilities currently operating in the United States. Research in this area will support risk assessments, well casing strength evaluations, subsurface safety valve testing and analysis, and investigations into equipment monitoring at both the subsurface and the facility level.