Pipeline Safety Research and Development Five-Year Program Plan

Fiscal Years 2016-2020

.

Department of Transportation

Pipeline and Hazardous Materials Safety Administration

October 2017

Outline

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Pipeline and Hazardous Materials Safety Administration

Pipeline Safety Research & Development Five-year Program Plan

Section 12 of the Pipeline Safety Improvement Act of 2002 (Pub. L. 107-355), as amended by Pub. L. 109-468, 112-90, and 114-183, requires the Secretary of the Department of Transportation (DOT) to develop a Pipeline Safety Research and Development (R&D) Five-year Program Plan.

Executive Summary

The DOT's Pipeline and Hazardous Materials Safety Administration (PHMSA) developed a Pipeline Safety R&D Five-year Program Plan to fund innovative research, provide multiple avenues for transparency and stakeholder input, and effectively and efficiently manage program- and project-level activities.

In furtherance of the DOT strategic goals of safety, infrastructure, innovation, and accountability and consistent with the *DOT Five-Year Transportation Research, Development, and Technology Strategic Plan*, PHMSA identified and set goals for six main program elements to address the top pipeline safety challenges we plan to work on between now and 2020. Innovative research solutions will be solicited, funded, and managed in the areas of Threat Prevention; Leak Detection; Anomaly Detection and Characterization; Anomaly Remediation and Repair; Liquefied Natural Gas (LNG) and Underground Natural Gas Storage; and Design, Materials, and Welding/Joining.

Wide-ranging stakeholder input will be sought to assist with identifying research gaps, designing research projects, and independently peer-reviewing research results. Measures will be taken throughout the research lifecycle to support the goals of this plan.

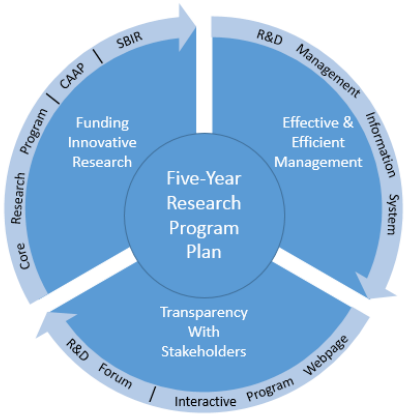
In order to maximize investments on mutual technological challenges, PHMSA will use public-private partnerships to leverage resources and expertise while providing for the donation of real pipeline samples for critical investigations. PHMSA will also seek research partnerships with academia and small businesses in order to maximize commercialization, optimize investment in innovation, and create opportunities for students to enter into the pipeline safety workforce of the future.

This plan includes two biennial reports covering Fiscal Years (FY) 2017-2018 and 2019-2020 that will document the progress towards achieving plan goals.

Pipeline Safety R&D Program Five-year Plan Goals

This plan has three overarching goals covering FY 2016-2020:

1. Funding Innovative Research;
2. Effective and Efficient Management; and
3. Transparency with Stakeholders.



Each goal incorporates a number of planned measures that will be taken to fund research, thereby producing marketable technology and information for decision makers. These planned measures will be executed as effectively and efficiently as possible—both at a program and a project level—while remaining transparent to stakeholders. The planned measures will enable the development of technical solutions for wide-ranging pipeline safety challenges within the following six Programmatic Elements:

1. Threat Prevention
2. Leak Detection
3. Anomaly Detection and Characterization
4. Anomaly Remediation and Repair
5. Design, Materials, and Welding/Joining
6. LNG and Underground Natural Gas Storage

when developing the research agenda within the programmatic elements, PHMSA will follow the consultation guidance provided by Congress, as described in Section 12 Paragraph (d)(2) of the Pipeline Safety Improvement Act of 2002.

This plan will create diverse opportunities within:

1. The core PHMSA research program;
2. The university program via the Competitive Academic Agreement Program (CAAP); and
3. Small business via the Small Business Innovative Research (SBIR) program

Introduction to Pipeline Safety

Energy products and hazardous materials are essential to sustain the American economy and our way of life. The United States uses petroleum hydrocarbons and natural gas as a primary source of energy to produce electricity, heat and cool homes and businesses, transport virtually all commercial and consumer products, travel for work and recreation, and provide the raw material for many other things we use.

More than 2.7 million miles of pipeline make up the United States' pipeline infrastructure, which is the primary means of transporting all natural gas and about two-thirds of our oil supply.

Everyone in the United States is a stakeholder in our national pipeline infrastructure, from which our citizens justifiably expect safe, reliable, secure, and environmentally responsible pipeline operations, as well as continued improvement in each of these areas.

The importance of energy pipelines to the United States economy and our standard of living dictates that all stakeholders, including the public, must assist with funding pipeline research. This enables the continual safety, supply reliability, productivity, security, and environmental performance improvements necessary for successful pipeline infrastructure.

Pipeline incidents, while relatively rare, remind us about consequences of failure. In order to provide all pipeline stakeholders with the tools and information they need, thereby enabling them to support our safety mission and protect the environment, we must invest in effective technologies, and the generation and promotion of new knowledge for decision makers.

Pipeline Research Vision and Mission

The vision of PHMSA's Pipeline Safety R&D Program is to support our mission to protect people and the environment by advancing the safe transportation of energy and other hazardous materials that are essential to our daily lives.

The mission of PHMSA's Pipeline Safety R&D Program is to sponsor R&D projects focused on providing near-term solutions that will improve the safety, reduce the environmental impact, and enhance the reliability of the Nation's pipeline transportation system.

This Pipeline Safety R&D Program Five-year Plan is designed to explain our research strategy for the next 5 years, but also to convey that we:

- Employ a coordinated and collaborative approach to address mutual pipeline challenges;
- Help remove technical and sometimes regulatory barriers for given challenges;
- Measure our research results, outputs, and impacts; and
- Are digitally transparent, posting all program processes, actions, and products on our program website: http://www.phmsa.dot.gov/pipeline/research-development.

Research Program Objectives

PHMSA's Pipeline Safety R&D Program reviewed congressional language about the direction for this program and used logic modeling to understand our inputs, outputs, and impacts, as well as to identify the stakeholders who drive our program inputs and the end users of the research program outputs. That review supported the driver that our R&D Program objectives should focus on the development of new or improved technology and the generation and promotion of knowledge for decision makers (Table 1). The logic modeling also supported the selection of our performance measures/metrics, as described in Section 11: Biennial Performance Reporting of the Five-year Research Plan.

Developing Technology	Promoting Knowledge
Fostering the development of new technologies so that pipeline operators can improve safety performance and more effectively address regulatory requirements.	Generating and promoting general knowledge for decision makers.

Table 1: Research Program Objectives

Developing Technology

Research-based technology development is a critical factor in the expansion of most, if not all, economic sectors of the United States. New technologies—which can make public utilities more efficient, reliable, and safe—allow the oil and gas industry to grow in tandem with this Nation's energy needs while maintaining a cleaner environment.[1]

The PHMSA Pipeline Safety R&D Program fosters the development of new and improved technologies that allow pipeline operators to enhance safety performance and more effectively address regulatory requirements. However, technology development is expensive, slow, and riddled with setbacks. Research programs must divert significant resources in time, process development, and end-user implementation to get it right.

By its nature, successful research rarely results in successful technology transfer. Technology analysis Robert Cooper cites studies indicating that only 55 to 65 percent of new products succeed after introduction to the market; the attrition rate of technologies in earlier stages of research is even greater. When considering companies launching their own research-derived products,[2] Cooper cites reports that state, "for every seven new product ideas, about four enter development and only one succeeds." The record of products involving a handoff between organizations—a government contractor to a manufacturer, for instance—is far worse. It is

[1] American Petroleum Institute. (2001). *State-of-the-Art Technology has Transformed the Oil and Natural Gas Industry.*
[2] Cooper, R.G. (2001). *Winning at New Products: Accelerating the Process from Idea to Launch*. Cambridge, MA: Perseus Publishing.

PHMSA's opinion that following three rules of thumb can improve a product's chance of success:

- Rule 1: Plan for technology transfer from day one;
- Rule 2: Involve end users (i.e. pipeline operators and regulators) from day one; and
- Rule 3: Integrate potential service providers into the plan as soon as possible.

Technology development should be transparent to potential end users, a process that begins in the pre-solicitation phase at R&D Forums and workshops sponsored by PHMSA and the pipeline industry. Information from these public events is available at: http://primis.phmsa.dot.gov/rd/workshops.htm.

The consensus reached at such events allows technology needs to align with threats and integrates end users into the design of required research milestones. At the pre-award review, which takes place before funding is awarded, diverse sets of end users evaluate project merits and further refine and align technology needs with identified threats. After funding is awarded, contractual milestones enable PHMSA and its partners to collaboratively assess technology development via a go or no-go approach. Under this approach, projects are evaluated and/or adjusted each quarter to address advances or setbacks and to move the work along a logical path, bringing it from a proof of concept to a pre-commercial technology.

PHMSA believes it is important for a transparent program to convey and articulate the story of its technology from proof of concept to commercialization, illustrating where in the development public funds were initially applied and when they were no longer appropriate. The execution under PHMSA's program is short term, meaning it allows 1 to 3 years for the deployment of solutions. However, some technology research has taken 5 or more years to commercialize. Because of this, technology research investigating the proof of concept or basic research is usually completed before PHMSA and its partners invest in deployable solutions.

Figure 1 illustrates this discussion, highlighting the technology readiness level based on seven logical steps split between two different phases.

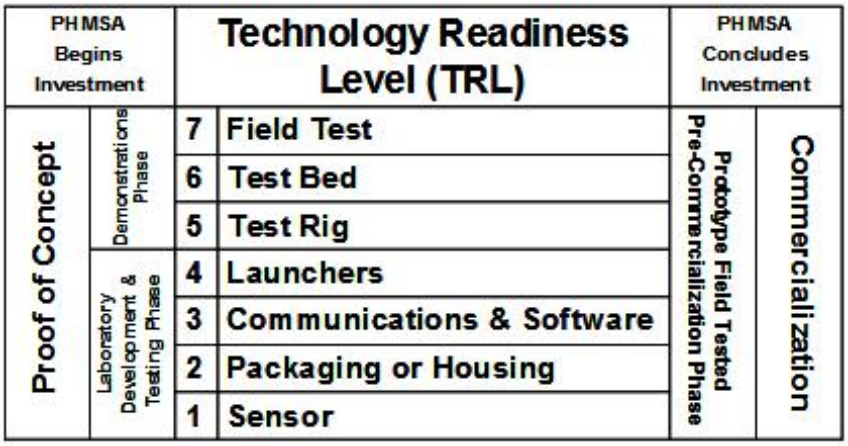


Figure 1: Custom Technology Readiness Level for Pipeline Safety Research

PHMSA technology demonstrations, which are specifically designed to ensure research projects develop technologies that work under field conditions, are used to validate the engineering approaches utilized during the scope of research for ultimate use in the field. Once the majority of the laboratory development and testing is completed, demonstrations are held. These demonstrations begin on a test rig (pipe in a warehouse), progress to a test bed (pipe buried in the ground), and finally reach the field test stage, where the technology is applied to a real, operational pipeline. Several research projects awarded by PHMSA factor demonstrations as part of the scopes of their projects.

Demonstrations are carried out according to a detailed demonstration test plan that includes strong input from both an advisory board and demonstration test participants. Researchers who are under contract with PHMSA hold several informal demonstrations throughout the work scope of their technology development projects. These informal demonstrations advance the technology until it reaches the level at which formal demonstrations—including collaboration between multiple government and pipeline stakeholders—are planned. PHMSA conducts formal events on a case-by-case, not annual, basis.

Promoting Knowledge

Research can generate an enormous amount of knowledge—the challenge is getting this knowledge into the hands of decision makers who can use it to affect change. Knowledge not transferred is unfortunate, wasteful, and can set back progress.

The PHMSA Pipeline Safety R&D Program works to develop and promote general knowledge for decision makers. PHMSA's categorization of general knowledge encompasses research focused on the feasibility of an emerging issue, parametric studies that consolidate knowledge into a single comprehensive report, and work that addresses issues that are not tied to any known industry consensus standards.

PHMSA awards these types of projects to generate and promote knowledge. Consensus is reached at collaborative events, such as research forums, regarding what general knowledge research is required. After consensus is reached, diverse merit-review panels assess proposed research and recommend general knowledge projects for funding.

To ensure transparency, PHMSA mandates several actions in the research contract that the researcher must take to promote project results, a process followed for all PHMSA R&D awards (i.e. technology and general knowledge). The following are examples of how awarded research is promulgated to decision makers:

- Dissemination is made at contract obligation for submitting research results to a public conference, forum, symposium, workshop, or trade journal;
- Dissemination is made at contract obligation for any application for a United States patent;
- Dissemination is made at contract obligation for an output or final meeting with invited decision makers and stakeholders, either via webinar or in person;
- Collaborative public events, such as research forums and workshops, where ongoing work or results are presented;
- Annual research peer reviews, where knowledge of the research is reviewed and promoted; and
- PHMSA's Pipeline Safety R&D Program website, where project progress and results are posted.

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.

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.

Table 2: Program Elements and Goals

The following subsections further describe the six program elements shown in Table 2.

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 of are 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, strengthening PHMSA's position as a developer of minimum safety standards for use in determining the location of new LNG pipeline facilities. Research in this area will support a wide range of safety system testing, 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 LNG and 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 foci on 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.

Implementation of this Program Plan

In carrying out this plan, PHMSA intends to consult as many of the stakeholders described in Section 12(d)(2) of the 2002 Pipeline Safety Improvement Act as possible and fund research within the six programmatic elements described in the previous section.

The five-step process depicted in Figure 2 and described in this section illustrates the time-tested approach PHMSA uses for our continued success. The steps within this process will underpin PHMSA's implementation of this plan.

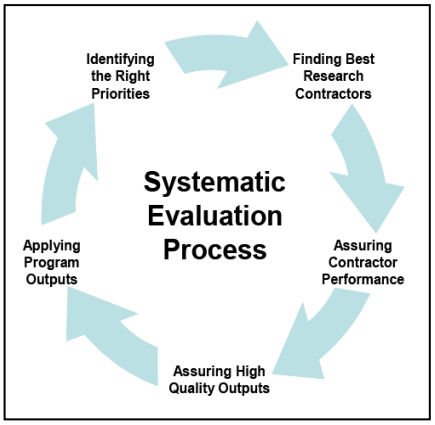


Figure 2: The Programmatic Process

1. Are the right research priorities identified?

PHMSA periodically holds Pipeline R&D Forums for stakeholders with an interest in pipeline safety. The forum, which is generally structured around the six programmatic elements, allows

government and industry pipeline stakeholders to identify technical gaps and challenges for future research. This results in a reduction of duplication across programs, incorporates ongoing research efforts, leverages funding, and broadens synergies. The national research agenda generated by these events is aligned with the needs of the pipeline safety mission, makes use of the best available knowledge and expertise, and considers broad stakeholder perspectives. Information from the Pipeline R&D Forums is publicly posted at: https://primis.phmsa.dot.gov/rd/workshops.htm.

2. Are the selected research contractors the contractors best suited for these priorities?

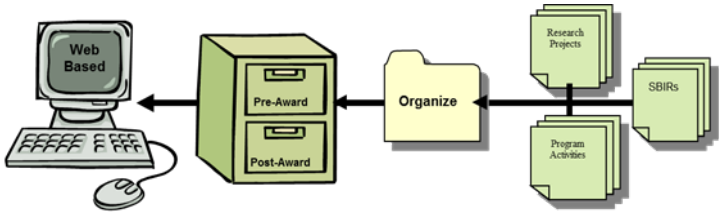
Research gaps identified in Pipeline R&D Forums are assessed within a competitive merit-review process that assures research awards are granted to the projects best suited to address identified technical priorities. A merit-review panel comprised primarily of representatives from Federal & State agencies uses approximately 20 focused evaluation criteria between submission rounds of whitepapers and requested proposals. The criteria are organized within the following three review categories:

- Relevance to PHMSA's mission and state of understanding;
- Soundness of project design and implementation; and
- Coordination and collaboration of work scopes and deliverables.

It is very difficult for just one researcher to comprehensively address identified technical challenges without a team of subcontractors. To address this issue, PHMSA encourages researchers to organize into teams, thereby increasing the credibility and applicability of the proposed work.

3. Are the awarded projects performing well?

In 2003, the DOT's Office of the Inspector General (OIG) issued a recommendation "for the program to complete the development of its internet-based Management Information System." PHMSA worked on the program capability of the Management Information System (MIS), improving its ability to monitor project progress, locate deliverables, and provide public access to research outputs. The DOT OIG favorably closed this recommendation in 2004, leading to a fully launched program known as the R&D MIS. The R&D MIS electronically monitors and tracks contractor performance as a project moves toward completion, providing the necessary oversight to ensure specific contractual milestones and accounting are systematically followed, as prescribed in the award documents. The system was designed to improve and maintain program quality, efficiency, accounting, transparency, and accountability. Additional oversight is provided by Agreement Officer's Representatives (AORs) who are trained, certified, and



designated to each project. The research project AOR also coordinates with co-funding organizations, keeping lines of discussion open regarding the project's quality and status.

Some of the many R&D MIS features include:

- Secure online submission and review of whitepapers and proposals;
- Tracking, inventory, and accountability features;
- Linking of program/project activities to procurement and financial requirements;
- Automated milestone notification for program/project/procurement officials;
- Reduction of workload for interfacing stakeholders;
- Rapid/accurate query functions; and
- Reduction in time between the initial solicitation and the final selection/awards.

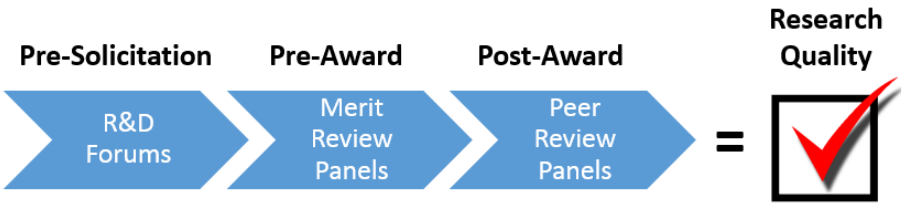
4. Are the program outputs of high quality?

Generating high-quality program outputs does not take place at the end, but rather starts at the beginning of the research process. In order to determine the most crucial research priorities, for example, stakeholders at Pipeline R&D forums will perform a pre-solicitation review of research gaps. Next, the pre-award review uses stakeholders to find the best contractors to conduct the research. Finally, the post-award peer-review process validates the program outputs will be of high quality and will still have the highest potential of producing the results sought by pipeline safety stakeholders.

In order to produce the highest outputs possible, the research program reviewed guidance from the Government Accountability Office and Office of Management and Budget (OMB) that aided in the development of the post-award process. To ensure the research program included feedback from our stakeholders, PHMSA added a specific brainstorming session on peer reviews into the agenda of the March 2005 Pipeline R&D Forum. Feedback from this session noted that peer reviews are important to validate quality, keep research targeted at achieving goals, and facilitate the knowledge transfer of results. Several perspectives gathered during the brainstorming session drove the newly implemented annual peer-review approach that addresses quality or results by academic peers who are free of conflicts of interest. A report documenting the project- and program-level peer-review results is available to the public on the program website: http://primis.phmsa.dot.gov/rd/annual_peer_review.htm.

In addition to creating a space for an annual peer review of PHMSA's core awarded research, the Pipeline R&D Forum and other events serve as an environment where active projects are presented in published papers or to large audiences of various technical backgrounds, thereby creating an opportunity for peer review. Feedback from these events and the associated annual reviews have allowed for modifications to project task foci to better align project scope with stakeholder needs, potentially making research projects more successful. These events also provide a venue for the selection of project AORs with backgrounds pertinent to the subject

matter of their research projects, generating the opportunity for further technical reviews throughout the duration of the projects.



5. Are the program outputs applied to the intended users?

Quantifying the desired impacts of research program objectives validates how program outputs are applied to the intended users; therefore, several specific systematic process features were put in place to generate quantifiable and sustainable data, as further described in the next section. Within the R&D MIS, this data is collected, tracked, and reported in near-real time to the public via the program website. Research outputs are also utilized by pipeline safety inspectors acting as the AORs on projects, resulting in considerable strengthening of PHMSA's pipeline safety technical knowledge base over the past few years.

Technology demonstrations are another measure used to promote research output to end users, a means of evaluating the merit of technologies that are reaching the prototype stage, and a way to expose technologies to the environments in which they must be successfully operated. Demonstrations also promote the deployment and utilization of new technologies through the observations and participation of pipeline operators, equipment vendors, standards organizations, and pipeline safety officials. While demonstrations are just one stage in a technology transfer process, they can still be considered a major milestone on the path to achieving an ultimate research goal.

Post-award Peer Reviews & Removing Conflicts of Interest

In 2004, the OMB put out a bulletin entitled “Final Information Quality Bulletin for Peer Review,” Pub. Law. No. 106-554-515(a), outlining the required procedures for Federal research programs. In response, the DOT generated procedures to further govern the implementation of the bulletin and PHMSA created a peer-review process aimed at uncovering technical problems, guiding projects, and offering technical expertise based on the available guidance. Prior to their appointment to a peer-review panel, potential panelists are judged to a rigorous standard, must certify that they will not disclose any information regarding the research projects, and are required to sign a form stating they have no conflicts of interest that might bias their judgment. This allows PHMSA to continue to facilitate peer-reviewed research while abiding by the OMB bulletin.

All panelists, prior to becoming official reviewers at peer-review events and regardless of their backgrounds, must sign a Non-Disclosure/Conflict of Interest form recusing themselves from reviewing any research project identified on their form as a conflict. PHMSA defines a conflict of interest as, "a current financial or other interest that conflicts with the service of an individual on the review panel because it could impair the individual's objectivity or create an unfair competitive advantage for a person or organization." Prospective panelists who do not agree to these conditions or do not sign the Non-Disclosure/Conflict of Interest form are prohibited from serving on a review panel.

Each panel is comprised of three reviewers so that one reviewer cannot completely determine the outcome of a review. Reviewers must also provide comments to support their evaluations in both an individual evaluation category and by overall strong and weak points for each project. These comments are summarized and noted in the peer-review report.

All potential panelists must submit their Non-Disclosure/Conflict of Interest forms to PHMSA for review. Combined with the potential panelists' resumes, this information allows PHMSA to determine the expertise, balance, and independence of the panel. As required on the form, panelists must disclose any financial conflicts of interest with any of the projects that will be peer reviewed in a given calendar year.

If a conflict or conflicts are determined, PHMSA will act in one or more of the following ways:

- Move the conflicted panelist to a different panel where no conflict exists;
- Allow the panelist to participate, provided they recuse themselves from reviewing the conflict-causing project(s); or
- If too many conflicts exist, excuse the panelist from participating in peer review for that calendar year.

Competitive Academic Agreement Program (CAAP)

CAAP, which was initiated in late FY 2013 under the Pipeline Safety R&D Program, enables academic research to focus on high-risk, high-reward solutions for wide-ranging pipeline safety challenges. CAAP also exposes graduate and Ph.D. research students to both the pipeline industry and common pipeline safety challenges as a way to illustrate how their engineering and technical disciplines are highly desired and needed in the pipeline field.

This program addresses longer-term innovation and works hand-in-hand with PHMSA's core research program, which, in the short term, is focused on demonstrating innovation and deploying it into the market. Two beneficial outcomes of this synergy are that we can connect basic research investigations with end-user challenges and provide successful CAAP project results to teams that can deploy solutions into the market. This research enterprise is designed to bridge the gap that so commonly causes research from academia to fail to reach the market.

CAAP has been successfully exposing students to pipeline safety challenges and finding them employment in the industry since 2013. In addition, some projects are intentionally handed off to PHMSA's core research program; hopefully, some or all of these innovation hand-offs will make it to the market, but only time will tell. Table 3 depicts CAAP's progress to date.

Annual Announcement	# Awards	PHMSA	Resource Sharing	# HS Students	# U-Grad Students	# Grad Students	# PhD Students	Total # Students	# Interns (a)	# Career Employed (b)
CAAP-1-13	8	$814K	$353K	1	23	19	16	59	3	4
CAAP-2-14	7	$719K	$391K		4	14	10	28	1	3
CAAP-3-15	11	$2,960K	$888K		15	19	19	53	2	
CAAP-4-16	3	$899K	$368K		2	7	1	10		
Grand Totals:	**29**	**$5,394K**	**$2,002K**	**1**	**44**	**59**	**46**	**150**	**6**	**7**

Table 3: CAAP Performance[3]

PHMSA Engineering & Research staff and pipeline inspectors are leading these initiatives as project managers. These PHMSA representatives visit university recipients to discuss project scope, tour the laboratories, and meet the students involved with their projects. Technical guidance is provided at these meetings to enhance the likelihood of success and to enable a better match with market needs. A picture from one of these kick-off meetings can be seen below:

Dr. Kawashima (far left) and three students from Columbia University in New York City

During their time at these meetings, PHMSA's representative delivers an overview presentation/seminar entitled "Pipeline Safety Challenges" to a broader set of engineering- or science-focused students at the university. Generally, anywhere from 12 to 30 students attend.

[3] "# Interns (a)" denotes the number of internships offered by engineering firms, research organizations, government agencies, or pipeline operators to students involved with CAAP research projects. "# Career Employed (b)" denotes the number of full-time career jobs/employment opportunities offered by engineering firms, research organizations, government agencies, or pipeline operators to students involved with CAAP research projects.

CAAP students participating at R&D Forum Poster Papers Sessions in 2014 (top) and 2016 (bottom)

PHMSA has incorporated CAAP as one of the factors used to help this research plan achieve success. CAAP research topics generally originate from R&D Forums and then are further tailored for academic investigations. PHMSA's program goal is to continue to get students involved in pipeline safety and to support the transition of successful CAAP projects into the core research program of demonstration and deployment, with the aim of reaching both end users and the market.

Interagency Coordination, Collaboration, and Resource Sharing

Since 2002, PHMSA has demonstrated its commitment to interagency coordination, collaboration, and resource sharing with a multitude of Federal and State agencies on various matters of research. This section will primarily focus on the Federal perspective of this cooperation.

A wide range of pipeline subject matter is investigated via PHMSA's research program, driving the need to actively engage with other Federal agencies that share an interest in PHMSA's objectives. Table 4 identifies these agencies and summarizes historical types of interagency engagement. The technical subject matter is wide-ranging, with participation common in the areas of interagency program meetings, research project meetings, participation at agency public events, participation at technology demonstrations, participation on pre-award merit-review panels, cost resource sharing, and participation in post-award peer reviews.

Federal Agency Name	Historical Subject Engagement	Pre-award Merit-review Panels	Agency Resource Sharing	Post-award Peer-review Panels
Department of Agriculture	Significant coordination/collaboration on various biofuel research projects.	Yes	No	No
Department of Commerce (DOC): National Institute of Standards and Technology	Significant coordination/collaboration and resource sharing on various materials research projects.	Yes	Yes	Yes
Department of Energy (DOE): National Energy Technology Laboratory, DOE: Advanced Research Projects Agency – Energy, DOE: Biomass Program	Significant coordination/collaboration and resource sharing on various gas technology, methane leak detection, and biofuel research projects.	Yes	Yes	Yes
Department of the Interior (DOI): Bureau of Safety and Environmental Enforcement	Significant coordination/collaboration and resource sharing on various safety research projects within our mutual area of jurisdiction covering the Outer Continental Shelf.	Yes	Yes	Yes
Environmental Protection Agency	Significant coordination/collaboration on methane leak detection and biofuel research projects.	Yes	No	No
State Agency Name				
California Energy Commission	Significant coordination/collaboration and resource sharing on threat prevention and leak detection research projects.	Yes	Yes	No
Various State Public Utility Commissions	Significant coordination/collaboration on various pipeline safety research projects.	Yes	No	No

Table 4: Interagency Coordination, Collaboration, and Resource Sharing

As indicated in Table 4, PHMSA continues to have frequent interagency actions with the DOC, DOE, and DOI, especially in the area of research project funding resource sharing. Some of these actions will be further described and quantified in the biennial reporting section of this plan. PHMSA will employ its interagency partnerships as one of the factors used to help this research plan achieve success.

Small Business Innovative Research (SBIR)

The SBIR program, which was designed to encourage innovation in manufacturing, was established under Executive Order 13329 in February 2004. The executive order assigns duties to the Small Business Administration, defines the duties of the agencies and departments that participate in the SBIR program, and states that continued technological innovation is critical to a strong manufacturing sector of the United States economy. It also recognizes that commercialization of technologies, products, or services funded through the SBIR program plays a crucial role in stimulating the United States economy. Further, the executive order acknowledges that the R&D work performed by small businesses participating in the SBIR

program has fostered technology development, contributed to our National defense, improved our health and welfare, protected the environment, and improved our production processes.

PHMSA strongly believes the SBIR program supports our overall goal of fostering/stimulating innovation. This program allows PHMSA to seek small business partners for research gaps unfilled by our core research program, as well as to bring in solutions from other economic sectors and apply them to the growing challenges facing pipelines. It should be noted that several grant recipients successfully completed their Phase I work and migrated into the core research program that helps bring their solutions to market by further connecting them with pipeline industry end users. PHMSA is also seeing success in projects still within the SBIR program; specifically, extremely promising Phase I recipients are receiving Phase II work and successfully bringing their products or technologies to full commercialization.

PHMSA understands how to balance participation in the SBIR program with wide-ranging program opportunities, leverage successes from other economic sectors, and recognize when we should promote further synergies within our core research program; because of this understanding, PHMSA will continue to participate in the SBIR program.

Biennial Performance Reporting of the Pipeline Safety R&D Program Five-year Plan

Since 2004, PHMSA has posted performance data on its program website year round and on a near-real-time basis. These performance metrics, which are qualitative and quantitative in nature, collectively provide the public with a holistic snapshot of to-date performance. The below set of metrics will be reported biennially for FY 2017-2018 & 2019-2020, along with other reporting categories for the designated reporting periods such as interagency coordination, collaboration, or resource sharing.

Fostering the Development of New Technologies

- The number of projects that developed new technology;
- The number of projects that demonstrated new technology;
- The number of United States patent applications that resulted from projects;
- The number of commercialized technology improvements; and
- The narrative description of the net improvement due to successfully commercialized technology.

Promoting Knowledge for Decision Makers

- The number of projects that promoted knowledge to decision makers;
- The number of publicly available final reports;
- 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 program website.

These performance metrics and a wealth of additional information are available from our program website: http://www.phmsa.dot.gov/pipeline/research-development/performance.

In addition, all projects awarded during the reporting period will be categorized by how they affect safety and itemized/summarized as carried out by Federal or non-Federal entities.

"Not everything that can be counted counts, and not everything that counts can be counted."
William Bruce Cameron

Summary

Since the modern inception of the Pipeline Safety R&D Program via the 2002 Pipeline Safety Improvement Act, significant progress has made in developing and managing this program. The combination of public-private partnerships, funding, and time with stakeholders is producing technology-focused results and providing the general knowledge needed to address critical safety and integrity functions. These investments address the need for advancements in the areas of diagnostic tool quality, unpiggable pipe testing, strength of materials, improved pipeline locating and subsurface mapping, outside force damage prevention, and leak detection.

The program development, execution, and performance measurements do not occur in a vacuum: virtually every step in our process incorporates time-tested procedures involving internal and external stakeholder review and input. One of the program's major goals is that this research enterprise be consistent, predictable, and transparent to all stakeholders.

PHMSA believes the following program hallmarks are necessary to strengthen and expand involvement of all relevant stakeholders in order to generate even more desired results:

- Reducing duplication;
- Leveraging resources;
- Improving research quality;
- Developing, deploying, and commercializing technology; and
- Generating and promoting general knowledge.

This Pipeline Safety R&D Program Five-year Plan will further enable PHMSA to be as transparent as possible, fund research that produces marketable technology and knowledge, and execute effective and efficient program- and project-level management. The actions executed throughout this timeframe will allow for the development of technical solutions for wide-ranging pipeline safety challenges, while the biennial reporting will track projects' progress and potential for success.

Acknowledgements

The program staff would like to thank the following organizations[4] for their past, present, and future support; their assistance directly contributes to this program's success:

- American Gas Association
- American Petroleum Institute
- American Public Gas Association
- American Society of Mechanical Engineers
- Association of Oil Pipe Lines
- California Energy Commission
- Department of Agriculture
- Department of Commerce: National Institute of Standards and Technology
- Department of Energy: Advanced Research Projects Agency – Energy
- Department of Energy: Biomass Program
- Department of Energy: National Energy Technology Laboratory
- Department of the Interior: Bureau of Safety and Environmental Enforcement
- Environmental Protection Agency
- Interstate Natural Gas Association of America
- NACE International
- National Association of Pipeline Safety Representatives
- National Energy Board of Canada
- Northeast Gas Association/NYSEARCH
- Operations Technology Development
- Pipeline Research Council International

Additionally, the great work being done by the research community plays a key role in making sure research results are used by end users to positively impact the public.

[4] This is considered to be a partial yet ever-growing list.

Program Website and Contacts

Program website: http://www.phmsa.dot.gov/pipeline/research-development.

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