Office of Pipeline Safety
Research & Development Strategic Plan

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

Final Draft
August 2004

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OPS R&D Strategic Plan

August 2004

"To improve the technology available to assess and repair pipelines, we have awarded almost eight million dollars, for three dozen research projects since March 2002." Testimony of Samuel G. Bonasso, Deputy Administrator, Research and Special Programs Administration (RSPA), before the Senate Committee on Commerce, Science & Transportation, June 15, 2004.

I. Introduction

The Office of Pipeline Safety (OPS) has regulatory responsibility for the safety of natural gas and hazardous liquid pipelines. Over the past several years, OPS has strengthened its role in assuring the safety of the nation's pipeline system in numerous ways, including promulgating new regulations on integrity management.[1,2,3] These new regulations, together with the new inspection processes being used by regulators to evaluate operator compliance, rely for their effectiveness on the operators' access to new technologies that support improved safety and integrity performance and on regulators' access to information on the appropriate use and limitations of these technologies. To address the need for new integrity-related technologies and information on the validity of these technologies, Congress has recently expanded the support for the OPS research and development (R&D) program[4]. As authorized by Congress, OPS is sponsoring research and development projects focused on providing near-term solutions that will increase the safe, reliable, and environmentally sound operation of America's energy transmission and distribution pipelines.

Technological innovation has enhanced pipeline safety in numerous ways, including: improving the toughness of pipeline materials; improving the ability to find and eliminate defects before they become hazardous; and creating better methods and systems for constructing, operating, and maintaining pipelines. Technology helps us understand risks to the public and to deal with them effectively. Technology has played a role in the steady decline in pipeline incidents even while the pipeline system is expanding. The future promise of technology includes a dramatic improvement in our capability to fabricate, construct, operate, and maintain the Nation's pipeline infrastructure.

According to a report by the Government Accountability Office (GAO), "Although pipeline incidents resulted in an average of about 24 fatalities [and 83 injuries] per year from 1989 to 2000, the number of pipeline incidents is relatively low when compared with those involving other forms of freight transportation. On average, about 66 people die each year in barge accidents, about 590 in railroad accidents, and about 5,100 in truck accidents."[5] Over the last 10 years, the number of safety incidents involving injuries to people

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[1] "Pipeline Integrity Management in High Consequence Areas for Hazardous Liquid Operators" (49 CFR Part 195); Rules effective May 29, 2001, and February 15, 2002 . <http://primis.rspa.dot.gov/iim/ruletextamended.htm>
[2] "Pipeline Safety: Pipeline Integrity Management in High Consequence Areas (Gas Transmission Pipelines)"; Final Rule. December 15, 2003. < http://primis.rspa.dot.gov/gasimp/docs/GasTransmissionIMRule.pdf>
[3] "Pipeline Integrity Management in High Consequence Areas (Gas Transmission Pipelines)". Final Rule (as amended), May 26, 2004. <http://primis.rspa.dot.gov/gasimp/docs/FinalRuleAmended_gas_full.pdf>
[4] Pipeline Safety Improvement Act of 2002 < http://ops.dot.gov/Pub_Law/107_cong_public_laws.pdf>
[5] General Accountability Office. GAO-02-517T, March 2002, page 3.

and damage to property has declined despite the growth in pipeline capacity. Nevertheless, recent accidents have demonstrated that pipelines can present significant hazards to the public when things go wrong. A primary objective of the OPS R&D Program is to develop technology to prevent future accidents and to reduce their consequences.

OPS, in a partnership with the pipeline industry, public interest groups, and other government agencies, has focused its crosscutting research on the critical issues in pipeline safety, issues that can be addressed through technology innovation. Clearly, the biggest challenge has been the prevention of damage from people digging around pipelines. Despite the progress that has been made from one-call systems and the leadership of the Common Ground Alliance, OPS strives to find other ways of protecting pipelines from outside force damage. Another challenge is finding defects in pipelines before they become hazardous to public safety. Defects can arise from corrosion, previous damage to pipe, or construction and fabrication related defects. Finding these defects depends on technology for internal or external inspection--such as smart pigs and visual inspection where the pipe is exposed--and on assessment involving the integration of data about the history of the pipeline, pipeline materials including coatings, and current pipe condition. Some defects become more serious over time and some remain benign over the life of the pipeline. A combination of technologies, some emerging and some improving, is needed for inspection, defect characterization, and evaluation. Other challenges include finding ways to repair pipelines, designing methods to operate, monitor, and maintain pipeline systems, and responding to emergency conditions.

Current OPS projects were started as a result of stakeholder guidance beginning in 2000 and the Pipeline Safety Improvement Act of 2002 (PSIA-2002). From 2002 to the present, OPS has issued four Broad Agency Announcements (BAAs) to solicit proposals for addressing R&D needs and opportunities. By September 2003, OPS had funded 25 projects from the first three BAAs with $10.6 million in funding including $5.6 million in industry cofunding, including 3 grants under the Small Business Innovative Research program, the latter through DOT's Volpe Center[6]. Detailed information on the OPS R&D program can be found on the website at http://primis.phmsa.dot.gov/rd/ as shown in figure I-1.

PSIA-2002 also set forth the requirement that the Department of Transportation (DOT), the Department of Energy (DOE), and the National Institute of Standards and Technology (NIST) in the Department of Commerce (DOC) "shall carry out a program of research, development, demonstration and standardization to ensure the integrity of pipeline facilities." These agencies, along with the Minerals Management Service (MMS), have agreed to areas of responsibility as described in a Five Year Interagency Research and Development Program Plan for Pipeline Safety and integrity and implemented in a Memorandum of Understanding.

In this R&D Strategic Plan, OPS presents answers to a number of questions:

1. What are we trying to achieve through the OPS R&D program? (Section II. Vision, Mission, and Strategic Objectives)
2. Around what topical research areas have we organized the program to achieve the objectives? (Section III. R&D Program Elements and Goals)
3. What are the main aspects of the current environment that have influenced the design of the R&D program? (Section IV. Situation Analysis)
4. How did we identify and verify the topical research areas on which the R&D program is focused? (Section V. Designing the Pipeline Safety Research Agenda)
5. What is the strategy for implementing and managing the R&D program? (Section VI. Strategy for R&D Management)

[6] DOT's Small Business Innovative Research program <http://www.volpe.dot.gov/sbir/index.html>

Further details are presented in an accompanying document, the OPS R&D Performance Plan. The Performance Plan focuses on critical issues, performance measurement and evaluation, program management, and methods for identifying pipeline safety needs, technology gaps and innovation opportunities.

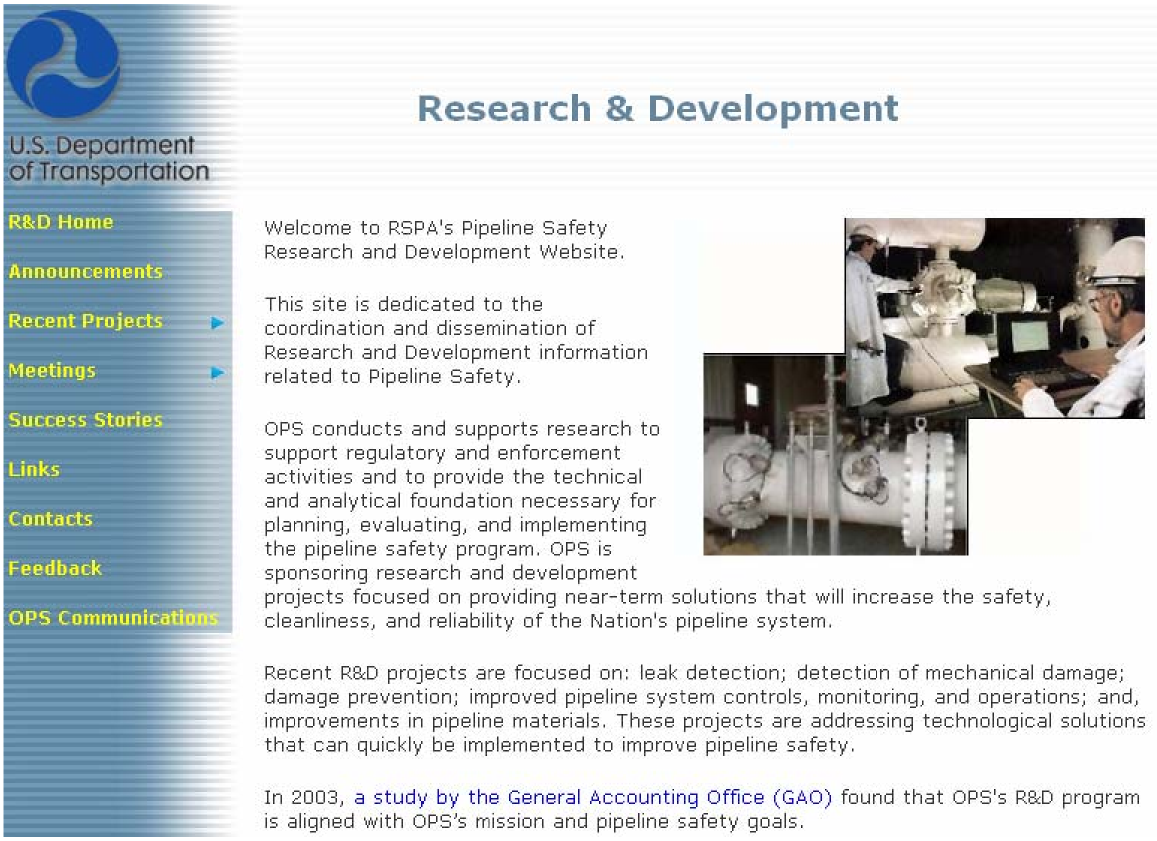

Figure I-1. Screenshot of the OPS R&D Home Page at http://primis.phmsa.dot.gov/rd/

II. Vision, Mission and Strategic Objectives

II.1 Vision and Mission

The Office of Pipeline Safety (OPS) regulates safety in the design, construction, operation and maintenance, and spill response planning for over 2.3 million miles of natural gas and petroleum pipelines. OPS is focused on the continual reduction in the number of incidents on natural gas and hazardous liquid pipelines resulting in death, injury, or significant property damage. OPS also aims to reduce spills that can cause environmental harm.

The vision of the OPS research and development (R&D) program is to support the mission of OPS which is "to ensure the safe, reliable, and environmentally sound operation of America's energy transportation pipelines". The mission of the OPS R&D Program is

> *To sponsor research and development projects focused on providing near-term solutions that will improve the safety, reduce environmental impact, and enhance the reliability of the Nation's pipeline transportation system.*

II.2 Strategic Objectives for the OPS R&D Program

Based on information gathered on pipeline safety issues, technology needs and gaps, and opportunities for technology innovation, OPS has established a set of strategic objectives. The objectives of the R&D program, are to improve pipeline safety, integrity and reliability by:

1. Developing technology that supports the OPS regulatory mission;

2. Focusing on near-term technology development needs and opportunities;

3. Conducting an effective program of technology transfer and communication with stakeholders;

4. Maximizing the return on the R&D investment by coordinating activities with other sources of R&D funding, including other federal agencies;

5. Efficiently and effectively managing the R&D program.

II. 3 Technology Planning Process

OPS uses a systematic process for planning and implementing the R&D program. The process starts with identification of critical issues that affect pipeline safety. Information is gathered from stakeholders, government agencies, state pipeline safety officials, analysis of pipeline safety incidents, R&D organizations, standards developing organizations, and the pipeline industry. Key inputs include the agenda of the President's Administration, Congressional guidance, and special studies from Government Accountability Office (GAO) and the National Academies. The R&D program is designed to satisfy the R&D investment criteria established by the Office of Management and Budget (OMB) including:

- Relevance: Programs must have clear plans; must be relevant to national priorities, agency missions, and customer needs; and must justify their claim on taxpayer resources.
- Quality: Programs must maximize quality through the use of clearly stated, defensible methods for awarding funding.

- Performance: Programs must maintain a set of high-priority, multi-year objectives with annual performance measures and targets.[7]

Ideas and proposals are solicited from R&D organizations, pipeline operators, and vendors through Broad Agency Announcements (BAAs). The white papers and proposals are reviewed and evaluated by a BAA Review Panel composed of OPS R&D professionals and independent, outside experts. Funded projects are managed by Contracting Officer's Technical Representatives (COTRs) as required under the Federal Acquisition Regulations (FARs).

The program is reviewed periodically by external groups including the Congress, the Government Accountability Office (GAO), the National Transportation Safety Board (NTSB), and the Administration through DOT's Office of the Inspector General and the President's Office of Management and Budget (OMB). OPS has established a Blue Ribbon Panel of stakeholder groups to review the direction of the program. OPS also reviews the program with the pipeline safety advisory committees (TPSSC and THLPSSC). Lastly, OPS conducts its own review of the program and individual projects through applications of performance measures and peer reviews. The details of performance measurement and program/project reviews are presented in the OPS R&D Performance Plan.

The results of the technology planning process are shown in figure II-1. The OPS R&D program is organized into eight (8) program elements. For each of the program elements, OPS has defined desired outputs of the work which relate directly to the identified needs and opportunities for innovative technology.

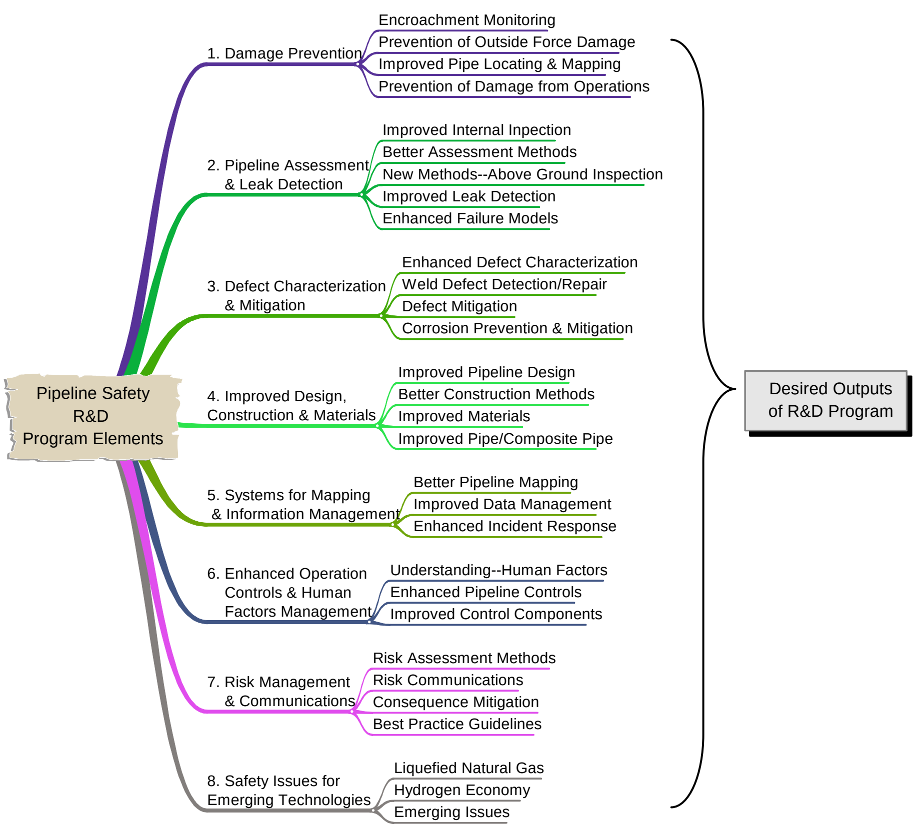

Figure II-1. Relationship of the R&D Program Elements to Desired Outcomes

[7] The application of the R&D investment criteria is described fully in section VI. Strategy for R&D Management.

III. R&D Program Elements and Goals

OPS has organized activities in the pipeline safety R&D program around eight R&D program elements. Each program element has associated safety issues, technology needs or gaps, and R&D opportunities. Ongoing and future planned projects are linked to at least one of these program elements. The program elements reflect the responsibilities of DOT in the Five Year Interagency R&D Program Plan and guidance from pipeline experts and stakeholder groups.

Program goals are associated with each program element. The goals define the desired outcomes for the R&D projects. Each goal bears a direct relationship to longer-term enhancement of pipeline safety. These relationships are described in the R&D Program Logic Model.[8] The program elements and related goals are presented in Table III-1 and described below.

Table III-1. Program Elements of OPS R&D Program

	Program Elements	Program Element Goals
1.	Damage Prevention	Reducing the number of incidents and accidents resulting from excavation damage and outside force
2.	Pipeline Assessment and Leak Detection	Identifying and locating critical pipeline defects using inline inspection, direct assessment and leak detection
3.	Defect Characterization and Mitigation	Improving the capability to characterize the severity of defects in pipeline systems and to mitigate them before they lead to incidents or accidents
4.	Improved Design, Construction, and Materials	Improving the integrity of pipeline facilities through enhanced materials, and techniques for design and construction
5.	Systems for Pipeline Mapping and Information Management	Enhancing the ability to prevent and respond to incidents and accidents through management of information related to pipeline location (mapping) and threats definition
6.	Enhanced Operation Controls and Human Factors Management	Improving the safety of pipeline operations through enhanced controls and human factors management
7.	Risk Management & Communications	Reducing the probability of incidents and accidents, and mitigating the consequences of hazards to pipelines
8.	Safety Issues for Emerging Technologies	Identifying and assessing emerging pipeline system technologies for opportunities to enhancing their safety

[8] The R&D Program Logic Model is published in the OPS R&D Performance Plan. Some aspects of the Logic Model, the relationships between program elements and desired outcomes, are illustrated in figure II-1.

III.1. Damage Prevention

Damage to pipe by excavation and outside force continues to be a leading cause of pipeline failure. Preventing or reducing such damage to pipelines would dramatically improve pipeline safety. Excavation damage is most often caused by contact with the pipe while digging around it. Much of the damage is caused by operators of backhoes, bulldozers, and even shovels who have failed to locate the pipe before digging. This type of damage is also called "third party damage", because it is often caused by parties other than the operator or contractors to the operator. Natural forces can also cause outside force damage. Such damage can result from earthquakes, earth movement from unstable soil conditions, and weather-related conditions such as frost heave. Figure III-1 shows outside force damage to above ground pipe. However, most outside force damage occurs on underground piping which can result in an immediate or a delayed rupture as illustrated in figure III-2.

Figure III-1. Above Ground Pipeline Damage

Figure III-2. Pipeline Rupture from Outside Force

Protecting the public from pipeline failures also means protecting the pipe from people. In 1997, OPS personnel began working with representatives from the pipeline industry, utilities, excavation contractors, state and local officials and members of the public to identify practices to reduce the potential for "hits" on line pipe. Representatives from each of these constituencies worked for over two years and produced a report entitled *Common Ground: Study of One-Call Systems and Damage Prevention Best Practices*, June 1999, documenting 130 best practices for mitigating this exposure.[9] New methods and technologies are needed to monitor activities near pipelines especially activities which encroach on the pipeline right-of-way. Aerial surveys and right-of-way patrolling while effective could be augmented by technologies for detecting encroachments.

OPS has published a rule requiring operators to conduct periodic inspections of pipeline facilities located in the Gulf of Mexico and its inlets in waters less than 15 feet deep. The intent is to maintain a depth-of-burial that will protect submerged pipelines subject to damage by surface vessels and their operations. Improved technologies may be needed to detect exposed pipe or protect the pipe which becomes a hazard to navigation.

Locating and mapping the exact location of buried pipe is critical to avoiding damaging contact. Maps generally do not present enough detail to locate pipe accurately enough for excavating in the proximity of pipe. Soil conditions, pipe materials, e.g. plastic pipe, and the presence of high-voltage power lines can all hinder accurate on-site pipe locating. Technology gaps in sensing, pipe locating, data integration, and digital mapping technologies need to be addressed, along with demonstration of the technologies. Innovation could

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[9] Office of Pipeline Safety. "Common Ground: Study of One-Call Systems and Damage Prevention Best Practices". June 1999. <http://ops.dot.gov/comgrnd.htm>

enhance the capability to integrate multiple technologies for detecting, mapping, and inspecting pipe such as radar, magnetic induction techniques, global positioning, and advanced image processing. Emerging fiber optics and acoustic technologies show promise in monitoring pipe condition and detecting contact with the pipe.

Concerns have been expressed that technologies designed for pipe protection and inspection could cause damage to the pipe. High levels of voltage from cathodic protection systems or magnetization effects from internal inspections have the potential for disbondment of pipe coatings or damage to the steel from hydrogen production at the pipe surface.

III.2. Pipeline Assessment and Leak Detection

Inspection and assessment of pipe condition are essential tools for determining the safety, reliability and soundness of pipe. Since much of the pipeline infrastructure is buried and inaccessible for visual inspection, it is necessary to use internal inspection, pressure testing, or assessment techniques that integrate information from which pipe condition can be determined. All new pipelines are pressure tested to determine that the line can be safely operated at its design conditions, a process called hydrostatic testing as illustrated by figure III-3. Because of the need to shut down a pipeline when pressure testing, it is often uneconomic to do so after the line is put into operation.

Figure III-3. Blowing Down a Pipeline After Hydrostatic Testing

Many pipelines can be inspected internally using a robotic device called a “smart pig” as illustrated in figure III-4. Smart pigs contain highly sophisticated instruments to measure and record specific conditions of the pipe wall including deformation of the pipe, wall thinning due to corrosion, dents and gouges, and geographic location. Pigging, also called *in-line inspection*, requires that the pipeline be constructed with facilities for launching and retrieving the inspection tools. The pipe itself must be constructed without short-radius bends that would compromise travel of the pig through the line. The pipe must have the same diameter from launcher to retriever. Even if the main line is piggable, there are sections of pipe, located at pumping or compressor stations, in which other means of inspection are required.

Smart pigs can be designed to detect wall thinning from corrosion, dents, gouges, wrinkle bends, and certain types of weld and crack defects. But today’s pigs are limited in their capabilities to detect other defects such as stress corrosion cracking in gas piping or longitudinal defects in pipe seams. And, pigs are limited in their capacity for identifying multiple safety-related conditions in a single inspection run or one type of pig. Significant investments are needed to expand the operating envelope of internal inspection tools.

Although new lines are uniformly constructed to accommodate in-line inspection devices, up to 30 percent of older transmission lines, principally gas transmission pipelines, cannot accommodate smart pigs. Some lines are too small to accommodate internal inspections. OPS, in partnership with industry, is exploring options for new types of internal inspections, non-intrusive inspection technologies, and above-ground methods. For more information on new inspection methods go to http://primis.phmsa.dot.gov/matrix/.

Figure III-4. Illustration of Smart Pig Inside Pipeline

In addition to pigging data, pipeline operators collect information on the condition of their pipelines from construction and fabrication records, operating (leak and failure) history, aerial and right-of-way surveys, soils data, and electrical surveys. Electrical surveys, based on cathodic protection data and close internal surveys, present a wealth of information from which the condition of the pipe and its coatings can be inferred. Integrating this information in a formal and systematic fashion, a process called *direct assessment*, can provide a picture of the pipe condition. Where direct assessment points to potential problems, additional inspections—visual, instrumented, external, or internal—can be performed. Methods and standards for direct assessment, principally for gas transmission pipelines, are being developed for internal corrosion, external corrosion, and stress corrosion cracking.

Pipe materials, fabrication, and pipeline construction practices have improved significantly over many decades. While many older pipelines continue to operate safely when well maintained, failure histories suggest the need for additional information on conditions leading to stress corrosion cracking and seam failures in certain types of pipe. New and enhanced failure models could help identify and remediate potential problems.

Leak detection continues to present a challenge, especially small leaks. Ecological and drinking water resources can be impacted by small hazardous liquid pipeline leaks that are not quickly detected. Among the possibilities for improving leak detection are monitoring systems that can detect small releases, sensors for small leak detection, technologies for aerial surveillance for airborne chemicals, improvements in the cost and effectiveness of current leak detection systems, and satellite imaging. New sensors, fiber optics, airborne leak detection, and remote leak sensing are all possibilities.

III.3. Defect Characterization and Mitigation

Key to understanding the integrity of pipelines is an ability to characterize the severity of defects and to mitigate them before they can lead to incidents or accidents. Some defects are critical and must be removed for safe operation. Some defects present longer term problems, especially when the defects are time-dependent. Detection and resolution of active corrosion is an example. Other defects, while detectable, are stable anomalies in the pipe and present no threat to pipeline operation. Clearly, it is absolutely necessary to be able to distinguish the severity of threat posed by a defect. Often defects will occur on the surface of the steel pipe underneath the exterior coating as illustrated in figure III-5. Among the methods used and under development by operators are defect evaluation criteria, systems for locating and sizing flaws, models of failure and fracture modes including the effect of potentially interacting defects, and corrosion growth models.

Knowledge is being accumulated on types of defects, mechanical properties of early generation seam welds, unique properties of vintage pipe, characterization of girth weld defects, and analyses of how seam or girth weld defects are related to pipe integrity. The industry practice of repairing any "crack-like" defects in seams has failed to adequately discriminate between critical defects and other anomalies. Consistent classification methods and assessment protocols will focus attention on conditions that compromise safety. Complementary programs examine methods for mitigating defects. Under development are advanced welding repair and remediation methods, including the mitigation of defects on in-service pipelines.

Figure III-5. Pipeline Defect (Wall Thinning Due to Corrosion)

III.4. Improved Design, Construction and Materials

Pipeline safety begins with materials, fabrication, design and construction. The pipe itself is manufactured from high-strength carbon steel. The pipe is made to strict engineering and metallurgical standards developed by the American Petroleum Institute.[10] Specifications include the physical, chemical, and mechanical properties of the steel in the pipe. Coatings are applied to the pipe to protect the pipe from corrosion. While pipe has been coated over the years with coal tar enamel or tape wraps, pipe manufactured today is typically coated with a tough fusion bonded epoxy (FBE) coating. Lengths of pipe, or sticks, are coated with FBE at the factory. After the pipe is welded in place, the welded joints are cleaned and coated in the field. Before being lowered into the ground and covered, the pipe is inspected and checked electrically to ensure that the surface of the pipe is adequately covered. Pipelines are bedded in the ditch and cathodically protected to maintain original condition. OPS is encouraging the development of new materials and new processes for design, fabrication, and construction. Among the promising areas are:

- The development of new higher-grade, high-strength pipe.
- Development of pipe for special conditions like the Arctic, deep sea, and sour gas operations.
- Improved pipe coatings applied in the factory or the field.
- Evaluations of padding and related construction practices.

[10] See http://api-ep.api.org/publications/.

- Best practice guidelines and standards for strain-based pipeline design.
- Higher-pressure pipeline designs.
- Modeling of performance characteristics and failure modes for welds and joints.
- Development of composite pipe.
- Improved techniques for directional drilling under roads and rivers.

III.5. Systems for Pipeline Mapping and Information Management

The National Pipeline Mapping System (NPMS) is a geographic information system (GIS) that depicts the location of hazardous liquid and gas transmission pipelines and liquefied natural gas (LNG) facilities under the jurisdiction of the Office of Pipeline Safety (OPS). The NPMS also depicts the locations of OPS-defined High Consequence Areas (HCAs) that are subject of the OPS Integrity Management (IM) regulations.[11] From 1998 until 2002, the NPMS was a voluntary initiative. The Pipeline Safety Improvement Act of 2002 required pipeline operators to submit mapping information to the NPMS.

The NPMS supports the OPS Integrity Management Program (IMP), inspection planning, pipeline incident/accident response, internal and external communications, and public right-to-know initiatives. The NPMS also supports the agency's mission by providing a geographic visualization and analysis tool for pipeline facility data to meet the needs of various stakeholders. These stakeholders include other federal government agencies, state pipeline safety agencies and other state agencies, local government agencies, emergency responders, and the public. The NPMS supports the OPS mission of safety and environmental protection by providing an Internet mapping tool and statistical database that help the OPS better identify risks, track effectiveness of proposed solutions, allocate resources, and meet the information needs of external users. Information on the NPMS can be found by visiting http://www.npms.phmsa.dot.gov/.

Systems for information management are developing rapidly. Besides mapping, information management technologies which might enhance pipeline safety include advanced database systems, data integration, analytical modeling, fiberoptic and wireless networks, and communications and control systems.

III.6. Enhanced Operation Controls and Human Factors Management

OPS continues to examine pipeline operations and controls with a view toward minimizing unsafe operations, reducing operator error, improving control systems, and mitigating consequences when accidents occur. In the past several years, OPS has examined excess flow valves, remote and automatically operated line pipe valves, and operator qualifications and training. Topics of interest include technologies and procedures designed to minimize operator error, research on the effects of managing pipeline controller shift change and potential solutions for minimizing those effects, human interface in incident/accident management and routine operations. Pipelines are controlled using Supervisory Control and Data Acquisition (SCADA) systems. SCADA systems present both opportunities for improving safety and vulnerabilities for common mode failure.

Human factors play a role in some pipeline incidents. The National Transportation Safety Board (NTSB) has collected data from pipeline failure investigations, issued publications and held meetings on the issue. The NTSB has charged the OPS to use the R&D Program to examine the role human factors play in the operation of complex pipeline systems. In three of its R&D Solicitations, OPS has sought projects on human factors where the results would bring greater awareness of the issue and improvements to safety. Good projects have been difficult to identify, and OPS continues to seek projects addressing human factors.

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[11] In general, High Consequence Areas (HCAs) are identified in areas of high population, places where people congregate frequently, or areas of unusual environmental sensitivity. See the discussion of the Integrity Management Program and HCAs in Section IV on the "The Revolution in Pipeline Safety Regulation".

III.7. Risk Management and Communications

Over the past decade, the emphasis on pipeline safety has shifted from corrosion control and post-accident reaction to more proactive measures, including greater levels of inspection, involvement of the public through communications, and prospective analysis of the dangers presented by pipelines. Risk analysis has become the tool of choice in these programs. Industry and government are using data from risk assessments to identify ways to make the system safer by looking at root causes of incidents. Risk assessments can guide regulators and operators to make decisions and take precautions in which the risks can be minimized or avoided entirely. Risk controls can involve both measures to prevent adverse events and measures to mitigate their magnitude. One reduces the likelihood; the other reduces the severity of impact. Another step in risk management is the monitoring of performance to determine whether risk control measures are being effective. Risk assessment can be particularly useful in making decisions in which the risks are uncertain and the impact of decisions unknown. For example, after many years of oil and gas operations in the Gulf of Mexico, a number of pipelines may require abandonment or removal in the coming years. Examining the various options will require an assessment of feasibility, safety, and costs.

The Pipeline Safety Improvement Act of 2002 directed the Secretary of Transportation in conjunction with the Federal Energy Regulatory Commission to "undertake a study of land use practices, zoning ordinances, and preservations of environmental resources with regard to pipeline rights-of-way and their maintenance. OPS and FERC sought the advice of the National Academies on the issues of risk-based guidance for land use planning around pipelines.

While the public generally recognizes that pipelines present a potential hazard to people and property, the extent of the danger is not well understood by the public or their local officials. From the information at hand, public and local officials are as likely to underestimate as to overstate the extent of the hazard. Little information is publicly available, even on the Internet, that would allow people to identify the hazard or to differentiate the potential hazard in one location from another. As we develop more understanding—and information—on pipeline safety risks, OPS will develop enhanced mechanisms for communicating those risks.

While it is feasible to conduct a risk assessment from national level data and statistics, the data for accurately discriminating pipeline risks at a more detailed level is limited. For segments of a pipeline in a particular locale, the local conditions might result in risks that are vastly different from the risk calculated on a national level. But information and data for risk assessments will get measurably better in the years ahead. Under the new Integrity Management Program (IMP), pipeline operators will be making risk-informed decisions on each of their pipeline segments in high consequence areas. Collecting and analyzing this information will allow OPS to focus its inspection, rulemaking, and technology development efforts.

III.8. Safety Issues for Emerging Technologies

OPS recognizes that new safety issues and new technology options will emerge in the future. The President has made expansion of domestic energy production a clear priority.

> "America will be more prosperous and more secure when we are less dependent on foreign sources of energy. Reliable and affordable energy is critical to our economic security, our national security, and our homeland security." Says President George W. Bush[12].

OPS expects renewed efforts to increase production and delivery of oil and gas in North America, most of which will be transported by pipeline. Importation of oil and liquefied natural gas (LNG) continues to grow.

[12]"President Commends Bipartisan Support for a National Energy Policy", November 18, 2003. <http://www.whitehouse.gov/news/releases/2003/11/20031118-7.html>

As LNG facilities are built or expanded, OPS must remain alert to safety issues in such areas as spill containment, sensors or other safeguards, materials, and LNG handling.

The President has called on government and industry to examine the potential for the gradual replacement of oil and gas by hydrogen, perhaps using much of the pipeline structure currently in place. The feasibility and safety of a Hydrogen Economy presents future challenges for OPS.[13] According to a National Research Council (NRC) report, "A transition to hydrogen as a major fuel in the next 50 years could fundamentally transform the U.S. energy system, creating opportunities to increase energy security through the use of a variety of domestic energy sources for hydrogen production while reducing environmental impacts, including atmospheric CO_2 emissions and criteria pollutants."[14]

[13] See http://www.whitehouse.gov/infocus/energy/

[14] "The Hydrogen Economy: Opportunities, Costs, Barriers, and R&D Needs." Committee on Alternatives and Strategies for Future Hydrogen Production and Use, National Research Council, National Academy of Engineering of the National Academies. Page ES-2. <www.nas.edu>

IV. Situation Analysis

Pipelines transport a significant fraction of the nation's energy on which our economic well being depends. The United States transports all of its natural gas and a large fraction of crude oil and petroleum products through 2.3 million miles of natural gas and hazardous liquid pipelines. About 20 percent are high-pressure, transmission pipelines that transport oil and gas from producing areas to major metropolitan markets. Many of these lines originate in the Southwest and the Gulf of Mexico and carry products to the Midwest, the Northeast, the Southeast, and the West Coast. Other lines carry oil and gas from Canada, the Rocky Mountains, and the traditional production areas in Appalachia.

IV.1. Need for Additional Pipeline Capacity

About 61 percent of the energy consumed in the United States comes from fossil fuels. [15] In 2002, the United States consumed an average of 19.7 million barrels/day of oil. The Department of Energy estimates that oil consumption could increase by nearly 50 percent in the next 20 years.[16] DOE reports that natural gas consumption increased by 35 percent in the past ten years. Current annual consumption of natural gas is estimated at 23 trillion cubic feet and forecasted to grow to 35 trillion cubic feet by 2025.[17] DOE projects that gas consumption will expand by a third over the next 10 years. Increasing amounts of liquefied natural gas (LNG) are being imported to meet growing energy demand as projected in figure IV-1.

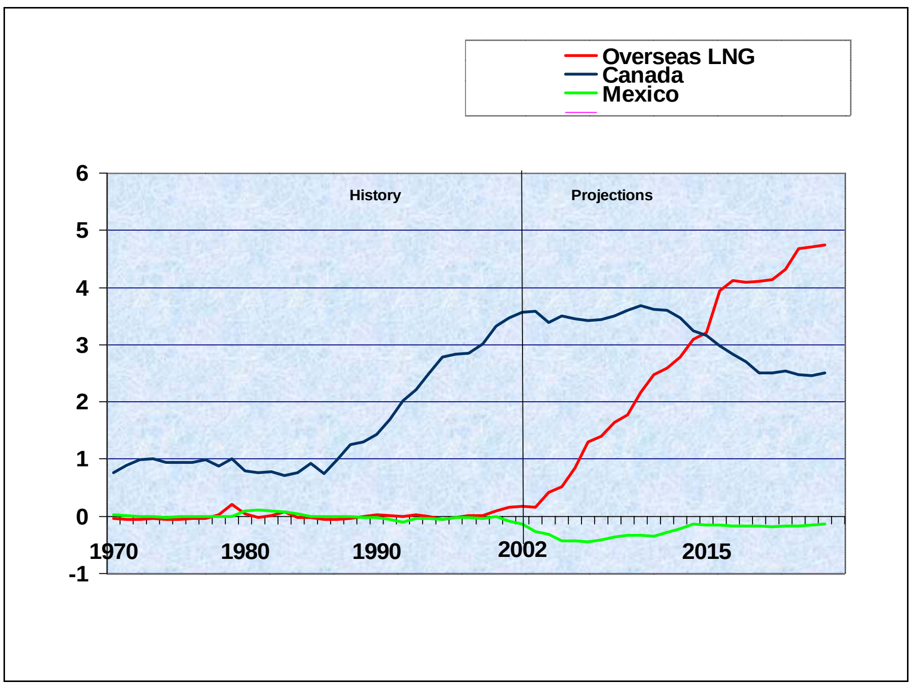


Figure IV-1. Projection of Net US Imports of Natural Gas, 1970-2025 (trillion cubit feet)

In order to provide oil and gas to growing and new markets, additional pipeline mileage will be needed. The National Petroleum Council has estimated that 38,000 miles of new interstate gas transmission lines and

[15] Energy Information Administration, Annual Energy Review 2002, < http://www.eia.doe.gov/aer/contents.html>
[16] "Market Trends—Oil and Natural Gas". Annual Energy Outlook 2004 with Projections to 2025. Energy Information Administration, U.S. Department of Energy, 2004. <http://www.eia.doe.gov/oiaf/aeo/gas.html>
[17] Department of Energy, DOE/FE0457, June 2003

255,000 miles of new gas distribution lines would be required to meet future natural gas demand by 2015. Along with this necessity for new mileage, maintaining the existing infrastructure will pose additional challenges for operators and regulators to enhance pipeline safety. Construction of additional pipelines cannot occur without public confidence in the safety of current pipelines and support for the expansion of the national pipeline infrastructure.

IV.2. Decreasing Safety Incidents on Pipelines

The number of incidents reported to OPS by industry continues to decline over time.[18] This is a reflection of the intensive efforts made by industry to improve safety and the regulatory efforts by OPS over several decades. The number of incidents for all types of pipeline systems is shown in Table IV-1. Improvements are reported on hazardous liquid lines, natural gas transmission and gathering lines, and gas distribution systems. New technology development is a contributor for this reduction in total pipeline incidents. This information is depicted graphically in figure IV-2.

Table IV-1. All Pipeline Incidents 1992 - 2003[19]

Year	Actual or Target	Hazardous Liquid Pipelines	Gas Distribution Systems	Gas Transmission and Gathering Systems	Total
1992	Actual	212	103	74	389
1993	Actual	229	121	95	445
1994	Actual	245	141	81	467
1995	Actual	188	97	64	349
1996	Actual	194	110	77	381
1997	Actual	171	102	73	346
1998	Actual	153	137	99	389
1999	Actual	167	118	54	339
2000	Actual	146	154	80	380
2001	Actual	130	124	87	341
2002	Actual	144	102	82	328
2003	Actual	128	143	98	369
2003	Target	126	132	69	327
2004	Target	120	125	65	310
2005	Target	114	119	62	295
2006	Target	108	113	59	280

Data as of 09/15/2004

The goal of OPS is to reduce the number of pipeline incidents or accidents by 5 % per year, from 380 per year in calendar year 2000 to 280 in 2006 as illustrated in figure IV-2. To do so will require intensive efforts in inspection and assessment. New technology will be a major factor in achieving the goal.

[18] Any pipeline incident must be reported when there has been an injury, fatality, fire, or explosion, a spill of 5 gallons or more, or where damage to property exceeds $50,000.

[19] Source: Office of Pipeline Safety. Incidents reported via RSPA 7100.1 (gas transmission), RSPA 7100.2 (gas distribution), and RSPA 7000-1 (hazardous liquid pipelines).[19]

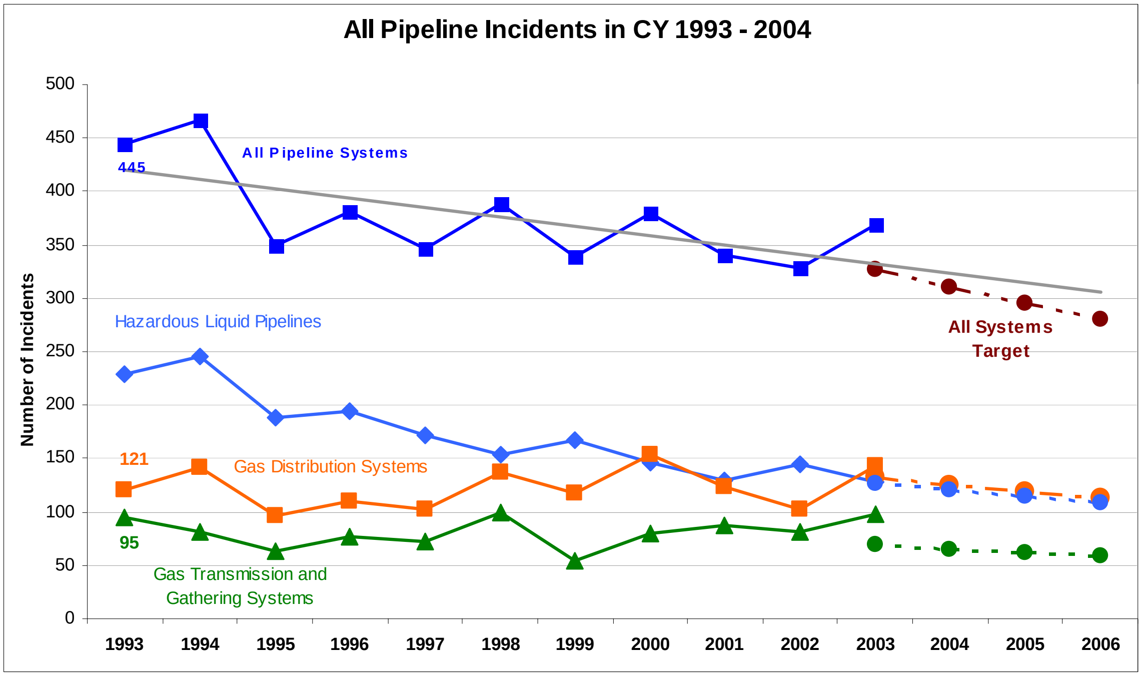


Figure IV-2. Chart Showing the Number of Pipeline Incidents from 1993 to 2003 Plus Goals

IV.3. Analysis of Pipeline Incidents

Both industry and safety regulators have examined the data on safety incidents to determine the fundamental causes. Incidents on gas pipeline systems from 1985 to 2003 were reported in four categories: construction causes and operator error, corrosion, damage by outside force, and a collection of causes labeled "other". From data for gas transmission systems, shown in figure IV-3, damage by outside force is listed as the cause of 38% of pipeline safety incidents. Safety incidents classified as "other" account for 26% of all incidents. 22% are caused by internal and external corrosion. And 13% are caused by construction defects and operating errors. The large percentage of incidents related to outside force and corrosion explains the emphasis on safety measures that address these causes.

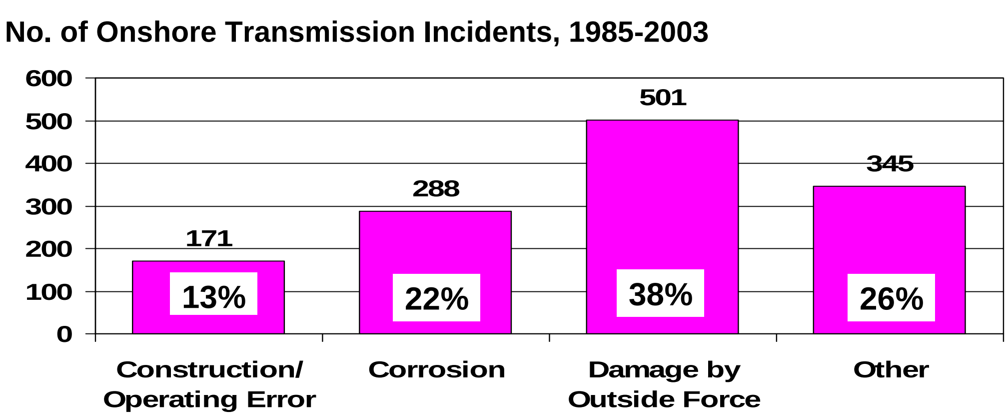
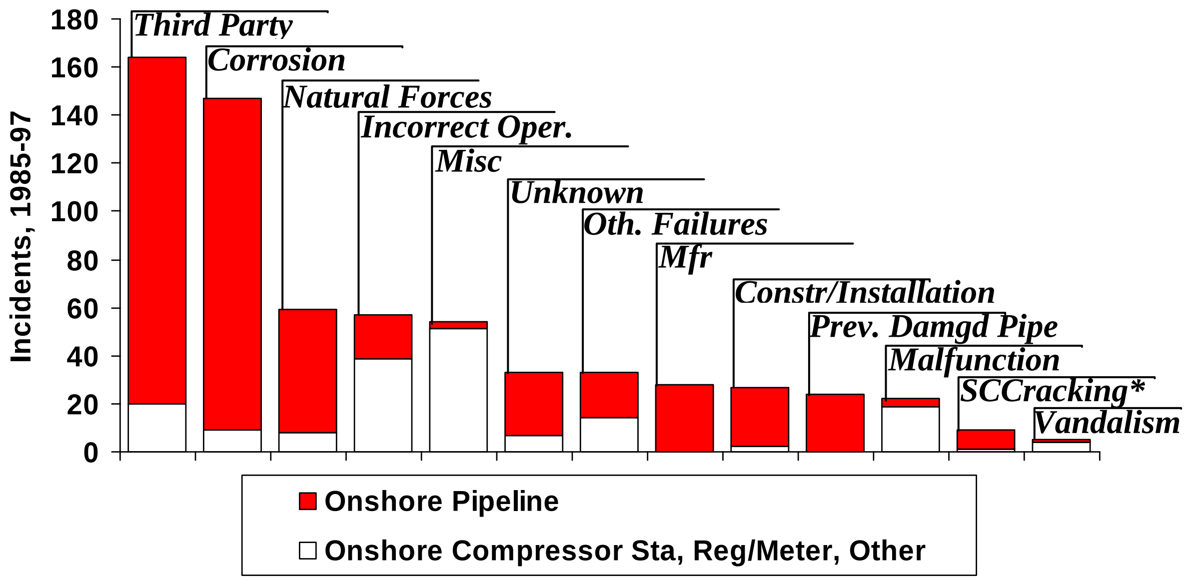


Figure IV-3. Safety incidents on gas pipeline systems reported to OPS in the years 1985-2003.

An industry research group, PRC International (PRCI), has taken OPS incident data and conducted further analyses. In a report by Kiefner and Associates[20], PRCI expanded the number of cause categories to 22. Some of the 22 causes have been combined to simplify the presentation. The data presented in figure IV-4 show onshore and offshore incidents reported by gas transmission and gathering system operators. Out of 662 incidents reported, about 75% occurred on pipeline segments. The rest occurred at such facilities as compressor stations, regulators, and meters. The cause labeled Natural Forces includes causes associated with cold weather, heavy rains or floods, lightning, and earth movement. Construction and Installation causes include defective fabrication welds and defective girth welds. Manufacturing defects include defective pipe and defective pipe seams. Corrosion includes both internal and external corrosion. Other causes are grouped into Other Failures, including gasket, O-ring, seal, and pump packing failures; threads, broken pipe, and coupling failures; and wrinkles, bends, and buckles in pipe.



*SCCracking: Stress Corrosion Cracking.
Recompilation of Kiefner and Associates analysis of RSPA Form 7100.2 for Pipeline Research Committee International (Contract No. PR-218-0801). Excludes incidents involving operators that file RSPA's Distribution System Annual Report, Form 7100.1-1).

Figure IV-4. Analysis of the most common causes of safety incidents on gas transmission and gathering systems from an analysis performed by Kiefner and Associates for the PRC International.

Third party damage is the leading cause of incidents, causing about 25% of the total. Another 5% is labeled Previously Damaged Pipe. Third parties also cause some of these failures. Corrosion as the second leading cause of safety incidents, occurring in 22% of the total of onshore incidents. The third highest category, safety incidents related to Natural Forces, accounts for 9% of incidents. Other significant categories of onshore incidents include Incorrect Operations, Manufacturing defects, Construction and Installation defects, system Malfunction, and Stress Corrosion Cracking (SCC). The few remaining incidents are grouped into Unknown, Miscellaneous, Other Failures, and Vandalism categories.

[20] J. F. Kiefner et.al. "Analysis of DOT Reportable Incidents for Gas Transmission and Gathering Systems Pipelines, 1985 through 1997". Prepared by Kiefner and Associates, Inc., Worthington, Ohio, for PRC International, 1999.

A better understanding of the causes of failures will help to focus efforts on safety-related conditions and focus technology development efforts on prevention of incidents and mitigation of consequences. Starting in 2004, OPS has expanded the categories of apparent causes of pipeline failure from 4 to 25 in incident reports from pipeline operators. These 25 are grouped into major categories of corrosion, natural forces, excavation damage, other outside force damage, material and/or weld failures, equipment malfunction or failure, incorrect operation, and other.

IV.4. The Revolution in Pipeline Safety Regulation

The public rightly expects that pipelines safety regulators will take every reasonable action to prevent accidents and minimize their consequences. Despite the fact that pipelines are getting safer, recently there have been several significant and visible accidents that have increased public concerns for their safety. These accidents have caused OPS and the Congress to reexamine the regulations on which we base our confidence in pipeline safety. OPS is focused on reducing both the number of incidents and their severity.

One of the drawbacks of the regulatory structure prior to the 1990s was the view of pipelines as a collection of components and procedures. This compartmentalization reflected the way companies were organized. As an example, pipeline operators often had separate departments for engineering and corrosion control. Operations to maintain pipeline integrity were perceived as a set of distinct activities as opposed to an integrated process. The most significant aspect of the new risk management efforts was the comprehensive, systematic manner in which companies began to approach their systems. Risk assessment led pipeline operators to integrate data on the condition of the system, engineering design, service history, and the physical environment in which the pipeline operated. Data integration is critical to integrity management.

The Pipeline Risk Management Demonstration Program was authorized in 1996 to test whether a structured and formalized process for identify pipeline-specific risks, whether allocating resources to the most effective risk control activities, and whether monitoring safety and environmental performance can lead to superior safety and environmental protection. Results of this program were used in the considerations for an Integrity Management Program (IMP).

In 1999, OPS set forth a plan to develop and promulgate integrity management rules for all pipeline systems under its jurisdiction. OPS established a list of priorities and began rulemaking to formalize testing and inspection requirements for pipelines. A rule for Integrity Management in high consequence areas applicable to liquid pipelines of 500 miles or greater was issued in December 1999. OPS received comment and promulgated the rule in December 2000.[21] OPS published a similar rule for Integrity Management in high consequence areas for natural gas transmission in late 2003.[22] The OPS has begun an initiative to develop rules for natural gas distribution systems. The IMP was made a requirement in the Pipeline Safety Improvement Act of 2002 (PSIA-2002).

The IMP requires that operators periodically assess all pipeline segments in high consequence areas through internal inspection, pressure testing, and other effective assessment methods. In general, high consequence areas are identified in areas of high population, places where people congregate frequently, or areas of unusual environmental sensitivity. The assessments must include analysis of information gathered from inspections, tests, surveillance and right-of-way patrols, cathodic protection surveys, and relevant data gathered from other sources such as the potential for pipe damage due to excavation.

Standards and regulations continue to be developed with the introduction of new technology and new understanding of pipeline risks. The focus of these efforts has shifted from preventing a recurrence of past incidents to a proactive system of integrity management. By anticipating problems, inspecting lines for

[21] See http://primis.rspa.dot.gov/iim/ruletextamended.htm
[22] See http://primis.rspa.dot.gov/gasimp/docs/FinalRuleAmended_gas_full.pdf

possible defects, and taking preventive measures to protect the public, both industry and government regulators expect to see further improvements in pipeline safety. This reexamination of the regulatory structure has identified a number of areas in which the safety performance of pipelines could be significantly improved through technology development and demonstration.

IV.5. New Technology Needed

Technology development through R&D has been a critical factor in expansion of most if not all economic sectors of the United States and the world. From new technologies, public utilities have become more efficient and reliable, new medicines and medical equipment have increased cure rates and life expectancy, and automobiles are designed for greater safety. Many of these statements can be made for the oil and gas industry and pipelines as well. According to the Department of Energy, the petroleum business has transformed itself into a high-technology industry.[23] Technology advances are making it possible for the oil and gas industry to grow in tandem with the nation's energy needs while maintaining a cleaner environment.[24]

The fact that pipelines are generally buried underground complicates inspection and condition assessment. Pipelines can be inspected visually and with special instruments but visual inspection means digging bellhole excavations at particular locations at considerable expense. New lines are pressure tested to ensure that the lines do not leak and can be safely operating at planned operating pressures. Bellhole inspections are useful when a piece of pipe is suspected of having defects and the excavation is needed for confirmation or characterization of the defect. Much can be learned from integration of data and knowledge of pipe condition from pressure tests; history of leaks or failures; electrical surveys that help to assess coating damage and the potential for active corrosion; knowledge of soil conditions; and operating history. Many pipelines were built or modified to accept internal inspection tools (smart pigs). Depending on the type of tool, in-line inspections can detect metal loss, wall thinning due to corrosion, damage from construction or outside force, and certain types of crack defects. No one method of inspection or assessment can provide a complete picture of pipeline condition.

Many pipelines cannot accommodate internal inspection tools. Other facilities such as pump and compressor stations have significant amounts of pipe, some buried and some above ground, that cannot be inspected internally with pigs as illustrated in figure IV-5. Certain defects are still extraordinarily difficult to detect or assess with accuracy, including crack-like defects. The challenges to OPS and industry are to find new methods of inspecting and assessing pipe condition and to expand our ability to integrate data from different methods for a more complete picture.

We have witnessed dramatic improvements in pipeline materials, fabrication, and construction over the past 50 years. Pipe is being made of higher-toughness, higher-strength steel with greater quality, especially in the welded seams. New coatings impervious to hostile soil conditions can now be applied in the field as well as the factory. Operators continue to get better at managing the systems in place through corrosion controls, cathodic protection, and electrical surveys. As materials and fabrication methods change, new models of materials performance and pipe failure modes will be needed.

Our understanding of defects is still lacking. Pipe failures can occur from three types of defects: static defects perhaps left during construction; time-dependent defects such as active corrosion, and random defects such as those caused by outside force. OPS will focus attention on specific defect types to understand their

[23] Department of Energy. "Environmental Benefits of Advanced Oil and Gas Exploration and Production Technology". 2001. <http://fossil.energy.gov/programs/oilgas/publications/environmentalbenefits/>
[24] American Petroleum Institute. "State-of-the-Art Technology has Transformed the Oil and Natural Gas Industry". 2001. <http://api-ec.api.org/printerformat.cfm?ContentID=CEE8B682-667C-11D5-BC6A00B0D0E15BFC>

frequency, the pattern of failure that can occur, methods of detecting, characterizing, and assessing such defects; root causes for the presence of defects; and defect mitigation.

Figure IV-5. Unpiggable Lines at a Compressor Station

Perhaps the most difficult challenge is the prevention of damage to pipe from human activity. One-call systems are making a difference. But technology is needed to detect the presence of unauthorized activities on the pipeline right of way. Aerial and foot patrols while necessary and useful are not enough. While demonstrably difficult to achieve in practice, innovative technology is needed to detect contact with pipe. Time after time pipelines have experienced delayed failures from contact with the pipe that has been unreported and gone undetected. As the demand for energy grows in the U.S. along with development along pipeline rights-of-way, OPS will examine strategies for mitigating risk to people in the proximity of pipelines. This may involve guidelines for land use in special cases, changes in construction, or improvements in pipeline monitoring and assessment. Technology will play a role in risk management.

IV.6. Changing Responsibilities for Pipeline Safety R&D

Research and development is a component of most economic sectors. The amount of private funding for R&D activities varies greatly from one sector to another as shown in figure IV-6. For example, one of the highest R&D investments as a percentage of net sales is the pharmaceutical industry. In the energy industry, only 0.5 percent of industry sales are reinvested into R&D. Industry consolidation of major oil and gas operators through numerous company mergers has resulted in reductions in energy-related R&D investments. Pipelines have become more, not less, competitive over recent years. Increasing competition limits the ability of pipeline operating companies to fund R&D. The pattern of reductions in total energy R&D can be seen in figure IV-7.

This phenomenon along with several major pipeline failures in the 1990’s has brought a greater R&D role for the government and OPS. Prior to legislation proposed in 1999, OPS had sponsored research and development at a modest level. In 1970, the first year of any research, the amount of money obligated for research was $308,000, whereas in the fiscal year 2001 budget, the amount was $2,744,000. Funding for R&D began to increase in the 1990’s as a result of two significant pipeline failures and the resulting emphasis on risk management. 1993 saw the release of 8000 barrels of diesel fuel into Sugarland Run, a tributary of the Potomac River, near Reston, Virginia. In 1994, a natural gas pipeline rupture in Edison, New Jersey, destroyed 15 apartment buildings resulting in the evacuation of 1500 people. Because these accidents occurred near major media markets, they were highly publicized. Congress reacted by increasing appropriations for research in 1995.

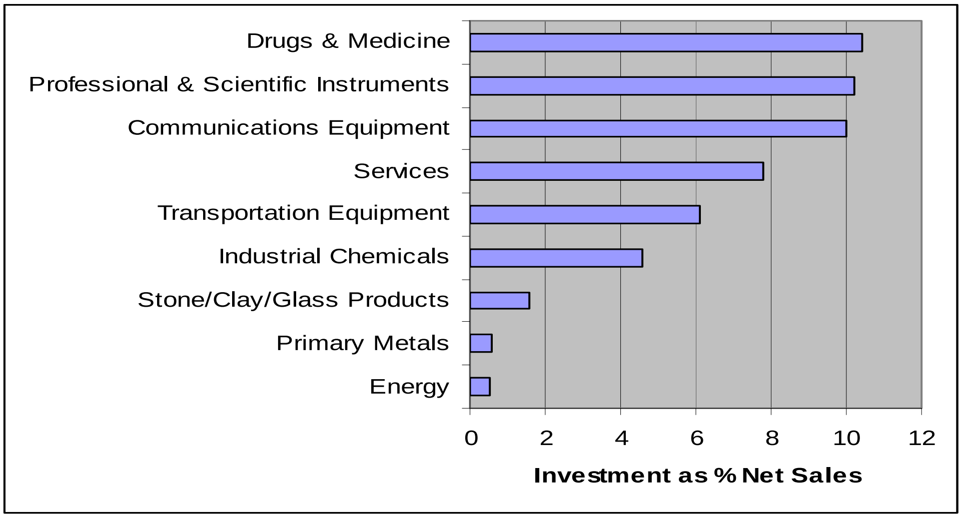


Figure IV-6. U.S. Economic Sectors and R&D Investment as Percentage of Net Sales.[25]

In 1997, a Memorandum of Understanding was established between OPS and the Gas Research Institute (GRI). The first research conducted under this MOU was a $3.1 million project with Battelle, Southwest Research Institute and Iowa State University to expand the ability of magnetic flux leakage pigs to detect mechanical damage. Industry funding for natural gas pipeline safety R&D has since declined. Research funded by GRI came from revenues collected through a uniform volumetric surcharge on the throughput of interstate natural gas pipelines. This changed in 1997 with the beginning of a phase out of the surcharge. The end of the surcharge in 2004 also reduces gas industry funding for pipeline safety R&D in the areas of gas distribution, gas storage, and LNG as well as funding for environmental research. OPS research funding was dramatically increased in fiscal year 2002 paving the way for a national pipeline safety research agenda.

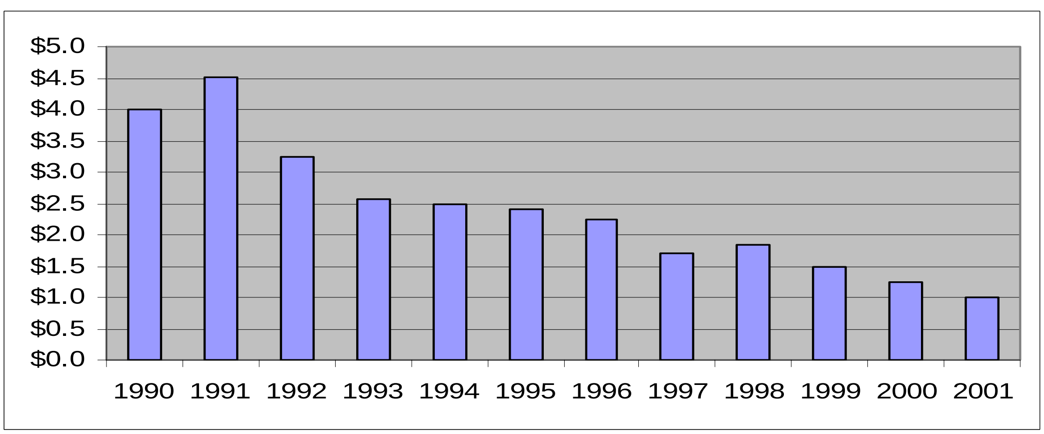


Figure IV-7. Total U.S. Energy RD&D Funding, 1990-2001 (billions of dollars)[26].

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[25] Source: 1995 Data from National Science Foundation, *Margolis & Kammen*, Science, 1999

[26] "Gas Industry Collaborative RD&D: 2005-2009 RD&D Plan & 2005 RD&D Program" Draft, May 26, 2004, figure 1-3, page 21, < http://www.gastechnology.org> (Source: National Science Foundation, Annual Surveys of RD&D)

V. Designing the Pipeline Safety Research Agenda

With all of the changes in pipeline safety regulation combined with new OPS responsibilities in research and technology development, OPS made special efforts to solicit the advice and guidance of stakeholder groups and outside experts in establishing a national pipeline safety research agenda. The agenda has also been influenced by recommendations from Congress, the Administration, State pipeline safety regulators, the Government Accountability Office (GAO), and the National Transportation Safety Board (NTSB). The pipeline industry has a long history of safety related research going back 50 years. OPS made use of prior work plus the expertise gained by industry and its R&D organizations.

V.1. Soliciting Ideas and Opportunities

In November 2001, OPS conducted a pipeline safety R&D workshop which brought together government agencies (federal, state, and local), research institutions, pipeline companies and their associations, standards organizations, and public representatives to begin identifying priorities needs and technologies for development as part of a national pipeline safety research agenda. The results of the workshop were molded into a set of focus areas. These focus areas in turn were the subject of a series of Broad Agency Announcements (BAAs) seeking promising projects to address the priority issues. BAAs were issued in 2002, 2003, and 2004. The solicitations requested ideas for tackling problems in the areas of damage prevention and leak detection; enhanced pipeline operations, controls, and monitoring; and improved pipeline materials and other safety improvements.

Another source of information on technology needs has come from the design and implementation of OPS regulatory initiatives in integrity management. In preparation for the integrity management rules, OPS worked with industry to evaluate the state of knowledge of threats to pipeline integrity and the availability of techniques to characterize threat significance. This evaluation has identified several areas in which current knowledge is incomplete and several prevalent pipeline conditions for which assessment technologies are lacking. This information has fed into the R&D project selection process, especially the issues of non-piggable pipelines and improved in-line inspection techniques.

The standards developing organizations (SDOs), with support from the pipeline industry, began the design of new engineering standards for integrity management. Out of this process additional issues have been identified. One key new standard has been the ASME B31.8S on Managing System Integrity of Gas Pipelines published by the American Society of Mechanical Engineers. Other standards are under development by NACE International, the American Petroleum Institute, and others.

The R&D priorities were used to guide the budget requests as presented in the Pipeline Safety Improvement Act of 2002 (PSIA-2002). Priorities were also reflected in the DOT FY 2003 Annual Budget Document for Pipeline Safety and subsequent budget documents.

V.2. The Joint Government and Industry Pipeline R&D Forum

In December 2003, OPS hosted the Joint Government and Industry Pipeline R&D Forum in partnership with the PRC International, Inc (PRCI) and the Gas Technology Institute (GTI). The Forum brought together over 130 representatives from state, and foreign government offices along with domestic and foreign natural gas and hazardous liquid pipeline operators. Participation included the National Institute for Standards and Technology, the Association for Oil Pipelines, the Interstate Natural Gas Association of America, and the American Gas Association. Overviews of current research efforts were presented by the Department of Energy, Department of Interior's Minerals Management Service, NYSEARCH/Northeast Gas Association, Solution Mining Research Institute, Gas Machinery Research Center, Interstate Natural Gas Association of America Foundation, and In-Line Inspection Association.

The Forum's goals included identifying key challenges facing industry and government, sharing information on current research efforts, and identifying research that can help to meet the challenges. A number of key technical challenges were identified including:

- Aging pipelines and facilities.
- Limitations in the strength of pipe materials and their resistance to mechanical and chemical damage.
- Limitations in existing techniques to locate steel and plastic pipe to avoid excavation damage.
- Absence of proven techniques to remotely monitor rights-of-way.
- Assessment of pipe segments that cannot internally inspected with pigs.
- Limitations on the ability to detect small leaks.
- Acceptability of in-service repair techniques.
- Limitations in the ability to evaluate the integrity of prime movers (e.g. pumps and compressors) to support preventive maintenance decisions.

In addition to these technical challenges, speakers at the Forum described several other institutional and communication issues, including:

- The need for R&D expenditures to be viewed as useful by the full range of operator constituents.
- Better communication of the value and impact of investments in pipeline R&D.
- Managing the continuity of supply while maintaining predictable prices.
- Preserving and expanding the pool of experienced and expert people in the industry.

V.3. The Blue Ribbon Panel

OPS created a Blue Ribbon Panel to ensure that the R&D Program is aligned with the needs of the pipeline safety mission, makes use of the best available knowledge and expertise, and considers stakeholder perspectives. The Blue Ribbon Panel has representatives from federal and state agencies involved in pipeline safety, industry R&D-funding organizations, pipeline trade associations, and standards organizations. At the June 2003 meeting, OPS sought the perspective of the Panel on R&D priorities, program design, and measures to evaluate the effectiveness of the R&D investment. At the May 2004 meeting, the Blue Ribbon Panel reviewed the scope and implementation of the Broad Agency Announcements (R&D solicitations), the program structure as embedded in the R&D Strategic Plan, the submissions to the OMB Program Assessment Rating Tool (PART) evaluation, and R&D performance measures.

Information from the R&D Forum and the Blue Ribbon Panel Meetings can be found on the OPS website at http://primis.phmsa.dot.gov/rd.

V.4. Guidance from State Pipeline Safety Officials

With the new regulatory requirements established in recent years, new challenges and responsibilities are created for OPS and its state partners, especially in the areas of evolving technical knowledge, increasing reliance on codes and standards, and effective inspection and oversight functions.

While the federal government is primarily responsible for developing, issuing, and enforcing pipeline safety regulations, OPS may authorize a state to act as its agent to inspect *interstate* pipelines, but retains responsibility for enforcement of the regulations. The pipeline safety statutes provide for state assumption of the *intrastate* regulatory, inspection, and enforcement responsibilities under an annual certification. A state agency which does not satisfy the criteria for certification may enter into an agreement to undertake certain aspects of the pipeline safety program for intrastate facilities on behalf of OPS. All but three states, Alaska, Hawaii, and Idaho, are currently participating in the natural gas pipeline safety program. Fifteen states participate in the hazardous liquid pipeline safety program. Most states have supported the concept of common stewardship in pipeline safety. The federal/state partnership is the cornerstone for assuring uniform implementation of the pipeline safety program nationwide.

The National Association of Pipeline Safety Representatives (NAPSR), established in 1982, is an organization of state agency pipeline safety managers who are responsible for the administration of their state's pipeline safety programs. NAPSR provides an effective mechanism for fostering the federal/state partnership through 52 state agencies whose mission is, "to strengthen state pipeline safety programs through promotion of improved pipeline safety standards, education, training, and technology". NAPSR has proposed to assist OPS in identifying technical pipeline issues and needs. After polling its Regional Chairs, NAPSR will collect and create a comprehensive list of prioritized technical needs. Annually, NAPSR will provide OPS with its “Top Five” list of pipeline technical issues and needs.

V.5. The Five Year Interagency Research &Development Program Plan

The Pipeline Safety Improvement Act of 2002 (PSIA-2002) mandated that federal agencies involved in pipeline safety R&D formalize a plan for coordination and cooperation. OPS has acted on the mandate in the PSIA-2002 initially by developing a Five Year Interagency R&D Program Plan to guide and integrate R&D and standards activities of the Department of Transportation (DOT), the Department of Energy (DOE) and its National Energy Technology Laboratory, and the National Institute of Standards and Technology (NIST).[27] While it is not one of the agencies formally required to participate in the development of the interagency five-year program planning, the Department of Interior (DOI) Minerals Management Service (MMS) was invited to contribute to the plan development. Processes described in the plan have been designed to better integrate the activities of each participating agency, including federal collaboration in seeking stakeholder perspective on critical issues, promising technologies and areas deserving the highest priority for R&D funding. These processes will serve to maximize the effectiveness of federal investment in R&D. Collaboration and communication activities for the participating agencies include the following.

- Semiannual interagency meetings to assess progress on projects and overall program effectiveness.
- Joint R&D solicitations, including publication of an integrated interagency procurement schedule to increase the predictability of the procurement process, thereby assisting proposing organizations to respond effectively to appropriate solicitations.
- Joint R&D Forums to gather stakeholder input on critical issues, candidate technologies and development priorities.
- Technology demonstrations involving interagency hand-off of R&D project responsibility as technologies mature.
- Technology applications and transfer promoted by joint agency efforts.

Procurements will continue to be the responsibility of the respective agencies. A Memorandum of Understanding (MOU) for the implementation of the Five Year R&D Plan was approved by the agencies in 2004. This MOU identifies program elements, as well as specific areas of agency expertise, and establishes a framework for coordination and collaboration by the participating agencies. The participating agencies recognize the need to work together to identify pipeline facility research priorities, discern the most promising research proposals, avoid duplication of research and development efforts, assure coordination and collaboration, advance technological solutions, and involve outside stakeholders. The pipeline safety act (PSIA-2002) identifies 10 categories of research, development, and demonstration. These ten categories together with the federal agencies having lead responsibility for related R&D are listed in Table V-1.

[27] “Five Year Interagency Research and Development Program Plan for Pipeline Safety and Integrity”. Jointly developed by the Department of Transportation, the Department of Energy, the National Institutes of Standards and Technology, and the Minerals Management Service. May 2004.

	Table V-1. Lead Agency Responsibilities for R&D Program Elements from PSIA 2002		
	Program Elements	**On-Shore**	**Off-Shore**
1.	Materials inspection	DOT	DOI
2.	Pipe anomaly detection	DOT	DOI
3.	Internal inspection and leak detection technologies	DOT	DOI
4.	Methods of analyzing content of pipeline throughput	DOT	DOI
5.	Pipeline security	DOT	DOI
6.	Risk assessment methodology	DOT	DOI
7.	Communication, control, and information systems surety	DOT	DOI
8.	Fire safety of pipelines	NIST	DOI
9.	Improved excavation, construction, and repair technologies	DOT	DOI
10.	Other appropriate elements	DOT	DOI
	a. Materials analysis & development	NIST	NIST
	b. Standardization activities	NIST	NIST

DOT was assigned responsibility for assuring the safety and integrity of hazardous liquid and natural gas pipelines through R&D activities designed to support identification, characterization, detection and management of risks to safety and integrity. DOE historically focused on developing new and advanced infrastructure technologies having greater developmental risk and expected to be commercialized over a longer time frame. The Administration has proposed to transfer responsibility for developing these pipeline safety technologies to the Department of Transportation's Office of Pipeline Safety. NIST was given responsibility for developing standards, advanced materials, and fire safety technologies. DOI through MMS took responsibility for assuring pipeline safety and integrity through regulation and inspection of offshore pipelines.

VI. Strategy for R&D Management

As an initiative of the President's Management Agenda, the Office of Management and Budget (OMB) has provided R&D investment criteria that R&D program managers should use to plan and assess their programs.[28] These are based on a review of the best R&D planning and assessment practices in government. The R&D investment criteria address not only planning, management, and prospective assessment but also retrospective assessment. Review of the results and impacts of completed R&D can determine whether the investments were well-directed, efficient, and productive as an essential element of validation of program design and confidence in the prospects for future work. The key investment criteria are (1) Relevance, (2) Quality, and (3) Performance. Programs which include industry or market-relevant activities must meet additional criteria.

VI.1. R&D Investment Criteria

To meet the test of *Relevance*, the R&D program must have complete plans, with clear goals and performance criteria relevant to the needs of the Nation. Programs must articulate the potential public benefits of the program with emphasis on the mission of the performing agency, the technical and scientific merit of the technological innovation, and the needs of the customers impacted by the program. Program relevance must be assessed periodically through retrospective external review.

To meet the test of *Quality*, programs must be awarded appropriately and assessed for quality of results in a clear and transparent manner. Value is placed on procurement processes for solicitation and award of contracts that are systematic, clear, and based on a competitive, merit-based process. Programs allocating funds through means other a competitive, merit-based process must justify the funding method and document how quality is maintained. Program quality must be assessed periodically through retrospective external review.

To meet the test of *Performance*, programs must be managed in a manner to produce intended results derived from short and long-term R&D objectives. Performance goals must be established for appropriate output and outcome measures, project schedules and milestones, and decision points. Programs must annually document both program inputs and program performance. Performance measures or metrics should be applied to promote performance and also innovation, cooperation, and dissemination of knowledge, applications, and tools.

For programs designed to be implemented by industry or introduce a product or concept in the marketplace, programs should demonstrate that federal investment is the best means to support federal policy goals. Programs must articulate public benefits of the program and justify the appropriateness in terms of market failure to motivate private investment. Programs must also assess the readiness of the market to adopt technologies. Program designs must include mechanisms for application of results and entry into the marketplace.

OPS has developed a set of management elements and associated management goals to guide the R&D program in terms of Relevance, Quality, Performance, and industry-related activities. OPS has organized these elements in the categories of (1) Program Management, (2) Coordination and Collaboration, (3) Communications, and (4) Technology Transfer. Activities in each of the elements are guided by management goals with expected results as listed in Table VI-1.

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[28] Appendix A: For Research and Development Programs: R&D Investment Criteria. "Instructions for the Program Assessment Rating Tool." http://www.whitehouse.gov/omb/part/2006_part_guidance.pdf

Table VI-1. Management Elements of OPS R&D Program

	Management Elements	Management Goals
1.	Effective and Efficient Program Management	Efficient and effective management of the R&D program
2.	Coordination and Collaboration with Other Agencies, Industry, and Other Stakeholders	Understand technology needs, assess technology gaps identified by stakeholders, and coordinate R&D activities with other agencies and R&D organizations
3.	Communication of R&D Program Activities, Results, and Impacts	Effective communication of program activities, results, and successes to stakeholders
4.	Technology Transfer and Application of Results	Effective and rapid deployment of technology from the R&D program

VI.2. Effective and Efficient Program Management

The guiding principle for management of the R&D program is the enhancement of pipeline safety. The goal of effectiveness means that every resource should be invested with a view toward maximizing impact. The goal of efficiency means that the goal of impact should be achieved as rapidly as possible with the least expenditure of resources. Effectiveness starts with strategic planning and program design against the backdrop of pipeline safety needs and technology gaps. Effectiveness is determined by measurement of performance against specific goals and performance metrics. R&D workshops, including the Joint Government/Industry R&D Forum, are mechanisms for gathering ideas, concepts, guidance, and knowledge from all stakeholders as input to program design. OPS seeks the cofunding of R&D projects through the solicitation process, both to leverage the funding resources in the OPS budget and to incorporate the interests of stakeholders. Cofunding organizations take a direct and focused interest in project results, quality, and impact. OPS has created a Blue Ribbon Panel to ensure that the R&D Program is aligned with the needs of the pipeline safety mission, uses the best available knowledge and expertise, and considers stakeholder perspectives. OPS will evaluate the program and the performance of individual projects through a peer review of projects using outside experts.

To accelerate the placement of R&D contracts in a competitive, merit-based process, OPS issues Broad Agency Announcements (BAAs) to solicit the best ideas for technologies and concepts in the form of white papers. Proposals are invited from organizations whose ideas have the greatest potential impact. OPS manages the activities of its contractors and grantees through a carefully planned and implemented program of oversight. At the completion of the competitive procurement process, each project is assigned to a certified Contracting Officer's Technical Representative (COTR) as required by the federal Acquisition Regulations.

Performance is measured through a set of performance measures that establishes program and project accomplishments against the performance goals. Specific performance goals and performance measures have been developed and are described in the OPS R&D Performance Plan. The results are reported to the Office of Management and Budget (OMB) as evidence for the Program Assessment Rating Tool (PART) evaluation. To aid OPS R&D managers with the inventory and organization of large responses to research solicitations and in the monitoring of project activities and retrospective reviews, a new Pre and Post Award Management Information System has been implemented. An R&D Logic Model has been developed in which each current project is described in terms of its principal activities, expected outputs of the project, the customers or stakeholders addressed by the project, the desired outcomes for the project within three years of completion, and the expected impact of the activity in terms of enhanced pipeline safety.[29] The Logic Model can be used to describe the program in terms of the relationship of activities to long term impacts on pipeline safety.

VI.3. Coordination and Collaboration with Agencies, Industry, and Other Stakeholders

The R&D program is not managed in a vacuum. OPS recognizes that other organizations, including government agencies, non-government research organizations, R&D funding organizations, and industry and its trade associations can contribute to the achievement of enhanced pipeline safety through their knowledge and efforts. Awareness and planning around closely-related programs can enhance the achievement of safety goals through program synergies and the leapfrogging of activities. Coordination can also avoid unnecessary and wasteful duplication of effort. In other sections we describe a number of coordination efforts such as the Joint Government/Industry R&D Forum and the Interagency Five-Year R&D Program Plan which coordinates activities among OPS, DOE, NIST, and MMS. Coordination activities include R&D workshops, external program reviews, joint technical conferences, and stakeholder reviews.

Since it inception in 1968, OPS has incorporated relevant engineering standards into the Pipeline Safety Regulations by reference. As the Standards Developing Organizations (SDOs) expand, revise, and refine the consensus engineering standards, OPS uses these standards as guidance and requirements for ensuring pipeline safety. Results of significant portions of the R&D program are designed to support rulemaking and standards development.

VI.4. Communication of R&D Program Activities, Results, and Impacts

OPS takes every opportunity to communicate the nature of the program—program descriptions, project activities, results, and impacts. OPS compiles and disseminates information on projects and the R&D program using a database and related website called PRIMIS, accessible by the public at http://primis.phmsa.dot.gov/rd. A central feature of PRIMIS is an R&D database called the "Research and Development Matrix". A screen shot of the R&D Matrix is shown below in figures VI-1.

On the website and in public forums, OPS communicates the results of projects, project descriptions, and technical reports coming out of projects. OPS encourages contractors to publish the results widely especially in technical conferences and peer-reviewed journals. OPS also announces upcoming public meetings, meetings with stakeholder groups such as the Blue Ribbon Panel, and other special events. As required by law, OPS publishes official notices in the Federal Register regarding rulemaking and special events.

VI.5. Technology Transfer and Application of Results

Successful completion of R&D projects is only part of the challenge. To ensure the effective and rapid deployment of technology from the R&D program, OPS requires that projects plan for technology transfer and application of project results. Technology transfer can be accomplished through targeted application in standards development, training programs, or commercialization of products or services. Technology transfer can involve effective communication to safety regulators, standards developing organizations, the pipeline industry, or public decision makers. Technology transfer can involve the capture of new knowledge as patents or know-how. Technology transfer can be embedded in new rulemaking directed at enhancing pipeline safety.

OPS uses technology demonstrations as a means of evaluating the merit of technologies that are reaching the prototype stage. Demonstrations expose the technologies to the environment in which the technology must

[29] See the OPS R&D Performance Plan for the R&D Logic Model.

be operated successfully. Demonstrations also promote the deployment and utilization of new technologies through observations and participation by pipeline operators, equipment vendors, standards organizations, and pipeline safety officials.

VI.6. The OPS R&D Performance Plan

Accompanying this strategic plan is an OPS R&D Performance Plan. The Performance Plan presents more detail on performance measures, the R&D Logic Model, ongoing projects, and other implementation plans.

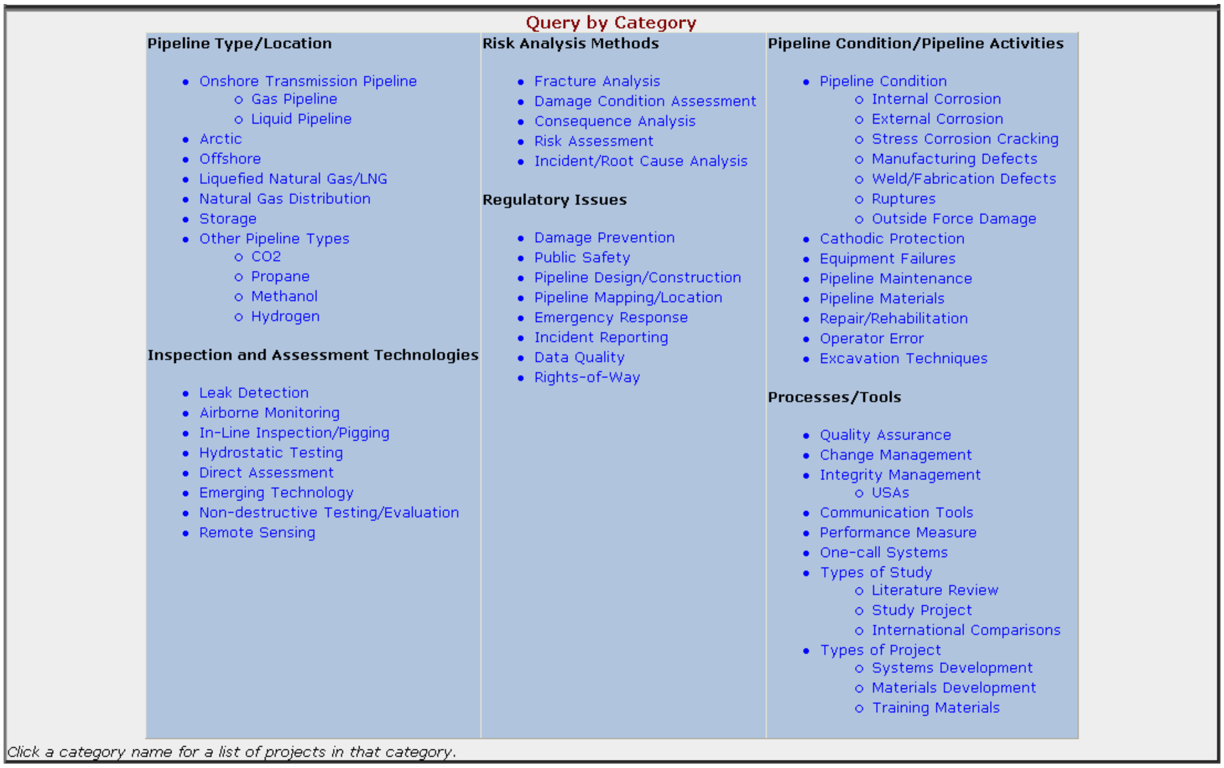

Figure VI-1. Screenshot of the R&D Matrix at http://primis.phmsa.dot.gov/matrix

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