Assessing America's Pipeline Infrastructure: Delivering on Energy Opportunities

By: Vern Grimshaw and John Rafuse
Foreword by: Brigham A. McCown

February 2014

United Transportation Advisors, LLC

TABLE OF CONTENTS

FOREWORD

Today, the United States stands at the precipice of an "energy renaissance." Driven by newly discovered resources, technological innovations, and a skilled workforce, America has rapidly transitioned from a net energy importer to a net exporter. Experts of all stripes agree that the question has shifted from whether we will embrace the energy revolution, to how we will best leverage our new resources.

Yet one of the most important considerations for meeting U.S. energy potential is often overlooked: how these resources will safely, efficiently and economically be transported to market. U.S. energy infrastructure will largely determine America's ability to develop its vast resources, which in turn will impact nearly every sector of the economy.

In his State of the Union Address this year, President Obama pledged to "keep working with the [energy] industry to sustain production" while simultaneously "strengthening protection of our air, our water, and our communities." As a former federal regulator, I commend the President's foresight. Sustaining production requires new standards, technologies, and investments to strengthen U.S. pipeline infrastructure.

Over the past two decades, the 2.6 million miles of U.S. pipelines have experienced fewer and less impactful incidents. However, more must be done to strengthen this vital artery of our economy. In this paper, contributors –Jack Rafuse and Vern Grimshaw – identify several areas where government and the energy industry can work together to maximize pipeline safety by ensuring a dynamic regulatory system that provides flexibility for incorporating new technologies and prioritizes research and development. To keep America running, and protect our communities and environment, authorities must ask: How can we work together to more safely and efficiently transport our energy resources from production fields to consumers?

Brigham A. McCown

INTRODUCTION

This paper provides an overview of U.S. pipeline infrastructure, offering insight into its history, performance, and barriers to long-term safety and efficiency.

The data, maps, graphs and charts are from government and industry sources, including the U.S. Energy Information Administration, Association of Oil Pipe Lines, and the Interstate Natural Gas Association of America. Other data is from background papers prepared by the Association of American Railroads and a recent Issues Brief by Diana Furchtgott-Roth of the Manhattan Institute for Policy Research (#23, June 2013).

This paper seeks to inform public policymakers in Washington that while America has tremendous opportunities given its vast energy resources, without incorporating new technology, finalizing needed regulations and providing timely siting approvals, and coordinating between industry and government, America's energy renaissance will not reach its maximum potential. A focus on bolstering U.S. pipeline infrastructure by incorporating new regulations, technologies, and reviews is necessary to improve safety and spur energy investment, the impact of which will be felt far beyond energy producing states.

The policy recommendations below combine the views of contributors based on their experience and expertise within the industry.

EXECUTIVE SUMMARY

The United States' energy delivery system – millions of miles of pipeline and rail infrastructure coupled with barge and truck capabilities – is the most sophisticated in the world. America's pipeline footprint is unparalleled when compared with other nations and is statistically the safest mode of domestic energy transport. Yet, despite its strong safety record, it is not without incident, as we are reminded by incidents in recent years that have disrupted communities and inflicted heavy clean-up costs.

Given the vast reserves of shale oil and gas, U.S. pipeline infrastructure will see significant traffic in the decades to come. The U.S. is expected to surpass Russia as the world's largest natural gas producer by 2015, and as the world's largest oil producer by 2016[i], in part, due to the system in place to move it to market.

However, current domestic production from shale oil and gas is outpacing new pipeline approvals. Existing infrastructure is not sufficient to move the expected increase in oil and gas resources. Research and development ("R&D") is providing new technologies that can improve the durability and availability of pipeline safety materials. However, a slow regulatory environment is not keeping pace with these emerging technological developments. This is impeding the expansion of infrastructure, which would help to more effectively transport energy resources throughout the country.

Delays in the regulatory process are forcing energy producers to forego the use of pipelines in lieu of less efficient shipping modes, which in turn could lead to an increase of avoidable accidents. In North Dakota, for example, forecasts predict as much as 90 percent of oil produced in 2014 will be transported by rail, up from 60 percent in 2013.[ii]

In short, by failing to act, regulators are effectively mandating inefficiencies into the system, which disrupt the market and stifle investment and development.

We recommend government and industry renew their focus on regulations and specifications governing pipeline infrastructure, including but not limited to the following:

1. Action by federal regulators (i.e., Pipeline and Hazardous Material Safety Administration) to review and revise the codes (49 CFR Part 192 and 195 in particular) necessary to improve pipeline transportation and enforcement as well as facilitate regulatory decision-making so that pipeline operators and owners can plan long-term investments;

2. Renewed focus and funding support for pipeline technology research and development efforts to ensure that the U.S. energy transportation system remains the safest for decades to come (see Appendix III: Pipeline and Hazardous Materials Safety Administration (PHMSA) list of projects); and

3. Emphasis on review and modernization of industry best practices and specifications surrounding emerging technology like improvements in composite pipe materials and leak detection technologies.

[i] Source: International Energy Agency
[ii] Source: http://goo.gl/NYk8jT

CHAPTER 1:
A HISTORY OF THE U.S. PIPELINE SYSTEM

Sparked by a boom in energy demand and rising transportation costs, America's first successful oil pipelines were constructed in the mid-1860s. Initially operated by gravity, the first lines moved crude oil from Pennsylvania production fields to nearby refineries and storage units. Within decades larger pipelines from Texas, California, Oklahoma and Kansas had largely replaced horse-carts and railcars as the primary methods of oil transportation. By World War II, the demand from industrial growth and the popularity of automobiles required an infrastructure of large, technically sound pipes, which phased out early smaller lines.

Today, there are about 2.6 million miles of pipeline that carry oil and natural gas in the U.S. alone. These lines are even able to "batch" and move different products at the same time – usually unseen and unknown to most people.

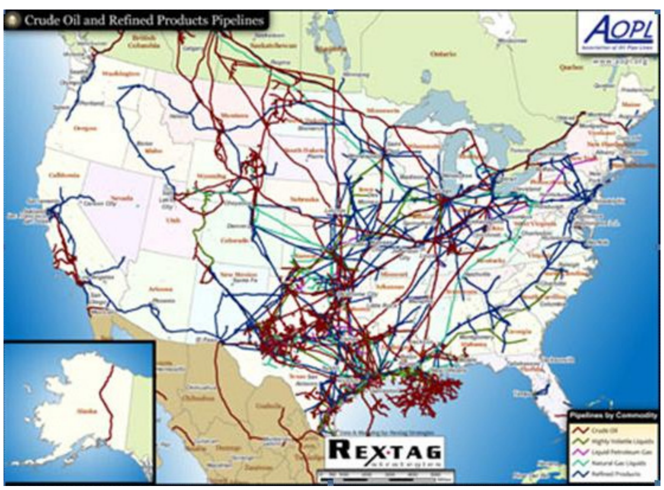

Figure 1: The Footprint – U.S. crude oil and petroleum product lines
Source: Association of Oil Pipelines

The domestic pipeline system makes up the largest, safest, most efficient, and most automated energy infrastructure in the world. Figure 1 details U.S. crude oil and petroleum product lines in North America. A recent report by the Congressional Research Service noted, "These transmission pipelines are integral to U.S. energy supply and have vital links to other critical infrastructure, such as power plants, airports, and military bases."

Recognizing the vital importance of America's pipelines, in 2004 President Bush signed legislation establishing the Pipelines and Hazardous Materials Safety Administration (PHMSA) within the U.S. Department of Transportation. Tasked to "protect people and the environment from the risks inherent in transportation of hazardous materials by pipeline and other modes of transportation," the organization is responsible for overseeing and ensuring the safety and security of the U.S. pipeline system, which carries 64 percent of the energy consumed in the U.S.

A Domestic Energy Boom: The Challenge of Keeping Up with Demand

Unlike any other time in recent history, the United States is now positioned to both meet energy needs at home and help supply international markets. Stimulated by greater domestic energy production and developing technologies, in 2013 America became a net exporter of energy.

One of the chief drivers behind America's energy resurgence is a product that in recent years has become a household name: natural gas. Found in shale formations near oil deposits, it is estimated the U.S. holds the second largest reserve of natural gas in the world – enough to meet American demand for over a century. Like other fuels, natural gas is shipped through the pipeline system – first to processing plants, then to local mains and distribution lines, and finally to homes, businesses, industrial customers, or overseas markets.

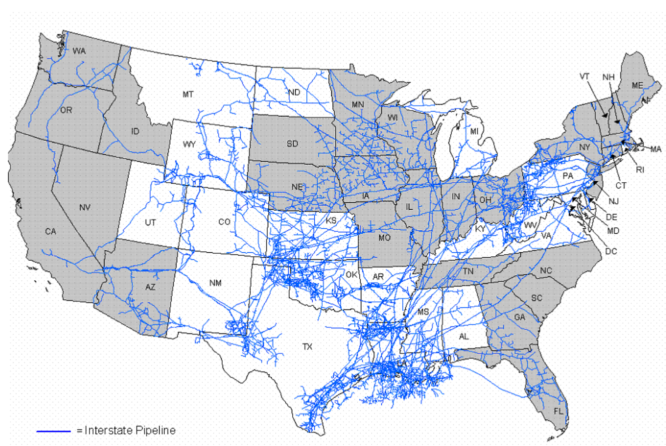

Figure 2: Interstate Natural Gas Supply Dependency, 2007
Source: Energy Information Administration, "Annual Report of Natural Gas and Supplemental Gas Supply and Disposition"

Figure 2 displays interstate gas pipelines with nearly two-thirds of U.S. states (shaded in grey) being almost entirely dependent on the interstate network for natural gas supply.

Yet our country's ability to harness the gains created by natural gas and other energy developments are threatened by a slow-moving regulatory policy. In 2011, President Obama signed the Pipeline Safety, Regulatory Certainty, and Job Creation Act (Pipeline Safety Act), which contained a broad range of provisions aimed at providing "the regulatory certainty necessary for pipeline owners and operators to plan infrastructure investments and create jobs." However, to date the administration has fallen short of issuing regulations necessary to unlock key infrastructure investments.

> "...our country's ability to harness the gains created by natural gas and other energy developments are threatened by a slow-moving regulatory policy."

In 2012, a study by the Interstate Natural Gas Association of America (INGAA) found that the time to obtain federal authorization for international pipeline projects increased significantly since 2005, when the Energy Policy Act was passed – ostensibly – to help streamline the process. As a result, investment in the U.S. pipeline infrastructure has fallen and technological developments that could further improve the safety and efficiency of the system have remained sidelined.

In 2012, U.S. natural gas pipeline investment plunged to its lowest level since 1997. Simply put, impediments in the regulatory process are preventing the level of pipeline construction necessary to fully realize our country's energy production possibilities.

In 2013, Congressman John Dingell, former Chairman of the House Energy and Commerce Committee, in a letter to Transportation Secretary Anthony Foxx expressed concerns about the need for more responsive regulation. Rep. Dingell noted that the demand for new and upgraded pipelines and regulations "likely will outpace" Department of Transportation abilities.

In fact, they already have. This month the Director of Mineral Resources for North Dakota told the Legislature's Government Finance Committee that he expects 90 percent of all Bakken oil to be shipped by rail in 2014, up from 60 percent in 2013.

Separately, INGAA president and CEO Donald Santa called for support of the pending Natural Gas Pipeline Permitting Reform Act. He points out that under the Energy Policy Act of 2005, the Federal Energy Regulatory Commission (FERC) was given the power to set deadlines for other agencies in the pipeline permitting process, but not the authority to enforce them – allowing agencies to "routinely ignore" deadlines. Santa suggests implementing a 90-day deadline for approving or denying authorization of the new pipeline projects and notes that companies typically work with FERC and other regulators for 12 to 18 months before submitting an application.

Now, as the pipeline industry stands wrapped in regulatory gridlock, investors are moving their funds elsewhere – buying rail tankers instead of waiting on pipeline approvals.

CHAPTER 2:

SAFETY AND EFFICIENCY: COMPETING MODES OF TRANSPORTATION

From the earliest ramshackle lines that moved oil from production fields to refineries, to the state of the art systems proposed for the Keystone XL pipeline today, the energy industry has constantly assessed and improved on its practices, procedures, and incorporation of new technology. Although railroad and barge still play an integral part of the energy distribution process, today pipelines move about two-thirds of all oil and petroleum products.

Table I: U.S. crude oil and petroleum product transport by Mode (billions of ton-miles)

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Share [c]
Crude oil, total	**376**	**376.6**	**384**	**380.4**	**374.1**	**376.3**	**366**	**335.5**	**372**	**336**	
Pipelines [a]	283.4	277	286.6	284.5	283.7	293.5	300.5	266.6	306.3	268.2	80
Water carriers	91	98.1	95.7	94.1	88.7	81.1	63.8	66.9	63.2	65.1	19
Motor carriers [b]	1.2	1.1	1.2	1.3	1.2	1.4	1.4	1.6	1.7	1.7	1
Railroads	0.4	0.4	0.5	0.5	0.5	0.4	0.4	0.4	0.7	1	0
Refined petroleum products, total	**497.3**	**493.2**	**480.6**	**502.9**	**528.4**	**529.7**	**489.4**	**499.9**	**485.9**	**474.1**	
Pipelines [a]	293.9	299.1	299.6	305.7	315.9	314	280.9	291.1	299.4	300.2	63
Water carriers	153.4	145.9	131.9	146	158.2	159.4	149.3	149.1	130.8	121.7	26
Motor carriers [b]	30.1	29.7	29.4	31.9	33.2	33.4	33.8	33.5	33.4	32.2	7
Railroads	19.9	18.5	19.7	19.3	21.1	22.8	25.4	26.2	22.3	19.9	4
Crude and petroleum products, total	**873.3**	**869.8**	**864.6**	**883.3**	**902.5**	**906**	**855.4**	**835.4**	**857.9**	**810**	
Pipelines [a]	577.3	576.1	586.2	590.2	599.6	607.5	581.3	557.7	605.7	568.4	70
Water carriers	244.4	244	227.6	240.1	246.9	240.5	213.1	216	194	186.8	23
Motor carriers [b]	31.3	30.8	30.6	33.2	34.4	34.8	35.2	35.2	35.1	33.9	4
Railroads	20.3	18.9	20.2	19.8	21.6	23.2	25.8	26.6	23	20.9	3

Notes:

a Beginning with 2006, pipeline data were taken from PHMSA F 7000-1-1. Previously, data were extracted from FERC Form No. 6, which included data for federally-regulated pipelines. For 2005, data for federally regulated pipelines were estimated to include about 90 percent of the total national ton-miles, so the pipeline statistics for that year were adjusted to include an additional 10 percent of ton-miles. From 1990 through 2004, the federally regulated estimate was 84 percent with a 16 percent addition for other pipeline ton-miles.

b The amount carried by motor carriers is estimated.

c Share shipped by mode in 2009 (percent)

Details may not add to totals due to rounding in the source publication.

Source: Association of Oil Pipelines, Shift in Petroleum Transportation, 1990-2009

Although evidence demonstrates that pipelines are the safest method of transportation for oil and gas, economics, simple timing or delays in the regulatory and permitting processes can force energy producers to use a variety of methods. For example, when a remote gas or oil field is established far from pipelines with the capacity to ship the product, there are typically three scenarios:

1. If economics are viable, a new gas gathering pipeline will be constructed to connect the production field to the nearest transmission system or processing facility.
2. For crude, if a new pipeline is not cost effective, developers may consider trucking crude to the nearest refinery or shipping it by rail.

3. If neither of the two options above is economically viable, the field will remain closed and undeveloped. Wellhead natural gas costs can fluctuate on demand, and developers closely predict long-term markets when considering investment (in recent years they have largely held between $3 and $4 per thousand cubic feet).

Because of the large initial capital investments, carriers will not build new lines unless a producer commits – and a production field demonstrates the ability – to ship for a term long enough to amortize the initial investment. Carriers will accept nominations from producers for fixed volumes and years, and size the system to accommodate those volumes. But even nominations present difficulties; shippers are reluctant to commit to certain capacity when regulatory and other uncertainties prevent them from being assured of future volumes.

"Despite the vast investment in infrastructure, today America's oil and natural gas production exceeds pipeline capacity."

When pipeline projects are delayed or bogged down, rail transportation is often the next best option for crude oil. Unit trains may also be more economical than pipelines if a receiving facility needs a specific grade of crude or if the produced crude is incompatible with a common carrier stream.

The major disadvantage to rail transportation is capacity. A 100 car train with 600 barrel per car capacity and a three-day round trip might average 10,000 bpd to 15,000 bpd capacity. A nominal sized pipeline would move 100,000 bpd to 200,000 bpd, the equivalent of ten to twenty trains daily. Not to mention, trains must then return to the oil field empty in order to be refilled; a pipeline, of course, does not.

More than 2.6 million miles of interstate pipelines cross America to deliver oil, natural gas and other refined products and distillates each year. By any measure – numbers of incidents, injuries, fatalities and fluids recovered – pipelines are the safest and most effective form of energy transportation. From 2005-2009 pipelines recorded 0.7 incidents per thousand miles, a 63 percent decrease from 1999-2001. The U.S. Department of Transportation estimates that pipeline is 450 times safer than rail on a per mile basis.

Despite the vast investment in infrastructure, today America's oil and natural gas production exceeds pipeline capacity. The Association of American Railroads says that from 2008 to 2011 the total share of oil and gas rail shipments grew from 2 percent of all carloads to 11 percent. In 2011, rail capacity in the Bakken shale area (Southern Alberta to the northern U.S. Great Plains), tripled to almost 300,000 barrels per day. In September 2012, U.S. railroads were on pace to deliver 200,000 carloads for the year, compared to 66,000 in 2011 and 9,500 in 2008.

Table 2: Comparative Statistics for Petroleum Incident Rates
Onshore Transmission Lines vs. Road and Railway (2005-09)

Mode	Avg. Billions Ton-Miles Shipment Per Year	Avg. Incidents Per Year	Incidents Per Billion Ton-Miles
Road*	34.8	695.2	19.95
Railway*	23.9	49.6	2.08
Hazardous Liquid Pipeline	584.1	339.6	0.58
Natural Gas Pipeline	338.5	299.2	0.89

*Only incidents involving and ton-mileage carrying those products carried by pipeline (petroleum products, liquid natural gas, etc.) are counted for road and railway

Sources: Ton-Mileage values are based on Tables 1-50 (for Natural Gas Pipeline) and 1-61 (all others) of the Department of Transportation, Research and Innovative Technology Administration, Bureau of Transportation Statistics "National Transportation Statistics", available at http://www.rita.dot.gov/bts/sites/rita.dot.gov.bts/files/publications/national_transportation_statistics/index.html, accessed April 2013. Incident and release volume data for Road and Railway were extracted from the Office of Hazardous Materials Safety "Incident Reports Database Search" at https://hazmatonline.phmsa.dot.gov/IncidentReportsSearch/, accessed April 2013. HL Pipeline release volumes were extracted from the Pipeline and Hazardous Material Safety Administration "Hazardous Liquid Accident Data - 2002 to 2009" file available at http://phmsa.dot.gov/portal/site/PHMSA/menuitem.ebdc7a8a7e39f2e55cf2031050248a0c/?vgnextoid=fdd2dfa122a1d110VgnVCM1000009ed07898RCRD&vgnextchannel=3430fb649a2dc110VgnVCM1000009ed07898RCRD&vgnextfmt=print, accessed April 2013.

CHAPTER 3:
RECOMMENDATIONS

I. Accelerate Regulatory Process for Pipeline Safety

PHMSA Regulations

It has been more than three years since the Department of Transportation announced in the Federal Register its comprehensive review of hazardous liquids and natural gas transmission pipeline regulations (49 Code of Federal Regulations Part 192 and 195 respectively). Since then, no notices, guidance or updates have been provided. As Congressman John Dingell pointed out in his letter to Secretary Foxx, "the lack of action on this front is not only disturbing to a public that is concerned about the safety of our quickly growing system of pipelines, but it is also unsettling to the industry, which has no certainty as to what the rules will be going forward."

In addition, the agency has yet to implement key elements of the Pipeline Safety Act of 2011, including technology integration for leak detection and remote-controlled shutoff valves and further evaluation and definition of high consequence areas. Promulgation of pipeline-related regulations would provide needed guidance and certainty to companies as they seek to make long-term investment in energy infrastructure.

Keystone XL Pipeline

Like any financial deal, timing is very important in the energy industry. Delays and setbacks can carry huge price-tags and often derail projects completely. The Keystone XL Pipeline and the consequences of its delay are a prime example.

The Keystone pipeline is a proposed cross-border project to transport crude oil from Alberta, Canada, to refineries in the southern United States. The initial plans for the pipeline project were introduced in 2005. In 2008, an extension project – Keystone XL – was proposed. Following more than five years of review and more than $5 billion invested by owner Transcanada, the Obama Administration has yet to make a decision on the 1,179-mile northern leg. Because the project crosses the U.S.-Canada border it requires presidential approval. The southern leg of the project began moving product last month.

Opposition to the Keystone XL pipeline comes largely from environmental and activist groups who have lobbied against the project, often using unsubstantiated arguments, such as: the crude oil from Canada is more corrosive and could damage the pipeline; other countries won't capitalize on U.S. inaction (China is and will); or other modes of transportation could just as effectively procure the resources.

For many, the Keystone XL pipeline issue has become a purely political issue. Still, away from the media attention of Keystone, there are many other proposed pipeline projects awaiting the same regulatory decisions, often for years. For the average project, a pipeline company may spend a year or more in preparation before formally applying for permits and then wait for years to get the necessary approvals before beginning construction and operation. And there is growing unrest the regulatory process will only continue to become more onerous.

> "Collaboration between government and the private sector helps improve the safety of the U.S. pipeline infrastructure."

II. Improve Government and Industry Coordination

Collaboration between government and the private sector helps improve the safety of the U.S. pipeline infrastructure. Recommended practices and specifications prepared through industry evaluation can better inform federal and state regulations. Federal agencies should place renewed emphasis on utilizing the vast resources of information available when preparing pipeline regulations and enforcing them.

Government and industry should also continue to work together to improve pipeline safety and reduce accidents, even before they happen. And in the unfortunate case when incidents do occur, the ensuing investigation provides an opportunity for regulators and companies to quickly work together to identify and correct the conditions that led to the incident and prevent future incidents.

The following examples demonstrate several instances in which collaboration helps improve pipeline regulations and safety:

- Organizations like the American Petroleum Institute (API), the American Society of Mechanical Engineers (ASME), the American Society for Testing and Materials (ASTM), and the National Association of Corrosion Engineers (NACE), and others develop industry standards for oil and gas industry. The Pipelines and Hazardous Materials Safety Administration (PHMSA), which formulates, implements and oversees regulation of the industry, regularly cites those standards as it promulgates rules.
- Workshops, guidance documents, and recommended practices yield best practices for government and industry for system design, operations, maintenance applications and incorporation of new technology. Working groups of individuals from government and industry take on specific issues and develop consensus recommendations.
- Creation of databases for leak and incident reporting can teach operators about crises and how to take corrective action.
- Establishment of one-call systems across the country, with uniform guidelines to prevent damage to underground facilities.
- Formation of entities like Common Ground Alliance, a member-driven organization dedicated to public safety, environmental protection and service integrity through effective damage protection practices. Industry, government (federal, state and local) and individuals comprise the membership.
- Funding government and industry academic research throughout the country to study specific industry issues beyond the interest of individual companies. Conferences sponsored by government and industry where papers are presented on a broad spectrum of issues. These conferences and papers also inform operators on new regulations, standards, and technology.
- The Gas Technology Institute (GTI) membership includes dozens of government and industry organizations and agencies whose primary focus is on research and development (R&D) projects applicable to the gas industry.

Additionally, the regulatory process is a long one, which requires input from all interested parties. The bureaucratic nature of the system can take an inordinate length of time. Greater coordination between industry and government can enable greater public participation and help streamline the process for regulatory modifications and permit reviews.

III. Rapidly Incorporate Advanced Technology and Innovation

With support from government agencies and academic research, the energy industry has continually invested in technology research to improve pipeline integrity. This research must be focused on providing a 21st Century energy delivery system. In order to fully realize the cost, safety, and efficiencies of these new technologies, the government must incorporate flexibility into the rulemaking process. Some of the more promising advancements that are already available, but may be facing unnecessary regulatory hurdles include leak detection, "smart pig" technology, and composite pipes.

> "Flexibility to incorporate emerging technologies must be incorporated into the rulemaking process."

Leak Detection Basic Research

PHMSA funds basic research and development on all aspects of pipeline safety (leak and mechanical damage detection and prevention; improved line system controls; and improved pipeline materials). There are 27 such projects from 2013 or planned for 2014 on the PHMSA website detailed in Appendix IV. Any new or improved technology must apply to a specific problem, be understood and managed by system operators, and prove cost-effective. The primary objective of all pipeline integrity improvements is to prevent, or substantially reduce the negative effect of, pipeline failures.

Research into leak detection and response to pipeline releases is done by PHMSA and the industry. There has been great improvement since "meter out vs. meter in" measurements as the only way to alert operators. New methods are being created, tested and applied to improve leak detection and awareness.

Leak detection can be categorized in one of three ways:

1. Real time monitoring to proactively curtail system operations;
2. Real time monitoring that alerts human controllers to evaluate system controls and determine the need for curtailing operations; and
3. On-the-ground observation or post-incident notification from third parties.

Typically operators optimize new leak detection systems to immediately identify the smallest leak, shut down the pipeline, and alert officials. Over-fine tuning, however, can result in false alarms, which interrupt operations and can cause controllers to assume any alarm is a false positive. On the other hand, if alarm limits are set too high in order to minimize false alarms, failures may go undetected for too long.

Leak detection systems must be compatible with the pipeline to serve as a tool for the controller without interfering with operations. Real time leak detection is common practice for the industry. Even so, when an alarm sounds, controllers evaluate the abnormality, analyze flow rates and pressures along the system, and assess the severity of the incident. New technology gives the controller better information with which to make those calls.

The simplest real-time monitoring measures the volume balance in pipeline segments by comparing the amount of outgoing product to the amount of incoming, or "meter-out to meter-in" balance. The system then analyzes differences that could suggest a segment leak. Other internal methods use volume balance with enhanced sensitivities and pressure monitoring, acoustic pressure wave analysis, and mass flow balancing.

Industry regularly explores ways to improve the sensitivity and reliability of internal and external monitoring systems. Several examples include:

- Meter design improvements incorporating software technology to adjust or correct for unique system anomalies.
- Sensor-related algorithms to model internal conditions unique to a specific pipeline segment (such as acoustic wave analysis or mass balancing).
- Evaluating the feasibility of external monitoring equipment (leak detection tubing or fiber optic leak detection).
- Real time leak detection capability is better in liquid pipelines than in gas systems (gas compressibility makes small changes in volume measurements more difficult to identify). The most effective means of leak detection for gas systems is acoustic monitoring, which much research aims to improve.
- Research continues with software-based dynamic modeling of flow parameters to improve reliability and sensitivity.

Smart Pig Technology

Researchers also use in-line inspection devices, or "smart pigs," that are sent through the pipeline to report inconsistencies along the route. Smart pig technology is capable of identifying minute irregularities, dents and gouges, internal and external corrosion, cracks and laminations, and anomalies in pipe weld seams joints. Smart pig capabilities still have limitations, particularly in identifying minute anomalies along longitudinal weld seams.

Pipe manufactured before the early 1970s by low current Electric Resistance Welding (ERW) proved to be vulnerable to failure. Research is focused on creating a better understanding of these types of failures and the means to improve detection capabilities.

Composite Pipe Technology

One example of technology innovation includes composite piping, consisting of a durable thermoplastic resin and fiberglass with a reinforced steel center, for oil and gas gathering. Composites have been proven in demanding oil and gas pipeline applications for decades and provide benefits to operators and owners including the ability to quickly install it in a variety of landscapes, less degradation over time, and lower costs for installation than traditional steel applications.

While its usage is restricted to low pressures by regulatory authorities, research confirms that it could safely be expanded. Most federal and state regulatory bodies limit usage to no more than 125 pounds per square inch in oilfield flow lines and small gas distribution systems. Expanded usage, while likely still not suitable for larger high-pressure, high-volume transmission pipelines, could prove more beneficial for moderate pressure gathering lines and trunk laterals than steel.

Used in the U.S. through a special permit process, this technology is in use globally including in Canada, Mexico, Russia, South America and Europe. Composites are either pure or a steel-composite hybrid, which uses steel as the primary carrier and is reinforced with composite materials to add strength and corrosion protection. The composite components are meant to add strength and protection from internal or external corrosion. Industry touts its enhanced flow rates, environmental performance and lower costs for maintenance.

Composites do have some limitations. Unlike steel, they have a higher susceptibility to mechanical damage from external sources, lower tolerance to external loading, limited unsupported span lengths, and inadequate underground support. Each of these factors can be alleviated during the design and installation of the systems.

APPENDIX I:

FREQUENTLY ASKED QUESTIONS

What kinds of oil and gas products move by pipelines? Oil pipelines move liquid petroleum and some liquefied gases. Crude oil lines move unrefined oil that varies in density, viscosity, sulfur content and other properties. Other product lines move more than 50 refined products, including: gasoline, home heating oil, diesel fuel, kerosene, jet fuels, liquefied ethylene, propane, butane and some petrochemical feed-stocks.

How do operators know if a leak or rupture has occurred? One pipeline uses several methods and technologies to identify possible weaknesses and prevent leaks or other accidents. Highly trained professionals digitally monitor flow rates and internal pressure; lines are frequently inspected on foot or from vehicles; computer programs compare historic inspection data; and new technologies allow "smart pigs" or other in-line machinery to move inside the pipe to spot variations in product thickness and other signs of pipeline weakness.

Who owns the crude oil and products shipped through the pipelines? Oil producers and traders contract with pipeline companies. Generally, pipeline companies are separate from the oil-producing companies and serve as "common carriers."

How are new pipeline routes determined? Potential routes respond to demand outlook, which is based on the predicted flow of crude oil from a producing field to a refinery or processing facility, or the expected flow of refined products from a refinery complex to various markets. During initial planning alternative routes are studied as well, and considerations like construction costs, projected market growth, demand for pipeline service over a contract term, shipping rates, and return on investment are all weighed.

Environmental factors are weighed as well to ensure local ecologies are not disturbed and that in the case of an incident, the procedures are in place to minimize harm to the surrounding areas. During this time, hearings and documentation are conducted to fully capture all the considerations of the project.

State governments oversee and regulate pipeline construction within their borders. There are no federal laws for siting liquid pipelines. In addition, pipeline companies negotiate with private and public property owners and sign contracts for land-use easements (rights-of-way) before anything can be done.

Are pipeline rates negotiated with shippers? Not generally. They are part of a tariff schedule published by pipeline companies and on file with the Federal Energy Regulatory Commission (FERC). All shippers pay the same rates, hence the term "common carrier." FERC allows negotiated rates if those are then published and available to all shippers.

Do shippers know the volumes, destinations, or routing of liquids being shipped by their competitors? No. Such disclosure is prohibited by law.

What moves petroleum through a pipeline? Generally, electric-motor centrifugal pumps, or at times, diesel engines or gas turbines move oil or gas products through a pipeline. The pumps are sited at originating and booster stations and are remotely controlled from computerized control centers staffed by highly-trained operators.

How far apart are the pumping stations? Between 20 and 100 miles depending on terrain and the pressure inside the line.

How safe are pipelines? By every measure they are the safest way to transport oil, gas, chemicals and other fluids based on mode-to-mode comparisons, ton-miles, injuries per incident, liquids recovered per incident, etc. Chapter 2 provides a more detailed discussion.

How fast does oil move through a pipeline? Product moves at 3 to 8 miles per hour depending upon line size, pressure and factors such as viscosity and density of the oil. Thus it takes 14 to 22 days] days to move refined oil product from Houston to New York City.

How can you tell a pipeline location? Pipelines are well marked, to prevent damage from digging (the most common cause of pipeline accidents) or other activity. Yellow, black and red warning signs and ID markers are located at frequent intervals along pipeline rights-of-way, and at water, rail and road crossings. County-by-county location information can be found in the National Pipeline Mapping System Public Map Viewer. Further, anyone planning to dig should call 811, the National "Call Before You Dig Center," which routes the call to the correct local information center. Utility companies then send a "locator" to mark underground wires, pipes and other utilities – a great service that works.

APPENDIX II:

COMMON ACRONYMS AND DEFINITIONS

Acronyms:

AOPL	Association of Oil Pipelines
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BCFD	Billion Cubic Feet per Day
BPD	Barrels per Day
CFR	Code of Federal Regulations
CGA	Common Ground Alliance
DOT	Department of Transportation
EIA	U. S. Energy Information Administration
ERW	Electric Resistance Weld
FERC	Federal Energy Regulatory Commission
GTI	Gas Technology Institute
HCA's	High Consequence Areas
INGA	Interstate Natural Gas Association of America
mcf	Thousand cubic feet
mmcf	Million cubic feet
NACE	National Association of Petroleum Engineers
NTSB	National Transportation Safety Board
OPS	Office of Pipeline Safety
PHMSA	Pipeline and Hazardous Materials Safety Administration
R & D	Research and Development

Definitions:

Composite pipe	Pipe made up of thermoplastic resin with reinforcing materials, or steel with a composite material wrapped on the outside or inserted inside as a liner; commonly used for gas gathering
Electric Resistance Welding	Joining the longitudinal seam of pipe by the welding process
Heat affected zone	The area at the end of pipe joints that is heated from the welding process
Lidar	A combination of the words light and radar. A process similar to radar but using light (laser) instead of sound
Smart Pigs	Devices installed into pipelines that move along with liquid or gas flow, instrumented to detect pipe anomalies
Ton miles	One ton of a commodity transported per one mile distance
Unpiggable pipeline	A pipeline system that cannot accommodate the movement of an internal inspection device

APPENDIX III:
INDUSTRY/ GOVERNMENT COORDINATION

Research and Development Program Awards

PHMSA annually funds grants to university research centers and other qualified entities to do studies on pipeline operations, maintenance and safety. This is a listing of the program awards for 2013 and those planned to start in 2014.

Projects started in 2013:

- Subsurface Multi-Utility Asset Location Tool
- INO Technologies Assessment of Leak Detection Systems for Hazardous Liquid Pipelines
- Real-Time Multiple Utility Detection During Pipe Installation Using Horizontal Directional Drilling (HDD) System
- Advanced Leak Detection LiDAR
- Advanced Development and Technology Transfer of a Methane/Natural Gas Microsensor
- Development, Field Testing and Commercialization of a Crack and Mechanical Damage Sensor for Unpiggable Natural Gas Transmission Pipelines
- EMAT Sensor for Small Diameter and Unpiggable Pipe
- Improve and Develop ILI Tools to Locate, Size, and Quantify Complex/Interacting Metal Loss Features
- Utilization of a Test Facility for Qualifying Processes for Inline Inspection (ILI) Technology Evaluation and Enhancements
- Above-ground Detection Tools Including Disbondment and Metal Loss for all Metals Including Cast-Iron Graphitization
- Evaluation of Structural Liners for the Rehabilitation of Liquid and Natural Gas Piping Systems
- Technology Transfer, Demonstrations and Post-Mortem Testing of Cast Iron and Steel Pipe Lined with Cured-in-Place Pipe Liners
- In-Ditch Validation Methodology for Determination of Defect Sizing
- The Effect of Pressurized Hydrogen Gas on the Fatigue Properties of the Heat-Affected Zones in X52 and X70 Pipelines
- Characterization of Modern High Toughness Steels for Fracture Propagation and Arrest Assessment

Projects planned to start in 2014:

- Improving Quality Management Systems (QMS) for Pipeline Construction Activities
- Radio Frequency Identification (RFID) Smart Corrosion Coupon”
- Scaling Factors and Self-Sensing in Composite Repairs of Corrosion Defects
- Permanently Installed Pipeline Monitoring Systems
- Proactive and Hybrid Sensing based Inline Pipeline Defects Diagnosis and Prognosis”
- Composite Self-sensing Thermal Sprayed Coatings for Pipeline Corrosion Prevention and Mitigation
- Mitigating External Corrosion of Pipelines Through Nano-Modified Cement-Based Coatings
- Advanced Nondestructive Characterization of Pipeline Materials”
- Enhanced Mitigation of Pipeline Biocorrosion Using A Mixture of D-Amino Acids with A Biocide

APPENDIX IV:

PIPELINE PROJECTS AND STATUS

The following list of liquid and gas pipeline construction projects was taken from **several current industry publications. It does not necessarily include all that are** being planned or in progress.

A SAMPLING OF RECENT COMPLETED, PLANNED OR PROPOSED GAS PIPELINE PROJECTS		
Cheniere Creole Trail Pipeline	Creole Trail Expansion Project	Expansion
Spectra Energy	Renaissance Gas Transmission Project	New Pipeline
Spectra Energy	NEXUS Gas Transmission	New Pipeline
Transcontinental Gas Pipe Line	Dalton Expansion Project	Expansion
Algonquin Gas Transmission	Algonquin Incremental Market (AIM)	Expansion
MDU Resources Group	ND to MN	New Pipeline
Great Basin Energy Development	Great Basin Energy Project	New Pipeline
Portland Natural Gas Trans Sys	Continent to Coast Exp Project	Expansion
Millennium Pipeline Co	Upstate Pipeline Project	Expansion
Port Dolphin Pipeline LP	Port Dolphin LNG Pipeline	New Pipeline
Constitution Pipeline Co	Constitution Pipeline	New Pipeline
Texas Eastern Transmission	Ohio Pipeline Energy Network	New Pipeline
Transcontinental Gas Pipe Line	Leidy Southeast Expansion	Expansion
NiSource Gas Trans & Storage	East Side Expansion Project	Expansion
Williams Partners	Virginia Southside Expansion	Expansion
ANR Pipeline	Wisconsin 2015 Expansion Project	Expansion
Elba Express Pipeline	Elba Express Compressor	Expansion
NET Mexico Pipeline	Eagle Ford System Expansion	New Pipeline
Transcontinental Gas Pipe Line	Transco Rockaway Delivery Project	New Pipeline
Texas Eastern Transmission	TETCO TEAM 2014 Expansion	Expansion
Gulf South Pipeline	Southeast Market Expansion	Expansion
Iroquois Pipeline Co	Iroquois NY Marc Project	New Pipeline
Texas Eastern Transmission	South Texas Expansion Project	Expansion
NiSource Gas Trans & Storage	West Side Expansion Project	Expansion
Columbia Gas Transmission	VEPCO-Warren County Project	Expansion
DCP Midstream	Lucerne pipeline	New Pipeline
Transcontinental Pipeline	Mobile Bay South III Exp Project	Expansion
Williams Partners	Northeast Connector	Expansion
Columbia Gas Transmission	Line MB extension phase 2	Expansion
Spectra Energy	NJ-NY Project	Expansion
Tennessee Gas Pipeline Co	Northeast Upgrade Project	Expansion
El Paso Natural Gas	Norte Crossing Project	New Pipeline
Dominion Transmission	Tioga Area Expansion Project	Expansion
Eastern Shore Natural Gas Co	Greenspring Expansion Project	Expansion
NET Midstream LLC	Eagle Ford Midstream Expansion	Expansion
Columbia Gas Transmission	Line MB extension phase 1	Expansion
Inergy Midstream, LLC	Inergy Marc I Hub Line Project	Expansion
Merchant Energy Partners LLC	East Cheyenne Storage Header	New Pipeline
Dominion Transmission	Appalachian Gateway Project	New Pipeline
Energy Transfer Partners LP	Rich Eagle Ford Mainline Exp II	Expansion

A SAMPLING OF RECENT COMPLETED, PLANNED OR PROPOSED GAS PIPELINE SYSTEMS (CONTINUED)		
National Fuel Gas Supply Corp	Northern Access Expansion Project	Expansion
Tennessee Gas Pipeline Co	Station 230C Project	Expansion
Equitrans	Sunrise Project	New Pipeline
Tennessee Gas Pipeline Co	Northeast Supply Divers Project	Expansion
Kinder Morgan Texas Pipeline	Samalayuca Crossing	Expansion
Equitrans	Blacksville Comp Station Project	Expansion
Mississippi Hub LLC	Mississippi Hub Storage Phase 2	New Pipeline
Texas Eastern Transmission	TETCO TEAM 2012 Expansion	Expansion
Dominion Transmission	Northeast Expansion Project	Expansion
National Fuel Gas Supply Corp	Line N 2012 Expansion	Expansion
Southern Natural Gas Co	South System Expansion III Ph 3	Expansion
ANR Pipeline	Marshfield Reduction Project	Expansion
Transcontinental Gas Pipe Line	Transco Mid-South Expansion Ph 1	Expansion
Texas Eastern Transmission	Philadelphia Lateral Exp Project	Expansion
Eastern Shore Natural Gas	2011 system expansion	Expansion
Transcontinental Gas Pipe Line	Northeast Supply Link Project	Expansion
Tennessee Gas Pipeline Co	MPP Project	Expansion
Millennium Pipeline	Minisink Compressor Project	Expansion
Transcontinental Gas Pipe Line	Mid-Atlantic Connector Expansion	Expansion
Transcontinental Gas Pipe Line	Transco Mid-South Exp phase 2	Expansion
Millennium Pipeline	Hancock compressor project	Expansion
Dominion Transportation Inc.	Sabinsville to Morrisville Project	Expansion
A SAMPLING OF RECENT COMPLETED, PLANNED OR PROPOSED CRUDE PIPELINE PROJECTS		
Magellan Midstream	New products pipeline to Little Rock, AR	New Pipeline
Kinder Morgan	New crude extension to Eagle Ford area	New Extension
NuStar Energy	South Texas Crude system expansion	Expansion
Explorer Pipeline	Extension of Diluent line Manhattan, IL	Extension
Magellan Midstream	New gathering system into Longhorn Pipeline, Barnhart, TX	New Pipeline
Navigator Energy	New crude system, Big Spring, TX	New Pipeline
Double Eagle Pipeline	New condensate system, La Salle County, TX	New Pipeline
KM Energy/Valero	New products system, Norco, LA to Collins MS	New Pipeline
Centurion Pipeline	New crude system, Colorado City, TX	New Pipeline
Sunoco Pipeline	Crude gathering,Granite Wash Shale area, TX	Expansion
Koch Pipeline	New pipeline to handle Bakke crude, ND	New Pipeline
Plains All American	Extension of Oklahoma Crude system	Extension
Kinder Morgan	Expansion of crude & Condensate line, Brazoria County, TX	Expansion
Centerpoint Energy	New crude gathering lines, Bakke area, ND	New Pipeline
Blueknight Energy	New pipeline extension from NM toCrane, TX	Extension
Holly Energy	New expansion of NM crude transportation system	Expansion

APPENDIX V:
INFORMATION ABOUT THE CONTRIBUTORS

JOHN (JACK) LAURENCE RAFUSE

Dr. Jack Rafuse, a former White House energy adviser and current principal of the Rafuse Organization, advises government agencies, policy institutes, corporations and associations on energy, international trade, sanctions, national security and their interrelationships. He provides research, analysis and policy advice to companies, coalitions, trade associations, institutes, and government agencies with a focus on energy, trade, sanctions and national security issues.

For more than 25 years, Dr. Rafuse held management positions with Unocal, a California-based international oil and natural gas company. During his tenure, he oversaw corporate planning, regulatory economics, issues analysis, and government relations in addition to international and domestic troubleshooting assignments. Before joining Unocal, Dr. Rafuse worked with a U.S. Navy Department Project Office, at the Center for Naval Analyses, the White House Energy Policy Office, the U.S. Office of Management and Budget (OMB) and the Federal Energy Administration.

Dr. Rafuse completed his PhD at the University of Notre Dame. He completed his undergraduate studies at Stonehill College. His work has been featured in the *Wall Street Journal*, the Chicago Tribune, *POLITICO*, the *Washington Times*, the *Detroit News*, and the *Orange County Register*, among other national and international publications.

VERN E. GRIMSHAW

A former Vice President of Unocal Pipeline, a subsidiary of California-based Unocal, an international oil and natural gas company, Vern Grimshaw now serves as an energy consultant, providing operational audits and compliance reviews for liquid pipeline companies.

With over 40 years of management and engineering experience, Mr. Grimshaw develops procedure manuals about the operation of crude oil and multi-product pipeline systems, and about spill prevention and spill response in compliance with federal and state regulations. He has directed several joint-venture pipeline partnerships. Much of Mr. Grimshaw's experience has been particularly focused on computer-oriented pipeline control and employee training. As an advisor, he helps companies and partnerships shape policy to ensure the safety and environmental sustainability of pipeline operations.

Mr. Grimshaw earned his bachelor of science in mechanical engineering at Oregon State University, and later completed management programs at Northwestern University. He is the co-author of "Transportation of Petroleum," which was published in *A Handbook of Energy Systems Engineering*.

BRIGHAM A. MCCOWN

Brigham A. McCown is a federal transportation safety and energy infrastructure policy expert. He currently serves as the managing director of United Transportation Advisors, a Southlake, Texas-based consulting firm that specializes in trucking and energy cases.

From 2003-2007 Mr. McCown served in several leadership roles during President George W. Bush's presidency in Washington D.C. Mr. McCown was appointed by Transportation Secretary Norman Y. Mineta as the first acting administrator and first full-time deputy administrator of the newly formed Pipeline and Hazardous Materials Safety Administration, where he was responsible for ensuring federal and state security and the safety and oversight of the transportation of energy products and other hazardous materials. Mr. McCown has also served as the first general counsel of the Federal Motor Carrier Safety Administration where he was responsible for legal oversight of the nation's trucking, motor coach, moving industry and NAFTA trucking issues for the U.S. Department of Transportation.

McCown accumulated over twenty six years of active and reserve duty as a naval officer and naval aviator prior to retiring in 2013. He also holds an honorary commission of Rear Admiral (LH) in the U.S. Maritime Administration. McCown graduated from Miami University in 1988 with a degree in diplomacy and foreign affairs. He later went on to receive his law degree from Northern Kentucky University in 1997.