Peer Review Report

Pipeline & Hazardous Materials Safety Administration

Pipeline Safety Research & Development Program

Peer Reviews Conducted
May 18 & 25, 2016

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EXECUTIVE SUMMARY

The Pipeline and Hazardous Materials Safety Administration's (PHMSA) Pipeline Safety Research and Development (R&D) Program has held annual structured peer reviews of active research projects since 2006 in accordance with mandates from the Office of Management and Budget (OMB) and the Office of the Secretary of Transportation (OST) to maintain research data quality. PHMSA holds these reviews virtually via teleconference and the Internet, saving time and resources. This execution works well for panelists, researchers, Agreement Officers' Representatives, and project co-sponsors, and facilitates attendance from all U.S. time zones, Canada, and Europe.

The annual peer review continues to build on an already strong and systematic evaluation process developed by PHMSA's Pipeline Safety R&D Program and certified by the Government Accountability Office. The 2016 peer review panel consisted of one Federal employee and five academic representatives.

Fifteen projects were peer reviewed by expert panelists using 11 evaluation criteria grouped within the following four evaluation categories:

1. Project management;
2. Approach taken for transferring results to end users;
3. Project coordination with other closely-related programs;
4. Quality of project results.

The rating scale possibilities were "Ineffective," "Effective," "More than Effective," or "Very Effective." During the May 2016 review, the average program rating throughout all the evaluation categories was "More than Effective." For this year, eight projects were rated "Very Effective," with 16 projects ranked as "More than Effective." The average sub-criteria were also rated highly, underpinning these findings. The majority of peered projects and the overall program rating remained the same from the 2015 rating of "More than Effective." Weakness in project management and communication with other related efforts contributed to the lack of change in the program average. Table 4 summarizes the overall program performance based on the summary of the reviewed projects. Table 5 itemizes the project ranking order, where projects of the same score have an equal ranking. Additional details are available in Section 7, Tables 4 and 5, and in Appendix C of this report.

PHMSA is satisfied with the process performed to conduct these reviews, as well as the calendar year (CY) 2016 findings and recommendations provided by the panelists. PHMSA accepts the findings and recommendations summarized in the report. The official PHMSA response memorandum may be found in Appendix A.

1.0 Introduction

The purpose of this document is to report findings from the research peer reviews held May 18th and 25th, 2016, for PHMSA's Pipeline Safety R&D Program. The findings and recommendations in this report are derived from the scoring and comments collected from the peer review panelists.

Department of Transportation (DOT) Operating Agencies (OA) are required to develop and execute a systematic process for peer reviews and for all influential and highly influential information that the OA plans to disseminate in the foreseeable future.

Through the Information Quality Act[1], Congress directed the OMB to "provide policy and procedural guidance to Federal agencies for ensuring and maximizing the quality, objectivity, utility, and integrity of information (including statistical information) disseminated by Federal agencies." A resulting OMB Bulletin, entitled "Final Information Quality Bulletin for Peer Review," prescribes required procedures for Federal programs.

The OST produced procedures governing modal implementation of this OMB Bulletin. These procedures, combined with the OMB Bulletin, serve as the basis and justification for the PHMSA Pipeline Safety R&D Program peer reviews.

The purpose of these peer reviews is to uncover technical problems, to keep projects on target or aligned with stakeholder needs, and to give technical guidance using technically competent, independent, objective experts. These reviews are held annually for active research projects, usually occurring in the second quarter of each calendar year.

2.0 Research Program Background

PHMSA regulates safety of the design, construction, operation, maintenance, and spill response planning for over 2.6 million miles of natural gas and hazardous materials pipelines. PHMSA is focused on the ongoing reduction of incidents on natural gas and hazardous liquid pipelines that result in death, injury, or significant property damage. Additionally, PHMSA aims to reduce spills that harm the environment.

The vision of the PHMSA Pipeline Safety R&D Program is to support the pipeline safety mission of PHMSA, which is "to ensure the safe, reliable, and environmentally sound operation of America's energy transportation pipelines." The mission of the PHMSA Pipeline Safety 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."

PHMSA has regulatory responsibility for the safety of natural gas and hazardous liquid pipelines. Beginning in 2001, PHMSA began strengthening its role in assuring the safety of the Nation's pipeline system in numerous ways, including promulgating new regulations on integrity

[1] Pub. Law. No. 106-554-515(a)

management.[2,3,4] These regulations—together with the new inspection processes used by regulators to evaluate operator compliance—rely on operator access to new technologies that support improved safety and integrity performance, and on regulator access to information on the appropriate use and limitations of these technologies. Congress expanded support for the PHMSA Pipeline Safety R&D Program in 2002 to address the need for new integrity-related technologies and information on the validity of these technologies[5] As authorized by Congress, PHMSA sponsors research and development projects focused on providing near-term solutions to increase the safe, reliable, and environmentally sound operation of America's energy transmission and distribution pipelines.

The R&D program contributes directly to the PHMSA mission by focusing on three program objectives:

1. Fostering the development of new technologies that can be used by operators to improve safety performance and more effectively address regulatory requirements;
2. Strengthening regulatory requirements and related national consensus standards;
3. Educating pipeline safety officials so industry and regulatory managers and PHMSA pipeline safety field inspectors can make better decisions regarding safety issues and resource allocation.

The R&D Program is organized around six program elements, each of which 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 the DOT in the Five-Year Interagency R&D Program Plan[6] and guidance from pipeline experts and stakeholder groups.

Program goals define the desired outcomes for the R&D projects, and are associated with each R&D program element. Each goal bears a direct relationship to longer-term enhancement of pipeline safety. Table 1 identifies these program elements and desired improvements.

[2] "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.phmsa.dot.gov/iim/ruletextamended.htm>
[3] "Pipeline Safety: Pipeline Integrity Management in High Consequence Areas (Gas Transmission Pipelines);" Final Rule. December 15, 2003. < http://primis.phmsa.dot.gov/gasimp/docs/GasTransmissionIMRule.pdf>
[4] "Pipeline Integrity Management in High Consequence Areas (Gas Transmission Pipelines);" Final Rule (as amended), May 26, 2004. <http://primis.phmsa.dot.gov/gasimp/docs/FinalRuleAmended_gas_full.pdf>
[5] Pipeline Safety Improvement Act of 2002. < http://ops.dot.gov/Pub_Law/107_cong_public_laws.pdf>
[6] Five Year Interagency R&D Program Plan. < https://primis.phmsa.dot.gov/rd/psrcjca.htm>

Table 1. Program Elements of PHMSA Pipeline Safety R&D Program		
	Program Element	**Program Element Goal**
1.	Threat Prevention	Develop new or improved tools, technology, or practices to reduce damage to pipelines that will prevent releases to the environment.
2.	Leak Detection	Develop new or improved tools and technology solutions to reduce the volume of product released to the environment.
3.	Anomaly Detection and Characterization	Develop new or improved tools, technology, and assessment processes to identify and locate critical pipeline defects and improve the capability to characterize the severity of such defects in pipeline systems.
4.	Anomaly Repair and Remediation	Enhance repair materials, techniques, processes, tools, and technology designed to quickly bring pipeline systems back online and serve the Nation.
5.	Design, Materials, and Welding/Joining	Improve the industry's ability to design and construct safe, long-lasting pipelines using the most appropriate materials and welding/joining procedures for specific operating environments.
6.	Alternative Fuels, Climate Change, and Other	Identify and resolve technical challenges that prevent the safe transportation of alternative fuels in pipelines and those problems that impact other emerging technological or policy issues on a national scale.

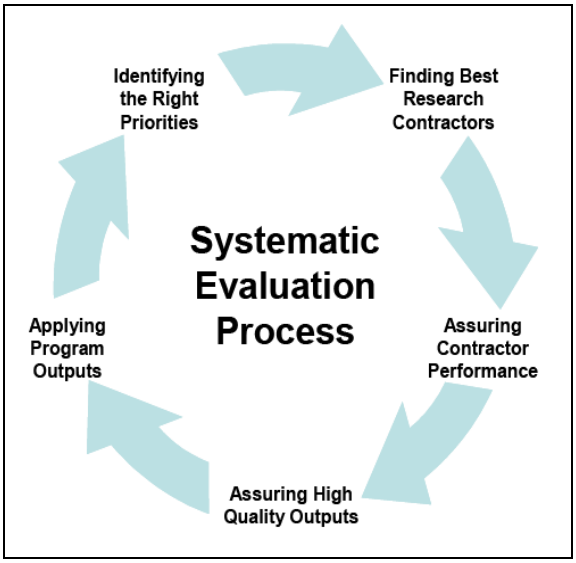
More information on the program strategy is outlined in the R&D Program Strategy portion of the program website at: http://primis.phmsa.dot.gov/rd/.

Research Program Quality

While the program addresses general R&D strategy, a systematic evaluation process was designed and implemented to raise and validate program quality. The process contains five steps and follows research projects from inception to implementation. Each step of this systematic process ensures that project outcomes will be relevant to PHMSA's mission, of high quality, and applied to the appropriate end users.

Figure 1 identifies the steps in the systematic evaluation process and how it follows the lifecycle of research projects. Please visit: http://primis.phmsa.dot.gov/rd/evaluation.htm to view more information on this process.

Figure 1. Systematic Evaluation Process



The quality of research projects is first established while identifying priorities. This roadmapping at joint government and industry R&D forums and other meetings collaboratively identifies the priorities and structures necessary for the projects to meet end user technical needs. This allows government and industry pipeline stakeholders to agree on the technical gaps and challenges for future R&D. It also minimizes duplication of programs, leverages funds, broadens synergies, and accounts for ongoing research efforts with other agencies and private organizations.

Appropriate priorities and good project design are refined while finding the best research contractors. A merit review panel composed of representatives from Federal and State agencies, industry operators, and trade organizations uses strong evaluation criteria to review research white papers and proposals.

PHMSA uses its Management Information System (MIS) to assure that awarded projects are performing well. The MIS electronically monitors and tracks contractor performance as the project moves toward completion, providing the necessary oversight to ensure contract accounting and specific contractual milestones are systematically followed as prescribed in the award documents. The system design improves and maintains program quality, efficiency, accounting, and accountability. Additional oversight is provided by Agreement Officers' Representatives (AORs) who are trained, certified, and assigned to each project in accordance with the Federal Acquisition Regulations.

The peer review is designed to further improve research project quality, keeping projects on track to meet their ultimate goal(s). If the first three steps of the systematic evaluation process are applied correctly and efficiently, PHMSA pipeline safety research projects have a higher probability of being successful, meaning that the results are used by end users.

3.0 Peer Review Panelists

Peer review panelists are chosen based on three criteria: expertise, balance, and independence. Specifics for choosing panelists are derived from the OMB Bulletin, and panelists can range from academics to active and/or retired regulators, academics, independent consultants, and standards development organizations.

The 2016 peer review panel consisted primarily of academic representatives, as well as one government employee. Table 2 identifies the panelists.

Each panelist provided a short biography describing work history and technical qualifications. These biographies are included in Appendix B.

Table 2. Peer Review Panelists

	Name	Affiliation
1	William Emery, Ph.D.	Professor, Department of Aerospace Engineering Science, Colorado Center for Astrodynamics Research, University of Colorado
2	Daniel Lind	Department of the Interior, Bureau of Safety and Environmental Enforcement
3	Yiming Deng, Ph.D.	Assistant Professor in Electrical Engineering, Director of the LEAP (Laboratory of Electromagnetic and Acoustic imaging and Prognostics) Research Group, University of Colorado-Denver
4	John Steele, Ph.D.	Associate Professor, Mechanical Engineering Department, Colorado School of Mines
5	Tingyue Gu, Ph.D.	Professor, Dept. of Chemical and Biomolecular Engineering, Ohio University
6	Hao Wang, Ph.D.	Assistant Professor, Department of Civil and Environmental Engineering, Rutgers, The State University of New Jersey

4.0 Panelist Charge

The Peer Review Panelist charge, initially developed in December 2005 and revised annually, is provided to each panelist prior to the review. It contains specific instructions regarding what is expected in terms of their review. This charge is important for the following reasons:

1. It focuses the review by presenting specific questions and concerns that PHMSA expects the peer reviewers to address.
2. It invites general comments on the entire work product. The specific and general comments should focus mostly on whether the scientific and technical studies have been applied in a sound manner.

The charge is a separate document not attached to this report. It is publicly available for each year's review at: http://primis.phmsa.dot.gov/rd/annual_peer_review.htm, and may be revised after researchers and panelists post review feedback.

5.0 Scope of the Peer Review

During the annual peer review of projects, the members of the panel review focused, high-level presentations from researchers addressing 11 evaluation criteria within 5 specific evaluation categories. Presentations are scheduled to take no more than 20 minutes, followed by 10 minutes reserved for panelist questions and possible written public questions.

In its entirety, the review of each project by the panelists should occupy approximately 2.5 hours. This includes time to review project background information, including: reporting, the advance copy of the review slides, 30 minutes of review and questioning from the panel, and time in post-review that may include follow-up questioning, a consensus review meeting, and analysis of the peer review report. An underlying R&D Program objective is to provide the best assessment of each project's performance addressing specific criteria without comparing one project to another. Scorecards for rating performance on the specified categories are provided to the panelists in which each category has equal rating from one to five. The scorecard included the following questions in four performance categories:

1. Project management

- Is the project being managed on budget and schedule?
- Is the project making progress toward the work scope objectives?

2. Approach taken for transferring results to end users

- Is there a plan for dissemination of results, including publication, reporting, and patents?
- How much end user involvement is incorporated into the scope of work?
- For results that may include marketable products and technologies, are commercialization plans established?

3. Project coordination with other related programs

- Does the project build on or make use of related or prior work?
- Is the work of the project being communicated to other related research efforts?
- Has consideration been given to possible future work?

4. Quality of project results

- Are the intended results supported by the work performed during the project?
- Are the intended results consistent with scientific knowledge and/or engineering principles?
- Are the intended results presented in such a manner as to be useful for identified end users?

Essentially, projects that rate well on these criteria are expected to have a high likelihood of success in the objectives they were designed to accomplish.

These criteria will provide a numeric rating, which will be converted and illustrated as "Ineffective," "Effective," "More than Effective," or "Very Effective." This rating conversion is illustrated in Table 3.

Table 3. Peer Review Rating Conversion	
Rating Scale	
Very Effective	4.5 – 5.0
More than Effective	3.0 – 4.4
Effective	1.9 – 2.9
Ineffective	0.0 – 1.8

The rating scale is defined to illustrate how well a project addresses the goals of the peer review.

Very Effective
The most clarity of method in accomplishing the purpose; producing the intended or expected result in a superior manner.

More than Effective
Better, clearer and more distinct in accomplishing the purpose; producing the intended or expected result in more than a satisfactory manner.

Effective
Adequate to accomplish the purpose; producing the intended or expected result in a satisfactory manner.

Ineffective
Not effective; not producing desired results; ineffectual or lacking in the details to support a satisfactory desired outcome.

6.0 Associated Research

Specific research project subject matter will vary from one annual peer review to another. Generally, subject matter falls within the six program elements shown in Table 1. Technical issues usually address metallurgical, structural, technological, and risk-based subjects commonly seen in the pipeline industry.

The research peer reviewed during the May 2016 review varied among multiple technological solutions and general knowledge-focused projects. A short description of each peer reviewed project is found in Appendix D.

7.0 Peer Review Findings

During the May 2016 review, the average program rating across all the evaluation categories was "More than Effective." For this year, 8 projects were rated "Very Effective," with 16 projects ranked as "More than Effective." The average sub-criteria were also rated highly, underpinning these findings. The majority of peered projects and the overall program rating remained the same from the 2015 rating of "More than Effective." Weakness in project management and communication with other related projects contributed to the lack of change in the program average. Table 4 summarizes the overall program performance based on the summary of reviewed projects. Table 5 itemizes the project ranking order, where projects of the same score have an equal ranking.

At the time of the reviews, the majority of the projects were approximately 20 to 30 percent complete, which means many of them will be further studied at future reviews.

The panelists made several recommendations during the course of the review. These recommendations were categorized into "Strong" and "Weak" points and were associated with each project. However, none of these comments identified critical actions required to salvage a project from failing, but instead recommended actions to further improve upon good performance.

Appendix C, Table 6 itemizes the strong and weak points collected from all 24 projects reviewed by the 6 panelists. These points were consistent among several panelists and are reflected in the scoring of multiple evaluation categories. Any specific recommendations will be disseminated to researchers and AORs as necessary so that individual decisions on scope changes can be determined.

Table 4. Summary of Total Average Score & Rating for the Review Categories and Sub-Criteria		
Review Categories and Sub-Criteria	**Score**	**Rating**
1. Project management	**4.3**	**More than Effective**
1.1. Is the project being managed on budget and schedule?	4.2	More than Effective
1.2. Is the project making progress toward the work scope objectives?	4.5	Very Effective
2. Approach taken for transferring results to end users	**4.2**	**More than Effective**
2.1. Is there a plan for dissemination of results, including publications, reporting, and patents?	4.1	More than Effective
2.2. How much end user involvement is incorporated into the work scope?	4.3	More than Effective
2.3. For results that may include marketable products and technologies, are commercialization plans established?	4.3	More than Effective
3. Project coordination with other related programs	**4.1**	**More than Effective**
3.1. Does the project build on or make use of related or prior work?	4.4	More than Effective
3.2. Is the work of the project being communicated to other related research efforts?	4.1	More than Effective
3.3. Has consideration been given to possible future work?	3.9	More than Effective
4. Quality of project results	**4.3**	**More than Effective**
4.1. Are the intended results supported by the work performed during the project?	4.4	More than Effective
4.2. Are the intended results consistent with scientific knowledge and/or engineering principles?	4.3	More than Effective
4.3. Are the intended results presented in such a manner as to be useful for identified end users?	4.2	More than Effective
Program Summary:	**4.2**	**More than Effective**

Table 5. Summary Ranking & Rating of Individually Reviewed Research Projects					
Rank	**Project ID**	**Project Title**	**Contractor**	**Rating**	**Score**
1	DTPH5615T00008	Statistical Review and Gap Analysis of LNG Failure Rate Table	*Gas Technology Institute*	Very Effective	4.7
1	DTPH5615T00016	Rapid Aerial Small Methane Leak Survey	*Ball Aerospace & Technologies Corp.*	Very Effective	4.7
1	DTPH5615T00019	Intrinsically Locatable Technology for Plastic Piping Systems	*Operations Technology Development*	Very Effective	4.7
2	DTPH5615T00005L	Comparison of Exclusion Zone Calculations and Vapor Dispersion Modeling Tools	*CH-IV International*	Very Effective	4.6
2	DTPH5615T00006	Characterization and Fitness for Service of Corroded Cast Iron Pipe	*Gas Technology Institute*	Very Effective	4.6
2	DTPH5615T00013	Development of an AMR Eddy Current-Based Crack Detection Sensor for the Live Inspection of UnPiggable Natural Gas Transmission Pipelines	*Northeast Gas Association/NYSEARCH*	Very Effective	4.6
3	DTPH5615T00007	Slow Crack Growth Evaluation of Vintage Polyethylene Pipes	*Gas Technology Institute*	Very Effective	4.5
3	DTPH5615T00014	Use of Electromagnetic Sensors to Quantify Strength and Toughness in Steel Pipelines In and Out Of Service	*Generation 2 Materials Technology LLC*	Very Effective	4.5
4	DTPH5615T00017L	Pipeline Damage Prevention Radar	*Ball Aerospace & Technologies Corp.*	More than Effective	4.4
4	DTPH5615T00018	EMAT Sensor for Small Diameter and Unpiggable Pipes; Prototype and Testing	*Operations Technology Development*	More than Effective	4.4
5	DTPH56-14-H-00002L	Consolidated Project Full Scale Testing of Interactive Features for Improved Models	*Electricore, Inc.*	More than Effective	4.3
5	DTPH5615T00015	Natural Gas Pipeline Leak Rate Measurement System	*Physical Sciences Inc.*	More than Effective	4.3

6	DTPH5615T00009	Development of Comprehensive Pressure Test Design Guidelines	*Kiefner Applus RTD*	More than Effective	4.2
7	DTPH5615T00010L	Human-Centric Approach to Improve Pipeline Non-Destructive Evaluation (NDE) Performance and Reliability	*Battelle Memorial Institute, Corporate Operations*	More than Effective	4.1
7	DTPH5615T00011	Development of a Hardness Tester for Quantification of Material Properties in Live Natural Gas Transmission Pipelines	*Northeast Gas Association/NYSEARCH*	More than Effective	4.1
7	DTPH5615T00012	Emissions Quantification Validation Process	*Northeast Gas Association/NYSEARCH*	More than Effective	4.1
8	DTPH56-14-H-00007	Improving Leak Detection System Design Redundancy & Accuracy	*Kiefner Applus RTD*	More than Effective	4.0
8	DTPH5615T00020	Combined Vibration, Ground Movement, and Pipe Current Detector	*Operations Technology Development*	More than Effective	4.0
8	DTPH5615T00003L	Critical Review of Candidate Pipeline Risk Models	*C-FER Technologies*	More than Effective	4.0
9	DTPH56-13-T-000010	Development of an Industry Test Facility and Qualification Processes for Inline Inspection Technology Evaluation and Enhancements	*Pipeline Research Council International (PRCI)*	More than Effective	3.8
9	DTPH5615T00001L	Approaches for Preventing Catastrophic Events	*Gas Technology Institute*	More than Effective	3.8
9	DTPH5615T00002L	White Paper on Risk Tolerance	*Kiefner Applus RTD*	More than Effective	3.8
9	DTPH5615T00004	Framework for Verifying and Validating the Performance and Viability of External Leak Detection Systems for Liquid and Natural Gas Pipelines	*C-FER Technologies*	More than Effective	3.8
10	DTPH56-14-H-00004	Improving Models to Consider Complex Loadings, Operational Considerations, and Interactive Threats	*Kiefner Applus RTD*	More than Effective	3.4

8.0 PHMSA Official Response to Panelists' Findings and Recommendations

The CY 2016 reviews were the ninth structured peer review of PHMSA's Pipeline Safety R&D Program. PHMSA is satisfied with the process for conducting these reviews, as well as the findings and recommendations provided by the peer review panelists. PHMSA accepts the findings and recommendations summarized in the report. The panel indicated that some immediate actions can be taken to further empower research projects to achieve contractual milestones. These recommendations are summarized in Appendix C, Table 6. PHMSA will address specific recommendations with the project co-sponsors and researchers, and will use these to improve the likelihood that project scopes can achieve proposed goals. The official PHMSA response memorandum can be found in Appendix A.

PHMSA will continue refining the annual peer review process as needed by incorporating feedback submitted by the researchers and peer review panelists. Other specific recommendations from panelists will be disseminated to researchers and AORs.

A number of initiatives are planned to provide further guidance on commercialization of technology projects and better coordination with projects' strengthening standards. These program initiatives will bring transparency to the panel's recommendations. PHMSA can still make improvements even with high annual ratings.

APPENDIX A

PHMSA Acceptance Memo

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

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

MEMORANDUM FOR THE RECORD

From: Alan K. Mayberry, Acting Associate Administrator for Pipeline Safety

Subject: Pipeline Safety Research Program Peer Reviews, May 18 & 25, 2016

SUMMARY

The Pipeline and Hazardous Materials Safety Administration (PHMSA) is pleased with the process for conducting these reviews, as well as the findings and recommendations provided by the peer review panelists. The calendar year (CY) 2016 average quality rating for the reviewed projects was "More Than Effective." Weakness in project management and communication with other related efforts contributed to the lack of change in the program average from CY2015. In addition, a number of suggestions were identified by the panelists for maintaining or improving research quality.

PHMSA will use feedback submitted by researchers and panelists to refine the process for holding annual peer reviews. Since none of the reviewed projects are rated "Ineffective," no immediate project modifications are warranted. Specific recommendations from panelists will be disseminated to researchers and Agreement Officers' Representatives who will decide if any scope changes are warranted.

PHMSA will continue refining the process, the review criteria, and the guidance so future review outcomes better support our goals.

RECOMMENDATION

The PHMSA Pipeline Safety Program accepts the findings and recommendations summarized in the Peer Review Report.

The Acting Associate Administrator for Pipeline Safety

APPROVED: _____

DISAPPROVED: _____

COMMENTS: _____

DATE: 8-26-16

APPENDIX B

Peer Review Panelist Bios

William Emery, Ph.D.

Bill Emery received his Ph.D. in Physical Oceanography from the University of Hawaii in 1975. He worked at Texas A&M University for a few years, then moved in 1978 to the University of British Columbia where he created a Satellite remote sensing program. Mr. Emery transitioned to the University of Colorado in 1987, where he was appointed professor in Aerospace Engineering Sciences. He is also an adjunct professor of Informatics at Tor Vergata University in Rome, and has authored more than 182 refereed publications, 2 textbooks, and more than 150 conference papers. He is a fellow of the Institute of Electrical and Electronics Engineers (IEEE) and the VP for publications with their Geoscience and Remote Sensing Society (GRSS). He received both the 2004 GRSS Educational Award and the 2009 GRSS Outstanding Service Award. He was the founding editor of Geoscience and Remote Sensing Letters in 2004 and its Editor-in-Chief for 6 years. He was recently elected the Chair of the IEEE Periodicals Committee, which oversees the publication of 171 journals. He is a Fellow of the American Meteorological Society (AMS; 2010), the American Astronautical Society (2011), and the American Geophysical Union (2012). He serves as the Editor in Chief of the AMS Journal of Atmospheric and Oceanic Technology.

Daniel Lind

Mr. Lind is currently a Systems Reliability Engineer for the Department of the Interior, Bureau of Safety and Environmental Enforcement. However, he has over 7 years of technical experience from a wide variety of government and private companies, some of which span multiple economic sectors including oil, gas, and the automotive industry. Mr. Lind has a Bachelor of Science degree in Mechanical Engineering (BSME) from the University of Miami and a Master of Science degree in Automotive Engineering (MSAE) from Clemson University.

Yiming Deng, Ph.D.

Dr. Deng is an Associate Professor with the Electrical and Computer Engineering Department of Michigan State University, East Lansing, USA. He was an Assistant Professor and Associate Professor with tenure at the University of Colorado Denver and Anschutz Medical Campus from 2009 to 2016. He obtained his Ph.D. at Michigan State University and his B.S. at Tsinghua University, both in Electrical Engineering. Dr. Deng has over 13 years of experience in the development of sensors and instrumentation, innovative numerical modeling for nondestructive evaluation (NDE), and structural health monitoring for transportation and energy applications. His current research focuses on high resolution and multi-wave NDE sensing and imaging systems involving the development of novel nonintrusive sensors, high fidelity multi-physics modeling for understanding NDE imaging physics, and experimental validation with sensor prototyping for critical energy and transportation infrastructures. Dr. Deng has published 31

peer-reviewed journal papers and more than 60 conference papers and presentations. He has external research funding from the Department of Defense (DOD), the United States Department of Transportation: Pipeline and Hazardous Materials Safety Administration (DOT: PHMSA), National Institutes of Health (NIH), the Gas Technology Institute (GTI), National Jewish Health (NJH), the National Natural Science Foundation of China (NSFC), the Association of Neuropsychology Students in Training (ANST), and private industries. Dr. Deng received the 2010 Faculty Grant Award from the American Society for Nondestructive Testing, served as a panelist for the National Science Foundation (NSF), the United States Department of Energy (DOE), DOT, the Hong Kong Research Grants Council (HKRGC), and is the Associate Editor of IEEE Transactions on Reliability (2015-2018) and Reliability & Maintainability (2014-2017).

John P. H. Steele, Ph.D., PE

Dr. Steele is a professor in the Department of Mechanical Engineering at the Colorado School of Mines, where he heads the laboratory for Robotics and Intelligent Machines (RIM). He received his Ph.D. in Engineering (Robotics) and his and his M.S. in Mechanical Engineering focused on tribology, both from the University of New Mexico. Dr. Steele also has a B.S. in Physics from New Mexico State University. Before going back to graduate school, Dr. Steele was a pipefitter and welder in Alaska, and worked on the construction of the Alaska Pipeline. His research focus is on the development of Intelligent Robots and Systems, with applications for automated welding and field robotics (e.g., underground mining, exploration, and search and rescue). He has worked on 3D stereovision systems for weld pool monitoring and control, and for autonomous navigation in underground environments. His research has also involved system health monitoring and remaining life predictions (PHM) using machine learning techniques for a variety of systems, e.g., wind turbines, hydro-turbines, and robots. He has published a number of peer-reviewed journal articles and conference proceedings, and given many presentations. Dr. Steele has had funding from the NSF, the DOD, the DOE, the DOT, the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF), the State of Colorado, and numerous industrial corporations. He has served as a reviewer for a number of journals, and is a past President of the Colorado Section of American Welding Society and the Colorado Section of the American Society of Mechanical Engineers. Recent work related to pipelines has been focused on anomaly alignment over multiple in-line inspections (ILIs), and prediction of remaining life.

Tingyue Gu, Ph.D.

Dr. Gu is affiliated with the Institute for Corrosion and Multiphase Technology at Ohio University. Since 2004, his research has focused on microbiologically influenced corrosion (MIC), its detection, and mitigation. He developed Biocatalytic Cathodic Sulfate Reduction (BCSR) theory to explain the mechanism of MIC by sulfate-reducing bacteria (SRB) biofilms. His research group demonstrated using experimental data that SRB utilize elemental iron as a substitute for organic carbon for energy production when there is a lack of organic carbon. He is the creator of a fully mechanisticMIC model, as well as MIC pitting prediction software known as MICORP. Dr. Gu's research group advocates the use of green biocide enhancers for MIC mitigation, which would use biodegradable chemicals to enhance the efficacy of existing chemicals. Dr. Gu holds a U.S. patent on using D-amino acids to enhance some oilfield biocides

with much improved efficacy. His current research also includes biofilm test kits and sensors. Dr. Gu has published over one hundred journal papers and book chapters, and has authored a monograph. Dr. Gu obtained his B.S. in Chemical Engineering from Zhejiang University, Hangzhou, China in 1985, and his Ph.D. in Chemical Engineering from Purdue University, West Lafayette, Indiana in 1990. Dr. Gu worked as a postdoctoral research associate from September of 1990 through January of 1991 at Purdue University, and then as a postdoctoral biotechnologist at Miller Brewing Company, Milwaukee, Wisconsin from February of 1991 through March of 1992. He worked on bioseparations research in both places, and then joined the faculty of Ohio University in March of 1992 as an assistant professor of Chemical Engineering. Dr. Gu is currently a full professor with tenure at Ohio University, and the graduate committee chair of Chemical Engineering. Dr. Gu is an associate editor of Bioresources and Bioprocessing journal (since 2014), and is on the editorial boards of Bioprocess and Biosystems Engineering journal (since 2006), Separation and Purification Technology (since 2014), and the Journal of Chemistry (since 2012). He has served as a reviewer for at least 90 scientific journals, and as an ad hoc reviewer for the NSF, the DOE, the Department of Agriculture (USDA), the DOT, and foreign agencies such as The Natural Sciences and Engineering Research Council (NSERC) of Canada, the French National Research Agency, and the Australian Research Council. Dr. Gu is a member of the American Chemical Society and the National Association of Corrosion Engineers (NACE) International.

Hao Wang, Ph.D

Dr. Wang is an Assistant Professor in the Civil and Environmental Engineering Department at the Rutgers, The State University of New Jersey, New Brunswick, USA. He obtained his Ph.D. at the University of Illinois at Urbana-Champaign, his M.S. at Virginia Tech, and his B.S. at Southeast University, all in Civil Engineering. Dr. Wang's research areas include material, structure, and mechanics challenges in a broad spectrum of infrastructure engineering, including highway, airport, pipeline, and railway engineering. His current research focuses on the development of a multi-functional coating system for infrastructure protection and repair, multi-scale characterization and modeling of infrastructure material, and life-cycle analysis. His research has been supported by the NSF, PHMSA, the Federal Railroad Administration (FRA), the Federal Highway Administration (FHWA), the Federal Aviation Administration (FAA), the Office of the Assistant Secretary for Research and Technology (OST-R), and several State transportation agencies. Dr. Wang has published more than 50 peer-reviewed journal papers and more than 30 conference papers. His research has been selected as the High Value Research Project of 2014 by the American Association of State Highway and Transportation Officials (AASHTO). Dr. Wang served as a panelist for the NSF and the DOT, and is an Editorial Board Member of the Journal of Testing and Evaluation published by the American Society for Testing and Materials (ASTM).

APPENDIX C

Table 6 – Peer Reviewed Project Strong and Weak Points

(In order as shown in Table 5)

Project Title	Strong Points	Weak Points
Statistical Review and Gap Analysis of LNG Failure Rate Table	Making good progress toward work scope objectives. Excellent plan for dissemination of results. Great end user involvement. Clear communication to other related efforts. Results to date seem well supported by performed work.	None of major mention.
Rapid Aerial Small Methane Leak Survey	Very good end user involvement. Great use of prior related project results. Good plan for dissemination of results and commercialization.	None of major mention.
Intrinsically Locatable Technology for Plastic Piping Systems	Promising results. Great end user involvement. Excellent plan for dissemination of results. Clear communication to other related efforts.	Suggestion to provide commentary on the durability of the flexible marker.
Comparison of Exclusion Zone Calculations and Vapor Dispersion Modeling Tools	Great end user involvement. Excellent plan for dissemination of results. Great use of prior related project results. Clear communication to other related efforts.	None of major mention.
Characterization and Fitness for Service of Corroded Cast Iron Pipe	On schedule. Results to date seem well supported by performed work. Great end user involvement. Very well planned out scope.	None of major mention.
Development of an AMR Eddy Current-Based Crack Detection Sensor for the Live Inspection of UnPiggable Natural Gas Transmission Pipelines	Very good end user involvement. Great use of prior related project results. Excellent technical progress.	Slightly behind schedule in one task area.

Project Title	Strong Points	Weak Points
Slow Crack Growth Evaluation of Vintage Polyethylene Pipes	Great end user involvement. Excellent plan for dissemination of results. Great use of prior related project results. Clear communication to other related efforts.	Suggestion to provide commentary on how detected data, finite element analysis, and risk analysis will be handled with future plastic pipes.
Use of Electromagnetic Sensors to Quantify Strength and Toughness in Steel Pipelines In and Out Of Service	Results to date seem well supported by performed work. Much rigor in testing on pipe samples.	More graphics could have better assisted in the physical application context of the technology.
Pipeline Damage Prevention Radar	Very good end user involvement. Great use of prior related project results. Good plan for dissemination of results and commercialization.	Suggested they consider testing SAR on different landscapes other than southwest or west.
EMAT Sensor for Small Diameter and Unpiggable Pipes; Prototype and Testing	Very good end user involvement. Great use of prior related project results.	Some concern over the level of prototyping and whether it will support moving to later phases and commercialization. Slightly delayed in some tasks. Better communications to other related research efforts needed.
Consolidated Project Full Scale Testing of Interactive Features for Improved Models	Very good end user involvement. Comprehensive scope built on prior successes.	Slightly behind schedule. Improve plan for dissemination of results beyond PRCI members.
Natural Gas Pipeline Leak Rate Measurement System	Very good end user involvement. Great use of prior related project results. Good plan for dissemination of results and commercialization.	Too much reliance on trade secret algorithms so some aspects of this effort could not be evaluated. Some debate over confidence of flux accuracy to support model prediction.
Development of Comprehensive Pressure Test Design Guidelines	Good use of prior work.	Looking for more information on how this scope fills gaps noted in any standards. Need more caveats to describe how survey results were used to understand the balance of the type of company responses.
Human-Centric Approach to Improve Pipeline Non-Destructive Evaluation (NDE) Performance and Reliability	Good use of prior work. Good end user involvement. Good progress to date.	Suggestion to add classroom training as part of the dissemination program.

Project Title	Strong Points	Weak Points
Development of a Hardness Tester for Quantification of Material Properties in Live Natural Gas Transmission Pipelines	Great use of prior related project results. Good end user involvement.	Improve plan for dissemination of results. Some tasks are delayed and on-time delivery is questionable for 2016. Transition from lab environment prototyping to field testing was not well discussed.
Emissions Quantification Validation Process	Very appropriate methodology developed for the project plan.	Delays in current project due to connection with ongoing separate project. Looking for additional avenues for dissemination of results. Results should be better presented quantitatively.
Improving Leak Detection System Design Redundancy & Accuracy	Very well organized and great steering committee. Great plan to disseminate results. Scope covering both liquid and gas pipelines.	Looking for more information on how to impact related API standard. More communications to other related research efforts are recommended.
Combined Vibration, Ground Movement, and Pipe Current Detector	Good progress to date.	Looking for more details on how work is formatted for end user use. More clarity needed on data fusion between sensor types.
Critical Review of Candidate Pipeline Risk Models	Very good literary search over multiple sectors.	Looking for more details to provide a more thorough review. Should be more specific on pilot study and how to apply the risk models to real pipeline safety problems.
Development of an Industry Test Facility and Qualification Processes for Inline Inspection Technology Evaluation and Enhancements	Well connected to industry partners and service providers.	Review occurred via the printed sides and was not presented;therefore further clarifications were hindered.
Approaches for Preventing Catastrophic Events	Scope seems well matched to the project goals.	Looking for more details to provide a more thorough review. The proposed approaches should be more focused on pipeline industry and be more specific.
White Paper on Risk Tolerance	Very good end user involvement. Knowledge potentially very important to resolving challenge.	The project-related survey seems inadequate to support focused conclusions. Looking for more details to provide a more thorough review.

Project Title	Strong Points	Weak Points
Framework for Verifying and Validating the Performance and Viability of External Leak Detection Systems for Liquid and Natural Gas Pipelines	Very strong end user involvement.	Slightly behind schedule. Looking for more clarity on how the goals of the project are supported by the stated tasks or scope. No detailed plan for the results dissemination. Need better communications to other related research efforts.
Improving Models to Consider Complex Loadings, Operational Considerations, and Interactive Threats	Good progress to date.	Looking for more clarity on definition of interactive threats. Some of this uncertainty casting doubt on whether or not project can be successful.

APPENDIX D

Peer Review Project Summaries
(In order as shown in Tables 5-6)

Additional summaries and publicly available reports are available at:
http://primis.phmsa.dot.gov/matrix/

Improving Leak Detection System Design Redundancy & Accuracy

Kiefner Applus RTD

Leak detection systems (LDSs) are an important part of any overall pipeline safety and integrity strategy. The benefits of reliably and rapidly identifying a leak so that the resulting fluid loss can be controlled and contained as soon as possible can be very significant, particularly in High Consequence Areas (HCAs). The mission of this project is standardize the approach to designing an appropriate LDS for all pipelines that will be accessible to all operators—including the smaller ones—without extended and laborious front-end engineering. A central part of this approach is to concentrate upon certain key issues: (a) beginning any LDS design process with a systematic focus on assessing requirements, (b) accepting that one single technology will probably not provide perfect performance for all objectives on a given pipeline; therefore, a key issue is exploring ways to combine multiple technologies/physical principles into one system in order to address each requirement optimally, and (c) allowing the operator to be able to predict performance—and therefore cost/benefit—more reliably from the design.

Natural Gas Pipeline Leak Rate Measurement System

Physical Sciences Inc.

This research will enhance capabilities to detect, locate, and quantify small natural gas pipeline leaks to prioritize remedial actions. We will assemble and evaluate via field tests a system comprising a cost-effective synthesis of side-scan lasers, sensitive laser-based point sampling, and advanced data processing algorithms installed on a mobile leak survey platform. The research results will lead to advanced products and methodologies to be deployed by the leak survey industry for reducing the environmental impact of natural gas.

Emissions Quantification Validation Process

Northeast gas Association/NYSEARCH

The overall objective of this project is to work collaboratively as an industry group and with others to identify, apply, and test a methodology or set of methodologies that allow a gas distribution operator to validate the accuracy of measuring, locating, and quantifying the methane emissions flow rate from non-hazardous natural gas infrastructure leaks. If successful in validating a technology or combination of technologies that can accurately quantify methane emissions, the proposed effort would allow more data-driven decisions based on the greenhouse

gas emissions contribution of individual non-hazardous leaks. This validated quantitative flow rate information could aid in prioritization of repair decisions.

Framework for Verifying and Validating the Performance and Viability of External Leak Detection Systems for Liquid and Natural Gas Pipelines

C-FER Technologies

Pipeline leak detection technology vendors offer a broad range of configurations and measurement approaches to pipeline operators. This project will develop an assessment framework consisting of procedures and guidelines to assist pipeline operators in selecting viable technologies and validating the performance of leak detection systems for specific applications. The framework will assist pipeline operators in collecting information from technology vendors, specifying and modeling the characteristics of the release events that need to be addressed, determining the viability of each technology, and conducting tests to evaluate technology performance. The project will also include a demonstration of the implementation of the framework for an example application. This will include assessing a variety of technologies to identify viable options and conducting performance evaluation tests on representative technologies.

Rapid Aerial Small Methane Leak Survey

Ball Aerospace & Technologies Corp

This R&D project is developing new airborne differential absorption lidar (DIAL) technology that substantially reduces the cost of methane leak surveys as compared to the ground based, vehicle-mounted, in-situ sensors used today. It will do this by swath-mapping broad areas of gas distribution networks 12 times faster per unit area than vehicle-mounted systems. The wide swath approach uses a combination of novel high-energy lasers and high-speed low-noise detectors, and includes high-speed electronics that perform signal processing 100 times faster than existing DIAL. The new instrument surveys broad areas more than five times faster than existing DIAL, which is designed to survey narrow transmission pipeline corridors and not gas distribution networks. The project includes end user participation to guide the research, support flight testing, and evaluate resulting test data. Academic collaboration with a University of Colorado research laboratory provides Grade 3 leak rate quantification, allowing prioritization of leak repair.

White Paper on Risk Tolerance

Kiefner Applus RTD

Pipeline organizations have always included risk management in the design, construction, and operation of their systems. However, as these systems age new materials are introduced, differing damage mechanisms are discovered, and other challenges arise, forcing pipeline organizations to rethink and redesign their risk management practices in order to manage risk and remain safe, reliable operators for transportation of hydrocarbons. The focus of developing

risk tolerance criteria should be on the control of risk as systems age and non-design-basis scenarios develop. This change in risk can stem from the increasing likelihood of a failure, e.g., crack growth in welds, or due to changes in the consequences, e.g., increased population and construction which would raise both the initiating event probability (for example, third party damage) and the consequences (for example, greater population density).

Approaches for Preventing Catastrophic Events

Gas Technology Institute

The goal of this project is to present a thorough and critical review of approaches for preventing catastrophic events, both within and outside the natural gas industry, in order to be able to select the most appropriate approach(es) and model(s), develop them further, and ultimately issue guidelines for effective implementation in risk models and integrity management programs. The aim is to obtain a structured review of existing methodologies, identify gaps, and prepare for the adoption and/or development of a suitable approach for the sector. There is an extensive list of approaches and methodologies, each of which might have a unique scope, address different sectors or stakeholders (policy makers, researchers, operators, etc.), have differing objectives, use various applied techniques and standards, and quantify risk uniquely.

Critical Review of Candidate Pipeline Risk Models

C-FER Technologies

The objective of this project is to conduct a critical review of the probabilistic quantitative risk analysis approach and use the review results to produce guidance for developing the next generation of pipeline risk models. This guidance will be based on an assessment of desirable model attributes related to accuracy, verifiability, transparency, practicality, and fit within the decision-making processes used by both operators and regulators. Available models in the pipeline and other industries will be reviewed and used as a basis for identifying various modelling options and assessing the benefits and limitations of each approach. A commentary on the potential application of the results to liquefied natural gas (LNG) and other pipeline facilities will also be provided.

Development of an Industry Test Facility and Qualification Processes for Inline Inspection (ILI) Technology Evaluation and Enhancements

Pipeline Research Council International

The project will standardize a process for evaluating in-line inspection technologies for the energy pipeline industry. The project will complete the design and construction of a highly flexible and modern pipeline pull test facility at Pipeline Research Council International's (PRCI) Non Destructive Evaluation repository, where a range of real-world pipeline test samples have been accumulated and are retained to support technology improvements and developments for pipeline inspection.

EMAT Sensor for Small Diameter and Unpiggable Pipes; Prototype and Testing
Operations Technology Development

The objective of this project is to build and test an Electro-Magnetic Acoustic Transducer (EMAT) sensor prototype to detect and quantify wall loss and longitudinal cracks in metallic pipes. The sensor will be used to assess small-diameter and unpiggable pipes containing fittings and other restricting features. The initial target pipe diameter is 8 inches; however, the commercial goal is to build tools that can navigate in 6- to 12-inch pipes. These sizes are typically used in unpiggable natural gas transmission and distribution systems. Other sizes will be considered based on industry needs.

A laboratory assembly (bench-scale unit) has been successfully completed and tested in Phase 1. The work tasks in this proposal build on the results from Phase 1, and include building a prototype of the unit with the data management system and a pull-out mechanism for internal testing of pipe sections with controlled and natural cracks and flaws, as well as establishing the performance criteria and assessing the minimum flaw sizes to be reliably detected by the device.

Development of an AMR Eddy Current-Based Crack Detection Sensor for the Live Inspection of UnPiggable Natural Gas Transmission Pipelines
Northeast gas Association/NYSEARCH

This is a project for the development, laboratory testing, field testing, and commercialization of an Anisotropic Magneto Resistive (AMR)-based eddy current (EC) sensor system for the live, in-line crack inspection of piggable and unpiggable natural gas pipelines. The sensor incorporates an eddy current-based technology, developed by Radiation Monitoring Devices, Inc. (RMD), that can be integrated onto the Explorer 6/8 robotic platform (6"-8" pipelines), which was developed with PHMSA cofunding and commercialized in 2010 by NYSEARCH and Invodane Engineering (through Pipetel Technologies, the commmercial service company of Invodane Engineering). NYSEARCH is currently partnering with RMD to develop the basic sensory technology, which will be integrated into the Explorer 6/8 in this proposed phase. While the proposed crack sensor will be built for the 6"-8" pipe size range, the design is expected to be easily scalable to platforms for other pipe sizes (both smaller and larger). This work will be conducted by a team consisting of NYSEARCH, RMD, and Invodane Engineering. The proposed project will require 27 months and will be completed with the commercialization of the technology.

Development of a Hardness Tester for Quantification of Material Properties in Live Natural Gas Transmission Pipelines
Northeast Gas Association/NYSEARCH

This project presents a plan for the development, laboratory testing, field testing, and commercialization of a device for the live, in-line, non-destructive quantification of material properties (toughness and strength) for piggable and unpiggable natural gas pipelines. The testing device will be integrated on the Explorer 20/26 robotic platform (20"-26" pipelines)

which was developed with PHMSA cofunding and commercialized in 2013 by NYSEARCH and Invodane Engineering (through Pipetel Technologies, the commercial service company of Invodane Engineering). While the testing device will be built for the 20"-26" pipe size range, the design is expected to be scalable to other pipe sizes. This robotic platform is already capable of carrying sensors for the detection of corrosion defects, cracks, dents, and ovality in pipelines. The proposed device will add to these existing capabilities, further enhancing the ability of the industry to characterize its pipeline assets, in particular as per the proposed PHMSA Integrity Verification Process (IVP). Prior to this proposal, NYSEARCH has provided funding to Invodane Engineering for a now-completed feasibility study in which the basic concept for the hardness tester device has been proven for further development, testing, and commercialization as proposed here.

Development of Comprehensive Pressure Test Design Guidelines
Kiefner Applus RTD

The objective of this project is to develop comprehensive guidelines for the design of pressure tests that could be incorporated into industry standards such as ASME B31.4, ASME B31.8, ASME B31.8S, and/or API RP 1160. These standards have been valuable test guidance and requirements for many years, but may no longer reflect the most current knowledge and industry needs. It is expected that the proposed work will draw heavily on what has been learned by pipeline operators and pressure-testing contractors who have performed pressure tests on thousands of miles of pipelines. The work also will take into account the significant amount pressure testing research carried out from the 1960s through the present by the Pipeline Research Council International (PRCI), PHMSA, and other organizations. In particular, the recent work sponsored by PHMSA on the behavior of electric resistance welded (ERW) pipe and on repair/replace considerations for pre-regulation pipe will be considered with respect to implications for best testing practices. This work is being proposed by a team of pipeline integrity specialists at Kiefner and Associates, Inc., an Applus RTD Company.

Comparison of Exclusion Zone Calculations and Vapor Dispersion Modeling Tools
CH-IV International

As detailed in the DOT's regulations in 49 CFR Part 193.2059, each LNG facility under the scope of 49 CFR Part 193 is required to calculate vapor dispersion exclusion zones in accordance with NFPA 59A (2001) as incorporated by reference. Interpretations issued by PHMSA in July, 2010 clarified certain requirements for performing vapor dispersion exclusion zone modeling to satisfy the requirements of 49 CFR 193.2059. The objective of this project will be to provide PHMSA with a comparison of the different methodologies used to determine a "single accidental leakage source," and a comparison of the modeling results for those single accidental leakage sources using the Dense Gas Dispersion Model (DEGADIS), Phast, and Flame Acceleration Simulator (FLACS) models approved by PHMSA for calculating vapor dispersion exclusion zones in accordance with 49 CFR Part 193.2059. This comparison will help PHMSA better define the criteria to determine a "single accidental leakage source" to be used for vapor dispersion exclusion zone calculations.

Statistical Review and Gap Analysis of LNG Failure Rate Table
Gas Technology Institute

The objective of this project is to strengthen safety and regulations related to LNG plants by analyzing data underlying and relevant to PHMSA's LNG Failure Rate Table, which defines expected failure frequencies of key LNG plant components. Results of the project will include specific recommendations to refine the LNG Failure Rate Data Table and the baseline threshold failure rate criterion of 5E-5 to 3E-5 failures per year. The work will also identify key knowledge gaps and desirable follow-on research, with the project team working in a collaborative manner with PHMSA and others. The project team will review relevant equipment failure data available globally, build an integrated database, and apply advanced and proven Bayesian network methodologies to analyze the data.

Improving Models to Consider Complex Loadings, Operational Considerations, and Interactive Threats
Kiefner Applus RTD

This project is designed to produce guidance, decision processes, and data regarding identifying/evaluating complex situations to prevent pipeline failures. Some pipeline failures suggest that more complex situations need to be accounted for than is currently the practice. Interactions of pipe defect conditions with variable loadings, increased loadings, complex loadings, or changing conditions have led to failures under conditions normally considered safe. The industry should be applying a second level of complexity to the evaluation of degraded conditions where one or all of the following circumstances could exist: (a) loadings are biaxial, (b) loadings vary with time, or (c) environments interact with conditions to adversely alter the condition's stability or rate of degradation. Recognizing and quantifying these effects will require integration of data from ILIs (perhaps from tools an operator would not normally use, such as slope-curvature tools or crack-detection tools), ground or aerial patrols, or at some sites, actual monitoring or measurement of changing conditions. Thus the outcome of this project will be guidance in the form of decision processes and data needs for identifying and evaluating complex and/or interactive situations.

Consolidated Project Full Scale Testing of Interactive Features for Improved Model
Electricore, Inc.

This project addresses pipeline crack growth as influenced by complex operational circumstances by expanding on existing work performed through PHMSA and PRCI. Through full-scale testing the team will gather data on mechanical damage interacting with secondary features: gouges (with cracks and micro-cracks), corrosion, and welds. The team will create a database which will be used by others to validate and improve burst and fatigue strength models. The team will also gather experimental data to estimate when cracks in stress corrosion cracking (SCC) colonies coalesce. The project will improve knowledge on the influence of complex loadings on both mechanical damage exposed to environmentally assisted cracking (EAC) or to combined pressure and high axial strains, and on crack growth dynamics of SCC. The primary

objectives of the project are to strengthen industry consensus standards and to generate data which will promote new knowledge. The project will improve safety and environmental protection by filling critical knowledge gaps on pipeline response to crack growth in mechanical damage and SCC as driven by complex loads and interacting threats.

Pipeline Damage Prevention Radar
Ball Aerospace & Technologies Corp.

Ball Aerospace will manage a 14-month program for demonstration and evaluation of a dual-band airborne Synthetic Aperture Radar (SAR) to reliably detect excavation damage threats in areas where the pipeline routes may be obscured by dense brush, forest canopy, low cloud cover, smoke, fog, haze, precipitation, or low light conditions. SAR is widely used by the DOD for threat detection, imaging, and change detection from airborne platforms. Pipeline damage prevention offers a new application where SAR increases the likelihood of excavation threat detection and improves safety. The proposed development enables reduced false positives, fewer repeat flight passes, and reduced weather-related aircraft downtime resulting in operations cost savings. Flight testing will begin near the SAR vendor's facility in Utah to verify aircraft interfaces, installation processes, flight operations, and to validate performance of SAR data processing algorithms optimized for detection and imaging of targets hidden beneath forest canopy. System demonstration flight testing will then be performed over foliage-covered pipeline located in California using aircraft and personnel contributed by our operator partner Pacific Gas and Electric (PG&E). A final report will include a detailed assessment of excavation damage threat detection performance in addition to a plan for commercialization of the airborne SAR.

Combined Vibration, Ground Movement, and Pipe Current Detector
Operations Technology Development

The objective of this project is to demonstrate the feasibility of a pipeline right-of-way (ROW) defense system based on stationary sensors mounted on, or adjacent to, the pipeline. The sensor data from multiple locations along the pipe will be wirelessly forwarded to a central location for further analysis in which analytics residing at a central location will correlate the data from multiple sensors to alert operators to events of interest occurring in the ROW with minimal latency. The proposed methodology is to apply sophisticated analytics based on Causal Bayesian Networks to data captured from multiple sensor types and locations within the ROW. The ability to simultaneously capture distinct categories of data from multiple locations will allow these analytics to more positively identify when an event of interest is occurring on the ROW. The following sensor types will be examined during the course of the proposed work: (a) acoustic vibration sensors mounted directly on the pipe to detect approaching threats or impacts, (b) strain gauges mounted directly on the pipe to determine changes in compressive or tensile stresses, (c) current sensors in metallic contact with the pipe to measure induced or cathodic protection currents, and (d) seismic or earth movement sensors in the soil adjacent to the pipe to determine the presence of earthquakes, subsidence, or washout events. The data storage, data analytics, and

user interface will be cloud-hosted so as to be available to sponsors and field test operators. It is anticipated that one or more gas utility operators will provide test sites.

Intrinsically Locatable Technology for Plastic Piping Systems

Operations Technology Development

The objective is to develop and test a viable solution for intrinsically locatable polyethylene (PE) materials with an integral electronic marking system. The project will complete the development, define and test the electronic marker capability, validate the attachment design, and perform laboratory and field testing. Operations Technology Development, NFP (OTD) plans to partner with Gas Technology Institute (GTI), 3M Company, and a large pipe manufacturer for this project. 3M will develop the electronic markers and work with the pipe manufacturer to attach the marker to the PE pipe, and GTI will provide third-party testing and analysis of the developed system. Electronic markers are detectable passive devices that do not use any batteries, and include electrical or mechanical resonators. Resonators can be energized by an above-ground transceiver (or portable locator) which causes them to generate their own magnetic field at their resonant frequency. The precise location of a buried electronic marker is indicated by the portable locator's display and sound output. Marking buried plastic pipe with an electronic marker gives a unique detection signature for each utility by frequency selection, gives near continuous location detection of the pipe path, and allows the estimation of the depth to the pipe.

Slow Crack Growth Evaluation of Vintage Polyethylene Pipes

Gas Technology Institute

This collaborative project will develop an integrated set of quantitative tools that will provide a structured approach to reducing operational risk in vintage plastic distribution systems susceptible to Slow Crack Growth failures. A novel endoscopic structured light scanning tool will be developed and prototyped for internal inspection of small diameter plastic pipe. The data generated by the tool will be reduced to essential parameters and synthesized with additional available system information including external conditions, inspection and leak records, historic data, and subject matter expertise into a fitness for service evaluation. This assessment will include a probabilistic estimate of the remaining effective lifetime of individual segments of vintage plastic pipe and a yes/no determination of whether a short-term pressure test is capable of validating the maximum defect size in the system. The Bayesian network methods employed are ideally suited to evaluating interacting threats, investigating root causes, and predicting the effect of mitigation strategies based on conditional probabilities calculated from available data.

Evaluation of Corroded Cast Iron Pipe
(Characterization and Fitness for Service of Corroded Cast Iron Pipe)
Gas Technology Institute

Cast iron gas mains have been installed since the 1830s and are still in service in many U.S. cities. Approximately 32,400 miles of cast iron main was estimated to be in service in 2012, with about 50% of these pipes located within four states: New Jersey, New York, Massachusetts, and Pennsylvania. Consistent with the 49 CFR federal requirements, local distribution companies (LDC) have developed procedures for surveillance of their cast iron facilities to identify problems and take appropriate action concerning leaks, breakage, and graphitization. Recent incidents have prompted state regulators to evaluate and modify the utilities' procedures regarding the frequency of cast iron surveillance. Cast iron pipelines' vulnerability and integrity are further highlighted in the PHMSA Safety Advisory Bulletin, which requires gas operators to implement a program, based on factors such as age, pipe diameter, operating pressure, soil corrosiveness, existing graphitic damage, leak history, and external loading, to identify and replace in a planned, timely manner cast iron piping systems. This project seeks to provide a Fitness-for-Service (FFS) model and method for operators to characterize and grade graphitic corrosion defects on cast iron natural gas pipe. This will lead to more educated monitoring, repair, and replacement decisions, as well as prioritizing replacement program decisions leading to improved safety and supply stability.

Human-Centric Approach to Improve Pipeline Non-Destructive Evaluation (NDE) Performance and Reliability
Battelle Memorial Institute, Corporate Operations

NDE is critical in operating pipelines safely and efficiently, but these inspections in the ditch are often riddled with unintentional human error. This can have serious consequences in the form of lost lives and staggering property damage. The Battelle Team proposes a powerful research program to tackle this critical deficiency and pilot both technology and human solutions in the next two to three years for future commercialization plans. Battelle has experts focused explicitly on human factor evaluations who will lead the investigation and closely collaborate with partnering NDE vendors Mistras Group, Inc., JENTEK Sensors, Inc., and Applus RTD. Extensive interviews, protocol reviews, field observations, and control tests with field pipe defects will be systematically analyzed to identify and prioritize detrimental human-shaping factors in the first 12 months. To ensure the most effective analysis, Battelle experts will optimize the well-established Saba™ Peak Performance System accompanied by Human Performance Technology Front-end Analysis. In the following one to two years, solutions will be developed and piloted, with Phase 2 dedicated to human interventions and Phase 3 to technology interventions.

Use of Electromagnetic Sensors to Quantify Strength and Toughness in Steel Pipelines in and out of Service

Generation 2 Materials Technology LLC

Generation 2 Materials Technology LLC (G2MT), in collaboration with Quest Integrity, proposes a two-year research program to develop a nondestructive testing technology to rapidly evaluate pipeline mechanical properties. This proposal is in response to the PHMSA Broad Agency Announcement (BAA) DTPH5615RA00001 for the topic "Development of Inspection Tools to Quantify Pipe Strength and Toughness." G2MT and Quest Integrity Group will collaborate to produce a new nondestructive electromagnetic sensor for assessment of bulk strength and toughness of new and vintage steel pipelines operating in any environment. The strength and toughness of the steel pipelines determined by the electromagnetic system will be linked with other inspection and materials characterization testing to provide improved Risk-Based Integrity Management. The proposed sensor development supports the mission of PHMSA to protect people and the environment from the risks inherent in the transportation of hazardous materials by providing an effective method to determine the actual integrity of steel pipelines in or out of service. The technology will enable optimized transport through pipelines by predicting the highest safe operating pressure based on real-world measurements of mechanical properties, including both strength and toughness.

APPENDIX E

The Peer Review Coordinator (PRC) organizes, coordinates, monitors, and facilitates the annual panel peer review. The PRC is the main contact for panelists, the researchers involved with a peer review, and for public inquiries. The PRC for the 2015 peer reviews was Mr. Robert Smith of PHMSA.

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