CALIFORNIA
ENERGY COMMISSION

Energy Research and Development Division

FINAL PROJECT REPORT

Pipeline Safety and Integrity Monitoring Technologies Assessment

Gavin Newsom, Governor

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APPENDIX A:
Industry Survey Form

The following sections present the industry survey form used to identify utilities' selections of new and emerging technologies for potential implementation in the natural gas pipeline system. The technologies include devices, systems, and new procedures which enhance integrity and safety management practices.

Survey Purpose

The California Energy Commission is sponsoring a project to identify new and emerging technologies. As a part of this project, the Gas Technology Institute (primary contractor) and Energy Experts International (subcontractor) are soliciting the industry input. The objectives of this survey are to:

- Outline natural gas operators' needs and technology gaps to enhance the integrity and safety of their system and reduce their operation costs
- Identify emerging new technologies which address the above needs and close to commercial availability.

The survey consists of 10 questions and may take about 15 minutes to answer. All survey responses are strictly confidential and will be aggregated to prevent identification of individual companies.

Operator and System Information

Utility Name/State: _____ /_____

Name (Optional): _____

The survey addresses both natural gas distribution and transmission systems. Although your company may have both systems, please select the one that best describes your area of involvement/expertise:

☐ Distribution System

☐ Transmission System (with pipes at a hoop stress of 20% or more of SMYS)

☐ Both

Please indicate your area(s) of technology expertise/interest (Check all that apply).

☐ Natural gas field operations and maintenance

☐ Integrity Management

☐ Data management and GIS system

☐ Planning, design, and engineering

☐ Regulatory

☐ Other, specify: _____

Rank the top four threat categories which have highest priorities in the integrity management of your system:

	1	2	3	4
▪ External corrosion	()	()	()	()
▪ Internal corrosion	()	()	()	()
▪ Excavation damage	()	()	()	()
▪ Manufacturer-related defects	()	()	()	()
▪ Welding and construction related	()	()	()	()
▪ Equipment failure (e.g., control equipment, couplings)	()	()	()	()
▪ Outside force (e.g., weather-related, flooding, earth movement)	()	()	()	()
▪ External Threats (e.g., vandalism, physical and cyber security)	()	()	()	()
▪ Other, specify _____	()	()	()	()

Technology Areas

In the following four Questions (5-8), indicate if your company have used, or would consider, new devices, systems, or procedures in the specified areas to improve integrity, safety, and costs of your operation. (Check all that apply)

Pipeline Monitoring and Health Assessment:

Have Used	Would Consider	Application Area	Specify Device/tool (If known)
		Right-of-Way (ROW) Encroachments (e.g., sensors, remote sensing)	
		Excavation Damage Detection & Prevention	
		Welding inspection (e.g., longitudinal seam welds)	
		Operating Pressure (MAOP) and Monitoring	
		Pipeline Testing and Monitoring (e.g., field monitoring and smart sensors).	

System Integrity Management:

Used	Will Consider	Application Area	Specify Device/Tool (If known)
		Pipe Locating (e.g., un-locatable facilities)	
		Leak Detection Sensors	
		External Direct Assessment (ECDA)	

		Internal Inspection of Piggable & Un-Piggable Pipes (e.g., UT, EMAT)	
		Land Movement and outside force (e.g., LIDAR)	
		Data Management and Threat Interaction	
		Modeling and Risk Assessment	

System Communication and Control:

Used	Will Consider	Application Area	Specify Device/System (If known)
		Automation & Management System	
		Communications Protocols	
		Response Awareness	
		Cyber-Physical Security	

Asset Life-Cycle Management:

Used	Will Consider	Application Area	Specify Device/System (If known)
		Asset Tracking and Traceability	
		Field Data Capturing	
		Visualization and GIS	

Other Technologies

Is your company involved in the support or the development of a new, or replacement of, devices/tools, systems, or procedures? Yes _____ No _____

If 'Yes', what technology and improvements are anticipated?

_____

Are there any other technologies that should be included?

_____

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APPENDIX B:
Pipeline and Hazardous Materials Safety Administration Gas Incident Records in California [2010 – 2016]

This appendix includes a list of natural gas significant incidents reported in California by the United States Department of Transportation Pipeline and Hazardous Materials Safety Administration from 2010 to 2016.[1] Significant incidents are those including any of the following conditions:

- Fatality or injury requiring in-patient hospitalization
- $50,000 or more in total costs, measured in 1984 dollars
- Highly volatile liquid releases and natural gas
- Liquid and gas releases resulting in an unintentional fire or explosion.

The incidents are compiled in Table B-1: Gas Transmission Incidents in California Reported by Pipeline and Hazardous Materials Safety Administration from 2010 to 2016, and Table B-2: Gas Distribution Incidents in California Reported by Pipeline and Hazardous Materials Safety Administration from 2010 to 2016.

1 PHMSA Incident Files. https://www.phmsa.dot.gov/data-and-statistics/pipeline/pipeline-incident-flagged-files

Table B-1: Gas Transmission Incidents in California Reported by Pipeline and Hazardous Materials Safety Administration from 2010 to 2016

REPORT_RECEIVED_DATE	UNINTENTIONAL_RELEASE	INTENTIONAL_RELEASE	FATAL	INJURE	IGNITE_IND	EXPLODE_IND	NUM_PUB_EVACUATED	PIPE_DIAMETER	RELEASE_TYPE	EST_COST_OPER_PAID	EST_COST_GAS_RELEASED	EST_COST_INTENTIONAL RELEASE	EST_COST_PROP_DAMAGE	EST_COST_EMERGENCY	EST_COST_OTHER	PRPTY	ACCIDENT_PSIG	CAUSE_DETAILS
9/26/2016	232	0	0	0	NO	NO	0		MECHANICAL PUNCTURE	0	1,000	0	450000	0	0	451,000	227	EXCAVATION DAMAGE BY THIRD PARTY
8/16/2016	12,398	0	0	0	NO	NO	0	10.75	RUPTURE	0	33,000	0	188587	0	0	221,587	650	EXCAVATION DAMAGE BY THIRD PARTY
7/5/2016	129000	0	0	0	NO	NO	0	12	RUPTURE	0	340000	0	773015	3226	0	1116241	857	ENVIRONMENTAL CRACKING-RELATED
6/13/2016	7990	0	0	0	NO	NO	0		OTHER	0	26000	0	5000	0	0	31000	734	MALFUNCTION OF CONTROL/RELIEF EQUIPMENT
2/8/2016	0	11500	0	0	NO	NO	0	34	LEAK	0	0	31000	100000	0	0	131000	546	CONSTRUCTION-, INSTALLATION-, OR FABRICATION-RELATED
12/14/2015	67,000	0	1	2	YES	YES	3	34	MECHANICAL PUNCTURE	1000000	176,000	0	642000	717000	0	2,535,000	660	EXCAVATION DAMAGE BY THIRD PARTY
11/24/2015	2,655	0	0	0	NO	NO	0	6	MECHANICAL PUNCTURE	0	0	0	300000	0	0	300,000	118	EXCAVATION DAMAGE BY THIRD PARTY
6/5/2015	0.01	20	0	0	NO	NO	0	3	LEAK	0	1	57	160000	0	0	160058	236	CONSTRUCTION-, INSTALLATION-, OR FABRICATION-RELATED
5/15/2015	7,200	200	1	11	YES	YES	0	12.75	OTHER	80000	21,100	600	1500000	350000	0	1,951,700	369	EXCAVATION DAMAGE BY THIRD PARTY
5/13/2015	1	749	0	0	NO	NO	0	10.75	MECHANICAL PUNCTURE	0	2	2148	85000	0	0	87,150	670	EXCAVATION DAMAGE BY THIRD PARTY
3/30/2015	3,784	204	0	0	NO	NO	6	10	MECHANICAL PUNCTURE	0	16,225	875	450000	0	0	467,100	264	EXCAVATION DAMAGE BY THIRD PARTY
2/27/2015	15175	0	0	0	NO	NO	0		OTHER	0	49396	0	5000	0	0	54396	734	MALFUNCTION OF CONTROL/RELIEF EQUIPMENT
2/6/2015	4250	0	0	0	NO	NO	0		OTHER	0	14000	0	5000	0	0	19000	720	MALFUNCTION OF CONTROL/RELIEF EQUIPMENT
1/23/2015	0.01	0.24	0	0	NO	NO	0	6.625	LEAK	0	0	2	100000	0	0	100002	380	EXTERNAL CORROSION
1/9/2015	0	0	0	0	NO	NO	0		OTHER	0	0	0	0	0	0	0	481	MISCELLANEOUS
12/22/2014	119000	0	0	0	NO	NO	100		OTHER	0	564525	0	5000	0	0	569525	764	MALFUNCTION OF CONTROL/RELIEF EQUIPMENT
11/21/2014	92,000	10,000	0	0	NO	NO		34	MECHANICAL PUNCTURE	0	414,000	45000	520000	0	0	979,000	640	EXCAVATION DAMAGE BY THIRD PARTY
11/25/2014	0	830	0	0	NO	NO	0	24	LEAK	0	0	3735	200000	0	0	203735	285	EXTERNAL CORROSION
9/23/2014	0	1099	0	0	NO	NO	0		OTHER	0	0	0	7500000	0	0	7500000	0	EARTH MOVEMENT, NOT DUE TO HEAVY RAINS/FLOODS
9/18/2014	1258.3	138.2	0	0	NO	NO		6	OTHER	0	4890	537	60000	0	0	65427	475	EXCAVATION DAMAGE BY OPERATOR (FIRST PARTY)
4/24/2014	0	617	0	0	NO	NO	0	16	OTHER	0	0	3125	0	50000	0	53125	680	OTHER INCORRECT OPERATION
4/10/2014	20	650	0	0	NO	NO	0		LEAK	0	0	0	0	80000	0	80000	311	EQUIPMENT NOT INSTALLED PROPERLY
12/20/2013	1,166		0	0	NO	NO		6	OTHER	0	3,300	0	200000	200000	0	403,300	300	EXCAVATION DAMAGE BY THIRD PARTY
11/25/2013	13,798		0	0	NO	NO		16	OTHER	0	40,000	0	100000	10000	0	150,000	585	EXCAVATION DAMAGE BY THIRD PARTY
9/27/2013	3000		0	0	NO	NO		4	LEAK	0	10000	0	195000	5000	0	210000	470	DAMAGE BY CAR, TRUCK, OR OTHER MOTORIZED VEHICLE/EQUIPMENT NOT ENGAGED IN EXCAVATION
7/30/2013	71596		0	0	NO	NO			OTHER	0	281157	0	100	900	0	282157	746	MALFUNCTION OF CONTROL/RELIEF EQUIPMENT
12/28/2012	4,700	0	0	0	NO	NO		6	RUPTURE	15000	16,000	0	465000	50000	0	546,000	412	PREVIOUS DAMAGE DUE TO EXCAVATION ACTIVITY
12/28/2012	7,010		0	0	NO	NO		12.75	MECHANICAL PUNCTURE	450	10,450	3000	350000	0	0	363,900	370	EXCAVATION DAMAGE BY THIRD PARTY
12/11/2012	51,000		0	0	NO	NO		8.625	MECHANICAL PUNCTURE	0	20,010	0	85000	0	0	105,010	318	EXCAVATION DAMAGE BY THIRD PARTY
11/3/2012	3200		0	0	NO	NO	0		LEAK	0	10800	0	0	25000	0	35800	280	EXCAVATION DAMAGE BY OPERATOR'S CONTRACTOR (SECOND PARTY)
10/19/2011	11	193	0	0	NO	NO	0	16	LEAK	0	0	5000	1740000	0	254000	1999000	341	EXTERNAL CORROSION
10/7/2011	1,500	1,500	0	0	NO	NO	0	12	MECHANICAL PUNCTURE	0	0	0	55000	5000	0	60,000	323	EXCAVATION DAMAGE BY THIRD PARTY
7/11/2011	2,000	0	0	0	NO	NO	0	16	MECHANICAL PUNCTURE	0	10,000	0	60000	0	0	70,000	360	EXCAVATION DAMAGE BY THIRD PARTY
6/20/2011	0	3000	0	0	NO	NO	0		OTHER	0	0	10000	30000	0	0	40000	285	MALFUNCTION OF CONTROL/RELIEF EQUIPMENT
6/24/2011	0	465	0	0	NO	NO	0		OTHER	0	0	2000000	0	1400000	0	3400000	493	OTHER INCORRECT OPERATION
12/29/2010	8,500		0	0	NO	NO		6	MECHANICAL PUNCTURE	0	0	0	82000	0	0	82,000	250	EXCAVATION DAMAGE BY THIRD PARTY
10/29/2010	12,000		0	0	NO	NO	0	12	MECHANICAL PUNCTURE	0	42,892	0	47000	620	0	90,512	402	EXCAVATION DAMAGE BY THIRD PARTY

Table B-1 [Continued]: Gas Transmission Incidents in California Reported by Pipeline and Hazardous Materials Safety Administration from 2010 to 2016

REPORT_RECEIVED_DATE	UNINTENTIONAL_RELEASE	INTENTIONAL_RELEASE	FATAL	INJURE	IGNITE_IND	EXPLODE_IND	NUM_PUB_EVACUATED	PIPE_DIAMETER	RELEASE_TYPE	EST_COST_OPER_PAID	EST_COST_GAS_RELEASED	EST_COST_INTENTIONAL RELEASE	EST_COST_PROP_DAMAGE	EST_COST_EMERGENCY	EST_COST_OTHER	PRPTY	ACCIDENT_PSIG	CAUSE_DETAILS
10/13/2010	47600	0	8	51	YES	YES	108	30	RUPTURE	50000000	263000	0	100000	0	5.08E+08	558363000	386	ORIGINAL MANUFACTURING-RELATED (NOT GIRTH WELD OR OTHER WELDS FORMED IN THE FIELD)
3/26/2010	1		0	0	YES	NO	0		OTHER	0	0	0	50000	5000	0	55000	10	OTHER OUTSIDE FORCE DAMAGE
6/15/2012	0	40	0	0	YES	NO	0		OTHER	32000	0	240	36000	1000	0	69240	51	NEARBY INDUSTRIAL, MAN-MADE, OR OTHER FIRE/EXPLOSION AS PRIMARY CAUSE OF INCIDENT
12/17/2014	36,589	140	0	0	NO	NO	0	10.75	MECHANICAL PUNCTURE	0	147,512	564	63821	31000	0	242,897	640	EXCAVATION DAMAGE BY THIRD PARTY
11/14/2014	0	28	0	0	NO	NO	0		OTHER	0	0	166	50603	600	0	51369	600	VALVE LEFT OR PLACED IN WRONG POSITION, BUT NOT RESULTING IN AN OVERPRESSURE
8/15/2014	27,750		0	0	NO	NO	0	10	MECHANICAL PUNCTURE	0	153,112	0	103375	168960	0	425,447	381	EXCAVATION DAMAGE BY THIRD PARTY
6/7/2013	11,300	0	0	0	NO	NO	0	10	MECHANICAL PUNCTURE	0	68,000	0	250000	1000	0	319,000	362	EXCAVATION DAMAGE BY THIRD PARTY
2/4/2013	1540	0	0	0	YES	NO	0		OTHER	300000	9250	0	650000	500	0	959750	763	OTHER INCORRECT OPERATION
8/5/2011	3,270	1,920	0	0	NO	NO	0	18	MECHANICAL PUNCTURE	0	13,000	7500	200000	1000	0	221,500	590	EXCAVATION DAMAGE BY THIRD PARTY
9/2/2010	63,410	3,790	0	0	NO	NO	0	26	MECHANICAL PUNCTURE	0	285,000	0	150000	10000	0	445,000	376	EXCAVATION DAMAGE BY THIRD PARTY
4/5/2012	5	395	0	0	NO	NO	0		MECHANICAL PUNCTURE	0	0	3200	60000	0	0	63200	400	EXCAVATION DAMAGE BY OPERATOR (FIRST PARTY)
9/1/2010	0	0	0	0	NO	NO	0	12.75	MECHANICAL PUNCTURE	0	0	0	75000	0	0	75000	35	EXCAVATION DAMAGE BY OPERATOR'S CONTRACTOR (SECOND PARTY)

Table B-2: Gas Distribution Incidents in California Reported by Pipeline and Hazardous Materials Safety Administration from 2010 to 2016

REPORT_DATE	LOCATION_CITY	GAS_RELEASED [MCF]	FATALITY	INJURY	IGNITE_IND	EXPLODE_IND	NUM_PUB_ EVACUATED	INCIDENT_AREA_TYPE	SYSTEM_PART_INV OLVED	Total Cost	CAUSE
9/21/2016	SAN DIEGO	210	0	0	NO	NO	100	UNDERGROUND	SERVICE	86260	OTHER INCIDENT CAUSE
9/9/2016	VISALIA	0	0	0	YES	NO	0	ABOVEGROUND	OUTSIDE METER/REGULATOR SET	192949	OTHER OUTSIDE FORCE DAMAGE
9/9/2016	DEER PARK	100	0	0	YES	NO	0	ABOVEGROUND	SERVICE RISER	55000	INCORRECT OPERATION
9/2/2016	WOODLAND HILLS	701	0	0	YES	NO	0	UNDERGROUND	MAIN	90946	EXCAVATION DAMAGE
8/16/2016	LOS BANOS	1500	0	0	NO	NO	0	UNDERGROUND	SERVICE	216602	EQUIPMENT FAILURE
8/15/2016	SAN JOSE	1500	0	0	NO	NO	1	UNDERGROUND	OTHER	193073	EXCAVATION DAMAGE
8/7/2016	LOS ANGELES	24	1	0	YES	NO	0	ABOVEGROUND	OUTSIDE METER/REGULATOR SET	201990	OTHER OUTSIDE FORCE DAMAGE
6/27/2016	SACRAMENTO	330.16	0	0	NO	NO	0	UNDERGROUND	MAIN	561860	EXCAVATION DAMAGE
5/27/2016	LOS ANGELES	48	0	0	YES	YES	16	ABOVEGROUND	OUTSIDE METER/REGULATOR SET	757694	OTHER OUTSIDE FORCE DAMAGE
4/13/2016	MORAGA	5200	0	0	NO	NO	19	UNDERGROUND	MAIN	124000	NATURAL FORCE DAMAGE
3/25/2016	LANCASTER	20	0	0	YES	NO	6	ABOVEGROUND	SERVICE RISER	143138	OTHER OUTSIDE FORCE DAMAGE
2/17/2016	OAKLAND	0	0	0	YES	YES	1	ABOVEGROUND	INSIDE METER/REGULATOR SET	155000	OTHER OUTSIDE FORCE DAMAGE
9/10/2016	CAMARILLO	0	0	1	NO	NO	0	ABOVEGROUND	MAIN	0	OTHER OUTSIDE FORCE DAMAGE
12/9/2015	STOCKTON	300	1	0	YES	NO	2	ABOVEGROUND	OUTSIDE METER/REGULATOR SET	106500	OTHER OUTSIDE FORCE DAMAGE
11/30/2015	SACRAMENTO	427.53	0	0	NO	NO	13	UNDERGROUND	MAIN	51838	EXCAVATION DAMAGE
9/25/2015	SANTA CLARA	100	0	2	YES	NO	15	ABOVEGROUND	OUTSIDE METER/REGULATOR SET	58537	OTHER OUTSIDE FORCE DAMAGE
9/15/2015	SAN DIEGO	32	0	0	YES	NO	1	ABOVEGROUND	OUTSIDE METER/REGULATOR SET	141310	OTHER OUTSIDE FORCE DAMAGE
9/10/2015	SANTA MONICA	38	0	0	YES	NO	1	ABOVEGROUND	OUTSIDE METER/REGULATOR SET	201423	OTHER OUTSIDE FORCE DAMAGE
8/13/2015	CORONA	861	0	0	NO	NO	0	UNDERGROUND	MAIN	256408	EXCAVATION DAMAGE
7/24/2015	STOCKTON	30	0	0	YES	NO	10	ABOVEGROUND	OUTSIDE METER/REGULATOR SET	57165	OTHER OUTSIDE FORCE DAMAGE
7/17/2015	UNION CITY	0.5	1	0	YES	NO	10	ABOVEGROUND	OUTSIDE METER/REGULATOR SET	55005	OTHER OUTSIDE FORCE DAMAGE
6/12/2015	LOS ANGELES	3185	0	0	NO	NO	100	UNDERGROUND	MAIN	56194	EXCAVATION DAMAGE
6/5/2015	SOUTH EL MONTE	71	0	0	NO	NO	0	UNDERGROUND	MAIN	190424	OTHER OUTSIDE FORCE DAMAGE
3/26/2015	SACRAMENTO	293	0	0	NO	NO	0	UNDERGROUND	MAIN	164860	EXCAVATION DAMAGE
2/27/2015	BALDWIN PARK	53	0	0	YES	NO	0	UNDERGROUND	MAIN	56518	OTHER OUTSIDE FORCE DAMAGE
2/25/2015	SAN BRUNO	27	0	0	YES	NO	3	ABOVEGROUND	OUTSIDE METER/REGULATOR SET	56384	OTHER OUTSIDE FORCE DAMAGE

Table B-2 [Continued]: Gas Distribution Incidents in California Reported by Pipeline and Hazardous Materials Safety Administration From 2010 to 2016

REPORT_DATE	LOCATION_CITY	GAS_RELEASED [MCF]	FATALITY	INJURY	IGNITE_IND	EXPLODE_IND	NUM_PUB_ EVACUATED	INCIDENT_AREA_TYPE	SYSTEM_PART_INV OLVED	Total Cost	CAUSE
2/19/2015	SAN JOSE	240.27	0	0	NO	NO	12	UNDERGROUND	SERVICE	94027	EXCAVATION DAMAGE
1/28/2015	OAKLAND	365	0	0	NO	NO	0	UNDERGROUND	OTHER	$326,500	CORROSION FAILURE
12/16/2014	SAN JOSE	25.91	0	0	YES	NO		ABOVEGROUND	OUTSIDE METER/REGULATOR SET	57098	OTHER OUTSIDE FORCE DAMAGE
12/8/2014	SAN JOSE	1228	0	0	NO	NO		UNDERGROUND	MAIN	109640	EXCAVATION DAMAGE
11/4/2014	KING CITY	102.17	0	1	YES	NO		ABOVEGROUND	OUTSIDE METER/REGULATOR SET	23410	OTHER OUTSIDE FORCE DAMAGE
10/30/2014	SAN JOSE	3251	0	0	NO	NO		UNDERGROUND	MAIN	99136	EXCAVATION DAMAGE
10/15/2014	LAFAYETTE	77.99	0	0	NO	NO		UNDERGROUND	MAIN	115315	EXCAVATION DAMAGE
9/23/2014	AMERICAN CANYON		0	0	NO	NO		ABOVEGROUND	OTHER	15400000	NATURAL FORCE DAMAGE
8/22/2014	NEWPORT BEACH	4021	0	0	NO	NO	20	UNDERGROUND	MAIN	525624	EXCAVATION DAMAGE
8/8/2014	SAN DIEGO	20	0	1	YES	NO	4	ABOVEGROUND	OUTSIDE METER/REGULATOR SET	21169	OTHER OUTSIDE FORCE DAMAGE
8/15/2014	MERCED	127	0	0	YES	NO		ABOVEGROUND	OUTSIDE METER/REGULATOR SET	52508	OTHER OUTSIDE FORCE DAMAGE
7/17/2014	ANTIOCH	3.59	0	0	NO	NO	0	UNDERGROUND	MAIN	70021	EXCAVATION DAMAGE
7/10/2014	SAN FRANCISCO	57	0	0	YES	NO		ABOVEGROUND	OUTSIDE METER/REGULATOR SET	10330	OTHER OUTSIDE FORCE DAMAGE
8/8/2014	SAN JOSE	67.5	0	0	NO	NO		UNDERGROUND	MAIN	67567	EXCAVATION DAMAGE
6/10/2014	CALABASAS	21	0	0	NO	NO	2	ABOVEGROUND	OUTSIDE METER/REGULATOR SET	202126	OTHER OUTSIDE FORCE DAMAGE
6/13/2014	MERCED	92.34	2	0	YES	NO		ABOVEGROUND	SERVICE RISER	3496	OTHER OUTSIDE FORCE DAMAGE
4/2/2014	CARMEL		0	0	NO	YES	1	ABOVEGROUND	MAIN	302000	INCORRECT OPERATION
3/18/2014	MONTCLAIR	548	0	0	NO	NO	0	UNDERGROUND	MAIN	1245288	OTHER OUTSIDE FORCE DAMAGE
2/13/2014	HEMET	14	0	0	YES	NO	6	UNDERGROUND	SERVICE	52284	OTHER OUTSIDE FORCE DAMAGE
11/21/2013	IRWINDALE	844	0	0	NO	NO	50	UNDERGROUND	SERVICE	86065	EXCAVATION DAMAGE
11/18/2013	TEMECULA	13	0	0	YES	NO	8	ABOVEGROUND	SERVICE RISER	50879	OTHER OUTSIDE FORCE DAMAGE
9/21/2013	OAKLAND	97.25	0	0	YES	NO		ABOVEGROUND	OUTSIDE METER/REGULATOR SET	75100	OTHER OUTSIDE FORCE DAMAGE
9/13/2013	RIVERSIDE	2987	0	0	NO	NO	0	UNDERGROUND	MAIN	599617	EXCAVATION DAMAGE
8/23/2013	HILMAR	30	0	0	YES	NO	0	ABOVEGROUND	OUTSIDE METER/REGULATOR SET	54165	OTHER OUTSIDE FORCE DAMAGE
8/23/2013	EL DORADO HILLS		0	0	YES	NO		UNDERGROUND	SERVICE	56000	EXCAVATION DAMAGE
7/22/2013	SAN JOSE		0	0	YES	NO		ABOVEGROUND	OUTSIDE METER/REGULATOR SET	802700	OTHER OUTSIDE FORCE DAMAGE

Table B-2 [Continued]: Gas Distribution Incidents in California Reported by Pipeline and Hazardous Materials Safety Administration From 2010 to 2016

REPORT_DATE	LOCATION_CITY	GAS_RELEASED [MCF]	FATALITY	INJURY	IGNITE_IND	EXPLODE_IND	NUM_PUB_ EVACUATED	INCIDENT_AREA_TYPE	SYSTEM_PART_INV OLVED	Total Cost	CAUSE
6/21/2013	MAMMOTH LAKES	10.9	0	0	NO	NO	0	UNDERGROUND	MAIN	3775	EXCAVATION DAMAGE
5/29/2013	GARDEN GROVE	11	0	0	YES	NO	3	ABOVEGROUND	SERVICE RISER	50866	OTHER OUTSIDE FORCE DAMAGE
5/22/2013	BAKERSFIELD		0	0	YES	NO		UNDERGROUND	MAIN	753200	EXCAVATION DAMAGE
5/22/2013	SAN JOSE	820	0	0	NO	NO		UNDERGROUND	MAIN	55000	EXCAVATION DAMAGE
4/22/2013	ATASCADERO	150	0	0	NO	NO	0	UNDERGROUND	MAIN	501000	OTHER OUTSIDE FORCE DAMAGE
4/24/2013	FRESNO	1690	0	0	NO	NO		UNDERGROUND	MAIN	300000	EXCAVATION DAMAGE
4/12/2013	BERKELEY		0	0	YES	NO		UNDERGROUND	SERVICE	102220	EXCAVATION DAMAGE
1/14/2013	ANAHEIM	162	0	0	YES	NO	0	UNDERGROUND	SERVICE	72000	MATERIAL FAILURE OF PIPE OR WELD
10/3/2012	STUDIO CITY	22	3	0	YES	NO	0	ABOVEGROUND	OUTSIDE METER/REGULATOR	13525	OTHER OUTSIDE FORCE DAMAGE
9/21/2012	INDIO	42	0	0	YES	NO	0	ABOVEGROUND	OUTSIDE METER/REGULATOR	1750	OTHER OUTSIDE FORCE DAMAGE
8/22/2012	CLAREMONT	1	0	0	NO	NO	0	UNDERGROUND	MAIN	76006	OTHER OUTSIDE FORCE DAMAGE
8/16/2012	ARCADIA	1	0	0	NO	NO	0	UNDERGROUND	MAIN	210005	OTHER OUTSIDE FORCE DAMAGE
8/8/2012	ROSEVILLE	0.01	0	0	YES	NO	3	ABOVEGROUND	OUTSIDE METER/REGULATOR	102000	OTHER OUTSIDE FORCE DAMAGE
8/21/2012	RANCHO MIRAGE	1	0	0	NO	NO	0	UNDERGROUND	MAIN	70506	OTHER OUTSIDE FORCE DAMAGE
7/12/2012	SAN FRANCISCO		0	1	YES	YES	20	UNDERGROUND	SERVICE	1000000	OTHER OUTSIDE FORCE DAMAGE
7/11/2012	LIVERMORE		0	0	YES	NO	2	ABOVEGROUND	OUTSIDE METER/REGULATOR	302000	OTHER OUTSIDE FORCE DAMAGE
7/9/2012	SALINAS		0	0	YES	NO	1	ABOVEGROUND	OUTSIDE METER/REGULATOR	152000	OTHER OUTSIDE FORCE DAMAGE
7/6/2012	SAN JOSE		0	0	NO	NO		UNDERGROUND	SERVICE	21000	OTHER OUTSIDE FORCE DAMAGE
5/18/2012	HILLSBOROUGH	872	0	0	NO	NO	0	UNDERGROUND	MAIN	53600	MATERIAL FAILURE OF PIPE OR WELD
5/9/2012	OAKDALE	1	0	0	YES	NO		ABOVEGROUND	OUTSIDE METER/REGULATOR	102000	OTHER OUTSIDE FORCE DAMAGE
3/9/2012	LOS ANGELES	19	0	0	NO	NO	6	UNDERGROUND	SERVICE	151415	OTHER OUTSIDE FORCE DAMAGE
10/26/2011	HANFORD	39	0	0	YES	YES	0	UNDERGROUND	SERVICE	76950	OTHER OUTSIDE FORCE DAMAGE
9/30/2011	CUPERTINO	120	0	0	YES	YES	5	UNDERGROUND	MAIN	612000	MATERIAL FAILURE OF PIPE OR WELD
4/21/2011	LAMONT	10	0	0	YES	NO	12	ABOVEGROUND	OTHER	1300	OTHER OUTSIDE FORCE DAMAGE
4/19/2011	TRUCKEE	158	0	0	NO	NO	10	UNDERGROUND	SERVICE	89876	MATERIAL FAILURE OF PIPE OR WELD
3/23/2011	GARDEN GROVE	11032	0	0	NO	NO	0	UNDERGROUND	MAIN	96000	EXCAVATION DAMAGE
2/7/2011	MODESTO		0	0	YES	NO		ABOVEGROUND	OUTSIDE METER/REGULATOR	102001	OTHER OUTSIDE FORCE DAMAGE
11/12/2010	ANTIOCH		0	0	YES	NO		ABOVEGROUND	OUTSIDE METER/REGULATOR	107000	OTHER OUTSIDE FORCE DAMAGE
10/7/2010	ROSEVILLE		0	0	NO	NO		UNDERGROUND	MAIN	293600	MATERIAL FAILURE OF PIPE OR WELD
9/27/2010	COTTONWOOD	25	0	0	YES	NO	0	ABOVEGROUND	OUTSIDE METER/REGULATOR	55000	OTHER OUTSIDE FORCE DAMAGE

Table B-2 [Continued]: Gas Distribution Incidents in California Reported by Pipeline and Hazardous Materials Safety Administration from 2010 to 2016

REPORT_DATE	LOCATION_CITY	GAS_RELEASED [MCF]	FATALITY	INJURY	IGNITE_IND	EXPLODE_IND	NUM_PUB_ EVACUATED	INCIDENT_AREA_TYPE	SYSTEM_PART_INV OLVED	Total Cost	CAUSE
9/24/2010	LOS ALTOS	27	0	0	YES	NO	0	UNDERGROUND	SERVICE	61000	EXCAVATION DAMAGE
8/17/2010	LOS ANGELES	0	1	1	YES	YES	100	ABOVEGROUND	OTHER	2000	OTHER OUTSIDE FORCE DAMAGE
8/11/2010	SAN DIEGO	94	0	0	YES	NO	5	ABOVEGROUND	SERVICE RISER	1300	OTHER OUTSIDE FORCE DAMAGE
7/20/2010	SACRAMENTO	4.6	0	4	YES	YES	0	ABOVEGROUND	OUTSIDE METER/REGULATOR	100000	OTHER OUTSIDE FORCE DAMAGE
7/20/2010	TAFT	10	0	0	YES	NO	1	ABOVEGROUND	OUTSIDE METER/REGULATOR	332000	OTHER OUTSIDE FORCE DAMAGE
7/12/2010	GERBER	100	1	0	YES	NO	0	ABOVEGROUND	OUTSIDE METER/REGULATOR	52000	OTHER OUTSIDE FORCE DAMAGE
6/30/2010	ANDERSON	10	0	0	YES	NO	0	ABOVEGROUND	OUTSIDE METER/REGULATOR	2000	OTHER OUTSIDE FORCE DAMAGE
6/14/2010	STOCKTON	10	0	0	YES	NO	1	ABOVEGROUND	OUTSIDE METER/REGULATOR	102000	OTHER OUTSIDE FORCE DAMAGE
6/14/2010	MODESTO	10	0	0	YES	NO	3	UNDERGROUND	OUTSIDE METER/REGULATOR	15000	OTHER OUTSIDE FORCE DAMAGE
3/11/2010	STOCKTON	10	0	0	YES	NO	0	ABOVEGROUND	OUTSIDE METER/REGULATOR	102500	OTHER OUTSIDE FORCE DAMAGE
5/10/2010	SACRAMENTO	10	0	0	YES	NO	0	ABOVEGROUND	OUTSIDE METER/REGULATOR	3000	OTHER OUTSIDE FORCE DAMAGE
5/10/2010	EUREKA	102	0	0	NO	NO	16	UNDERGROUND	MAIN	2500	NATURAL FORCE DAMAGE

APPENDIX C:
National Transportation Safety Board Gas Accident Records in California

This appendix lists reported accidents by the National Transportation Safety Board (NTSB) in California pipeline system from 1976 to 2016.[2] The list included the characteristics of the pipeline and causes of the accidents.

Report Number	NTSB Title	Accident Date	Report Date	City	Notes
PAR-76-08	Standard Oil Company of California, Pipeline Rupture	6/16/1976	12/9/1976	Los Angeles	8-inch, API 5L X-46 pipe carrying gasoline. Cause: Pipe ruptured by excavation equipment
PAR-81-04	Four Corners Pipeline Company Pipe Rupture and Fire	12/1/1980	8/18/1981	Long Beach	10-inch steel pipe. Liquid transmisson. Cause: overpressure of the pipeline and rupture at location thinned by internal corrosion
PAR-82-01	Pacific Gas and Electric Company Natural Gas Pipeline and Puncture	8/25/1981	2/25/1982	San Francisco	16-inch gas main at pressure 32 psi. Cause: Puncture by a drill used by a contractor to set tiebacks for excavation shoring
PAB-10-01	Explosion, Release, and Ignition of Natural Gas, Rancho Cordova, CA	12/24/2008	5/18/2010	Rancho Cordova	1/2-inch DuPont Aldyl A polyethylene service pipeline fed by a 2-inch DuPont Aldyl A polyethylene gas main. Pressure at 55 psi. Cause: Unmarked and out-of-specification polyethylene pipe with inadequate wall thickness slipped out of the Metfit coupling.
PAR-11-01	Pacific Gas and Electric Company Natural Gas Transmission Pipeline Rupture and Fire	9/9/2010	8/30/2011	San Bruno	30-inch natural gas transmission pipeline. Cause: Inadequate quality assurance and quality control in 1956 during Line relocation, which allowed the installation of a substandard and poorly welded pipe section with a visible seam weld flaw.

[2] NTSB Accidents Records. https://www.ntsb.gov/investigations/AccidentReports/Pages/AccidentReports.aspx.

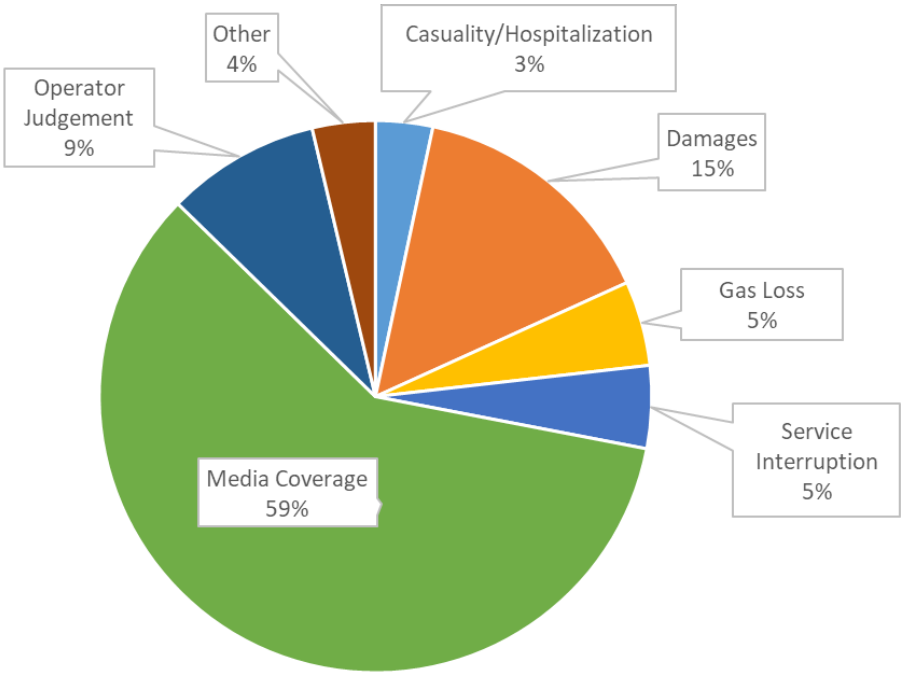
APPENDIX D:
Incident Records, California Public Utility Commission Safety Reports

The California Public Utility Commission (CPUC) publishes an annual safety report which lists gas and electric service safety incidents in accordance with Senate Bill 1409 requirements. The Senate Bill, Section 911, requires the CPUC to publish an annual safety report. The report lists investigations into reported gas or electric service safety incidents.

The incidents reported from 2015 to 2017 were compiled and analyzed to characterize the main threats in the California gas distribution pipeline system. A total number of 865 incidents were reported during this period. Some of these reported incidents were listed in multiple years, depending on the duration of their investigations. The incidents were reported according to a set criterion based on the consequences of casualty, hospitalization, damage, and service interruption.

The CPUC reports also include other non-significant incidents which were reported by media coverage or recorded based on operator judgement. A breakdown of the CPUC reported incidents by reason of investigation is shown in Figure D-1. A major portion of the records were reported based on media coverage and operator judgment.

Figure D-1: Reported Gas Incidents in California by Reason of investigation

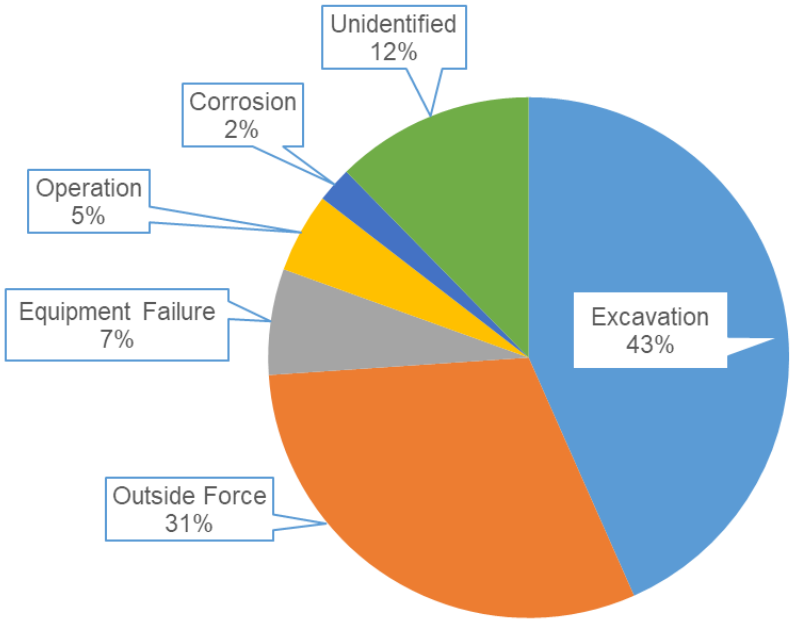


Source: Compiled from California Public Utilities Commission Annual Reports, 2015 to 2017

Reported Incidents by Cause

A breakdown of the CPUC reported incidents by cause is shown in Figure D-2. The figure shows that excavation damage and outside force are the primary threats to the gas pipeline system. About 93% of the excavation incidents were caused by third-party damage with the remaining incidents resulting from excavations by the utilities and their contractors (first and second-party incidents). The percentages of excavation and outside force threats in these records are higher than those from PHMSA records, mainly because PHMSA records repot only significant incidents rather than by the other reasons shown in Figure D-1. Table D-1 shows a breakdown of the damages caused by natural forced in California in this period and Figure D-3 shows a breakdown of reported incidents by facility type.

Figure D-2: Reported Gas Incidents in California by Threat



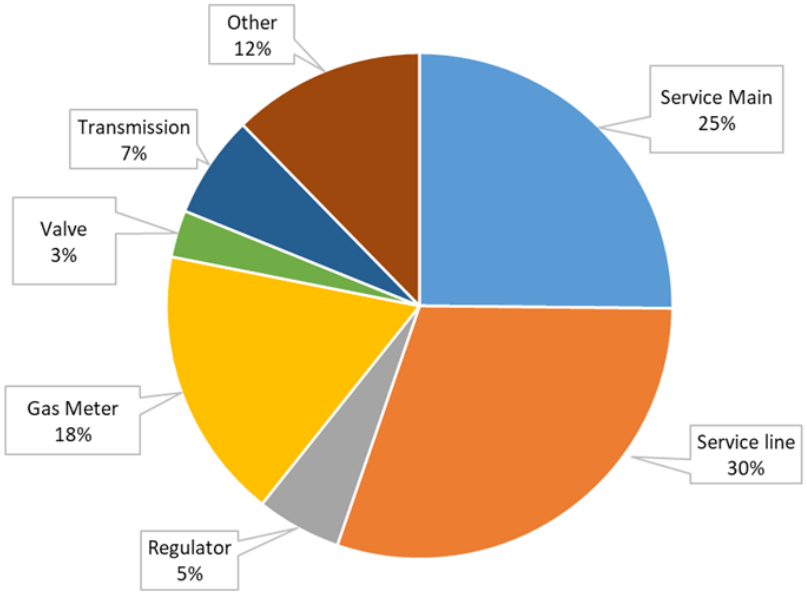
Source: Compiled from California Public Utilities Commission Annual Reports, 2015 to 2017

Table D-1: Breakdown of Damages by Natural Force

Natural Force Damage	%
Debris & Fallen Objects	10.2%
Flood & Land slide	7.9%
Vehicle hits	33.2%
Structural/wild fire	48.7%

Source: Compiled from California Public Utilities Commission Annual Reports, 2015 to 2017

Figure D-3: Reported Incidents by Facility Type



Source: Compiled from California Public Utilities Commission Annual Reports, 2015 to 2017

APPENDIX E:
Examples of Recent Commercial Pipeline Technologies

Natural gas pipeline operators use a vast volume of technologies to address their needs. This appendix provides examples of recent commercial technologies in the market. Due to the nature of technology developments, the data in the appendix does not cover all the technologies used by the operators or recently introduced to the market. Earlier standard technologies used in transmission pipelines were presented in an earlier report.[3]

The technologies address the following three categories presented in the main report:

- Damage prevention and mitigation
- Threats and integrity management
- Pipeline risk and information management

The applicable matrix of technologies benefits are:

- Increase safety
- Reduce operations costs
- Greater reliability
- Environmental benefits
- Customer appeal

The material presented in the appendix is for information only and mainly retrieved from current literature and public domains. This appendix does not endorse any of the technologies or products listed, and the information does not represent any warranty or representation with respect to its accuracy, completeness, or that its use may not infringe privately-owned rights. Inasmuch, the authors do not assume any liability with respect to the use of these technologies by any third party, which is at the third party's sole responsibility.

3 California Natural Gas Pipeline Assessment: Improving Safety through Enhanced Assessment and Monitoring Technology Implementation. California Energy Commission. Report CEC-500-10-050. 2013.

Project/Technology Name:

Acoustic Pipe Locator (APL)

Performer/Contractor:	**Commercializer:**
Operations Technology Development (OTD)	SENSIT Technologies

Program Area:

1. Damage Detection and Prevention - Pipe locating

Project/Technology Description:

The APL pipe locator is a hand-held device which sends an acoustic signal into the ground and detects reflection from the pipe at the ground level. The technology provides the ability to locate plastic pipes at depths up to five feet.

As part of the research for this development, a PHMSA-funded project developed an algorithm for improved locating of pipes without tracer wire.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The technology addresses the industry need to detect and locate buried underground natural gas pipes, particularly plastic pipes. Most of the current electro-magnetic locating technologies are based on the detection of metallic pipes. Few current technologies address plastic pipes buried without, or with damaged, tracer wires commonly used to identify pipe locations.

Applicable Metrics:

Increase Safety - Greater Reliability: Plastic pipes buried a few feet under the ground are subject to excavation damages resulting in leaks and failures. This technology provides a method for detecting and locating these pipes.

References:

- SENSIT Technologies, www.gasleaksensors.com
- PHMSA, https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=365

Project/Technology Name:

Metallic Joint Locator (MJL)

Performer/Contractor:	**Commercializer:**
Operations Technology Development (OTD)	SENSIT Technologies

Program Area:

1. Damage Detection and Prevention - Pipe locating

Project/Technology Description:

The Ultra-Trac MJL provides an easy way to locate cast-iron joints, chill rings in welded steel pipe, metallic tapping tees, metallic flanges, and metal repair clamps. In field tests, the MJL was also able to detect bell and spigot joints for an eight-inch-diameter water main buried at a depth of six feet.

Impact of Project/Technology on Technological Advancement to Gas Industry:

Natural gas utilities needed a technique to accurately locate features on metallic piping. The concept focused on locating bell and spigot joints on cast iron piping. The change in cross section at such features produces a change in how the piping interacts with a magnetic field. The concept was proven in the laboratory and was also broadened to include such features as welds.

Applicable Metrics:

Increase Safety – Reduce operations costs: The technology increases the safety of excavation damage by locating cast iron pipes, and the reliability of pinpointing the joints locations. This reduces the costs associated with excavations for leak repairs at the cast iron joints.

References:

- Metallic Joint Locator Development. Operations Technology Development. OTD Project Report 1.7.d. Sept. 2010.
- SENSIT Technologies, www.gasleaksensors.com

Project/Technology Name:

Satellite-Based Pipeline Encroachment Monitoring

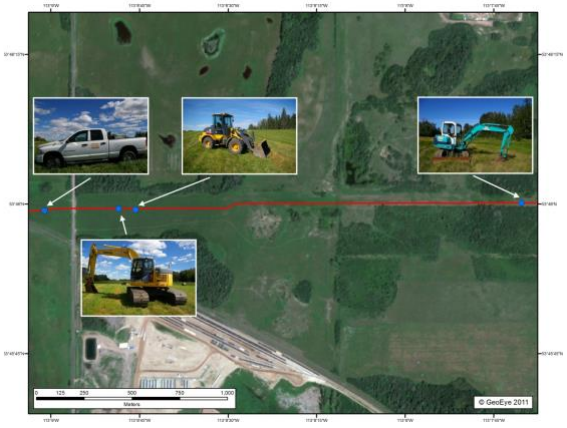
Performer/Contractor:	**Commercializer:**
Pipeline Research Council International (PRCI)	C-Core

Program Area:

1. Damage Detection and Prevention – ROW Encroachment

Project/Technology Description:

The technology provides the capabilities of a new generation of Interferometric Synthetic Aperture Radar (InSAR) satellites that are now in orbit and operational. One key capability investigated was the use of the higher resolution beam modes available from all these newer satellites.



Impact of Project/Technology on Technological Advancement to Gas Industry:

Satellite monitoring offers unique advantages to the industry in meeting the objectives of managing third party encroachment and potential for mechanical damage. PRCI Satellite Technology Evaluation for ROW encroachment – accessing an expanded satellite Network. Optical and SAR (RADARSAT-1). Prior results show 80%+ detection with less than 15% false call and it Reports in 3.5 hours.

Applicable Metrics:

Increased Safety: The technology enhances safety using new InSAR satellites in terms of increased probability of detection of pipeline encroachment events over older satellites.

References:

Satellite-Based Pipeline Encroachment Monitoring. Final Report. PRCI. Contract PR-394-113703-R03. 2012.

Project/Technology Name:

Radar Monitoring of Slope Stability along Pipeline ROW

Performer/Contractor:	**Commercializer:**
Pipeline Research Council International (PRCI)	iRadar

Program Area:

1. Damage Detection and Prevention – ROW Monitoring

Project/Technology Description:

The technology is a ground-based synthetic aperture radar (SAR) for Monitoring of Slope Stability along Pipeline ROW. The radar technique uses two or more synthetic aperture radar (SAR) images to produce images of surface deformation.

Impact of Project/Technology on Technological Advancement to Gas Industry:

This technique can achieve sub-millimeter changes in deformation over spans of days to years. Its applications include geophysical monitoring of earth environments such as landslides, terrain subsidence, falling rocks, glaciers, avalanches and volcanoes, as well as remote monitoring of engineering structures such as bridges, buildings, towers, dams and roads.

Applicable Metrics:

Increased Safety, Greater Reliability: This technology enhances safety, reliability and damage prevention by providing a tool for inspecting aboveground movements in landslides and other outside force threats.

References:

http://www.iradar.com.my/

Project/Technology Name:

Portable Methane Detector (PMD)

Performer/Contractor:	**Commercializer:**
Operations Technology Development (OTD)	SENSIT Technologies

Program Area:

1. Damage Detection and Prevention – Leak Detection

Project/Technology Description:

The handheld PMD is a small, lightweight, battery operated instrument used to survey, pinpoint, and grade leaks using filtered infrared spectroscopy technology. The device has a high sensitivity of 1 ppm to detect methane leaks in a range of 0-100% gas volume for faster natural gas leak classification.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The sensor uses optical-detection technology to provide sensitivity and cost advantage over conventional techniques which use flame ionization detectors. It allows for pipeline leak detection during walking or vehicle operations for greater user survey flexibility. The sensor is designed to be intrinsically safe in both indoor or outdoor environments.

Applicable Metrics:

Increase Safety - Reduce Operations Costs – Greater Reliability: Leak survey of belowground gas pipelines provides first indication of pipeline damage due to corrosion, excavation damage, and other threats. Leak detection initiates the utilities' response for inspection, repair, and replacement of the damaged pipe segments before further catastrophic consequences such as fire or explosion occur.

The PMD improves the efficiency of leak surveys, is less costly to maintain than other technologies, and can detect leaks from low ppm to 100% gas.

References:

SENSIT Technologies, www.gasleaksensors.com

Project/Technology Name:

Differential-Absorption Lidar (DIAL) Methane Monitor

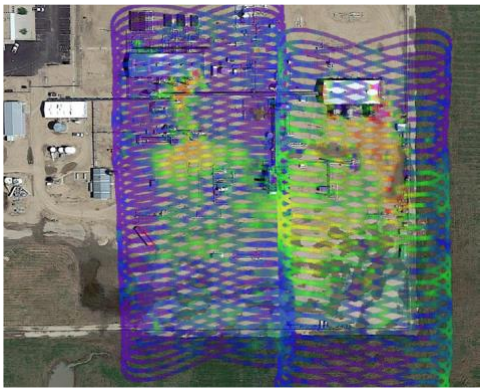
Performer/Contractor:	**Commercializer:**
Ball Aerospace & Technologies	Ball Aerospace & Technologies

Program Area:

1. Damage Detection and Prevention – Leak Detection

Project/Technology Description:

Methane Monitor is a differential-absorption lidar (DIAL) methane detection system that uses two lasers of slightly different infrared wavelengths to map the ground and measure atmospheric methane. Methane strongly absorbs one of the wavelengths (at about 1,645.55 nm, the "on-resonance beam") and is virtually transparent to the other—at about 1645.4 nm, the "off-resonance beam"). DIAL makes 1,000 to 10,000 measurements per second, firing the off- and on-resonance beams a few nanoseconds apart. The lasers light bounces off the ground and scatters back to the receiver, and the system calculates the intensity differences between the returns to measure the amount of methane in the beams' paths.



Impact of Project/Technology on Technological Advancement to Gas Industry:

Enables LIDAR measurements with single-engine, fixed-wing aircraft, reducing operating costs and improving safety compared to helicopter-based sensors. Cruising in calm conditions at an altitude of 500 to 1000 meters, Methane Monitor can detect methane leaking at 50 cubic feet per hour, while sweeping a corridor up to 60 meters wide and providing real-time heat-map images of methane plumes overlaid on ground images.

Applicable Metrics:

Increased Safety - Technology can reduce the time to detect, localize, and address leaks in natural gas infrastructure over large areas.

References:

http://www.ball.com/aerospace/Aerospace/media/Aerospace/Downloads/D3242-Methane-Monitor_0518.pdf?ext=.pdf
http://spectrum.ieee.org/tech-talk/at-work/test-and-measurement/catching-fugitive-methane-on-the-fly

Project/Technology Name:

Vehicle Methane Detector (VMD)

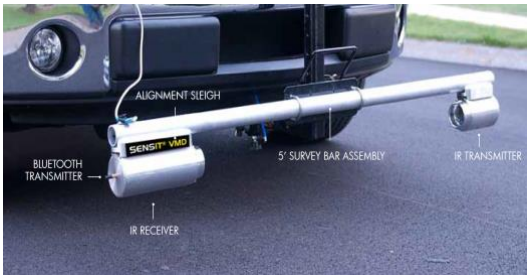
Performer/Contractor:	**Commercializer:**
SENSIT Technologies	SENSIT Technologies

Program Area:

1. Damage Detection and Prevention – Leak Detection

Project/Technology Description:

The detector is a vehicle-mounted instrument used to detect, grade and map gas leaks along underground pipelines. The survey bas includes an IR transmitter and receiver for natural gas detection. The display unit in the vehicle provides the gas concentration, GPS location and the detection level alarms.



Impact of Project/Technology on Technological Advancement to Gas Industry:

The VMD increases the efficiency and accuracy of mobile methane leak surveys, using an open path infrared absorption spectroscopy.

Applicable Metrics:

Increase Safety - Reduce Operations Costs – Greater Reliability: Leak survey of belowground gas pipeline systems provides an indication of pipeline damage. The detection initiates the utilities response for inspection, repair, and replacement before further catastrophic consequences occurs. The VMD improves the efficiency and speed of leak surveys through mobile monitoring.

References:

SENSIT Technologies, www.gasleaksensors.com

Project/Technology Name:

Flow Stopping Mainline Control Systems

Performer/Contractor:	**Commercializer:**
Operations Technology Development (OTD)	Kleiss MCS

Program Area:

1. Damage Detection and Prevention - Damage Mitigation and Repair

Project/Technology Description:

Marketed as the Kleiss MCS inflatable stopping system, it is used to stop the flow of gas in polyethylene, steel, cast-iron, and PVC pipes at diameters up to 18 inches and pressures up to 60 psig. The system provides safe operation with a gas tight seal and two pressure gauges to monitor the pressure in the stopper and in the pipeline without having to make additional taps. The system, which is manufactured in Europe, has demonstrated its operation and potential savings.

Impact of Project/Technology on Technological Advancement to Gas Industry:

Current line stopping equipment are heavy, require mechanical assists to operate, costly to maintain, and are time consuming (welding time and drilling). The new technology can be used in larger diameter cast iron and steel piping systems that operate at operating pressures up to 60 psig and have limited options to control gas flow.

Other options for shutdown of these pipes are either valves which may negatively impact customers or costly line stoppers. Another benefit is related to the natural gas industry's move to the use of larger diameter polyethylene (PE) pipe. Currently, manual and hydraulic squeeze tools are used to squeeze the PE pipe to stop the flow of gas. However, squeezing vintage pipes may lead to premature failure due to the brittle nature of the aged PE material.

Applicable Metrics:

Increase Safety - Reduce Operations Costs: Effective natural gas flow control is critical to LDCs' operations ranging from reducing costs and accelerating routine construction and maintenance activities to responding to emergency situations resulting from third party damages on PE piping systems.

References:

- Kleiss Bag Stopping Evaluation Project, Operations Technology Development, OTD Project Report 5.12.g, Oct 2015.
- Mainline Control Systems, www.mainlinecontrolsystems.com

Project/Technology Name:

NO-BLO® DBS System

Performer/Contractor:	**Commercializer:**
Operations Technology Development (OTD)	Mueller Company

Program Area:

1. Damage Detection and Prevention - Damage Mitigation and Repair

Project/Technology Description:

The Mueller DBS System is a portable system of tools that allows field technicians to perform many tasks related to the gas service line, including meter replacement and work on any part of the meter set, such as risers and regulators, even removal and replacement of defective service line pipes and fittings.

Impact of Project/Technology on Technological Advancement to Gas Industry:

Current No-Blow gas stoppage and repair technologies are commonly used in service abandonment and renewal, main tapping and stopping, and valve change out. The replacement if gas meter valves can be easily and safely performed with this tool when there is no convenient gas shut off means exist between the gas main and the valve.

The system can be used on many brands of gas meter valves, and on many prefabricated meter risers.

The tool works safely on pressurized gas lines at up to line pressure of 60 psig. It has proven useful for replacing valves damaged by vandalism and other abuses. It also provides a quick, efficient way to change out large numbers of valves during replacement programs.

Applicable Metrics:

Increase Safety - Reduce Operations Costs – Greater Reliability: The tool works safely on pressurized gas lines at up to line pressure of 60 psig. It has proven useful for replacing valves damaged by vandalism and other abuses. It also provides a quick, efficient way to change out large numbers of valves during replacement programs.

References:

- No-Blow Tooling Finalization. Operations Technology Development. OTD Project Report 2.11.c. Jan 2014.
- Mueller Company. www.muellercompany.com

Project/Technology Name:

Keyhole Pipeline Inspection Camera System

Performer/Contractor:	**Commercializer:**
Northeast Gas Association, NYSEARCH Invodane Engineering	ULC Robotics

Program Area:

1. Damage Detection and Prevention - Damage Mitigation and Repair

Project/Technology Description:

The ULC Robotics' PRX250K Keyhole Camera Inspection System is used in live gas mains to detect and assist in the repair of water ingress, locating blockages, verify installations, repairs, and other issues involving 2 to 12 inch diameter gas distribution mains.

A power drive motorized cable feeder is used to insert the camera in the live main, allowing the inspection work to be accomplished through small 18-inch diameter keyhole cuts in the pavement.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The PRX250K contains unique features such as a motor driven cable feeder and self-deploying centering system provides a high yield on equipment investment as well as faster, more reliable inspections in live lines.

Applicable Metrics:

Reduce Operations Costs – Greater Reliability: The use of the camera in the multiple pipeline operations provides a cost-effective method utilizing small keyhole cuts in the pavement which can be reinstated to the original pavement condition. The camera increases the reliability of the repair operation and detects flaws and blockages of the gas line system.

References:

ULC Robotics. www.ulcrobotics.com

Project/Technology Name:

Odorant Effectiveness

Performer/Contractor:	**System and Status:**
Gas Technology Institute	Developed Guidelines

Program Area:

1. Damage Detection and Prevention - Damage Mitigation and Repair

Project/Technology Description:

The project provides a "Practical Pipeline Operator Guide" to manage odor fade issues associated with typical gas system operating conditions and materials of construction. This required identification, prioritization, and quantification of the variables that lead to odor fade.

The project developed and validated a predictive model that can be used to counter odor fade. The model incorporated a methodology to enable the validation of additional combinations of gas, system, and material variables/scenarios. Based on a gap analysis, the chemical and physical phenomena responsible for odorant fade were defined and ranked based on thermodynamic prescreening and prior testing and experience.

The model consisted of simulation software packages that were validated through physical tests in the field. Software was used to simulate combinations of variables to determine how they affect odorant levels with respect to time, pressure, temperature and other conditions. Fluid flow simulation software was used to evaluate gas system piping scenarios.

Impact of Project/Technology on Technological Advancement to Gas Industry:

Information gained from this project was used to prepare a suggested revision to Chapter 7 of the current edition of the AGA Odorization Manual (AGA XQ0005), last revised in 2000. It was announced at an AGA workshop held in Denver in November 2013 that a team was being formed to begin revisions to the manual in 2014. Recommendations were also made for further testing.

Applicable Metrics:

Increased Safety, Environmental Benefits: Odorant fade can result in natural gas leaks going undetected, potentially resulting in gas loss to the environment as well as flammable or explosive conditions. This research will help identify odorant fade in a timely manner, allowing the operator to act and ensure safe operation.

References:

PHMSA, https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=363

Project/Technology Name:

Lift Assists for Pavement Breakers and Rock

Performer/Contractor:	**Commercializer:**
Operations Technology Development (OTD)	Integrated Tool Solutions

Program Area:

1. Damage Detection and Prevention - Damage Mitigation and Repair

Project/Technology Description:

The pneumatic device is attached to conventional pavement breakers and jackhammers to assist workers in lifting the jackhammer after the pit penetrates pavements and rocks and assist in repositioning the pit for the next penetration.

Impact of Project/Technology on Technological Advancement to Gas Industry:

Most of the utility workers' injuries and fatigue result from using heavy pavement breakers during pipeline repair and restoration operations. The technology reduces the worker's effort in lifting heavy jackhammers during breaking and allows the utilities to employ a wider range of the workforce to be involved in these operations.

Applicable Metrics:

Increase Safety: The ergonomically-designed jackhammer lift assist reduces operator stress and fatigue; therefore, drastically reducing the risk of jackhammer related back injuries as well as improving job efficiency and productivity. The lift assist makes breaking easier, less physically demanding, and faster, thus reducing operation costs.

References:

Integrated Tool Solutions. www.integratedtoolsolutions.com

Project/Technology Name:

Assessment of Vehicle-Barrier Design for Aboveground Facility Protection

Performer/Contractor:	**System and Status:**
Operations Technology Development (OTD)	Developed Guidelines

Program Area:

1. Damage Detection and Prevention - Damage Mitigation and Repair

Project/Technology Description:

The study evaluated safety requirements, design guidelines, and installation practices of structural barriers to protect aboveground gas pipelines and facilities from vehicular damage. The study assisted gas utilities in: a) Determining the conditions when a protective barrier is required, b) selecting the appropriate types of protection, c) identifying procedures for design of barriers and protection systems, and d) identifying the criteria for testing and evaluating barriers.

Impact of Project/Technology on Technological Advancement to Gas Industry:

Under 49 CFR 192 Subpart P, the Distribution Integrity Management (DIM) program requires distribution pipeline operators to identify the threats that may affect the safety and performance of their facilities. The 49 CFR 192.317 requires that aboveground lines “must be protected from accidental damage by vehicular traffic or other similar causes, either by being placed at a safe distance from the traffic or by installing barricades”. The 49 CFR 192.353 also requires that outside meters and regulators are protected from anticipated vehicular damage.

Applicable Metrics:

Increase Safety: The report addressed the safety concerns of vehicle crashes with aboveground gas and electric utility assets (including utility poles) near the highways. The study aims at reducing the current estimate of 12% of highway vehicle crashes occurring with above ground utility objects and poles.

References:

Assessment of Vehicle-Barrier Design for Aboveground Facility Protection. Operations Technology Development. OTD Project Report 5.10.j. July 2011.

Project/Technology Name:

Guided-Wave Evaluation as Hydro-testing Equivalent

Performer/Contractor:	**System and Status:**
Operations Technology Development (OTD)	Developed Guidelines

Program Area:

2. Threats and Integrity Management - Anomaly Detection and Characterization

Project/Technology Description:

Guided Wave Ultrasonic Testing (GWUT) has been shown to be a promising technology for inspecting casings and other difficult-to-access sections of pipe. The project provided a validation methodology that could be used as the basis for a new standard that could be referenced by 49 CFR Part 192. The GWUT identified the anomalies that would have been found by hydrostatic testing to pressures equivalent to the pipe's Specified Minimum Yield Strength (SMYS).

Impact of Project/Technology on Technological Advancement to Gas Industry:

GWUT is a promising technology for inspecting casings and other difficult-to-access sections of pipe. Numerous R&D efforts have been undertaken to evaluate GWUT. However, the results have never been combined to provide a validation of GWUT's effectiveness in detecting anomalies, relative to pressure testing.

If used as a standalone tool, GWUT is currently considered an "Other Technology" in 49 CFR 192.921 and thus requires authorization (i.e., notice must be given to PHMSA) and compliance with a PHMSA "18-point checklist". See: http://primis.phmsa.dot.gov/gasimp/notifications.htm.

Applicable Metrics:

Increase Safety - Reduce Operations Costs: The ability to use GWUT to inspect casings and other difficult-to-access pipe sections will facilitate integrity management inspection in a cost-effective manner. Additionally, the use of GWUT as a stand-alone inspection tool will provide a means of compliance where, in some situations, no alternative exists.

References:

Guided Wave Equivalency to a Hydro-test. Operations Technology Development. OTD Project Report 4.8.a. March 2010.

Project/Technology Name:

Low Frequency Electromagnetic Technique (LFET)

Performer/Contractor:	**Commercializer:**
TesTex	TesTex Inc.

Program Area:

2. Threats and Integrity Management - Anomaly Detection and Characterization

Project/Technology Description:

The Low Frequency Electromagnetic Technique (LFET) is used to detect anomalies in above-ground, uninsulated piping. The piping can be painted or coated.

The system rapidly scans areas of piping to achieve greater than 90% coverage. It is used as a quantitative tool or as a rapid screening tool. In the screening mode, an A-Scan ultrasonic is used to prove-up any flaw indications. This technology is applicable to magnetic and non-magnetic piping. Cast iron or other cast materials can also be tested.

Impact of Project/Technology on Technological Advancement to Gas Industry:

Various R&D efforts have been undertaken to evaluate various electromagnetic technologies. Although implementing this technology requires access to the pipe in excavated sections, it provides a rapid and reliable process for t=detecting anomalies on the pipe surface.

Applicable Metrics:

Increase Safety – Increase reliability: The technology provides a reliable direct-contact technology for accessing anomalies on pipe sections where initial indications prompted excavation to inspect the pipe. The device provides a stand-alone inspection which increases reliability of the pipe surface evaluation.

References:

http://testex-ndt.com/services/pipe-pipeline-inspections/

Project/Technology Name:

Robotics Systems for Inspecting Unpiggable Transmission Pipelines

Performer/Contractor:	**Commercializer:**
Northeast Gas Association, NYSEARCH	Pipetel Technologies

Program Area:

2. Threats and Integrity Management - Anomaly Detection and Characterization

Project/Technology Description:

This project completed the development of two robotic systems for in-line, live inspection of unpiggable transmission natural gas pipelines. Two robotic platforms were developed: 1) Explorer II, which carries a remote field eddy current (RFEC) sensor for the inspection of 6- and 8-inch diameter unpiggable pipelines, and 2) TIGRE, which carries a magnetic flux leakage (MFL) sensor for the inspection of 20" to 26" unpiggable pipelines.

Explorer II

TIGRE

Impact of Project/Technology on Technological Advancement to Gas Industry:

The project resulted in the commercial deployment of reliable, economically viable technology for inspecting unpiggable pipelines.

Applicable Metrics:

Increased Safety, Greater Reliability: This technology enhances safety, reliability and damage prevention by providing a tool for inspecting unpiggable pipelines.

References:

- PHMSA, https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=353 (NYSEARCH/Northeast Gas Association and Invodane Engineering Ltd., DTPH56-10-T-000008, Final Public Report – "Completion of Development of Robotics Systems for Inspecting Unpiggable Transmission Pipelines", February 19, 2013.

Project/Technology Name:

Magnetic Tomography method for inspecting pipelines (MTM)

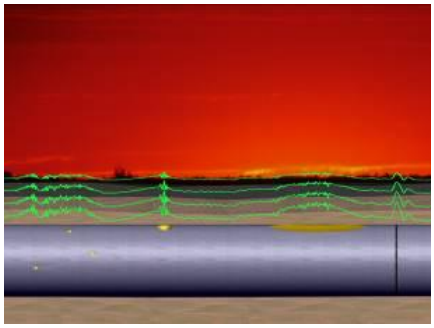
Performer/Contractor:	**Commercializer:**
Pipeline Research Council International (PRCI)	TRANSKOR-K

Program Area:

2. Threats and Integrity Management - Anomaly Detection and Characterization

Project/Technology Description:

This NDA technology is an external above ground inspection method for pipeline anomalies. It consists of applying a magnetic field as an operator walks along the pipeline axis with magnetometer. Diagrams of the Stress-Deformed Conditions (SDC) are analyzed to identify the anomalies.



Impact of Project/Technology on Technological Advancement to Gas Industry:

National Grid completed a project to evaluate the MTM for pipeline inspection. During 2011 and 2012, the MTM system was tested on 13 sections of pipe on the National Grid transmission system. Analysis of the results showed that the MTM system has the ability to locate anomalies in a buried pipeline.

Comparison of the MTM data with ILI results has shown that there is a good correlation between anomalies detected by both systems. The trials also included two pipelines where existing strain gauges were fitted to evaluate ground movement with respect to mining activities. A comparison between the strain gauge measurements and the MTM data showed a correlation between the estimated stress in the stress concentration zones and the stress recorded by the strain gauges.

Applicable Metrics:

Increased Safety, Greater Reliability: This technology enhances safety, reliability and damage prevention by providing a tool for inspecting anomalies from aboveground.

References:

- http://www.rezayat-commercial.com/site_media/uploads/brochures/transkor_new.pdf
- http://www.smarternetworks.org/Project.aspx?ProjectID=1388

Project/Technology Name:

Stress Concentration Tomography

Performer/Contractor:	**Commercializer:**
Pipeline Research Council International (PRCI)	Speir Hunter Ltd.

Program Area:

2. Threats and Integrity Management - Anomaly Detection and Characterization

Project/Technology Description:

The SCT™ utilizes the measurable relationship between stress and magnetization: changes in localized stress on the pipeline wall cause predictable changes in the pipeline's natural magnetic field. The analysis of this remotely collected magnetic data is then used to determine the presence of defects, their location and their magnitude of stress.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The device complements ILI inspection and delivers an accurate map of the pipeline route including its depth of cover. The technology is useful in areas of soil erosion as it will help reduce the possibility of damage through mechanical impact from farming and excavation equipment. It is also useful to an operator who has acquired pipelines with incomplete records. The technology can also be used to report the location of a specific girth weld and thereby enhance the accuracy of excavations.

Applicable Metrics:

Increased Safety, Greater Reliability: By targeting specific sections to monitor known defects on a longer pipeline, SCT™ eliminates the need to initiate a full-length "pig" run. This means less downtime and more savings.

References:

https://www.speirhunter.co.uk/about-sct-tm

Project/Technology Name:

A Quantitative Nondestructive Pipeline Stress Assessment Tool

Performer/Contractor:	**Commercializer:**
Generation 2 Materials Technology	Generation 2 (G2MT)

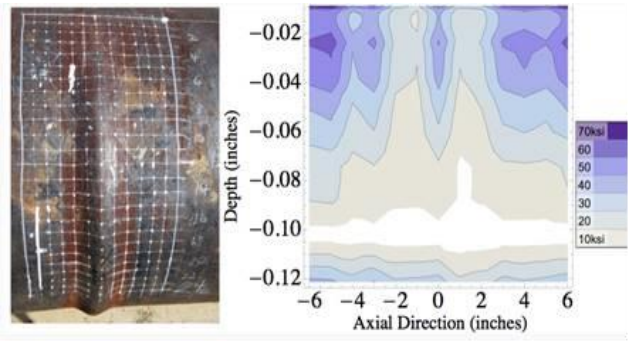
Program Area:

2. Threats and Integrity Management - Pipeline Testing and Stress Analysis

Project/Technology Description:

The G2MT's eStress™ system is used in the residual stress assessment of pipeline damage. The system was developed through PHMSA for non-destructive in-service detection of damage severity for steel pipes. The tool measures residual stresses around pipeline damage areas to determine the susceptibility to failure.

The technology is coupled with advanced modeling techniques to quantitatively measure the local stress and map the stress around the entire area.



Impact of Project/Technology on Technological Advancement to Gas Industry:

Residual stress is a critical factor that determines the cracking susceptibility of pipeline steels, but existing methods for measuring mechanical damage in pipeline steels are incapable of quantifying the residual stress levels. A larger gouge or dent does not necessarily signify worse damage than a smaller gouge or dent; it is more important to focus on the actual residual stress levels induced by damage.

Applicable Metrics:

Increase safety: Knowledge of the residual stress levels provides an accurate means to assess the severity of the damage and improve the pipeline integrity, ultimately reducing the amount of unnecessary removal and repair applications.

References:

- http://www.g2mt.com/nondestructive-testing-residual-stress-pipeline-damage/
- https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=441
- Generation 2. http://www.g2mt.com/

Project/Technology Name:

Hardness Tester for Quantification of Material Properties in Live Transmission Pipelines

Performer/Contractor:	**Commercializer:**
Northeast Gas Association, NYSEARCH	Invodane Engineering

Program Area:

2. Threats and Integrity Management - Pipeline Testing and Stress Analysis

Project/Technology Description:

The project integrates an in-line non-destructive tool for the quantification of material properties (toughness and strength) for piggable and unpiggable natural gas pipelines.

The device performs indentation tests for toughness measurements and is integrated onto the commercial Explorer 20/26 inspection platform (see picture). While the hardness tester was built for used with the Explorer platform for 20”-26” pipe size range, the design is scalable to other pipe sizes.

Impact of Project/Technology on Technological Advancement to Gas Industry:

In response to the 2010 San Bruno incident, PHMSA published the draft integrity verification process (IVP) that requires the establishment of a materials documentation process by all pipeline operators in the US. The reason for this process is to document the basis used by each operator for establishing a pipeline’s MAOP. In the absence of proper material documentation, tests need to be carried out to establish the pipeline’s MAOP. The technology provides an in-line tool that would be able to carry a non-destructive test from the inside of the pipe.

Applicable Metrics:

Increase safety - Greater Reliability: The newly developed hardness tester will add to the existing capabilities of in-line non-destructive testing platforms, thus further enhancing the ability of the industry to characterize its pipeline assets, as per the proposed PHMSA Integrity Verification Process (IVP).

References:

https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=646

Project/Technology Name:

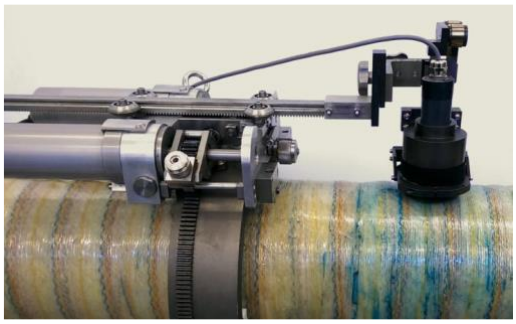
Dynamic Response Spectroscopy (DRS)

Performer/Contractor:	**Commercializer:**
Sonomatic – Innovation Inspection Technology	Sonomatic Inc.

Program Area:

2. Threats and Integrity Management - Pipeline Testing and Stress Analysis

Project/Technology Description:



The Dynamic Response Spectroscopy (DRS) is an ultrasonic inspection technique for corrosion mapping through challenging coatings, such as composite wraps, where existing ultrasonic techniques are ineffective. This technique has been designed to look through the composite repairs to measure the remaining wall thickness of the underlying metallic pipe. The DRS probe excites the steel pipe with a range of low ultrasonic frequencies, which pass easily through the coating/wrap.

Using advanced algorithms, these frequencies are extracted from the returning signal at each location and used to determine the steel thickness.

Impact of Project/Technology on Technological Advancement to Gas Industry:

Inspection of pipework through composite repair wraps will provide the pipeline operators with accurate data related to the current status of the depth of the defect below the composite repair.

Applicable Metrics:

Greater Reliability: The measurements increase the quality control and assurance of pipe repairs using composite wraps. Measurement of the actual defect size will enable in service integrity assessment of the repaired pipework, especially beneficial for long lifetime repairs where internal corrosion is present.

References:

http://www.sonomatic.com/advanced-inspection/applications/pipelines/

Project/Technology Name:

Leak-Rupture Boundary Calculator and Training Manual

Performer/Contractor:	**System and Status:**
Operations Technology Development (OTD)	Developed Guidelines

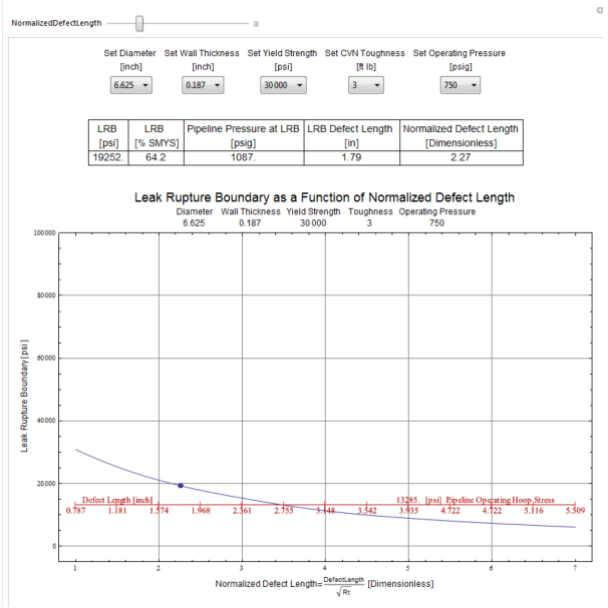
Program Area:

2. Threats and Integrity Management - Pipeline Testing and Stress Analysis

Project/Technology Description:

The project developed a calculator for operators to determine the leak-rupture boundary of a pipe segment based on properties such as its diameter, toughness, and yield strength. The operators can use the calculator for risk modeling and consequence analysis.

The calculator determines if the pipe segment would fail by leak instead of rupture when operated at a specific percentage of SMYS with known yield strength, toughness, diameter, and wall thickness.



Impact of Project/Technology on Technological Advancement to Gas Industry:

The calculator provides operators and regulators with a new body of knowledge regarding the boundary between failure by leak and failure by rupture. The results provide an enhanced understanding of the parameters influencing failure modes to allow integrity management programs to consider the proximity of a pipe segment's operating pressure in relation to the leak-rupture boundary. The information could also be used by regulators to update integrity management regulations to reflect the risk associated with different pipe materials.

Applicable Metrics:

Increase Safety: For pipelines operators to ensure that their limited assessment resources are focused on the highest-risk segments. The calculator provides the technical basis to understand which segments could possibly fail by leak versus rupture.

References:

Leak-Rupture Boundary Determination. Operations Technology Development. OTD Project Report 4.9.a. Oct 2012.

Project/Technology Name:

Synergi Distribution Integrity Management Risk Model

Performer/Contractor:	**Provider:**
DNV.GL (Noble Denton)	GL Noble Denton, DNV.GL

Program Area:

3. Pipeline Risk and Information Management - Data Management and Information Systems

Project/Technology Description:

Synergi Pipeline software enables gas distribution network and pipeline operations to documents risk, schedule and track inspection and compliance activities. It fits into existing GIS and enterprise management systems. The software integrates the early version of 'Uptime' software and data management system for the integrity management of gas distribution and transmission pipeline assets.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The DIMP program requires utilities to identify the threats that may affect the safety and performance of the distribution facilities.

Applicable Metrics:

Increase Safety - Reduce Operations Costs: The software integrates the risk analysis at individual asset level or on a regional or spatial basis. It develops inspection, corrosion, leak survey scheduling and tracking to reduce distribution pipeline risks. It also reduces operations costs by identifying and planning mains replacement program assets.

References:

DNV.GL, www.dnvgl.com

Project/Technology Name:

LocusMap Mobile GIS Solution for Traceability of Pipes

Performer/Contractor:	**Commercializer:**
Operations Technology Development (OTD)	LocusView

Program Area:

3. Pipeline Risk and Information Management - Data Management and Information Systems

Project/Technology Description:

LocusMap is software used in new distribution lines installations for tracking and traceability of pipes, fittings, and fusions data. The software is a mobile GIS tool creating features directly in a GIS format and allows field-collected data to be directly integrated into the enterprise GIS with minimal back-office processing.

Barcode scanning and high-accuracy GPS are used to automate data entry in the field and create high-accuracy maps.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The DOT DIMP program requires utilities to identify the threats that may affect the safety and performance of the distribution facilities.

Applicable Metrics:

Increase Safety - Reduce Operations Costs: The software integrates data management at individual asset levels into the utility's GIS database for integrity management inspection and data tracking and traceability. It reduces data management and operation costs by accurately identifying the underground assets through barcode scanning and high accuracy GPS systems.

References:

LocusView. www.locusview.com

Project/Technology Name:

First Responders DVD

Performer/Contractor:	**Commercializer:**
AEGIS Insurance Services	Developed Guidelines

Program Area:

3. Pipeline Risk and Information Management - System Risk Modeling and Security

Project/Technology Description:

AEGIS is a mutual insurance company that provides coverage and risk management services to the energy industry. The training program consists of two volumes presented in video and DVD formats. The first volume includes nine videos which present the gas delivery system, damage prevention, and how to safely detect, respond, and deal with natural gas fire. The second volume includes eleven videos and covers hazards associated with main leaks, odorant releases, LNG, and case studies.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The training program videos provide material to the public and first responders for understanding, recognizing, avoiding, and dealing with the hazards of natural gas.

Applicable Metrics:

Increase Safety: The DVD training product help gas companies better educate first-responding personnel about natural gas emergencies. Learning modules with realistic scenarios cover a variety of issues to enhance public and worker safety. The training also serves to improve emergency-response effectiveness and coordination.

References:

AEGIS Insurance Service.
https://www.aegislink.com/aegislink/resources/education/loss_control.html

APPENDIX F:
Examples of Pipeline Technologies Near Commercialization

This appendix provides examples of in-development and close-to-commercialization technologies in the last five years. Due to the nature of technology development, some technologies may move to commercialization within a short period from the publication of the report.

The information in the appendix was retrieved from current literature and public domains and does not represent all technologies in development. The technologies address the following three categories presented in the main report:

- Damage prevention and mitigation
- Threats and integrity management
- Pipeline risk and information management

The applicable matrix of technologies benefits is:

- Increase safety
- Reduce operations costs
- Greater reliability
- Environmental benefits
- Customer appeal

Project/Technology Name:

ORFEUS – Look Ahead Technology for HDD

Performer/Contractor:	**System and Status:** Device development and field evaluation
TT Technology and Consortium of European Union Companies.	

Program Area:

1. Damage Prevention and Mitigation - Pipe Locating and Excavation Damage Prevention

Project/Technology Description:

ORFEUS is a pre-commercial system based on Ground penetrating Radar (GPR) Technology. The system is attached to the Horizontal Directional Drilling (HDD) head for obstacle detection during drilling. The system is used to detect cross bores when the installed gas lines inadvertently transects a sewer line. The technology has a maximum "look ahead" range of approximately 20 inches.

Impact of Project/Technology on Technological Advancement to Gas Industry:

ORFEUS is a full scale European Union-financed project aiming at furthering the HDD drill tip radar that was previously proven under an earlier project entitled "Optimized Radar to Find Every Utility in the Street" to a commercial stage.

The ORFEUS Radar System has been field-demonstrated in Germany, France, and Slovenia with successful initial results. The unit was also demonstrated at PG&E utility test site in April 2017.

Applicable Metrics:

Increase safety: HDD offers significant benefits for urban environments by minimizing the disruption caused by street works. However, the increased use of HDD operations for pipeline installations, especially in urban environments, has raised the need to reduce the threat of damage to other underground infrastructure, especially sewer mains and laterals. The GPR-based real-time obstacle detection system will increase the safety of the HDD installations.

References:

ORFEUS. Operational Radar For Every drill string Under the Street. D5.19 Demonstration Completion Report D5.19. 2015.

Project/Technology Name:

GPS Excavation Encroachment Notification System (GPS EENS)

Performer/Contractor:	**System and Status:** Device development and field evaluation
Gas Technology Institute	

Program Area:

1. Damage Prevention and Mitigation - Excavation Damage Prevention

Project/Technology Description:

The GPS EENS system consists of sensors unit box installed in the excavation equipment. The unit includes a GPS system with instrumentation to characterize the excavator's movement and operation. The unit connects to the satellite system and communicates with a dashboard to notify the utilities and operators of excavation encroachment at the location of the pipeline.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The device implements a GPS-based excavation encroachment notification system and technology which enhances the real-time situational awareness of excavators and reduces the risk of third-party damage to utility infrastructure. The system augments emergency response and provides information and alerts to utility operators and first responders when excavation equipment operates at or near pipelines.

Applicable Metrics:

Increase safety: According to U.S. Department of Transportation records, excavation damage causes about 25% of pipeline incidents. The project reduces the risk of excavation damage to buried gas facilities. It characterizes excavators' behavior by analyzing and transferring data from a low-cost sensors unit installed in excavators and increases the awareness of construction equipment activity.

References:

GPS Excavation Encroachment Notification System (GPS EENS). California Energy Commission. Project PIR-15-015.

Project/Technology Name:

Small Unmanned Aerial System (sUAS) Gate Station and Pipeline Assets Inspection

Performer/Contractor:	**System and Status:** Device testing and field demonstration
Northeast Gas Association - NYSEARCH	

Program Area:

1. Damage Prevention and Mitigation - Excavation Damage Prevention

Project/Technology Description:

The sUAS (drone) is being evaluated for inspections of gate stations and pipelines. NYSEARCH, working with its contractor Pictometry, deployed sUAS for test flights in 2015. Following this successful deployment, NuAir Alliance assisted NYSEARCH in obtaining an exemption to fly test flights without pre-approval. As a result, the project team has collected high resolution imagery of multiple gate station assets. Additional flights are now planned for other test areas.

Impact of Project/Technology on Technological Advancement to Gas Industry:

sUAS is a field demonstration project to improve the efficiency and effectiveness of gate station and pipeline inspections while providing the opportunity to reduce the cost or provide the opportunity for additional inspections for the same cost, lower the risk to employees and provide a permanent record of the inspection event.

Applicable Metrics:

Increase safety: sUAS offers benefits to increase worker safety by providing visual access to location that have previously been challenging to access. Safety advantages are also anticipated due to the opportunity for more frequent inspections at reduced cost.

Reduced cost: Facility inspections often include the need to provide access to locations that may require additional or specialized equipment or are located beyond easy access from a roadway. sUAS could reduce or eliminate the need for costly or specialized equipment to gain access to company facilities.

References:

NYSEARCH. Copyright 2016. http://www.nysearch.org/news-info_110216.php

Project/Technology Name:

Real Time Monitoring of Pipelines for Third Party Damage

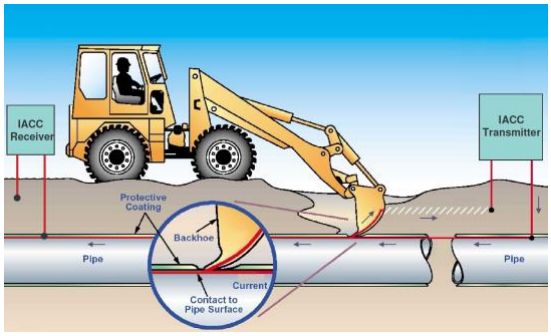
Performer/Contractor:	**System and Status:** Technology development
Southwest Research Institute (SwRI)	

Program Area:

1. Damage Prevention and Mitigation - Excavation Damage Prevention

Project/Technology Description:

Impressed alternating cycle current (IACC) monitoring method for detecting third-party contact with pipelines in real time. The project improves detection range and reduces potential interference from noise sources, including those from CP systems. This is accomplished through the refinement of IACC signal excitation and processing parameters. Potential effect of the IACC on the proper functioning of CP systems addressed.



Impact of Project/Technology on Technological Advancement to Gas Industry:

The IACC method is a promising new method for monitoring third-party contact of pipelines. This method will allow existing pipelines to be retrofitted for monitoring without excavation through the use of existing cathodic protection (CP) test points. The method could be readily applied to new pipelines. Guidelines will be developed for use by a vendor/developer to begin development of a commercial version of an IACC system.

Applicable Metrics:

Increase safety: This method will allow existing pipelines to be retrofitted for monitoring without excavation through the use of existing cathodic protection (CP) test points.

References:

Real Time Monitoring of Pipelines for Third Party Damage. NETL-DOE, Agreement DE-FC26-03NT41878. 2006.

Project/Technology Name:

Right of Way Automated Monitoring Threat Prevention

Performer/Contractor:	**System and Status:**
Electricore, Inc.	System development [Project cancelled]

Program Area:

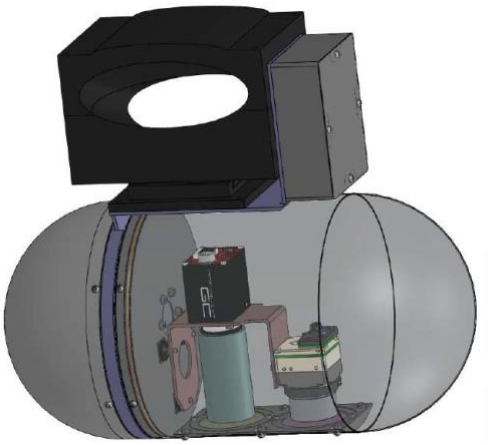
1. Damage Prevention and Mitigation - Excavation Damage Prevention

Project/Technology Description:

The project proposed to develop an integrated, autonomous sensor/detector system for near real-time detection, identification and notification of threats and leaks. Primary focus areas were Right-of-Way (ROW) threat and leak detection.

The project objectives were to:

- Develop integrated sensing suites to provide improved, cost-effective aerial surveillance to patrol pipeline ROW.
- Develop communications systems for prompt reporting of threats (including on-board data processing systems for threat identification and screening and data analysis/modeling for threat assessment.



Concept Illustration of the Camera Pod

Impact of Project/Technology on Technological Advancement to Gas Industry:

Preventing third-party damage, including unauthorized access on pipeline ROWs and mechanical damage, is a significant ongoing challenge for pipeline operators. Another ongoing challenge is timely leak detection, so that appropriate action can be taken. This project would have presented a consolidated research and development program to develop, test, and implement an integrated technology package for automated monitoring, assessment, and reporting of various threats to energy transportation pipelines.

Applicable Metrics:

Increased Safety, Greater Reliability: This project would have improved pipeline safety and reliability of service by advancing the state of current technologies for pipeline ROW monitoring and surveillance.

References:

PHMSA, https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=389

Project/Technology Name:

Monitor and Report Encroachments on the Pipeline Right-of-Way

Performer/Contractor:	**System and Status:** System development and demonstration
Gas Technology Institute	

Program Area:

1. Damage Prevention and Mitigation - Excavation Damage Prevention

Project/Technology Description:

The system is co-funded by the California Energy Commission and OTD and it includes stationary vibrating sensors (see picture) installed near the ground surface at the pipeline right-of-way (ROW). The sensors make use of advanced wireless technology that enables monitoring miles of range with very low power. The technology enables the system to "learn" noise characteristics and alerts the appropriate personnel of the construction activities.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The technology deploys and demonstrates a pipeline monitoring system that can detect encroachments and alert operators of activity in the ROW in real time. This project applies stationary sensors to provide continuous monitoring of the pipelines. The system would not cover the entire ROW area but risk reduction is achieved by targeting the most active excavation equipment areas and the highest consequence lines.

Applicable Metrics:

Increase safety: The system reduces the risk of excavation damage to buried gas facilities. It characterizes the excavation behavior and transfers the data to a notification station.

References:

Technologies to Monitor and Report Encroachments on the Pipeline Right of Way. California Energy Commission. Project PIR-14-014.

Project/Technology Name:

Embedded Passive RF Tags towards Intrinsically Locatable Buried Plastic Materials

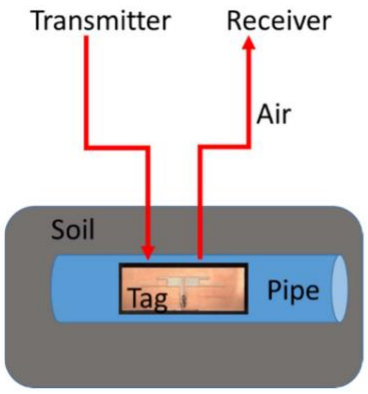
Performer/Contractor:	**System and Status:** System design and development
University of Colorado Denver	

Program Area:

1. Damage Prevention and Mitigation - Pipe Locating and Excavation Damage Prevention

Project/Technology Description:

This project developed a low-cost, small thin-film sensor using passive Radio-frequency identification (RFID) tags which use electromagnetic fields to automatically identify and track stored information. Passive tags collect energy from a nearby RFID reader's radio waves. The RF tags can directly be embedded in plastic pipes to detect the pipes buried in soils. The tags will be able to withstand high temperature processing of plastics and stress involved with horizontal tunneling/drilling of buried pipes.



Impact of Project/Technology on Technological Advancement to Gas Industry:

The embedded RF tags will have the capability to locate buried plastic pipes and have integrated sensing functionality, which can measure the strain-stress changes in the plastic materials. The vast amount of acquired sensing data from individual tags may be integrated to an advanced signal processing for better data categorization and mining.

Applicable Metrics:

Increase safety: Accurate and reliable locating by identifying and characterizing the buried plastic pipes from the ground surface is critical and imperative for damage prevention.

References:

https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=628

Project/Technology Name:

Intrinsically Locatable Plastic Materials

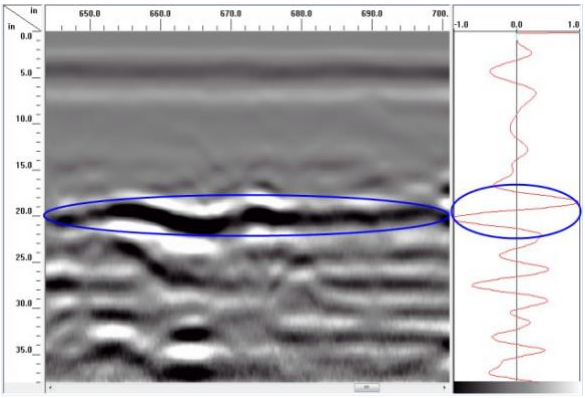
Performer/Contractor:	**System and Status:** Technology investigation
West Virginia University	

Program Area:

1. Damage Prevention and Mitigation - Pipe Locating and Excavation Damage Prevention

Project/Technology Description:

The project included investigating the use of Ground Sensory Technologies such as Ground Penetrating Radar (GPR) (see picture) and Infrared Thermography (IRT) for buried pipe location. It also investigates the possibility of buried pipe detection using Fourier Transform Infrared Spectroscopy (FTIR), which has future potential for mounting on aerial drones for rapid mapping.



Impact of Project/Technology on Technological Advancement to Gas Industry:

The project investigates multiple technologies to advance the state-of-the-art in plastic pipe manufacturing and subsurface detection using a combination of innovative material (carbon or glass fiber reinforced polymers) and ground sensory technologies. These fabrics can be wrapped around existing plastic pipes to significantly strengthen them.

Applicable Metrics:

Increase reliability: The project will provide alternative material and accurate, reliable locating of buried plastic pipes from the ground surface for enhancing damage prevention.

References:

https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=632

Project/Technology Name:

Electromagnetic Strategies for Locatable Plastic Pipe

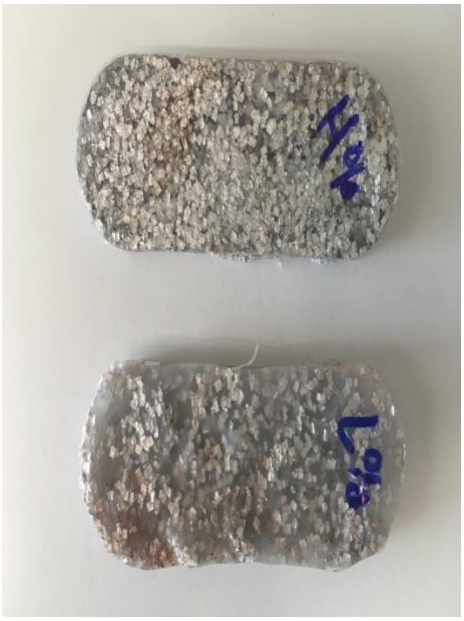
Performer/Contractor:	**System and Status:** Technology investigation
University of Tulsa	

Program Area:

1. Damage Prevention and Mitigation - Pipe Locating and Excavation Damage Prevention

Project/Technology Description:

The project investigated two strategies for fabricating plastic pipe that are intrinsically responsive to electromagnetic interrogation from the surface. The first strategy is to incorporate encapsulated magnetic nanoparticles (see figure) that will exhibit a strong response to EM radiation from the surface. This approach has two significant advantages when compared to previous attempts. First, microcapsules will reduce some of the deleterious effects on mechanical properties that the inclusion of conductive particles can have. Second, the potential for self-healing of crack damage is introduced. The second strategy is to investigate the production of antennas that can be used with either active or passive RFID systems to provide both location and pipe data.



Impact of Project/Technology on Technological Advancement to Gas Industry:

The project will investigate characterization of the utility type, depth, and pipe size. The information will also provide data about neighboring pipes to enable a distributed map of the utilities. This approach is focused on fabricating pipe structures in such a way as to produce a continuous production line to ensure cost-effective, locatable, plastic pipe.

Applicable Metrics:

Increase safety: Unlocatable utilities are a significant source of accidents throughout the US and add significant costs to construction from repair of accidental damage to locating the utilities. One of the largest issues is the widespread use of plastic pipes. These materials are difficult to detect with traditional utility locating systems even when their location is approximately known.

References:

https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=633

Project/Technology Name:

Pipeline Damage Prevention Radar

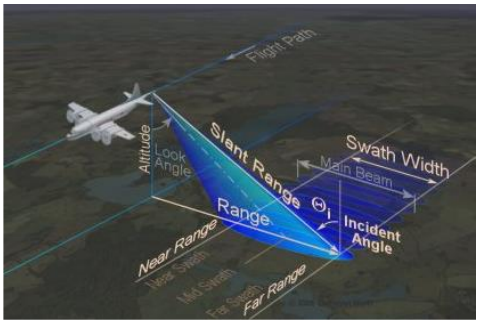
Performer/Contractor:	**System and Status:** Technology investigation
Ball Aerospace & Technologies Corp.	

Program Area:

1. Damage Prevention and Mitigation - Pipe Locating and Excavation Damage Prevention

Project/Technology Description:

The laser-illumination remote sensing technique measures atmospheric methane concentrations from an airborne platform (see picture). Similar flight-detection technology utilizes a dual-band airborne Synthetic Aperture Radar (SAR) to reliably detect excavation damage threats.



The technology will be evaluated 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.

Flight tests were performed to verify aircraft interface, installation processes, flight operations and validate performance of SAR data processing algorithms.

Impact of Project/Technology on Technological Advancement to Gas Industry:

SAR is widely used by the U.S. Department of Defense 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.

Applicable Metrics:

Increase safety: The proposed development enables reduced false positives, fewer repeat flight passes and reduced weather-related aircraft downtime resulting in operations cost savings.

References:

- https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=652
- http://www.ball.com/aerospace/markets-capabilities

Project/Technology Name:

Intrinsically Locatable Technology for Plastic Piping Systems

Performer/Contractor:	**System and Status:** Technology investigation
Operations Technology Development, OTD	

Program Area:

1. Damage Prevention and Mitigation - Pipe Locating and Excavation Damage Prevention

Project/Technology Description:

This project developed and tested a technology to intrinsically locate polyethylene (PE) materials with an integral electronic marking system. Electronic markers are detectable passive devices that do not use batteries. They include electrical or mechanical resonators. Resonators can be energized by an above-ground transceiver which causes them to generate their own magnetic field.

OTD partnered 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. GTI will provide third-party testing and analysis of the developed system.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The project will complete the development, define and test the electronic marker capability, validate the attachment design, and perform laboratory and field testing

Applicable Metrics:

Increase safety: 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 estimation of the depth to pipe.

References:

https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=654

Project/Technology Name:

Breakaway Disconnect Shutoff Product

Performer/Contractor:

Operations Technology Development (OTD)

System and Status: Device development, commercialization stage.

Program Area:

1. Damage Prevention and Mitigation - Damage Mitigation and Repair

Project/Technology Description:

The system is a breakaway disconnect and shutoff fitting installed in meter set assemblies (MSA) and other aboveground gas systems to reduce the risk from vehicle collision or ice/snow falling from a building. A Beta prototype is available in 2016 with a commercialization plan with OPW Engineered Systems.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The technology addresses the need to protect outdoor gas meter systems with an automatic gas shutoff when subjected to physical damage from outside forces. The damages to meter sets from outside forces include vehicular damage and damages from extreme weather conditions such as heavy snow and ice.

Applicable Metrics:

Increase safety: The shutoff device is installed at the meter riser below to gas meter to reduce the risk resulting from hazardous events due to vehicular impacts when the meter is at the driveway or road proximity. The device mitigates the risk when installed on new and replaced services but cannot be easily installed on existing services.

References:

Breakaway Disconnect/Shut-off for Meter Risers. Operations Technology Development. OTD Project 5.11.s. 2012.

Project/Technology Name:

Intelligent Shutoff Device

Performer/Contractor:	**System and Status:** Device development,
Operations Technology Development (OTD)	commercialization stage with Lorax

Program Area:

1. Damage Prevention and Mitigation - Damage Mitigation and Repair

Project/Technology Description:

The shutoff valve is attached to the service line with the termination fitting attaches to the riser. An inner and outer PE line system are attached to the valve and the termination fitting. The gas flows in the inner system at normal operating conditions. If leak occurs, gas is released which closes the valve.

The system is designed to detect small flow and is compatible with Internet-of-Things (IoT) to notify utilities of the status of flow.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The technology addresses the need to protect outdoor gas meter systems with an automatic gas shutoff when subjected to physical damage from outside forces. The damage to meter sets from outside forces includes vehicular damage and extreme weather conditions such as heavy snow and ice.

Applicable Metrics:

Increase safety: The intelligent shutoff device is installed in commercial and small industrial service lines to detect leaks and shutoff gas flow when the lines are subjected to third-party excavators and vehicular damage.

References:

Development of an Intelligent Shutoff Device for Commercial and Industrial Customers. OTD Project 5.12.a. 2012.

Project/Technology Name:

Valve Position Confirmation Technology

Performer/Contractor:

Northeast Gas Association - NYSEARCH

System and Status: Feasibility study, pre-commercialization stage

Program Area:

1. Damage Prevention and Mitigation - Damage Mitigation and Repair

Project/Technology Description:

A feasibility study to examine the equipment and methodology to use the sound of gas flow through a valve to confirm the exact position of critical valves in gas distribution systems.

Field tests, using acoustics and an innovative tool delivery system proved the concept and highlighted the feasibility of combining acoustic and visual methods to identify the position of ball, gate and plug valves used in various applications in the gas distribution system. More work is planned to expand the program to other users, incorporate feedback, ruggedize the system, and make it field portable prior to commercialization.

Impact of Project/Technology on Technological Advancement to Gas Industry:

Valve testing is a regular part of a pipeline operations and safety program. This technology ensures that the positioning of the valve during testing is as indicated by visual assessment. This technology would improve the ability to conduct a thorough inspection.

Applicable Metrics:

Increase safety - Greater Reliability: This technology increases safety by providing a means of performing the inspection under live conditions while ensuring that the valve functions properly through its rated range of application.

References:

NYSEARCH, Copyright 2016. http://www.nysearch.org/news-info_110216.php

Project/Technology Name:

Mitigating Pipeline Corrosion Using a Smart Thermal Spraying Coating System

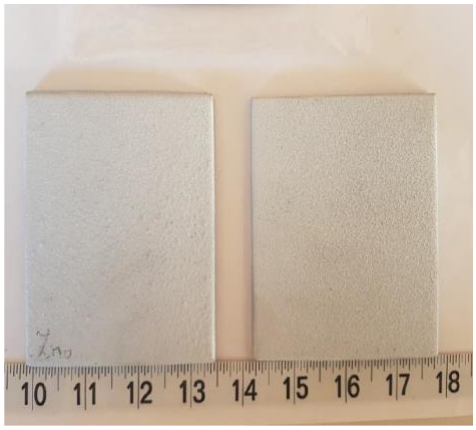
Performer/Contractor:	**System and Status:** Technology investigation
North Dakota State University	

Program Area:

1. Damage Prevention and Mitigation - Damage Mitigation and Repair

Project/Technology Description:

The technology is funded by PHMSA to investigate corrosion mitigation for pipelines through the advances of smart thermally sprayed coatings. An initial study was carried out for the feasibility of utilizing thermal spraying as a coating method for pipeline corrosion prevention. The experimental results demonstrated positive corrosion resistance improvements using a thermal sprayed Al-Zn coating (see picture). Although, the cost of coating material is relatively higher in this method, the long-term application can justify this technique with cost reduction associated with maintenance.



Impact of Project/Technology on Technological Advancement to Gas Industry:

Common methods to mitigate corrosion include cathodic protection and coating such as polymeric and metallic coatings. Polymeric coatings dominate the coating techniques due to their good performance on separating metal from the surrounding corrosive environments. However, corrosion may still develop beneath the polymeric coatings in random locations. A strong metallic coating from high corrosive resistant materials deposited by thermal spraying techniques can be considered as a potential alternative. These coatings can separate pipes from surrounding environments and exhibit cathodic protection properties.

Applicable Metrics:

Increase safety: Corrosion is recognized a major cause of the failure of on-shore underground steel pipes, which results in increase in maintenance cost and system downtime.

References:

https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=634

Project/Technology Name:

In-situ Sensors for Cathodic Protection Interrelationships Modeling

Performer/Contractor:	**System and Status:** Technology development
Sencontrology, Inc.	

Program Area:

1. Damage Prevention and Mitigation - Damage Mitigation and Repair

Project/Technology Description:

This PHMSA-funded project modeled cathodic protection (CP) penetration pipelines by using interconnected electrochemical and ultrasonic-type sensing technologies with polyurethane foam systems. Results provide the basis for future commercialization of sensor module designs and data acquisition for monitoring CP levels, soil conditions, coating performance and corrosion rates in underground pipelines.

Impact of Project/Technology on Technological Advancement to Gas Industry:

Effective CP systems are vital to pipeline integrity and safety. Protective coatings must be able to conduct CP current if disbondment occurs. Polyurethane foam sack breakers have operational advantages over sand bags as the foam conforms to any ditch configuration and allows immediate backfill and foam breakers are sprayed around the pipe in place, so the foam adheres to the pipe and does not degrade overtime. Data acquired from sensor-driven CP modeling could be used to mitigate corrosion in underground oil and gas pipelines and manage infrastructure.

Applicable Metrics:

Increased safety: Foam has many advantages over sand bags in terms of installation and operation and, in turn, allows more effective management of cathodic protection.

Reduced cost: Transportation costs to the jobsite are considerably lower for foam than sand bags. Future additional savings will be realized from lower pipeline maintenance costs.

References:

- PHMSA, https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=563
- SBIR-STTR, https://www.sbir.gov/sbirsearch/detail/691165
- Sencontrology. Inc. http://www.sencontrology.com/current-pursuits/

Project/Technology Name:

Application of Aerosol Spray for Pipeline Sealing

Performer/Contractor:	**System and Status:** System development
Technology Development, University of California, Davis, Western Cooling Energy Center (WCEC)	

Program Area:

1. Damage Prevention and Mitigation - Damage Mitigation and Repair

Project/Technology Description:

The system consists of an adhesive mist which is sprayed into the pipeline or other target area. The aerosol naturally heads toward leaks where the blown air leaves the pipeline and settles, plugging the leak.

This preliminary evaluation continues to develop and test sealants and sealing techniques for natural gas pipelines.

Development of sealants for pipelines are challenging since they could clog valves and other mechanisms. Researchers are testing sealants for both 14-inch diameter pipes and 1.6-inch diameter gas lines.

Impact of Project/Technology on Technological Advancement to Gas Industry:

Preliminary research suggests smaller aerosol particles might be needed than used in

building envelope and duct applications. The product is estimated to be three to five years from commercialization.

Applicable Metrics:

Increased Safety, Greater Reliability: In a benefit analysis performed for the Energy Commission, it is estimated that if the sealant is successful and applied to 30 percent of California natural gas pipelines, aerosol pipeline sealing could save more than 100 million therms of natural gas per year from leaks, saving more than $130 million a year. The cost of sealing pipelines would be less than hand repairs that require excavation.

References:

Project Agreement 500-98-014, CEC annual report, 2015.

Project/Technology Name:

Mitigation of Pipeline Bio-Corrosion Using a Mixture of D-Amino Acids with a Biocide

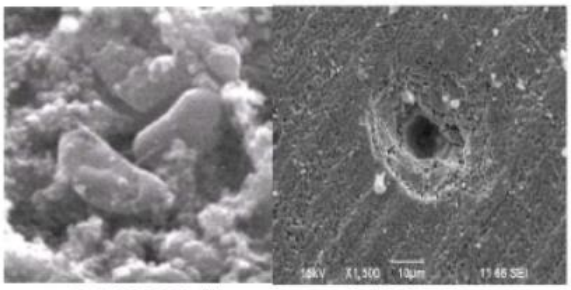
Performer/Contractor:	**System and Status:** Technology development
Ohio University	

Program Area:

1. Damage Prevention and Mitigation - Damage Mitigation and Repair

Project/Technology Description:

This project developed a new biocide enhancer technology to mitigate biofilms in the prevention of Microbiologically-Influenced Corrosion (MIC). Sessile cells in biofilms require considerably higher biocide concentrations than planktonic cells to treat. D-amino acids have been found to be biocide enhancers in biofilm mitigation and were evaluated in this project. Field biofilms were used to validate the new environmentally friendly biocide enhancer technology. In the next phase of this project, field trials will be conducted to validate the technology.



(a) SRB Biofilm (b) MIC Pit

Impact of Project/Technology on Technological Advancement to Gas Industry:

Pipeline corrosion is a serious threat to pipeline integrity and safety. MIC corrosion amounts to 20% of all corrosion losses. The 2006 BP Alaskan oil spill originated from a 0.25" pinhole that was likely caused by MIC. The leak led to a major spike in world oil prices, disrupted production at Prudhoe Bay for several months, and resulted in financial losses and government fines totaling many millions of dollars.

Applicable Metrics:

Increased Safety: Mitigating corrosion reduces threat risk to pipeline integrity and safety.

Environmental Benefits: The new biocide enhancer technology is environmentally friendly.

References:

PHMSA, https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=512

Project/Technology Name:

Mitigating External Corrosion Through Nano-Modified Cement-Based Coatings

Performer/Contractor:	**System and Status:** Technology development
Columbia University	

Program Area:

1. Damage Prevention and Mitigation - Damage Mitigation and Repair

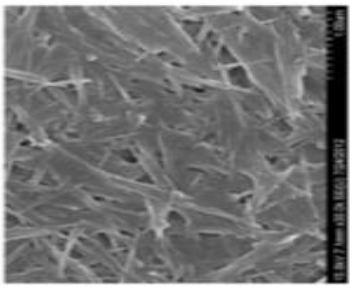
Project/Technology Description:

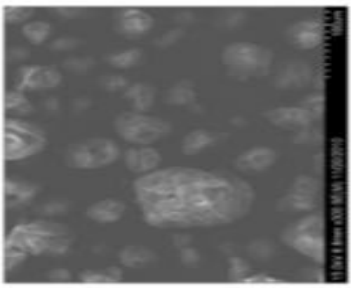
This technology addresses three main tasks:

1) Develop a processing technique to produce the cement-based coating by effective dispersion of nanomaterials through sonication (physical method) and surfactant treatment (chemical method).

2) Characterize key properties of the coating material relevant to coating applications: rheology, porosity, dimensional stability, and crack resistance.

3) Characterize key hardened properties: porosity and crack resistance under fatigue and restrained shrinkage. The result of the project is an engineered cement-based coating material with superior sealing properties that is also easy to use.





Impact of Project/Technology on Technological Advancement to Gas Industry:

External corrosion is a critical concern for pipelines. The advantage of cement-based coatings over other types is that they can be engineered to have mechanical properties to provide structural stability for the pipeline, as well as to offset buoyancy.

Applicable Metrics:

Increased Safety: Mitigating corrosion reduces threat risk to pipeline integrity and safety.

References:

PHMSA, https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=510

Project/Technology Name:

Internal (Trenchless) Repair Technology for Gas Transmission Pipelines

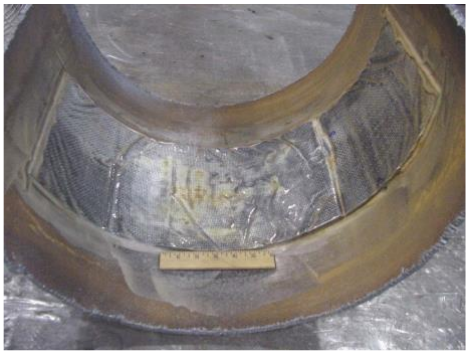
Performer/Contractor:	**System and Status:** Technology development
Edison Welding Institute (EWI)	

Program Area:

1. Damage Prevention and Mitigation - Damage Mitigation and Repair

Project/Technology Description:

The DOE-funded project develops and evaluates internal repair methods for pipelines by performing a laboratory demonstration of internal repair and specifications for a prototype system. The system performs combined internal inspection and repair of pipelines. Four technologies (fiber-reinforced composite liner repair, deposited weld metal repair, adhesively bonded steel patch repair, and adhesively bonded/helically wound steel strip repair) were reviewed and evaluated.



Impact of Project/Technology on Technological Advancement to Gas Industry:

internal repair technology which could restore the pressure carrying capability of a damaged natural gas pipeline offers the potential for substantial impact for the gas industry. Adhesively bonded/helically wound steel strip repair was the most promising technology evaluated, not only because of its apparent ability to restore a damaged pipe section's burst pressure to beyond that corresponding to 100% of the specified minimum yield strength (SMYS), but also because it lends itself well to field deployment and the material itself is inexpensive.

Applicable Metrics:

Increased safety: Minimize the significant costs associated with the excavation and external repair or replacement of a suspect area. This is particularly true in lines where access by external means is difficult (e.g., water, railroad and road crossings). Such technology potentially offers an opportunity to better maintain natural gas infrastructure and enhances reliability and safety of gas delivery by reducing the likelihood of a product loss event by providing an alternative to traditional repair methods.

References:

Internal Repair of Pipelines. Final Technical Report. NETL-DOE. Award No.: DE-FC26-02NT41633. 2006.

Project/Technology Name:

Smart Pipeline Network - Pipe & Repair Sensor System

Performer/Contractor:	**System and Status:** Device development, pre-commercialization
Odyssian Technology LLC	

Program Area:

1. Damage Prevention and Mitigation - Damage Mitigation and Repair

Project/Technology Description:

This project was Phase I of the development of a Pipe and Repair Sensor System (sensor SLEEVE). When combined with the Seal Sensor System (proposed separately), this technology will allow for a Smart Pipeline Network with integrated sensor networks that provide for continuous real-time leak detection of hazardous liquid and natural gas.

Impact of Project/Technology on Technological Advancement to Gas Industry:

Phase I focused on a pipe and repair sensor system for liquid petroleum-based pipeline systems. Phase II will expand the sensor system for use with natural gas. Once developed, the pipe/repair sensor network is expected to help operators continuously monitor the "health" of the pipeline system and to detect leaks. Other commercial applications will include gasoline stations, oil storage facilities, methane plants, oil and gas transportation, and off-shore oil rigs.

To date, there has been industry interest in the sensor SLEEVE™ but it has not yet been commercialized.

Applicable Metrics:

Increased safety – Greater reliability: The capability to detect leaks without false alarms will help to detect potential pipeline threats accurately, so that appropriate action can be taken sooner.

Reduced cost: The MR sensor is inexpensive.

References:

PHMSA, https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=444

Project/Technology Name:

Smart Pipeline Network - Cased Pipe for Monitoring and Sensor System

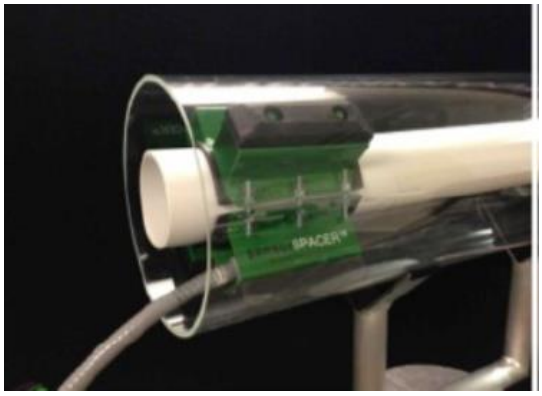
Performer/Contractor:	**System and Status:** Device development, pre-commercialization
Odyssian Technology LLC	

Program Area:

1. Damage Prevention and Mitigation - Damage Mitigation and Repair

Project/Technology Description:

This project was Phase I of a multi-channel cased pipe system (sensor SPACER) for liquid pipeline systems. When combined with the Seal Sensor System (proposed separately), this technology allows for a Smart Pipeline Network with integrated sensors that provide for continuous real-time leak detection of hazardous liquid and natural gas.



The cased pipe system will have an internal support structure allowing access along its longitudinal axis, while securing the carrier pipe to the casing pipe. Access is designed to support monitoring, an integrated sensor system, and wireless transmission of data.

Impact of Project/Technology on Technological Advancement to Gas Industry:

Phase I focused on a multi-channel cased pipe system for use with petroleum-based liquids. Phase II will expand the cased pipe system for use with natural gas. Once developed, the new multi-channel cased pipe system, in conjunction with the networked sensing system, will help operators continuously monitor the “health” of the pipeline system and detect leaks.

To date, it has not yet been commercialized.

Applicable Metrics:

Increased Safety, Reduced Operations Costs, Greater Reliability: This technology allows for real-time leak detection so that timely repairs can be made to ensure safe, reliable operation. This proactive approach also results in lower costs to the operator.

References:

PHMSA, https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=443

Project/Technology Name:

Smart Pipeline Network - Seal Sensor System

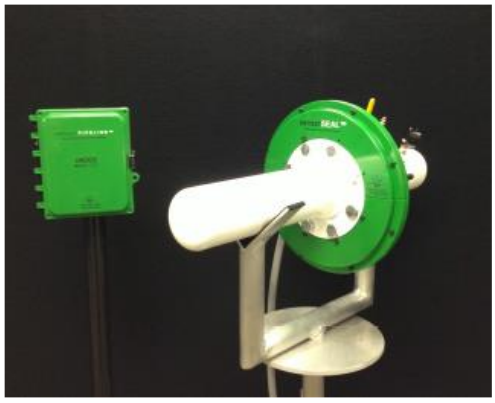
Performer/Contractor:	**System and Status: D**evice development, pre-commercialization
Odyssian Technology LLC	

Program Area:

1. Damage Prevention and Mitigation - Damage Mitigation and Repair

Project/Technology Description:

This project focused on the development of a Seal Sensor System (sensor SEAL™). When combined with the Pipe and Repair Sensor System (proposed separately), this technology allows for a Smart Pipeline Network with integrated sensors that provide continuous real-time leak detection of hazardous liquid and natural gas. The networks includes smart seals or sensor boots that provide a means for detecting leakage of fittings typically found in a pipeline pumping station. A network topography and control architecture will be developed to provide an intelligent control.



Impact of Project/Technology on Technological Advancement to Gas Industry:

Phase I focused on a Seal Sensor System for liquid pipeline systems. Phase II expands the sensor system for use with natural gas. The Seal Sensor System is expected to be capable of pinpointing leaks and sensing the state of the seals. The seal sensor network helps operators continuously monitor the “health” of the pipeline system and detect leaks.

The Seal Sensor System has not yet been commercialized.

Applicable Metrics:

Increased Safety, Reduced Operations Costs, Greater Reliability: This technology allows for real-time leak detection so that timely repairs can be made to ensure safe, reliable operation. This proactive approach also results in lower costs to the operator.

References:

PHMSA, https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=442

Project/Technology Name:

Permanently Installed Pipeline Monitoring Systems

Performer/Contractor:	**System and Status:** Device development
University at Buffalo	

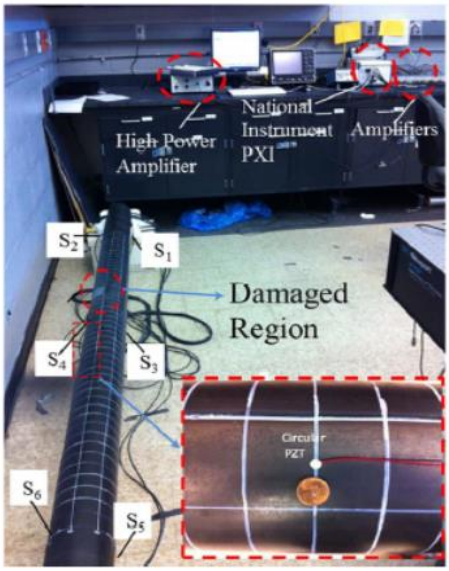
Program Area:

1. Damage Prevention and Mitigation - Damage Mitigation and Repair

Project/Technology Description:

This PHMSA-funded project designed and implemented a built-in monitoring system for assessing corrosion damage in pipelines. The system will be able to operate in two monitoring modes: 1) real-time continuous and 2) periodic, routinely-scheduled inspections.

The system is based on permanently installed arrays of low-profile piezoelectric transducers which have the capability of transmitting and receiving guided ultrasonic waves over the length of the pipeline. Signal processing algorithms based on probabilistic concepts were developed to perform damage localization (e.g. leaks) and damage characterization (e.g. defect sizing).



Impact of Project/Technology on Technological Advancement to Gas Industry:

The rate of corrosion can be reduced by appropriate mitigation strategies. Since corrosion processes are cumulative, periodic inspection is not always optimal for identifying areas that require timely action to mitigate corrosion. There is a need to change from periodic inspections, based on fixed time intervals, to a more cost-effective condition-based inspection (risk-based). This can be achieved by equipping pipelines with sensing and analysis systems to enable real-time, continuous and autonomous monitoring.

Applicable Metrics:

Increased safety: This is a proactive approach to facilities monitoring, which will help to detect potential pipeline threats (corrosion or mechanical damage) so that they can be addressed sooner, resulting in more effective integrity management.

Greater reliability: Proactively addressing known threats results in safer operation and enhanced reliability of facilities.

References:

PHMSA, https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=507

Project/Technology Name:

Self-Sensing in Composite Repairs of Corrosion Defects

Performer/Contractor:	**System and Status:** Device development
University of Tulsa	

Program Area:

1. Damage Prevention and Mitigation - Damage Mitigation and Repair

Project/Technology Description:

The PHMSA-funded technology focused on the investigating scaling and self-sensing in composite repairs of corrosion defects. Scaling was researched through a fatigue test program that compared the performance of patch-type composite repairs on small-scale pipeline specimens (6-inch NPS) to the performance of the same repairs on a large-scale specimen (60-inch diameter). Self-sensing was addressed through the development and testing of a resistive-based, self-sensing composite system. The material allowed for the monitoring of the composite bond using small, low-voltage electronics.

Impact of Project/Technology on Technological Advancement to Gas Industry:

Composite repairs of pipeline and pressure equipment are a growing segment of the corrosion mitigation industry. Use of composite repairs has expanded since the technique was introduced in the early 1990's. In addition, industry acceptance of composite repairs has grown since the initial products came on the market.

Applicable Metrics:

Increased safety: The repair of large steel pipes and containers using patch repair reduced the corrosion threats and results in safer operation and enhanced reliability of facilities.

References:

PHMSA, https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=506

Project/Technology Name:

Miniature, High Accuracy Tunable Mid-IR Laser Spectrometer for CH4/C2H6 Leak Detection

Performer/Contractor:	**System Status:**
Aeris Technologies (ARPA-E MONITOR program)	Device Development

Program Area:

1. Damage Prevention and Mitigation - Leak Detection

Project/Technology Description:

The system combines a compact spectrometer based on a mid-infrared laser, multi-port sampling system, and advanced computational approach to enable highly sensitive, accurate methane leak quantification and localization. The approach will use artificial neural networks and dispersion models to quantify and locate leaks with increased accuracy and reduced computational time in a diverse range of meteorological conditions and well pad configurations. At each well pad, a control unit will house the core sensor, a computing unit to process data, and wireless capability to transmit leak information to an operator, while the multi-port gas-sampling system will be distributed across the well pad.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The project goal is to be able to detect and measure methane leaks smaller than 1 ton per year from a 10x10 meter site.

Applicable Metrics:

Increase Safety - Reduce Operations Costs

Safety and fugitive emissions could be improved by ability to detect and contain methane leaks more quickly. The researchers hope to reduce annual monitoring costs from $25,000 to below $3,000 annually.

References:

https://arpa-e.energy.gov/?q=slick-sheet-project/methane-leak-detection-system-0

Project/Technology Name:

Advanced Development of a Methane/Natural Gas Microsensor

Performer/Contractor:	**System and Status:** Device development and pre-commercialization
Northeast Gas Association and Applied Nanotech	

Program Area:

1. Damage Prevention and Mitigation – Leak Detection

Project/Technology Description:

The project developed a microsonator (MR) methane/natural gas sensor. The technology is based on a pair of tuning fork micro-resonators and is used in a commercial hydrogen sensor. The project developed two prototype devices: 1) an analytical methane/natural gas sensor/instrument which include all necessary outputs, alarm signal, LCD display, operator setting of instrument parameters, and dual power capabilities, and 2) a safety monitor sensor with alarm only; which lacks some functions and hardware elements. The second sensor offers the same performance but at reduced cost.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The MR methane/natural gas sensor can be adapted to LDC needs as an analytical in-line or off-line measurement tool for gas operations applications or as fixed safety monitoring (alarm) device for residential, commercial or industrial applications. The MR sensor was tested for robustness, accuracy and, and cost. An important advantage of the MR sensor is that it will not produce false alarms in the presence of other hydrocarbons and organic vapors, a problem that has existed in other sensors in the market.

Applicable Metrics:

Increased safety: The capability to detect leaks without false alarms will help to detect potential pipeline threats accurately, so that appropriate action can be taken sooner.

Reduced cost: The MR sensor is inexpensive.

Greater reliability: The MR sensor is designed to be accurate and robust. Proactively addressing known threats results in safer operation and enhanced reliability of facilities.

References:

PHMSA, https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=495

Project/Technology Name:

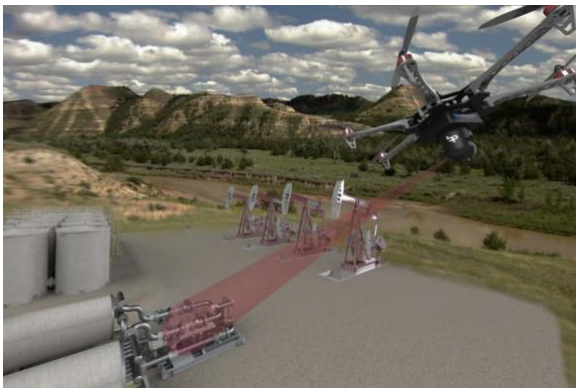
Mobile LiDAR Sensor for Rapid and Sensitive Methane Leak Detection Applications

Performer/Contractor:	**System Status:**
Bridger Photonics (ARPA-E MONITOR program)	Device Development

Program Area:

1. Damage Prevention and Mitigation - Leak Detection

Project/Technology Description:



Bridger's complete light-detection and ranging (LiDAR) remote sensing system will use a near-infrared fiber laser amplifier in a system mounted on a ground vehicle or an unmanned aerial vehicle (UAV), which can be programmed to survey multiple well pads a day. Data captured by the LiDAR system will provide 3D topographic and methane absorption imagery using integrated inertial navigation and global positioning system data to show precisely where a methane leak may be occurring and at what rate.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The project goal is to develop a mobile methane sensing system capable of surveying a 10 x 10 meter well platform in just over five minutes.

Applicable Metrics:

Increase Safety - Reduce Operations Costs

Safety and fugitive emissions could be improved by ability to detect and contain methane leaks more quickly. The goal is for one device to be able to service up to 85 sites, costing $1,400 to $2,220 a year to operate per wellsite.

References:

https://arpa-e.energy.gov/?q=slick-sheet-project/mobile-methane-sensing-system

Project/Technology Name:

Autonomous Coded Aperture Mini Mass Spectrometer (autoCAMMS) based Methane Sensing System

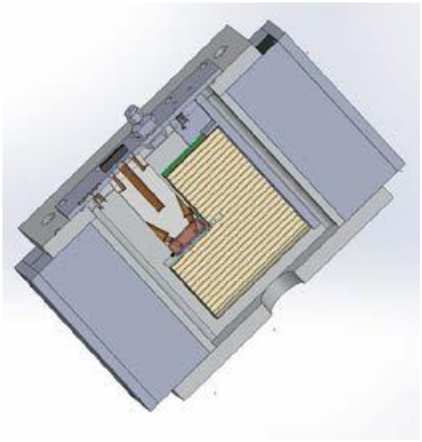
Performer/Contractor:	**System Status:**
Duke University (ARPA-E MONITOR program)	Device Development

Program Area:

1. Damage Prevention and Mitigation - Leak Detection

Project/Technology Description:

The project is developing a coded-aperture miniature mass spectrometer environmental sensor (CAMMS-ES) for use in a methane monitoring system. The team will also develop search, location, and characterization algorithms. Spatially coded apertures and corresponding reconstruction algorithms increase the throughput of the spectrometer, enabling continuous sampling without diminishing resolution. The coded aperture will also provide advanced specificity and sensitivity for detecting methane and other volatile organic compounds (VOCs) associated with natural gas production.



Impact of Project/Technology on Technological Advancement to Gas Industry:

The researcher team's end goal is to commercialize a mass spectrometer that weighs around 20 pounds and fits in a backpack. This could be used throughout the natural gas system to localize and characterize methane and VOC emissions.

Applicable Metrics:

Increase Safety - Reduce Operations Costs

Safety and fugitive emissions could be improved by ability to detect and contain methane leaks more quickly.

References:

https://arpa-e.energy.gov/?q=slick-sheet-project/advanced-spectrometer-methane-detection

http://camms.pratt.duke.edu/news/arpa-e-supports-miniaturized-mass-spectrometer-project-duke

Project/Technology Name:

Micro-structured Fiber for Infrared Absorption Measurements of Methane Concentration

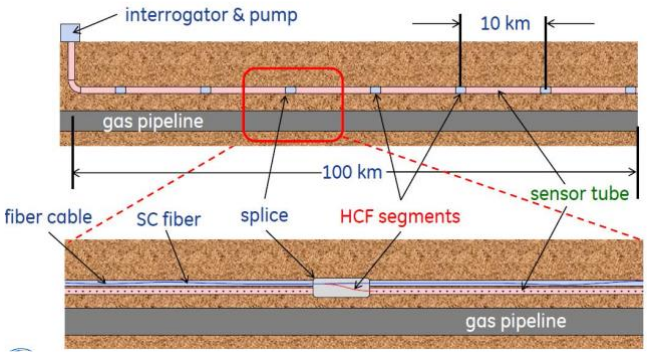
Performer/Contractor:	**System Status:**
General Electric (ARPA-E MONITOR program)	Device Development

Program Area:

1. Damage Prevention and Mitigation - Leak Detection

Project/Technology Description:

Project is designing, fabricating, and testing a hollow core, micro-structured optical fiber for long path-length transmission of infrared radiation at methane absorption wavelengths. Micrometer-sized side-holes allow gases to penetrate into the hollow core. A combination of techniques allows quantification and localization of methane in the hollow core.



Impact of Project/Technology on Technological Advancement to Gas Industry:

Hollow core fiber segments can be linked together in a design that can span over 100km and enable continuous pipeline.

Applicable Metrics:

Increase Safety - Reduce Operations Costs

Safety and fugitive emissions could be improved by ability to detect and contain methane leaks more quickly. The fiber detector is expected to be cost competitive with other highly selective methane detectors and offer innovative capabilities for more cost-effective methane monitoring.

References:

https://arpa-e.energy.gov/?q=slick-sheet-project/optical-fibers-methane-detection

Project/Technology Name:

An Intelligent Multi-modal CH4 Measurement System (AIMS)

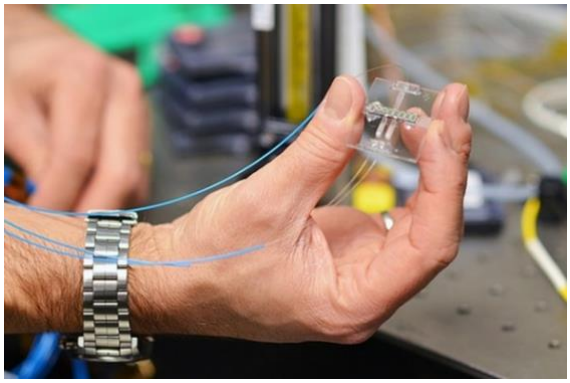
Performer/Contractor:	**System Status:**
IBM (ARPA-E MONITOR program)	Device Development

Program Area:

1. Damage Prevention and Mitigation - Leak Detection

Project/Technology Description:

Project is developing an energy-efficient, self-organizing mesh network to gather data over a distributed methane measurement system. Data will be passed to a cloud-based analytics system using custom models to quantify the amount and rate of methane leakage. System will use new, low-cost tunable diode laser absorption spectroscopy (TDLAS) optical sensors for methane detection.



Impact of Project/Technology on Technological Advancement to Gas Industry:

While today's optical sensors offer excellent sensitivity and selectivity, their high cost and power requirements prevent widespread adoption. To overcome these hurdles, IBM and its partners plan to produce a miniaturized, integrated, on-chip version that is less expensive and consumes less power.

Applicable Metrics:

Increase Safety - Reduce Operations Costs

At a planned cost of about $300 per sensor, IBM's sensors will be 10 to 100 times cheaper than TDLAS sensors on the market today. By advancing an affordable methane detection system that can be customized, IBM's technology could enable producers to more efficiently locate and repair methane leaks, and therefore reduce overall methane emissions.

References:

https://arpa-e.energy.gov/?q=slick-sheet-project/multi-modal-methane-measurement-system
https://www.scientificamerican.com/article/a-tiny-detection-chip-could-find-methane-leaks-autonomously/

Project/Technology Name:

Ultra-Sensitive Methane Leak Detection System for the Oil and Gas Industry Exploiting a Novel Laser Spectroscopic Sensor with Revolutionary High Performance / Low Cost

Performer/Contractor:	**System Status:**
LI-COR Biosciences (ARPA-E MONITOR program)	Device Development

Program Area:

1. Damage Prevention and Mitigation - Leak Detection

Project/Technology Description:

Cost-effective, highly sensitive optical methane sensors that can be integrated into mobile or stationary methane monitoring systems. A laser-based sensor utilizes optical cavity techniques, which provide long path lengths and high methane sensitivity and selectivity, but previously have been costly. The team will employ a novel sensor design developed in parallel with advanced manufacturing techniques to enable a substantial cost reduction.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The sensors are expected to provide exceptional long-term stability, enabling robust, unattended field deployment and reducing total cost of ownership.

Applicable Metrics:

Increase Safety - Reduce Operations Costs

The proposed sensor technology could decrease the expense of today's monitoring technologies and enable widespread adoption of methane monitoring and mitigation at natural gas well pads.

References:

https://arpa-e.energy.gov/?q=slick-sheet-project/optical-sensors-methane-detection

Project/Technology Name:

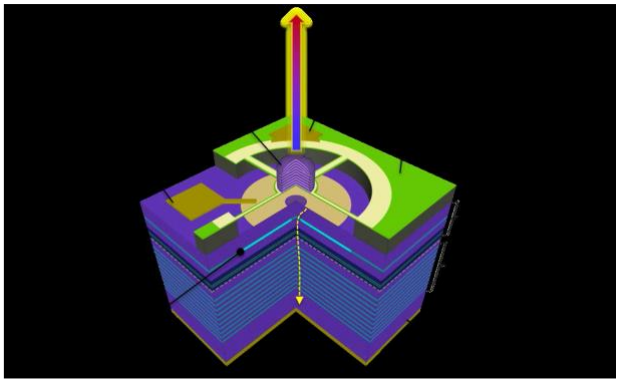
Tunable Laser for Methane Sensing

Performer/Contractor:	**System Status:**
Maxion/ThorLabs (ARPA-E MONITOR program)	Device Development

Program Area:

1. Damage Prevention and Mitigation - Leak Detection

Project/Technology Description:



Low cost, tunable, mid-infrared (mid-IR) laser source to be used in systems for detecting and measuring methane emissions. The new architecture is planned to reduce the cost of lasers capable of targeting methane optical absorption lines near 3.3 microns, enabling the development of affordable, high sensitivity sensors. The team will combine Micro-Electro-Mechanical-System tunable Vertical Cavity Surface Emitting Laser (MEMS-VCSEL) technology with an Inter-band Cascade Laser (ICL) active core.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The unique design offers advantages in manufacturing that are expected to yield a factor-of-40 reduction in the cost of the laser source, and the wide tunability will allow the same laser design to be shared across multiple applications.

Applicable Metrics:

Increase Safety - Reduce Operations Costs

When integrated with a full methane detection system, this technology could enable significant reduction in the cost associated with identifying, quantifying, and locating methane leaks as compared to currently available technologies.

References:

https://arpa-e.energy.gov/?q=slick-sheet-project/tunable-laser-methane-detection

Project/Technology Name:

System of Printed Hybrid Intelligent Nano-Chemical Sensors (SPHINCS)

Performer/Contractor:	**System Status:**
Xerox PARC (ARPA-E MONITOR program)	Device Development

Program Area:

1. Damage Prevention and Mitigation - Leak Detection

Project/Technology Description:

Printable sensing arrays that will be integrated into a cost-effective, highly sensitive methane detection system. The system will be based on sensor array foils containing multiple printed carbon nanotube (CNT) sensors and supporting electronics. Each sensor element will be modified with dopants, coatings, or nanoparticles such that it responds differently to different gases. Through principal component analysis and machine learning techniques, the system will be trained for high sensitivity and selectivity for components of natural gas and interfering compounds.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The goal is to be able to detect methane emissions with a sensitivity of 1 ppm and localize the source of emissions to within 1 meter, offering enhanced precision when compared to current equipment.

Applicable Metrics:

Increase Safety - Reduce Operations Costs

By using low-cost printing techniques, the project team's system could offer an affordable alternative to more expensive optical methane detectors on the market today. Total system costs under $350 per site per year; sensor cost target of ≤ $15 each.

References:

https://arpa-e.energy.gov/?q=slick-sheet-project/system-printed-hybrid-intelligent-nano-chemical-sensors-sphincs
https://www.plusplasticelectronics.com/energy/
http://www.arpae-summit.com/paperclip/exhibitor_docs/16AE/PARC_a_Xerox_Company_931.pdf

Project/Technology Name:

RMLD-Sentry for Upstream Natural Gas Leak Monitoring

Performer/Contractor:	**System Status:**
Physical Sciences, Inc. (ARPA-E MONITOR program)	Device Development

Program Area:

1. Damage Prevention and Mitigation - Leak Detection

Project/Technology Description:

Miniaturized laser-based Remote Methane Leak Detector (RMLD) integrated with miniature unmanned aerial vehicle (UAV), known as the Instant-Eye, to create the RMLD-Sentry. The measurement system is planned to be fully autonomous, providing technical and cost advantages compared to manual leak detection methods. The team anticipates that the system would have the ability to measure ethane, as well as methane, which would allow it to distinguish biogenic from thermogenic sources.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The RMLD-Sentry will locate well pad leak sources and quantify emission rates by periodically surveying the well pad, circling the facility at a low altitude, and dynamically changing its flight pattern to focus in on leak sources. When not in the air, RMLD-Sentry will monitor emissions around the perimeter of the site. If methane is detected, the UAV will self-deploy and search the well pad until the leak location is identified and flow rate is quantified using algorithms to be developed by the team.

Applicable Metrics:

Increase Safety - Reduce Operations Costs

PSI's design is anticipated to facilitate reduction in methane emissions at natural gas sites at an annualized cost of about $2,250 per year - a fraction of the cost of current continuous monitoring systems.

References:

https://arpa-e.energy.gov/?q=slick-sheet-project/methane-leak-detection-system
https://www.newswire.com/news/monitoring-fugitive-methane-emissions-utilizing-advanced-small-unmanned-9500029

Project/Technology Name:

goGCI - Portable Methane Detection Solution

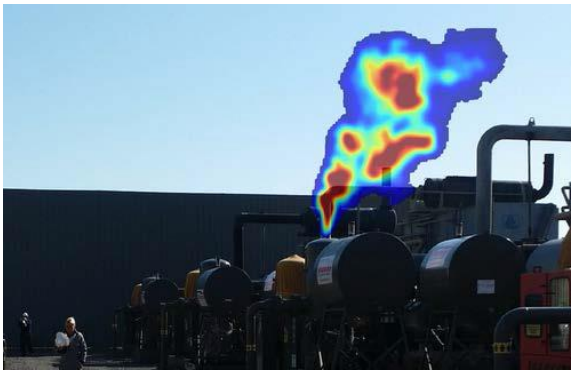
Performer/Contractor:	**System Status:**
Rebellion Photonics (ARPA-E MONITOR program)	Device Development

Program Area:

1. Damage Prevention and Mitigation - Leak Detection

Project/Technology Description:

Portable methane gas cloud imagers that can wirelessly transmit real-time data to a cloud-based computing service, allowing data on the concentration, leak rate, location, and total emissions of methane to be streamed to a mobile device, like an iPad, smartphone, or Google Glass. The infrared imaging spectrometers will leverage snapshot spectral imaging technology to provide multiple bands of spectral information for each pixel in the image.



Impact of Project/Technology on Technological Advancement to Gas Industry:

Similar to a Go Pro camera, the miniature, lightweight camera is planned to be attached to a worker's hardhat or clothing, allowing for widespread deployment. By providing a real-time image of the plume to a mobile device, the technology's goal is to provide increased awareness of leaks for faster leak repair.

Applicable Metrics:

Increase Safety - Reduce Operations Costs

This system could enable significant reduction in the cost associated with identifying, quantifying, and locating methane leaks as compared to currently available technologies.

References:

- https://arpa-e.energy.gov/?q=slick-sheet-project/portable-methane-detection-system
- https://www.forbes.com/sites/christopherhelman/2015/02/11/rebellion-photonics-thriving-on-fumes/#783dd76930ad
- http://www.cbsnews.com/news/worlds-first-hyperspectral-video-camera-detects-explosive-gas-leaks/

Project/Technology Name:

Frequency Comb-Based Remote Methane Observation Network

Performer/Contractor:	**System Status:**
University of Colorado, Boulder	Device Development

Program Area:

1. Damage Prevention and Mitigation - Leak Detection

Project/Technology Description:

Ground-based laser sends invisible, eye-safe laser beams to retroreflectors. Reduced-cost, dual frequency comb spectrometer with frequency comb consisting of 105 evenly spaced, sharp, single frequency laser lines covering a broad wavelength range that includes the unique absorption signatures of natural gas constituents like methane. The team has shown that frequency comb spectrometers can measure methane and other gases at parts-per-billion concentration levels over kilometer-long path lengths.

Impact of Project/Technology on Technological Advancement to Gas Industry:

Current, long-range sensing systems cannot detect methane with high sensitivity, accuracy, or stability. The frequency combs will be able to detect and distinguish methane, ethane, propane, and other gases without frequent calibration. When integrated into a complete methane detection system, the combs could lower the costs of methane sensing due to their ability to survey large areas or multiple gas fields simultaneously.

Applicable Metrics:

Increase Safety - Reduce Operations Costs

When integrated into a complete methane detection system, the innovation aims to improve the accuracy of methane detection while decreasing the costs of systems.

References:

- https://arpa-e.energy.gov/?q=slick-sheet-project/frequency-combs-methane-detection
- http://www.kunc.org/post/cu-engineers-using-lasers-track-gas-leaks

Project/Technology Name:

Continuous Open Path Methane Monitors

Performer/Contractor:	**System Status:**
Acutect/Sensit (EDF Methane Detector Competition)	Device Development

Program Area:

1. Damage Prevention and Mitigation - Leak Detection

Project/Technology Description:

Continuous open path monitors for methane that utilize laser absorption spectroscopy. Laser absorption spectroscopy works by directing an infrared laser to a reflector that returns a signal to the monitor's detector. The infrared laser signal is swept across an absorption peak, an electromagnetic wavelength, associated with methane. If methane is present, the reflected signal is attenuated, or weakened, whereas if no methane is detected, no such attenuation occurs. By comparing the two signals, after appropriate filtration and averaging, the amount of methane present is calculated. In field testing with PG&E following lab testing by SwRI in EDF Methane Detector Challenge.

Impact of Project/Technology on Technological Advancement to Gas Industry:

These monitors do not require frequent calibration and only require a periodic wipe-down of dust from the reflectors and the solar panels used to maintain battery charge. Acutect's units transmit analog or cellular signals for both raw data and real-time alerts.

Applicable Metrics:

Increase Safety - Reduce Operations Costs

Continuous 24-hour monitoring offered by this technology could cut the time it takes to detect leaks from months to hours. This would lead to improved environmental performance and operational efficiency of gas infrastructure.

References:

- http://business.edf.org/acutect-continuous-open-path-methane-monitors/
- http://www.gastechnology.org/CH4/Documents/14-Peter-Foller-CH4-Presentation-Oct2015.pdf

Project/Technology Name:

Methane Sensing Solutions for Oil & Gas

Performer/Contractor:	**System Status:**
Quanta3 (EDF Methane Detector Competition)	Device Development/Field Testing

Program Area:

1. Damage Prevention and Mitigation - Leak Detection

Project/Technology Description:

Laser Absorption Spectroscopy system that can perform continuous monitoring of a well-site. Sensor is ultra-precise, specific to methane, and does not require calibration. In field tests with StatOil and Shell following lab testing by SwRI in EDF Methane Detector Challenge.

Impact of Project/Technology on Technological Advancement to Gas Industry:

Low-cost ($1-2k target), low-power sensors (10W) can be used for stationary, handheld, and drone-mounted applications monitoring well sites or other natural gas installations.

Applicable Metrics:

Increase Safety - Reduce Operations Costs

Technology would reduce the time to detect and address leaks in natural gas infrastructure.

References:

- http://www.quanta3.com/overview.html
- http://www.expressnews.com/business/eagle-ford-energy/article/The-laser-that-could-solve-30-billion-methane-10894214.php
- http://www.shell.ca/en_ca/media/news-and-media-releases/news-releases-2017/shell-launches-methane-detection-pilot.html

Project/Technology Name:

UAS-Mounted Open Path Laser Spectrometer

Performer/Contractor:	**System Status:**
JPL/UC Merced	Device Development

Program Area:

1. Damage Prevention and Mitigation - Leak Detection

Project/Technology Description:

NASA Open Loop Laser Spectrometer (OPLS) with parts per billion accuracy developed for Mars exploration is mounted on Unmanned Aircraft System (UAS) for detecting methane leaks. Prototype system was tested in the Merced Vernal Pools and Grassland Reserve. System envisioned to be deployed with Vertical Takeoff and Landing (VTOL) or fixed-wing drones. Researchers are developing leak surveillance, localization, and quantification methods.

Impact of Project/Technology on Technological Advancement to Gas Industry:

Could be used for surveying natural gas infrastructure in hard to reach areas. 1000x more sensitive than current handheld survey instruments.

Applicable Metrics:

Increase Safety - Reduce Operations Costs

Technology would reduce the time to detect, localize, and address leaks in natural gas infrastructure.

References:

- http://www.ucmerced.edu/news/2016/nasa-uc-merced-successfully-test-miniature-methane-sensor
- https://www.arb.ca.gov/cc/oil-gas/Christensen_CMS_jun6.pdf
- http://www.nbcbayarea.com/news/local/Researchers-Explore-New-Use-for-Drones-Detecting-Methane-Leaks-417383103.html

Project/Technology Name:

In-Line Inspection Technology to Detect and Measure Pipeline Girth Weld Defects

Performer/Contractor:	**System and Status:** Device development and field demonstration
Diakont Advanced Technologies, Inc.	

Program Area:

2. Threats and Integrity Management - Anomaly Detection and Characterization

Project/Technology Description:

Funded by the California Energy Commission, the girth-weld scanning technology uses an EMAT girth weld scanner (GWS) module mounted on an ILI inspection platform. Diakont used their pipeline testing experience to streamline future iterations of the tool, including smaller diameter pipes and increased ability to navigate bends, and to optimize marketing efforts.

Impact of Project/Technology on Technological Advancement to Gas Industry:

Current Commercially available in-line inspection include hydro-testing, external ultrasonic testing, and magnetic flux leakage (MFL) technology. This technology uses an EMAT weld scanner module mounted on existing remotely operated diagnostic inspection system (RODIS).

Applicable Metrics:

Increase safety - Greater Reliability: The technology can potentially early weld defections and increase the reliability of girth-weld inspection for pipeline operators, thus increasing pipes safety and allowing the potential for increased inspection scope and frequency.

References:

In-Line Inspection Technology to Detect, Locate, and Measure Pipeline Girth Weld Defects. Field Demonstration. California Energy Commission. Report CEC-500-2015-028. 2015.

Project/Technology Name:

Proactive and Hybrid Sensing Based In-line Pipeline Defects Diagnosis and Prognosis

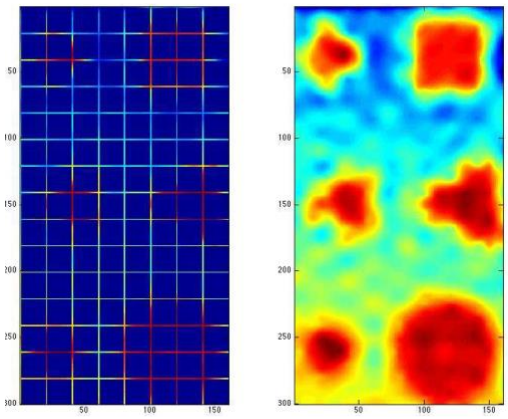
Performer/Contractor:	**System and Status:** Technology development
University of Colorado Denver and Arizona State University	

Program Area:

2. Threats and Integrity Management - Anomaly Detection and Characterization

Project/Technology Description:

The PHMSA-funded technology is a nondestructive (NDE) hybrid sensing technique, thermos-electromagnetic-acoustic (TEA) method to detect and characterize types of pipe damage with high resolution and sensitivity. The NDE detection results are integrated with probabilistic methods and mechanical analysis to develop an accurate time-dependent reliability analysis. The NDE results, along with residual strength calculation and uncertainty analysis are used in the reliability evaluation and risk assessment. Pipeline failure risk is expected to be significantly reduced by this approach to pipeline defect diagnosis and prognosis.



Impact of Project/Technology on Technological Advancement to Gas Industry:

Advanced sensor technologies to detect material loss and change in properties in various pipeline materials, including both metals and plastics, show promise in gas pipeline applications. Over the past two decades, methods have been developed to identify, characterize and evaluate material loss anomalies. Higher-resolution geometry tools and combination sensors with a more robust capability to detect and characterize anomalies are needed, but development of these technologies is still in the early stages.

Applicable Metrics:

Increased safety: This is a proactive approach to facilitate pipe monitoring, which will help to detect potential pipeline threats (corrosion or mechanical damage) so that they can be addressed sooner, resulting in more effective integrity management.

Greater reliability: Proactively addressing known threats results in safer operation and enhanced reliability of facilities.

References:

PHMSA, https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=508

Project/Technology Name:

Real-Time Active Pipeline Integrity Detection System for Gas Pipeline Safety Monitoring

Performer/Contractor:	**System and Status:** System development and field demonstration
Acellent Technologies. Inc.	

Program Area:

2. Threats and Integrity Management - Anomaly Detection and Characterization

Project/Technology Description:

The Real-Time Active Pipeline Integrity Detection (RAPID) was funded by the California Energy Commission and consists of a network of sensors placed on new and existing pipelines at regular intervals. The sensors are small piezoelectric sensors/actuators embedded in a thin dielectric film that is applied on the pipelines. The sensors monitor and evaluate the vibrations caused by the flow and the hardware wirelessly transmits the data to computers for monitoring and analysis.

Impact of Project/Technology on Technological Advancement to Gas Industry:

Structural health monitoring (SHM) is increasingly being evaluated by the pipeline industry as an alternative method to improve the safety, reliability, and reduce operational costs of pipeline systems. The RAPID system provides an early indication of physical damage of the line and Acellent is already manufacturing the units and demonstrated a prototype at PG&E facilities. A new project will implement the installation of the sensors in the field.

Applicable Metrics:

Increase safety - Greater Reliability - Reduce Operations Costs: The monitoring technology can potentially provide early identification of defects and allow for remedial strategies to be defined before damage leads to failure; thus, increasing the safety and reliability of the pipeline system. The sensor network will also eliminate costs associated with expensive inspections or shutting down the pipeline for service.

References:

Real-Time Active Pipeline Integrity Detection System for Gas Pipeline Safety Monitoring. California Energy Commission. Report CEC-500-2015-095. September 2015.

Project/Technology Name:

EMAT Sensor for Small Diameter and Unpiggable Pipes

Performer/Contractor:	**System and Status:** Device development and field evaluation.
Quest Integrated, Inc.	

Program Area:

2. Threats and Integrity Management - Anomaly Detection and Characterization

Project/Technology Description:

The project is co-funded by PHMSA and OTD to develop a device which can be pulled via an umbilical through pipe samples and uses Electromagnetic Acoustic Transducer (EMAT) to detect and quantify longitudinal cracks. A laboratory 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 includes 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.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The technology is applicable as a non-contact system which can run in dry and wet pipe environments. It can also be used to identify pipe wall thickness and estimate metal loss. The initial prototype runs in 8-inch pipes with a commercial target to test 6 to 12 inch unpiggable pipes.

Applicable Metrics:

Increase safety: The technology can potentially detect cracks and defections. The increase of the reliability of crack detection increases pipes safety and reduces the potential of increased inspection frequency.

References:

https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=653

Project/Technology Name:

Explorer (EXP) 20/26 Cleaning Tool Field Demonstration

Performer/Contractor:	**System and Status:** Device development, commercialization stage
Northeast Gas Association - NYSEARCH	

Program Area:

2. Threats and Integrity Management - Anomaly Detection and Characterization

Project/Technology Description:

The project demonstrated the effectiveness of a cleaning tool consisting of an array of brushes mounted on the commercial EXP robot, which is used to conduct in-line inspections of live, unpiggable natural gas pipelines. Cleaning is performed by both light scraping of the tool's brushes on the pipe wall and by "jetting" with the gas flow serving to carry the debris downstream to a diverter assembly that directs the dirt contaminated gas stream through a coalescing filtration system. The clean filtered gas then flows back through the diverter assembly into the pipe. The removed debris consists of metal shavings created by tapping the gas main. The device is in a commercialization stage with Invodane.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The technology addresses one of the challenges faced during in-line inspections. Full visual and testing instrument access is key for proper inspection of the interior of a pipe. This cleaning technology improves the ability to conduct a thorough inspection leading to increased safety.

Applicable Metrics:

Increase safety - Greater Reliability: In-line inspection is one of the primary methods to ensure pipelines are free of defects or to identify those in need of corrective action. This cleaning technology provides a means of performing the inspection under live conditions while ensuring that the cleaning debris is diverted and removed.

References:

NYSEARCH, Copyright 2016. http://www.nysearch.org/news-info_110216.php

Project/Technology Name:

Explorer 20/26 Unpiggable Pipeline Inspection Platform Rescue Tool

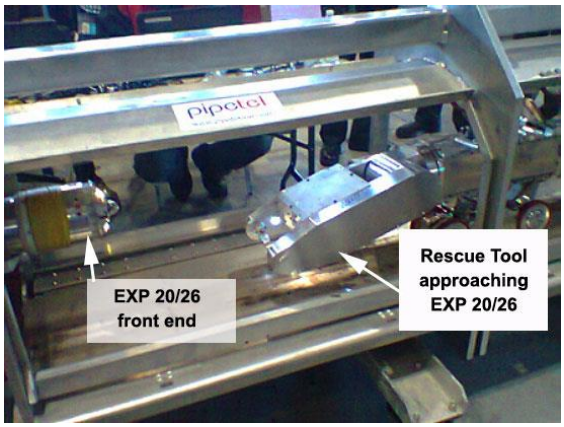
Performer/Contractor:	**System and Status:** Device development, commercialization stage
Northeast Gas Association - NYSEARCH	

Program Area:

2. Threats and Integrity Management - Anomaly Detection and Characterization

Project/Technology Description:

The rescue tool is designed to provide in-line assistance to the inspection robot in case of malfunction or problems with battery supply or wireless communication. The rescue tool was demonstrated at Con Edison's Van Nest facility in October 2016. This activity was successful in that the rescue tool operated as expected to pull the main robotic platform, weighing 1,500 pounds and simulated as stranded, from a 20-inch pipeline.



Impact of Project/Technology on Technological Advancement to Gas Industry:

The technology addresses one of many challenges faced during in-line inspections with tetherless inspection platforms. Full visual and testing instrument access and inspection platform removal are key for proper inspection of the interior of a pipe.

Applicable Metrics:

Reduce Operations Costs - Greater Reliability: In-line inspection is one of the primary methods to ensure pipelines are free of defects or to identify those in need of corrective action. This rescue tool provides inspection personnel with an increased reliability by ensuring the inspection platform can successfully perform its task and be recovered for future use.

References:

NYSEARCH, Copyright 2016. http://www.nysearch.org/news-info_110216.php

Project/Technology Name:

ERW and Longitudinal Seam Welds

Performer/Contractor:	**System and Status:** Device demonstration
Pipeline Research Council International (PRCI)	

Program Area:

2. Threats and Integrity Management - Anomaly Detection and Characterization

Project/Technology Description:

The evaluation project provides operators with a comprehensive framework and guidance for integrity management of longitudinal seam welded pipe (see picture).

The project evaluated various NDA technologies and summarized the applicability of ILI technologies of MFL, USCCD and EMAT in characterizing long seam features for in-ditch analysis of ERW pipe weld seam anomalies.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The round-robin tests of NDE tools using ERW samples evaluated standardized NDE protocols for in-ditch NDE of ERW seam features.

Applicable Metrics:

Increase safety: External inspection and corrosion monitoring are one of the critical components of a pipeline integrity program. Real-time monitoring of ERW seams provides an effective means to detect and correct welding issues.

References:

PRCI Natural Gas Pipeline Integrity Research. Research Operations, California Energy Commission Staff Workshop. July. 2015.

Project/Technology Name:

Assessment of Integrity of Composite Wrap Repairs

Performer/Contractor:	**System and Status:** Technology evaluation
Pipeline Research Council International (PRCI)	

Program Area:

2. Threats and Integrity Management - Anomaly Detection and Characterization

Project/Technology Description:

The project assesses ultrasonic and electromagnetic inspection techniques for composite overwrap repairs for pipelines.

Examples of the new techniques evaluated in this project include Dynamic Response Spectroscopy (DRS) "Multi-skip" UT, Sonomatic Electromagnetic LFET/ OSET, and TesTex Inductosense (WAND) – embedded sensors.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The evaluated technologies provide an advancement in the inspection of composite repair materials, bond quality between the composite material and the pipe, and the inspection of the pipe underneath the repair.

Applicable Metrics:

Increase safety: Inspection of disbondment between the composite repair and the pipe is one of the critical components of pipeline repair. Monitoring after the application of the repair provides an effective means to detect and correct these issues.

References:

NDE & Inspection techniques applied to the assessment of integrity of composite wrap repairs (NDE 2-3). PRCI, 2017.

Project/Technology Name:

Innovative Sensors for Pipeline Crawlers to Assess Pipeline Defects and Conditions

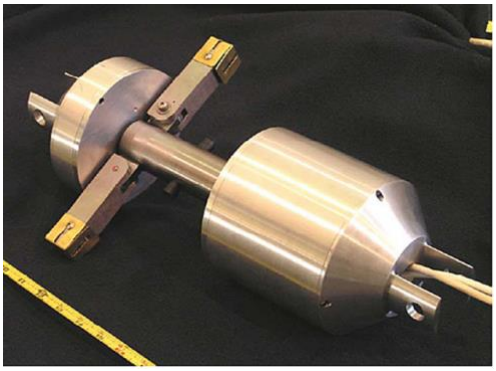
Performer/Contractor:	**System and Status:** Technology development
Battelle Columbus Laboratories	

Program Area:

2. Threats and Integrity Management - Anomaly Detection and Characterization

Project/Technology Description:

The electromagnetic sensors (based on eddy current technology) are integrated with a robotic platform (crawler) to conduct internal natural gas pipeline inspections. Combinations of sensor types were used to assess a wide range of pipeline conditions, including corrosion (pitting, localized, and extended), mechanical damage, cracking, and seam weld defects. Small physical size and weight, as well as low electrical power consumption, were the primary design constraints for the crawler systems.



Impact of Project/Technology on Technological Advancement to Gas Industry:

This combined inspection tool provides a means of non-destructive pipeline examination and provides a technique for inspecting a large portion of the pipeline infrastructure that cannot be inspected with existing equipment (unpiggable pipelines). The rotating permanent magnet system has the potential for inspecting unpiggable pipelines since the magnetizer configurations can be sufficiently small with respect to the bore of the pipe to pass obstructions that limit the application of many inspection technologies.

Applicable Metrics:

Increase safety: The system can crawl slowly inside a pipeline and maneuvers past the physical barriers that limit internal inspection applicability, such as bore restrictions, low product flow rate, and low pressure.

References:

Innovative Sensor for Pipeline Crawlers: Rotating Permanent Magnet Inspection. NETL-DOE and PRCI. Contract No. DE-FC26-03NT41881. December 2006.

Project/Technology Name:

Circumferential MFL In-Line Inspection for Cracks in Pipelines

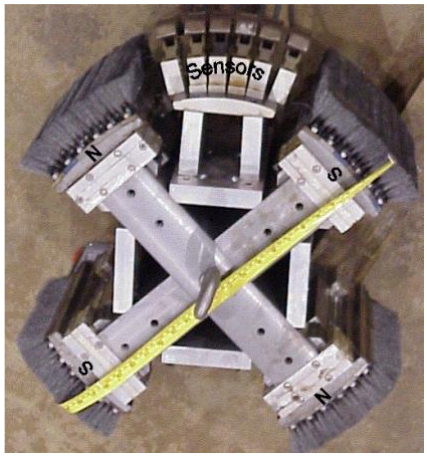
Performer/Contractor:	**System and Status:** Technology development
Battelle Columbus Laboratories	

Program Area:

2. Threats and Integrity Management - Anomaly Detection and Characterization

Project/Technology Description:

In this DOE-funded research, two technology enhancements to improve detection of cracks using MFL technology were investigated: (1) combining high- and low-magnetization technology for stress detection and (2) combining axial and circumferential MFL methods.



This technology works by orienting the magnetic field around the pipe rather that along the axis. By orienting the magnetic field in the circumferential direction, the axial defects that were magnetically transparent disrupt more of the magnetic field and can be more easily detected.

Impact of Project/Technology on Technological Advancement to Gas Industry:

Circumferential MFL is a new implementation that has potential to detect and quantify axially oriented defects such as cracks, seam weld defects, mechanical damage, and groove corrosion. The technology also provides the ability for improved detection of axially oriented volumetric defects. While successful results were obtained, circumferential MFL can only detect larger cracks.

Applicable Metrics:

Increase safety: The system provides the ability of the detection of cracks in both axial and circumferential directions, this reducing the threats of pipeline failure due to metal and weld fatigue and defects.

References:

Circumferential MFL for In-Line Inspection for Cracks in Pipelines. NETL-DOE. Agreement No. DE-FC26-01NT41159. December 2003.

Project/Technology Name:

Technology for Early Detection of Internal Corrosion of Pipeline Integrity

Performer/Contractor:	**System and Status:** Technology development
Southwest Research Institute (SwRI)	

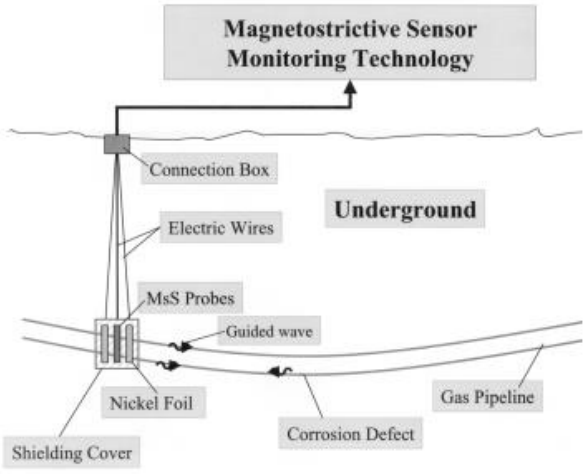
Program Area:

2. Threats and Integrity Management - Anomaly Detection and Characterization

Project/Technology Description:

Magnetostrictive sensor (MsS) technology involves the launching of a mechanical "guided wave" pulse of a relatively low frequency (typically under 100 kHz) along a pipeline. Signals reflected from defects or welds are detected at the launch location in the pulse-echo mode.

This technology can quickly examine a long length of piping for defects such as corrosion and circumferential cracking from a single test location and is already used commercially for inspection of aboveground piping in refineries and chemical plants.



Impact of Project/Technology on Technological Advancement to Gas Industry:

The potential impact of a successful method of determining extent and location of buried pipeline corrosion from a fixed signal location would be significant if successfully achieved.

Applicable Metrics:

Increase safety: The project would minimize the efforts and costs associated with internal inspection or excavation-based inspection methodologies. The enhancement in pipeline monitoring would permit more frequent system evaluation resulting in an increase in overall safety and integrity of the natural gas infrastructure.

References:

Monitoring Technology for Early Detection of Internal Corrosion of Pipeline Integrity. NETL-DOE. Agreement No. DE-FC26-02NT41319. 2003.

Project/Technology Name:

Inspection of Fusion Joints in Plastic Pipe

Performer/Contractor:	**System and Status:** Technology development
Edison Welding Institute	

Program Area:

2. Threats and Integrity Management - Anomaly Detection and Characterization

Project/Technology Description:

This project uses laser-based inspection technology to evaluate weld images based on the "weld zone inspection method" (WZIM). The WZIM is designed to develop laser-based imagery of fusion joint bond line under heated conditions and automatically and digitally compare the images to a database of known faulty joint characteristics to indicate joint acceptability.

The WZIM specifically addresses "cold fusion" defects, a weak interface bond between the pipe-ends being joined that accounts for the majority of failures experienced in the field.

Impact of Project/Technology on Technological Advancement to Gas Industry:

This method can be applied to NDE of all types of PE butt fusion joints and materials. The potential impact is to maintain the nation's natural gas infrastructure through enhanced inspection capability for polyethylene pipe to improve the overall safety and reliability of the natural gas distribution network.

Applicable Metrics:

Increase safety- Increase reliability: Successful implementation of this in-situ inspection method will improve the reliability and safety of plastic pipe systems for natural gas distribution. It will also minimize the cost and need for expensive destructive quality assurance (QA) tests.

References:

Inspection of Fusion Joints in Plastic Pipe. NETL-DOE. Award No: DE-FC26-03NT41882. 2005.

Project/Technology Name:

State-of-the-Art (SOA) Corrosion Sensors

Performer/Contractor:	**System and Status:** Device demonstration, commercialization stage
Northeast Gas Association - NYSEARCH	

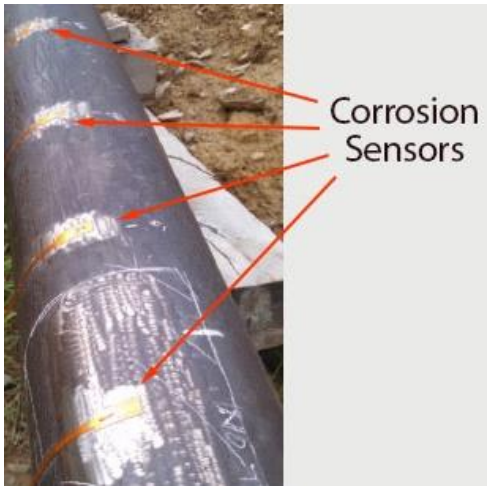
Program Area:

2. Threats and Integrity Management - Anomaly Detection and Characterization

Project/Technology Description:

NYSEARCH, with its contractor Analatom, completed lab and field testing on corrosion sensors currently used by aircraft for corrosion monitoring. While primarily applied to coated steel, these sensors can measure corrosion rates in real time on the external surfaces of pipe using a unique linear sensor array.

The tests provided positive confirmation that the micro-linear polarization resistance sensors can be practically applied to provide real-time monitoring of corrosion on natural gas pipelines. More work is needed to further validate their use and to advance it to commercialization.



Impact of Project/Technology on Technological Advancement to Gas Industry:

The technology addresses one of many challenges of an effective corrosion monitoring program to measure corrosion rates in real-time specifically in conditions where corrosion potential is known or suspected to exceed the norm. This technology improves the ability to conduct a thorough inspection leading to increased safety.

Applicable Metrics:

Increase safety: External inspection and corrosion monitoring are one of the critical components of a pipeline integrity program. Real-time monitoring provides an effective means to detect and correct corrosion issues.

References:

NYSEARCH, Copyright 2016. http://www.nysearch.org/news-info_110216.php

Project/Technology Name:

Eddy Current-Based Crack Detection Sensor for Unpiggable Transmission Lines

Performer/Contractor:	**System and Status:** Technology investigation, pre-commercialization
Northeast Gas Association, NYSEARCH	

Program Area:

2. Threats and Integrity Management - Anomaly Detection and Characterization

Project/Technology Description:

The PHMSA-funded project develops and tests an Anisotropic Magneto Resistive (AMR) Eddy Current (EC)-based sensor for live, in-line inspection of 6 to 8-inch diameter, unpiggable natural gas pipelines.

The sensor system has been proven through a separate feasibility study to function with a minimal power requirements. The AMR EC crack sensor is suited to the operational characteristics of the Explorer series of robotic platforms where space and power are inherently limited.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The sensor incorporates an eddy current based technology, developed by RMD Inc., that can be integrated onto the Explorer 6 - 8 inches robotic platform, which was developed with PHMSA co-funding and commercialized in 2010 by NYSEARCH and Invodane Engineering (through Pipetel Technologies, the commercial service company of Invodane Engineering).

Applicable Metrics:

Increase safety: In-line inspection is one of the main procedures for integrity management of steel transmission lines. Crack damage is recognized as a major reason for failure of on-shore underground steel pipes. The crack detection sensor reduces the risks of failure and results in decrease in maintenance cost and system downtime.

References:

https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=648

Project/Technology Name:

Explorer 30/36

Performer/Contractor:	**System and Status:** Technology demonstration, commercialization stage
Northeast Gas Association, NYSEARCH	

Program Area:

2. Threats and Integrity Management - Anomaly Detection and Characterization

Project/Technology Description:

The Explorer 30/36 tool is one of a series of pipeline robots designed by Invodane Engineering, including Explorer 6/8, Explorer 10/14 and Explorer 20/26. The system is battery-powered to inspect 30 to 36-inch pipe diameters. Pacific Gas and Electric

Company (PG&E) tested the 20-ft long robot in its gas transmission pipelines as part of the utility's effort to increase pipeline safety throughout their service area.

Impact of Project/Technology on Technological Advancement to Gas Industry:

Unlike traditional "smart pigs" used for in-line inspection and propelled by natural gas within the pipeline, the untethered Explorer robotic tools are battery-powered and controlled wirelessly. This allows Explorer robots to navigate through live pipelines that are considered "unpiggable" because of low-pressure conditions or other restrictions including sharp bends and plug valves.

Applicable Metrics:

Increase safety: : In-line inspection is one of the primary methods to ensure pipelines are free of defects or to identify those in need of corrective action. This technology provides a means of performing the inspection under live conditions in unpiggable large diameter pipes.

References:

NYSEARCH, Copyright 2016. http://www.nysearch.org/news-info-item1.php

Project/Technology Name:

Pipeline Integrity Assessment Using In-Line Inspection (ILI)

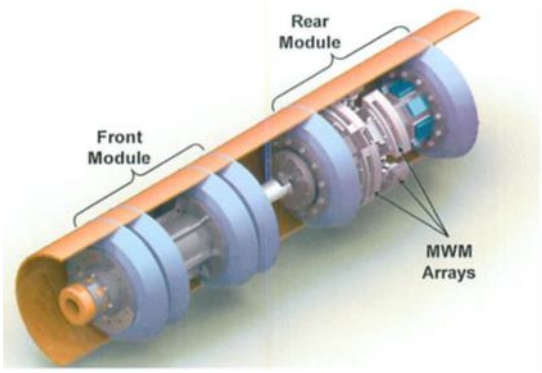
Performer/Contractor:	**System and Status:** Device demonstration, pre-commercialization stage
JENTEK Sensors Inc.	

Program Area:

2. Threats and Integrity Management - Anomaly Detection and Characterization

Project/Technology Description:

This PHMSA-funded project investigated two technologies: Structured Waveform Magnetic Field (SWMF) and Low-Frequency Eddy Current with Saturating Field. These technologies have the potential to produce an ILI tool that can exceed these limitations and provide ID, mid-wall, and OD defect inspection (corrosion and cracks) under ILI operating conditions. Project results will serve as a basis for future commercialization of ILI tool designs.



Impact of Project/Technology on Technological Advancement to Gas Industry:

This research effort is focused on technology for enhanced ILI tools that can be easily deployed, ideally at a lower cost and with fewer personnel and infrastructure compared to existing tools. It demonstrated the feasibility for ERW weld crack detection, internal and external corrosion imaging, longitudinal stress mapping and post weld heat treatment assessment using an advanced MWM-Array. Existing arrays are limited by current technology and not always practical for certain ILI approaches or defects.

Applicable Metrics:

Increased safety – Reduce costs: The technology aimed at reducing the cost of the ILI tool, improving its sensitivity, and making it easier to use will encourage wider use. More repetitive ILI runs are planned to detect more defects, providing more effective integrity management.

References:

PHMSA, https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=562

Project/Technology Name:

Above-Ground Detection Tools for Disbondment, Metal Loss, and Cast-Iron Graphitization

Performer/Contractor:	**System and Status:** Device development
Gas Technology Institute	

Program Area:

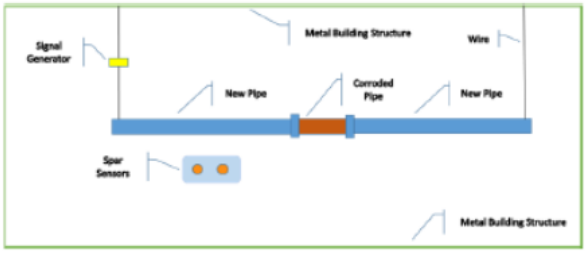
2. Threats and Integrity Management - Anomaly Detection and Characterization

Project/Technology Description:

The Above-ground Detection Tool consists of a mobile platform for detecting coating disbondment, graphitization and external corrosion by measuring the pipe's magnetic field signatures from above ground.

Alternating current is applied to the test pipe, generating magnetic fields which are affected by corrosion and disbondment.

A suite of sensors moves along the pipe with stops at specific intervals to take readings, which are geo-referenced at the location and time when they are captured. An operator is able to review the data and intervene in the platform operation if needed.



Impact of Project/Technology on Technological Advancement to Gas Industry:

The technology is a process for detecting corrosion threats and coating disbondment through an external direct assessment (ECDA) process; with the potential of adding a practical tool to the pipeline inspection procedures.

Applicable Metrics:

Increased safety: This is a proactive approach to facilitate monitoring, which will help to detect potential pipeline threats (corrosion or mechanical damage) so that they can be addressed sooner, resulting in more effective integrity management.

References:

PHMSA, https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=500

Project/Technology Name:

Development of Tools for Assessing the Severity and Life of Dent Features

Performer/Contractor:	**System and Status:** Model development
BMT Fleet Technology Limited	

Program Area:

2. Threats and Integrity Management - Pipeline Testing and Stress Analysis

Project/Technology Description:

This project used elements of the previously validated dent assessment tool to develop a mechanical damage assessment strategy, validate it and ultimately develop an easily applied mechanical damage fatigue life assessment tool. The existing BMT "plain" dent assessment model was extended to consider 1) geometry of dents interacting with welds and 2) operating conditions, such as the effect of line pressure.

Typical Pipe Dent Damage

The primary objective of the project was to predict the local stress-strain state of a dented pipeline segment and to develop criteria for ranking and estimating the remaining life of dents.

Impact of Project/Technology on Technological Advancement to Gas Industry:

Failures in transmission pipelines are often the result of mechanical damage. Results of this research provide a useful tool for assessing mechanical damage and useful remaining life of dents.

Applicable Metrics:

Increased Safety, Greater Reliability: This technology enhances safety, reliability and damage prevention by providing a tool for assessing mechanical damage (dents, gouges).

References:

PHMSA, https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=358

Project/Technology Name:

Radio Frequency Identification (RFID) Smart Corrosion Coupon

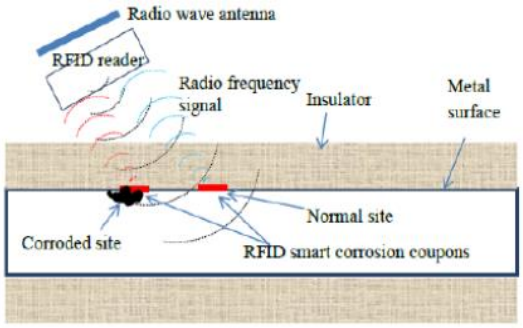
Performer/Contractor:	**System and Status:** Device development
Texas A&M Engineering Experiment Station	

Program Area:

2. Threats and Integrity Management - Pipeline Testing and Stress Analysis

Project/Technology Description:

The technology is funded by PHMSA for a "smart" corrosion coupon using Radio Frequency Identification (RFID) technology to perform continuous real-time wireless monitoring of corrosion. This combined the advantages of RFID technology and the conventional corrosion coupon to develop a better corrosion management system. The "smart" corrosion coupons can emit signals indicating the corrosion status of the monitored points on demand, by embedding passive RFID tags inside layers of support materials, which act like conventional corrosion coupons.



Impact of Project/Technology on Technological Advancement to Gas Industry:

The "smart" corrosion coupon combines the advantages of RFID technology and the conventional corrosion coupon. Results are expected to benefit the gas by significantly simplifying the current corrosion inspection process and improving the accuracy and effectiveness of resources (human and equipment) available.

Applicable Metrics:

Increased safety: The technology reduces the likelihood of having incidents related to corrosion, therefore boosting the overall safety performance of pipeline systems. This approach will also help to detect potential pipeline threats (corrosion or mechanical damage) so that they can be addressed in more effective integrity management action.

References:

PHMSA, https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=505

Project/Technology Name:

Electromagnetic Sensors to Quantify Strength and Toughness in Steel Pipelines

Performer/Contractor:	**System and Status:** Technology investigation, pre-commercialization
Generation 2 Materials Technology (G2MT)	

Program Area:

2. Threats and Integrity Management - Pipeline Testing and Stress Analysis

Project/Technology Description:

G2MT technologies provide services for integrity inspection of pipeline stresses and conditions (see picture). The project developed a nondestructive testing technology to rapidly evaluate pipeline mechanical properties.

The strength and toughness of the steel pipelines determined from the electromagnetic system will be linked with other inspection and materials characterization testing to provide improved Reliability Based Integrity Management.

Impact of Project/Technology on Technological Advancement to Gas Industry:

At the completion of this research program, the electromagnetic system was planned to be commercialized and ready for inspectors to begin offering services to the pipeline industry.

Applicable Metrics:

Increase safety: Reduces 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 the strength and toughness.

References:

https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=649

Project/Technology Name:

Realistic Strain Capacity Models for Pipeline Construction and Maintenance

Performer/Contractor:	**System and Status:** Model development
Center for Reliable Energy Systems	

Program Area:

2. Threats and Integrity Management - Pipeline Testing and Stress Analysis

Project/Technology Description:

This project extended existing compressive and tensile strain capacity models to realistic design and application scenarios. At least two failure modes, tensile rupture and compressive buckling, are possible when pipelines are subjected to large longitudinal strains. Current practice is to treat these failure modes separately.

Project components were to develop a unified Strain Base Design (SBD) methodology in which compressive and tensile strain limit states can be analyzed in a consistent manner, and to bring compressive strain models to the same level of refinement and consistency as the tensile strain models.

Pipe wrinkle formed at high internal pressure

Impact of Project/Technology on Technological Advancement to Gas Industry:

The industry and regulators are expected to benefit from the outcome of this project through 1) enhanced safety from the refined compressive strain design models and 2) more effective allocation of resources to address varying levels of threats to pipeline safety and integrity in the event of large ground movements. Both new pipeline construction and maintenance of existing pipelines are expected to benefit as well.

Applicable Metrics:

Increased Safety, Greater Reliability: This technology enhances safety and reliability by providing a means of identifying threats due to large ground movements, based on strain capacity modeling.

References:

PHMSA, https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=361

Project/Technology Name:

Comprehensive Study to Understand Longitudinal ERW Seam Failures

Performer/Contractor:	**System and Status:** Analytical study
Battelle Memorial Institute	

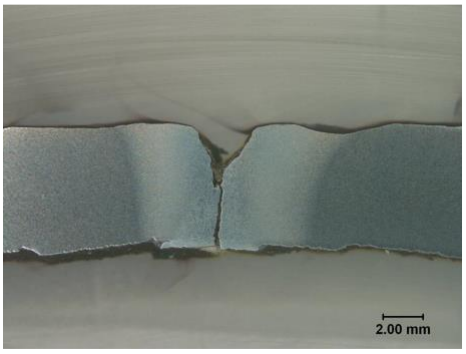
Program Area:

2. Threats and Integrity Management - Pipeline Testing and Stress Analysis

Project/Technology Description:

The project had the objective of integrating industry and PHMSA data to quantify vintage seam failure statistics, focusing on ERW pipes.

Based on an understanding of longitudinal ERW seam failures, the analysis aimed at assessing the effectiveness and effects of ILI inspection tools, hydrostatic pressure tests, and spike pressure tests for various pipe material strength characteristics.



Photomicrograph of Failed Seam Weld

Impact of Project/Technology on Technological Advancement to Gas Industry:

This project was a result of NTSB Recommendation P-09-001 to PHMSA to conduct a comprehensive study of ERW pipe properties and identify actions that can be implemented by pipeline operators to eliminate catastrophic longitudinal seam failures in low frequency (LF) ERW pipe.

Results of this study will provide a comprehensive understanding of ERW pipe properties and actions that can be taken to reduce or eliminate the possibility of catastrophic longitudinal seam failures in ERW pipe.

Applicable Metrics:

Increased Safety, Greater Reliability: A comprehensive understanding of ERW pipe properties provides pipeline operators with a proactive approach to pipeline integrity and safe, reliable operation.

References:

- National Transportation Safety Board, Safety Recommendation P-09-001. https://www.ntsb.gov/investigations/AccidentReports/_layouts/ntsb.recsearch/Recommendation.aspx?Rec=P-09-001
- PHMSA, https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=390

Project/Technology Name:

Laser Peening for Preventing Pipe Corrosion and Failure

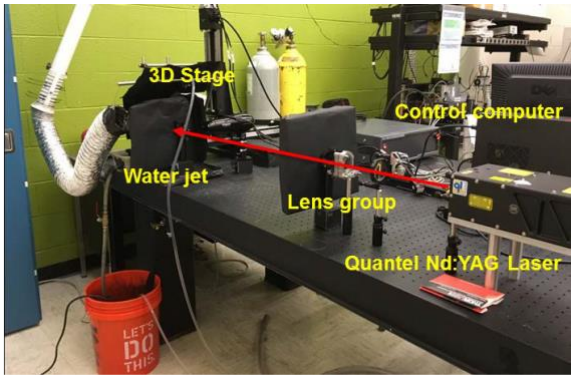
Performer/Contractor:	**System and Status:** Technology investigation
University of Nebraska	

Program Area:

2. Threats and Integrity Management - Pipeline Testing and Stress Analysis

Project/Technology Description:

The PHMSA-funded project addresses the challenge of Stress Corrosion Cracking (SCC). Laser peening will increase the corrosion resistance of pipeline steels. Laser peening, which employs laser-induced shock waves to create compressive residual stress in the metal surfaces of the pipelines, will significantly enhance their corrosion resistance.



The laboratory system uses Nd:YAG laser with a pulse energy of ~ 650 mJ with lens groups, a beam delivery system, a control system, and a power system to construct a compact laser peening system (see figure).

Impact of Project/Technology on Technological Advancement to Gas Industry:

The corrosion resistance of pipelines will be enhanced by the compressive residual stress created by laser-induced shock waves during laser peening. It is anticipated that using laser shock peening in the construction of a pipeline will highly improve the reliability, safety, and lifespan of the nation's pipeline transportation system.

Applicable Metrics:

Increased Safety: Mitigating stress corrosion reduces threat risk to pipeline integrity and safety.

References:

https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=570

Project/Technology Name:

Low-Cost Sensors for Natural Gas Pipeline Monitoring and Inspection

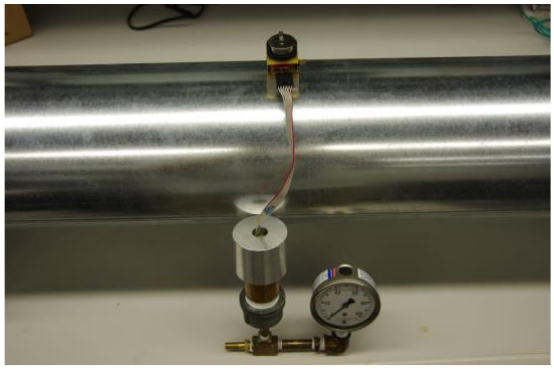
Performer/Contractor:	**System and Status:** System development and laboratory testing
University of California, Berkeley	

Program Area:

2. Threats and Integrity Management - Pipeline Testing and Stress Analysis

Project/Technology Description:

Micro-electro-mechanical sensors (MEMS) were funded by the California Energy Commission and are low-cost solution to provide real-time data to monitor the pipeline integrity. Micro-fabrication techniques are used to produce small and inexpensive, but complex sensors to measure many relevant variables such as instantaneous gas pressure, gas flow velocity, humidity inside the pipe, and vibration of the pipe.



Impact of Project/Technology on Technological Advancement to Gas Industry:

Common technologies for integrity management and diagnostic of pipeline flaws are intermittent and require data reporting or offline operations, which result in costly testing and/or disruption of service. Current off-the-shelf sensors are expensive, thus preventing ubiquitous deployment. The MEMS sensors provide small-scale inexpensive system for monitoring the various variables which provide indications of the health of the pipeline system.

Applicable Metrics:

Increase safety - Reduce Operations Costs: The low cost (less than $18 each) of the monitoring sensors can potentially provide a substantial reduction in monitoring costs and allow a widespread deployment to provide real-time data such as changes in pressure and flow of natural gas. The sensors could also reduce operational and maintenance costs, especially by reducing shut off and inspection time.

References:

Low-Cost Sensors for Natural Gas Pipeline Monitoring and Inspection. California Energy Commission. Report CEC-500-2014-104. Jan 2015.

Project/Technology Name:

Development and Field Testing of a Highly Sensitive Mercaptans Instrument

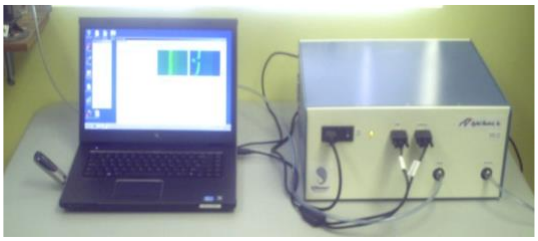
Performer/Contractor:	**System and Status:**
Northeast Gas Association, Applied Nanotech Inc.	Technology development, pre-commercialization

Program Area:

2. Threats and Integrity Management - Pipeline Testing and Stress Analysis

Project/Technology Description:

The project developed and field-tested a portable, low-cost instrument for the measurement of hydrogen sulfites and mercaptans, which are found in natural gas, renewable natural gas, biogas, and landfill gas. The instrument allows the detection and measurement of such compounds at the part per billion (ppb) level, serving as an artificial human nose. A follow-up phase will be needed to build a market-ready instrument and commercialize it.



Impact of Project/Technology on Technological Advancement to Gas Industry:

This technology makes it possible to detect ppb-level measurements of mercaptans in the field, where it is impractical to use and transport costly benchtop, laboratory-grade gas chromatograph instruments.

Applicable Metrics:

Increased Safety, Reduced Operations Costs, Greater Reliability: This technology allows for highly sensitive, accurate leak detection in the field so that timely repairs can be made to ensure safe, reliable operation. This proactive approach also results in lower costs to the operator.

References:

PHMSA, https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=367

Project/Technology Name:

High Accuracy Mapping for Damage Prevention and Emergency Response

Performer/Contractor:	**System and Status:** System development and demonstration
Gas Technology Institute	

Program Area:

3. Pipeline Risk and Information Management - Data Management and Information Systems

Project/Technology Description:

The system develops a high accuracy maps to reduce excavation damage and builds a situational awareness tool for gas industry operations and emergency response.

The subcontractor (LocusView) will deploy the high accuracy mapping systems in Pacific Gas and Electric (PG&E) service areas and develop workflows to support the business processes and situational awareness tools.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The technology will enable more effective and systematic decisions to the California pipeline company. This will improve pipeline safety, reduce losses during unanticipated events, and reduce operating costs.

Applicable Metrics:

Improve public safety by promoting situational awareness through high-accuracy maps during emergencies. The system will also increase operational efficiencies by providing high accuracy maps during routine operations.

References:

High Accuracy Mapping for Excavation Damage Prevention and Emergency Response. California Energy Commission. Project PIR-15-014. 2016.

Project/Technology Name:

Risk Analysis of Aldyl-A Plastic Pipes

Performer/Contractor:	**System and Status:** Model development and evaluation
Gas Technology Institute	

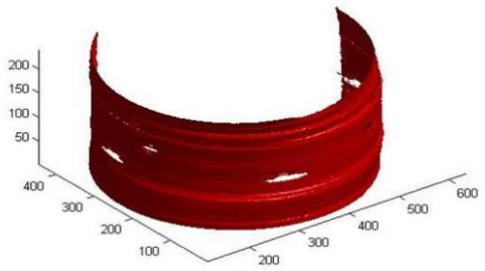
Program Area:

3. Pipeline Risk and Information Management - System Risk Modeling and Security

Project/Technology Description:

The project develops an integrated set of quantitative tools which provide a structured approach to reducing risk in vintage plastic pipes susceptible to Slow Crack Growth failures.

An endoscopic structured light scanning tool was developed for internal inspection of small diameter plastic pipes. The data generated are synthesized with available properties such as external conditions, leak records, and historic for fitness for service evaluation. The assessment includes a probabilistic estimate of the remaining effective lifetime of vintage plastic pipe.



Impact of Project/Technology on Technological Advancement to Gas Industry:

The integrated set of tools provides a structured approach to reducing operational risk in vintage plastic pipes. The tools provide a probabilistic estimate of the remaining lifetime and a yes/no determination of whether a short-term pressure test is capable of validating the maximum defect size in the system.

Applicable Metrics:

Increase safety: This assessment will determine whether a short-term pressure test is capable of validating the maximum defect size in the system. Bayesian network methods are used to evaluate the interacting threats, investigate root causes, and predict the effect of mitigation strategies based on conditional probabilities.

References:

Slow Crack Growth Evaluation of Vintage Polyethylene Pipes. Project DTPH5615T0007. https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=643

Project/Technology Name:

Models for Complex Loadings, Operational Considerations, and Interactive Threats

Performer/Contractor:	**System and Status:** Data modeling and procedure
Kiefner, Applus RTD	

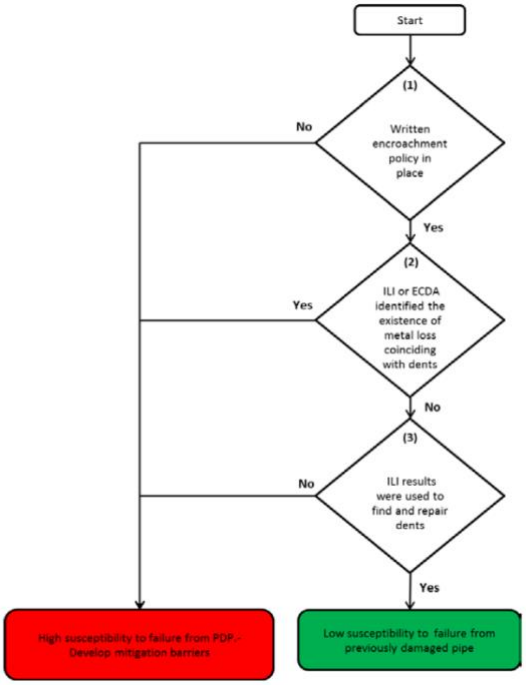
Program Area:

3. Pipeline Risk and Information Management - System Risk Modeling and Security

Project/Technology Description:

This study reviewed reportable accidents to determine the types and frequencies on interacting threats. It developed guidance for pipeline operators for identifying and evaluating complex, higher-risk situations involving integrity threat interactions.

An analysis was performed to determine the interacting threats and form procedures to evaluate the significant threat interactions. An analytical tool was presented in the form of flow charts (see figure) to consider mitigative responses to reduce the risk of a pipeline failure from such threat interactions.



Impact of Project/Technology on Technological Advancement to Gas Industry:

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.

Applicable Metrics:

Increase Safety: The procedure and flow chart model enhances the understanding of interacting threats to pipeline integrity and reduces the risk of incidents from such interactions. Important threat interactions were identified and guidance was provided to assist operators with addressing such threats in their integrity management plans.

References:

PHMSA, https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=557

Project/Technology Name:

Gas Situational Awareness System (GSAS) for Emergency Response

Performer/Contractor:	**System and Status:** Data and system modeling
Gas Technology Institute	

Program Area:

3. Pipeline Risk and Information Management - System Risk Modeling and Security

Project/Technology Description:

This project develops a Gas Situational Awareness System (GSAS) to be used for major events that require response by more than one emergency responder, utility, or agency.

The data model is a collection of tables describing the information to be tracked during a disaster to enable a utility to manage and perform restoration activities with a much greater awareness of the disaster situation. The data incorporated into the model are used for required reporting to all levels of regulatory authority.

Impact of Project/Technology on Technological Advancement to Gas Industry:

The GSAS system provides status information to all responders allowing them to know the extent of the event, the availability of infrastructure—such as accessibility to roads, bridges (open or closed), electric status (on or off) and the like—for each structure within the impacted area. GSAS also feeds information to each of the emergency responding organizations and utilities so they can plan the details of their response and define where and when to deploy people and materials.

Applicable Metrics:

Increase Safety: The system provides a data exchange methodology for critical natural gas infrastructure operators and government agencies ensuring a coordinated response, allowing them to share information, provide situational awareness, and assist with decision support during disasters.

References:

http://www.gastechnology.org/Solutions/Pages/Developing-a-GSAS-4-Emergency-Response.aspx

Project/Technology Name:

Repair/Replacement Considerations for Pre-Regulation Pipe

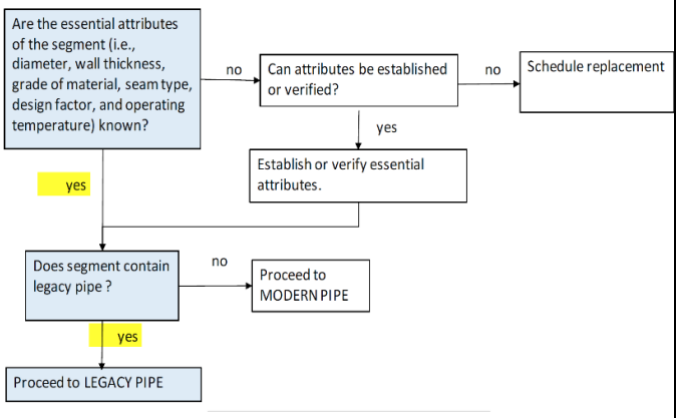
Performer/Contractor:	**System and Status:**
Kiefner Applus RTD	Guidelines and procedures

Program Area:

3. Pipeline Risk and Information Management - System Risk Modeling and Security

Project/Technology Description:

The project established guidelines for implementing "pre-regulation" pipeline repair/replace program. Pre-regulation generally refers to pipelines installed prior to November 12, 1970, when federal pipeline safety regulations were first promulgated. The process (see figure for a case example) provides a standardized method for pipeline operators to decide which of their pre-regulation pipelines can be maintained safely or replaced. Guidelines are presented as factors to consider in making repair/replace decisions and mitigative responses to avoid pipe replacement.



Impact of Project/Technology on Technological Advancement to Gas Industry:

The guidelines address natural gas transmission pipelines as well as special considerations associated with natural gas distribution pipelines and hazardous liquid pipelines. The guidelines will be made suitable for inclusion in consensus pipeline safety standards including ASME B31.4 and ASME B31.8.

Applicable Metrics:

Increased Safety - Greater Reliability: The guidelines will enhance safety by providing standardized methods for integrity management and risk management.

References:

PHMSA, https://primis.phmsa.dot.gov/matrix/PrjHome.rdm?prj=559