NETL Research & Innovation Center
Midstream Sensor and Material Technology

Presenter: Dr. Paul R. Ohodnicki, Jr.
paul.ohodnicki@netl.doe.gov

NATIONAL ENERGY TECHNOLOGY LABORATORY

U.S. DEPARTMENT OF ENERGY | Fossil Energy
OFFICE OF OIL & NATURAL GAS

Solutions for Today | Options for Tomorrow

February 15, 2018

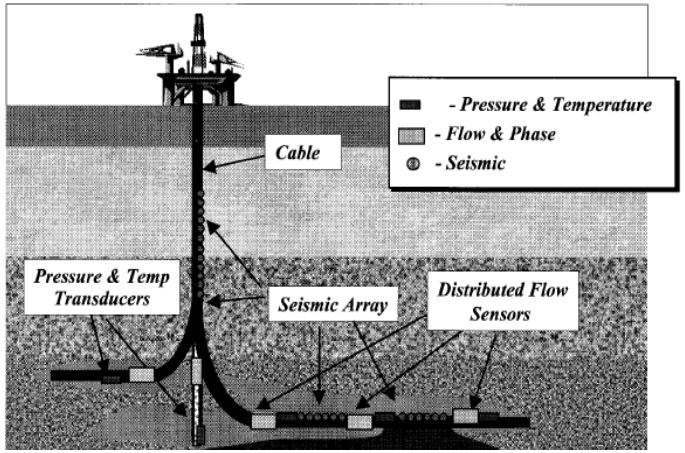
Embedded Sensing in Fossil Energy Applications

NATIONAL ENERGY TECHNOLOGY LABORATORY

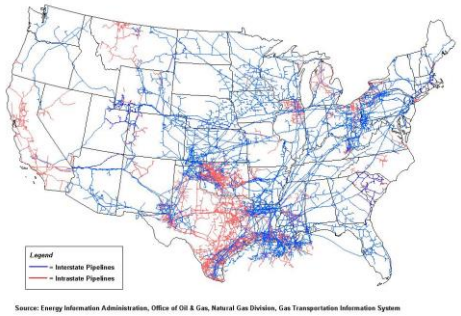
Needs for increased visibility span all aspects of the US Energy Infrastructure

Power Generation

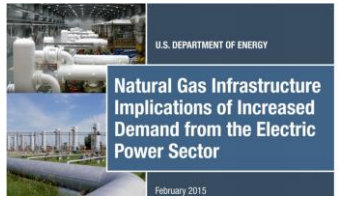
Unconventional Oil & Gas



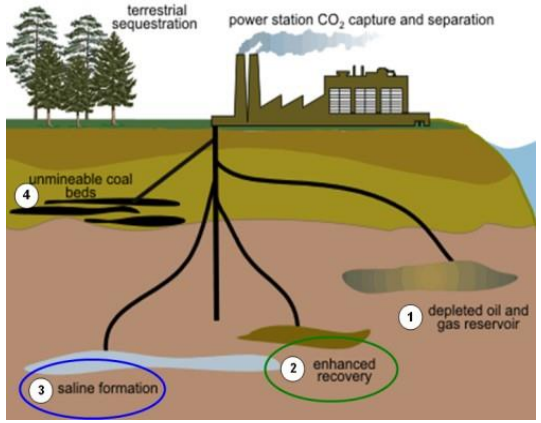
Natural Gas Infrastructure



Properties of Methane	
Chemical Formula	CH_4
Lifetime in Atmosphere	12 years
Global Warming Potential (100-year)	28–36

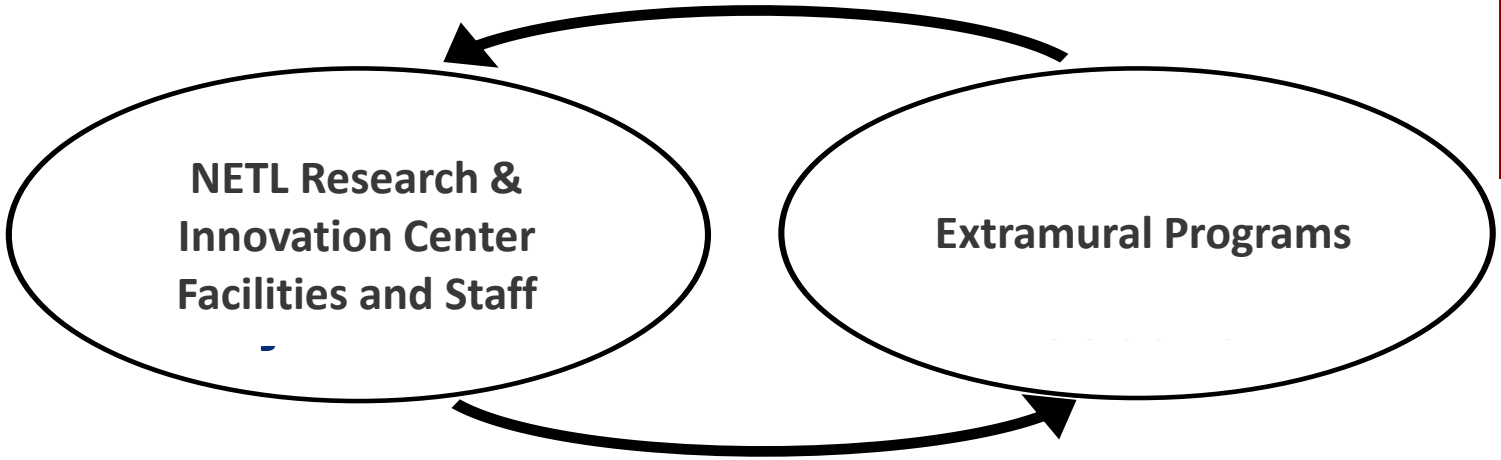


CO_2 Sequestration



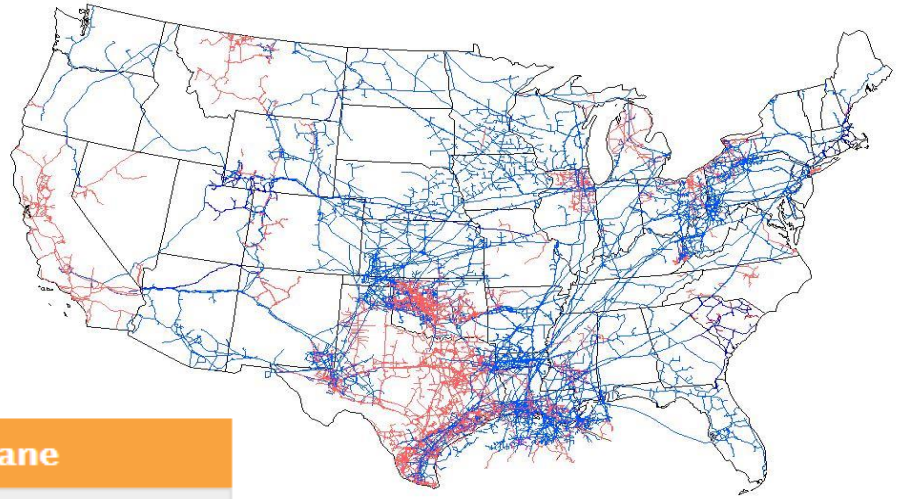
Ubiquitous Embedded Sensors Combined with Geo-spatial Data Analytics is a Requirement to Achieve Desired Visibility Across the Entire Fossil Energy Infrastructure : *NETL Initiative*

Engagements with Extramural Programs

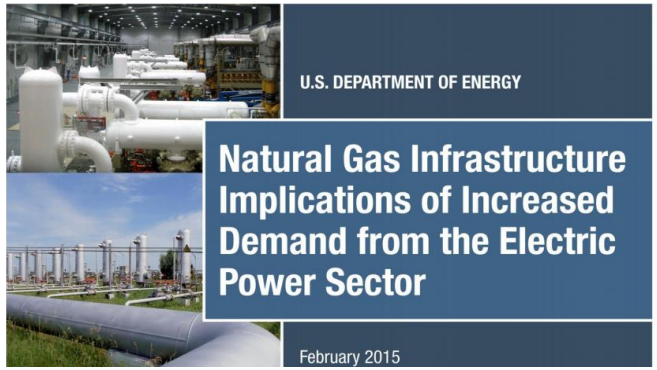


The Team Seeks Synergistic Interactions with a Broad Range of Extramurally Supported NETL Funded Projects to Help Drive the FE Mission in Support of Our Program Offices.

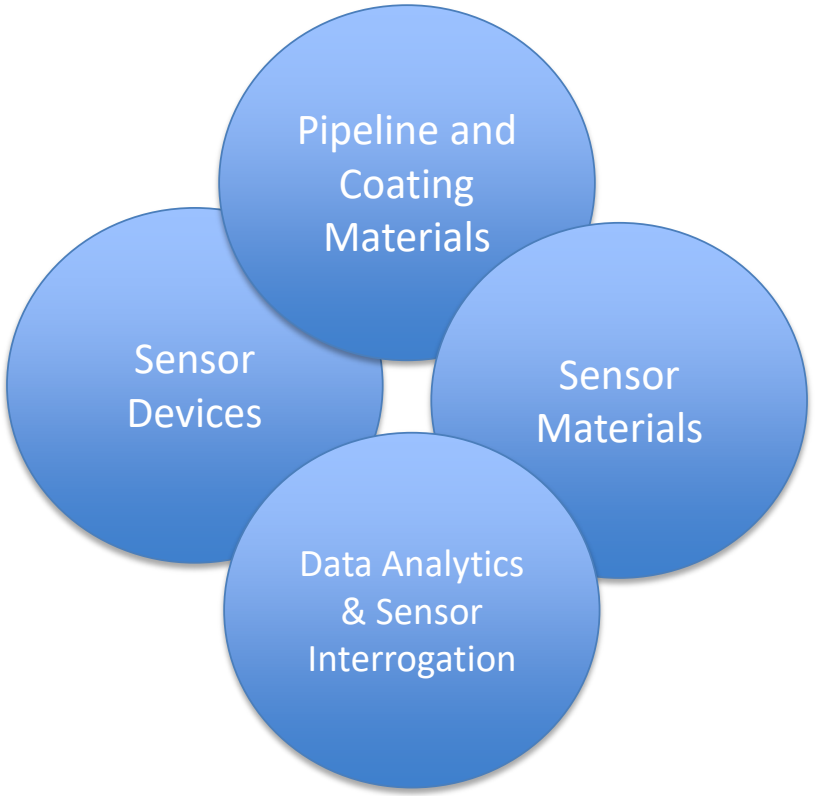
Natural Gas Infrastructure Reliability & Resiliency



Properties of Methane	
Chemical Formula	CH_4
Lifetime in Atmosphere	12 years
Global Warming Potential (100-year)	28–36



http://energy.gov/sites/prod/files/2015/02/f19/DOE%20Report%20Natural%20Gas%20Infrastructure%20V_02-02.pdf



A Program was Established to Develop New Sensor and Material Technologies for Monitoring, Detection, and Mitigation of Failures and Events in Natural Gas Infrastructure.

Conventional Monitoring Technologies

Pipeline Explosion Caused by Corrosion

http://wvpublic.org/post/ntsb-determines-cause-december-2012-sissonville-pipeline-explosion#stream/0

Primary Emphasis : Detecting Presence of Leaks and Failures

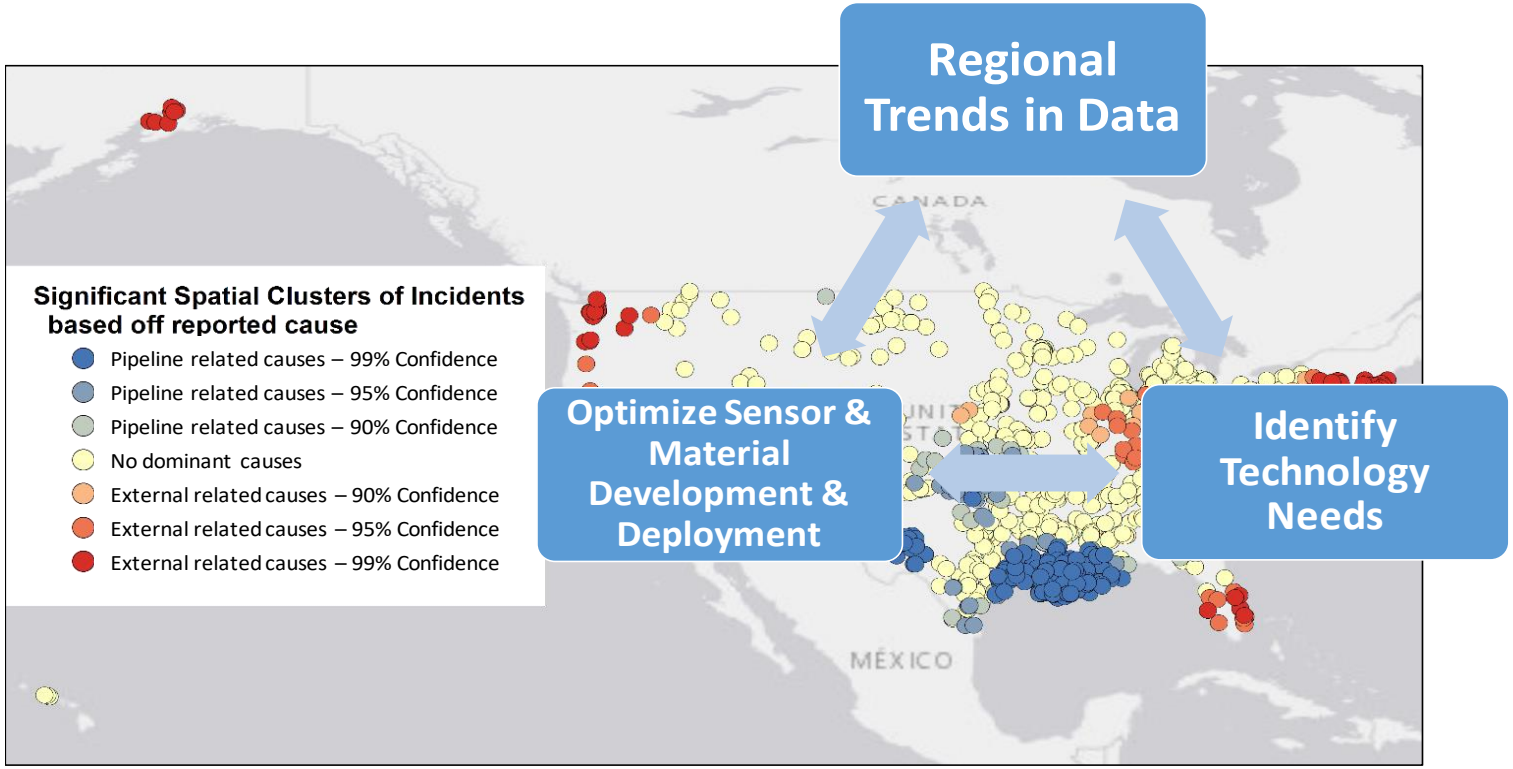
- Internal Leak Detection Systems: Measured Flow Rates and Computational Models
- Periodic In-Line Inspections
- Monitoring of Local Geohazards (Ground Movements and Seismic Events)
- External Inspections, Including Aerial Surveys
- Optical Fiber Based Leak Detection Systems: Indirect Measurement (Temperature, Strain, Acoustic)

Conventional Monitoring Techniques Identify Leaks and Events Once they Have Occurred to Enable Faster Responses, But are Limited in Capability to Identify Failures Before they Occur.

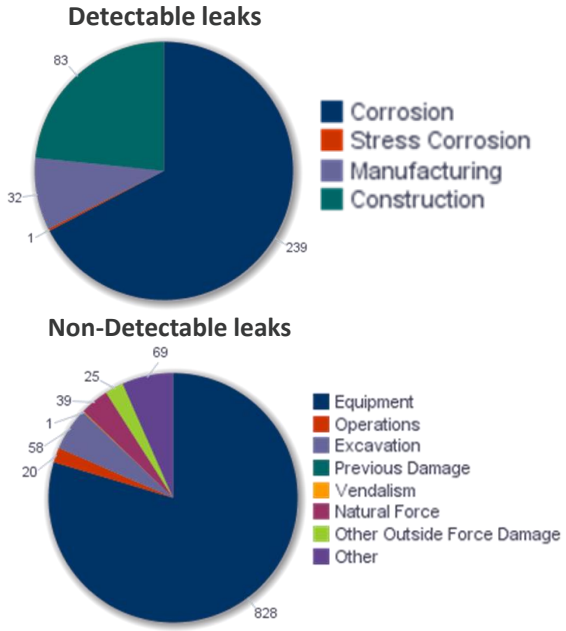
Data Analytics, Sensors & Materials Technology

NATIONAL ENERGY TECHNOLOGY LABORATORY

Goal = Optimized Sensor and Protection Systems to Prevent Failures and Leaks

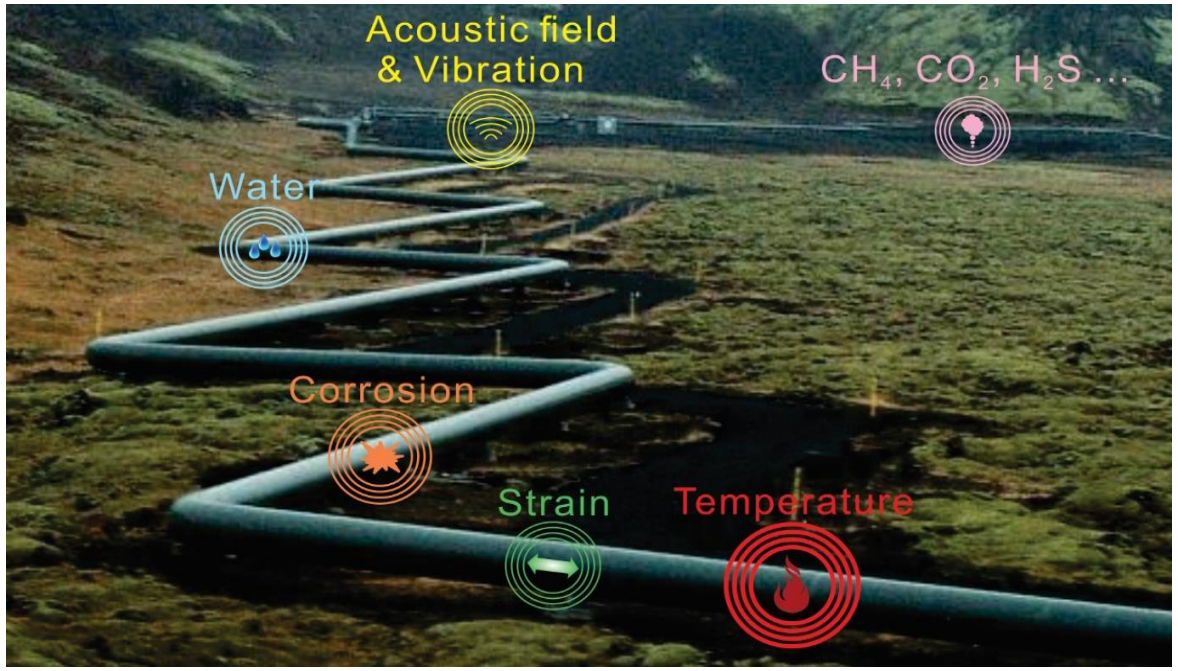


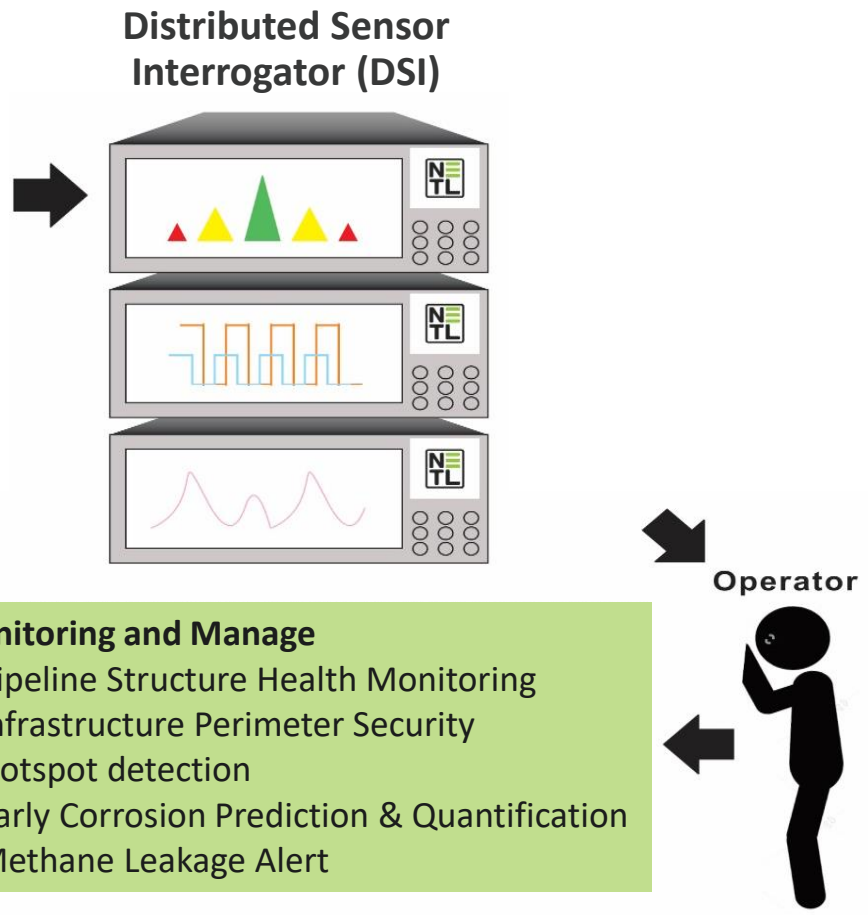
Gas Transmission Leak Sources



Analytics Methodologies can Be Developed and Applied in Parallel with New Sensor and Materials Research and Development Efforts to Impact Infrastructure Risks and Resiliency.

Intelligent and Flexible Pipeline Infrastructure





Emphasis Within NETL Research & Innovation Center:

- Optimized Sensor Network & Interrogation (Range, Resolution, Cost)
- Internal Corrosion On-Set Detection and Prevention
- Methane Leak Detection & In-Pipe Gas Composition Monitoring

Monitoring and Manage

- Pipeline Structure Health Monitoring
- Infrastructure Perimeter Security
- Hotspot detection
- Early Corrosion Prediction & Quantification
- Methane Leakage Alert

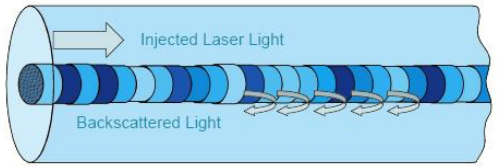
Key Questions for Industry: What are the Cost Constraints and Value of the Information Content?

Suite of Complementary Sensing Technologies

NATIONAL ENERGY TECHNOLOGY LABORATORY

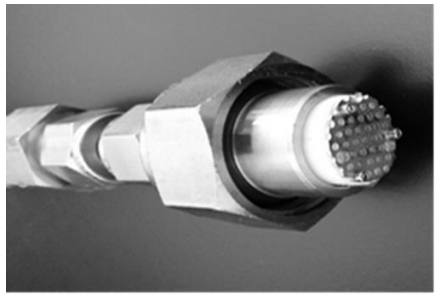
Distributed Optical Fiber Sensors

Imperfections in fiber lead to Rayleigh backscatter:

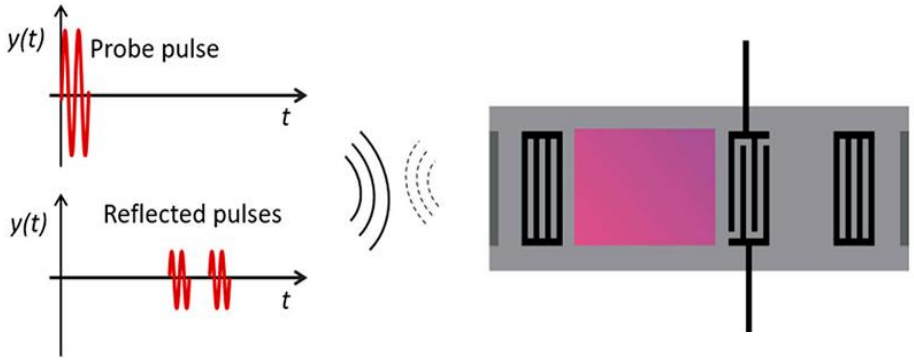


Rayleigh backscatter forms a permanent spatial "fingerprint" along the length of the fiber.

Advanced Electrochemical Sensors



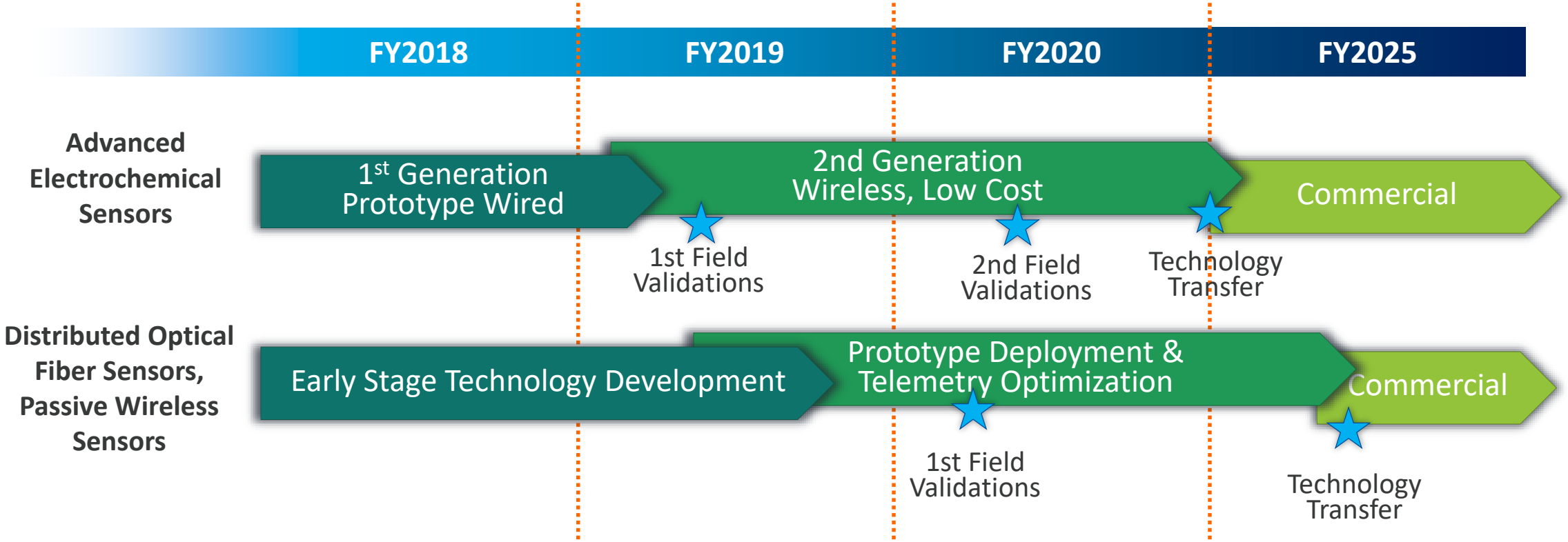
Passive Wireless Sensors



	Geospatial Attributes	Cost	Targeted Function	TRL
Distributed Optical Fiber Sensors	Linear Sensor Adjustable Distance and Resolution	Cost Per Sensor "Node" Low	Temperature, Strain, Gas Chemistry (CH_4, CO_2, H_2O, etc.) Early Corrosion Detection	2-3
Passive Wireless Sensors	Point Sensor	Low	Temperature, Strain, Gas Chemistry (CH_4, CO_2, H_2O, etc.) Early Corrosion Detection	2-3
Advanced Electrochemical Sensors	Point Sensor	Moderate to High	Humidity and Corrosion Rate Monitoring	3-4

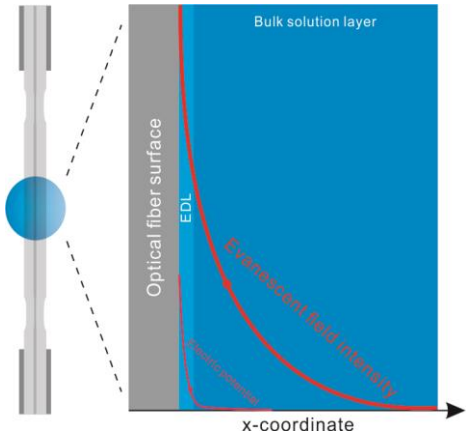
Three Synergistic Sensor Platforms with Complementary Cost, Performance, and *Geospatial Characteristics* are Being Developed with an *Emphasis on Corrosion & Gas Composition*.

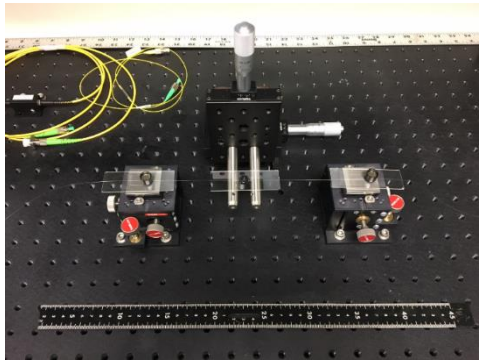
Suite of Complementary Sensing Technologies

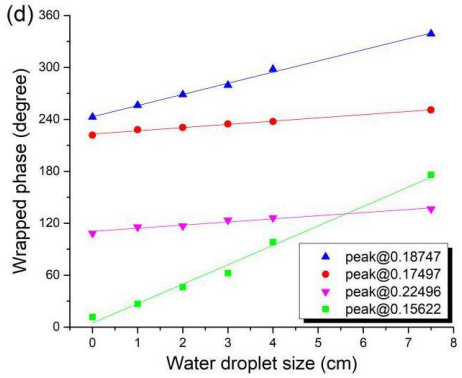


Sensing Platforms Under Development Have Complementary Technology Readiness Levels. Notional Timelines Illustrate the Progression Towards Commercialization with Industry Partnerships.

Early Successes and Accomplishments

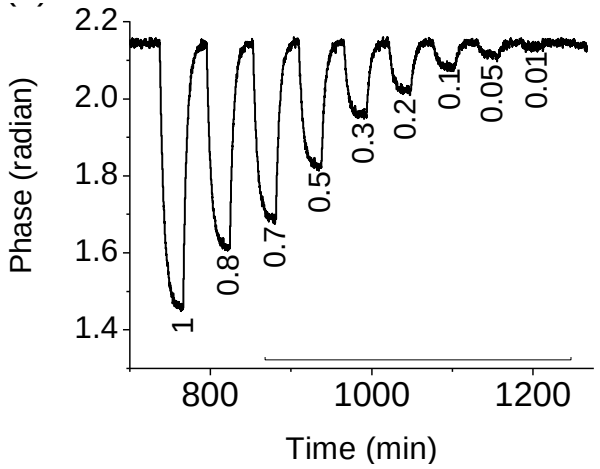


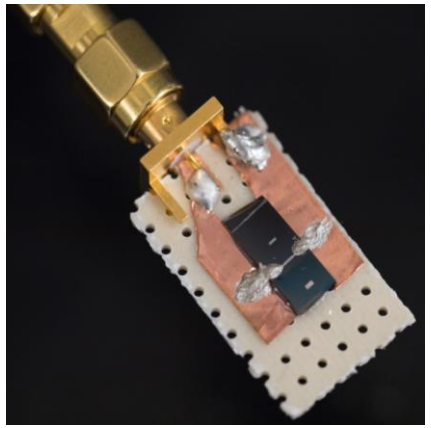




Technology #1: Optical Fiber Based Water Condensation Detection and Characterization

Provisional Patent Application Filed, Publications In Press for Corrosion 2018





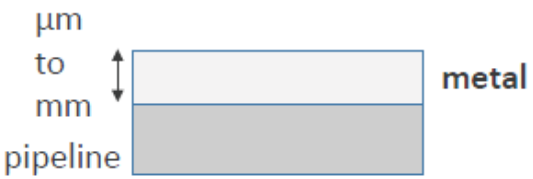
Technology #2: Successful Demonstrations of Wireless Chemical Sensing

Manuscript Submitted, Under Review, J Devkota, KJ Kim, PR Ohodnicki, JT Culp, DW Greve, JW Lekse, arXiv preprint arXiv:1712.08468

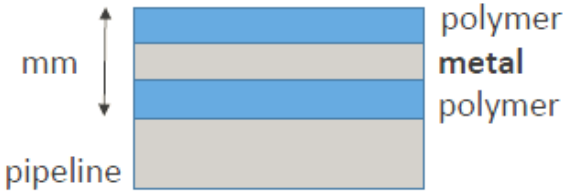
Suite of Complementary Material Technologies

NATIONAL ENERGY TECHNOLOGY LABORATORY

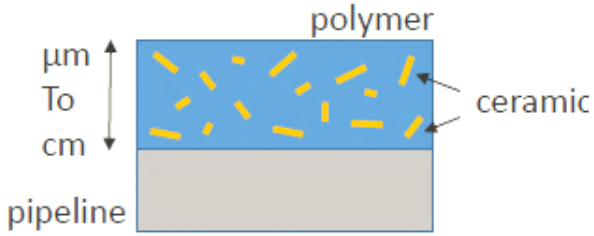
Metallic Coatings



Polymer / Metal / Polymer Liners



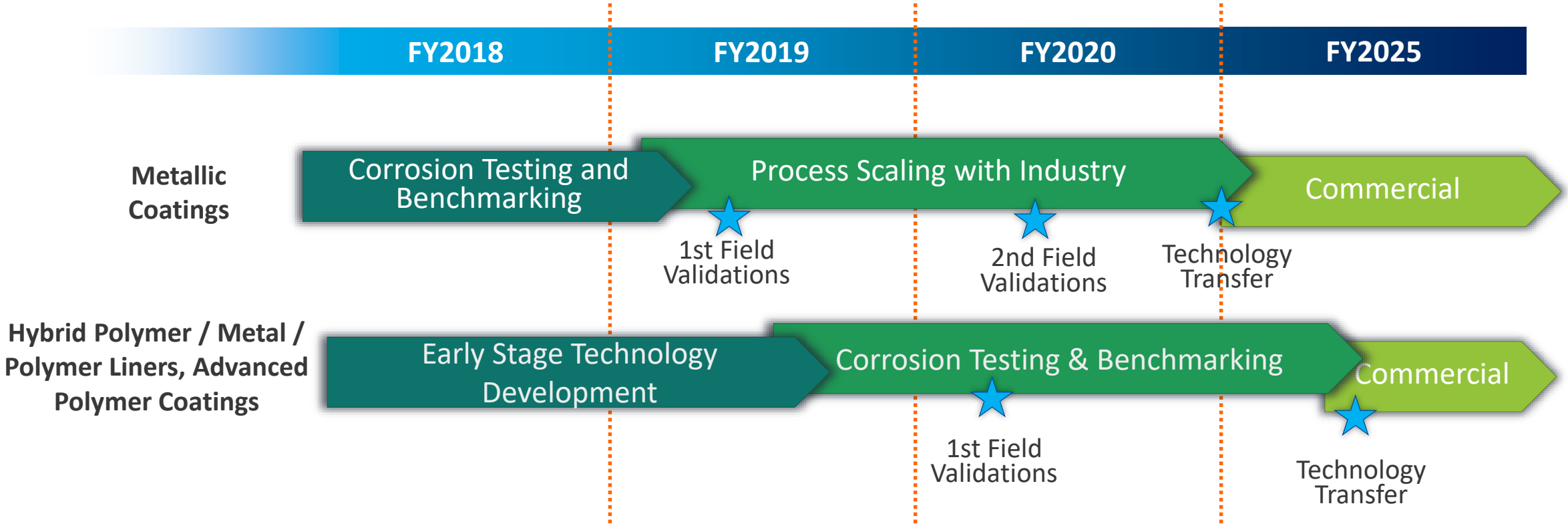
Engineered Polymer Coatings



	Deployment Strategy	Cost	Targeted Function	TRL
Metallic Coatings	Thermal spray	$5-250/ft2	Sacrificial Coating Controls Corrosion of Pipeline.	3-4
Polymer / Metal / Polymer Liners	Pull-through and inflate	$10K/mile	Hybrid Liner Slows the Transport of Water and Corrosive Gas Species to the Pipe Interior Surface	2-3
Engineered Polymer Liners	Spraying and/or fluidic coating	TBD	Hybrid Polymer Coating Slows the Transport of Water and Corrosive Gas Species to the Pipe Inferior.	2-3

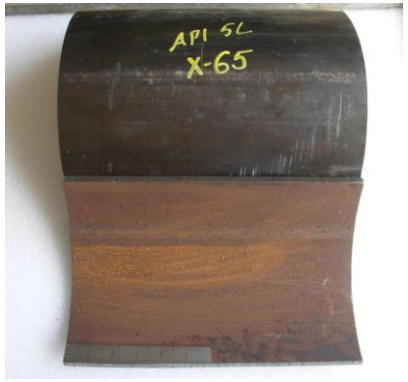
A Suite of Synergistic Coatings and Liner Technologies are Being Developed to Improve Corrosion Resistance for More Resilient and Flexible Natural Gas Pipelines.

Suite of Complementary Material Technologies



Material Technologies Under Development also Have Complementary Technology Readiness.

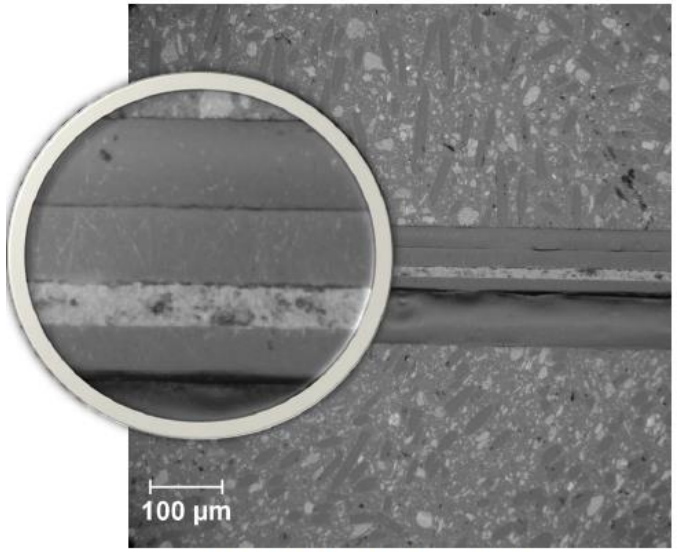
Early Successes and Accomplishments



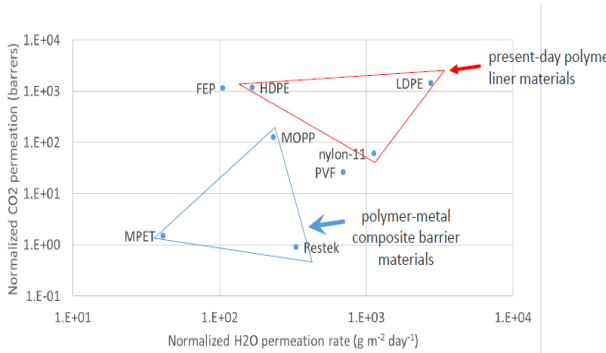
Thermal sprayed Zn samples, front and back after testing.

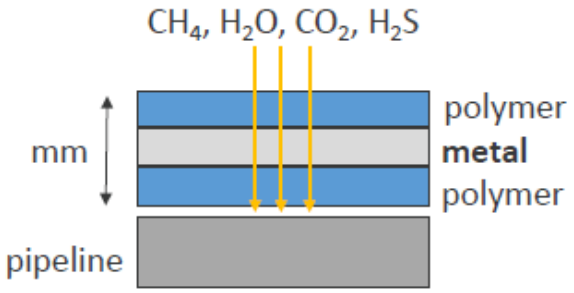
Material	Temp, °C	Gas	Pressure, bar(g)	Corrosion, mm/y	Corrosion of Sac. Couple, mm/y
X65	40	air	0	0.12	
X65	40	CO_2	0	0.16	
X65	40	CO_2	3	0.94	
Al	40	CO_2	3	0.04	
Zn	40	CO_2	3	0.09	
X65-Coupled to Al	40	CO_2	3	0.01	0.78
X65-Coupled to Zn	40	CO_2	3	0.01	0.10

Technology #1: Zn and Zn-alloy Based Coating Layers are Showing Significant Improvements Relative to Base Alloys in Terms of Corrosion.



Metallic film thickness: 13.9 µm

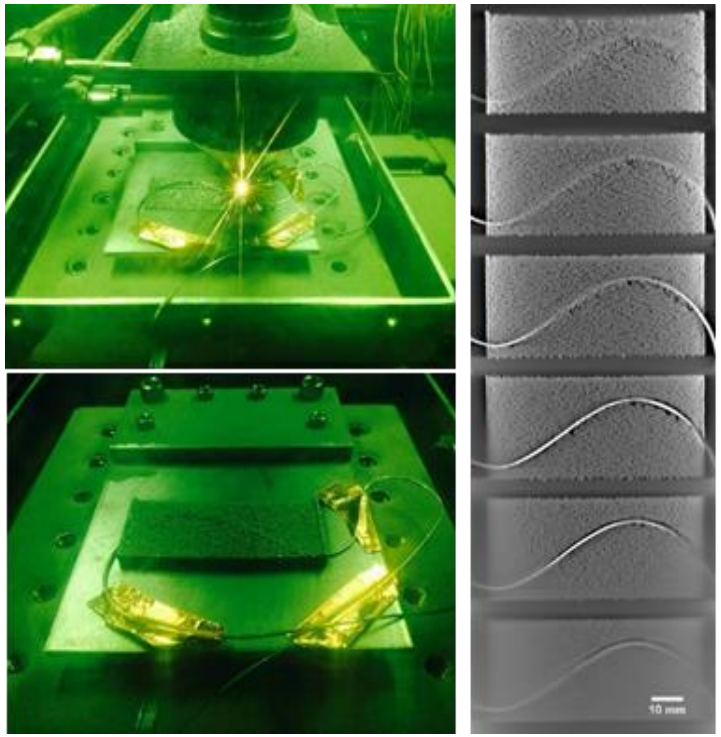


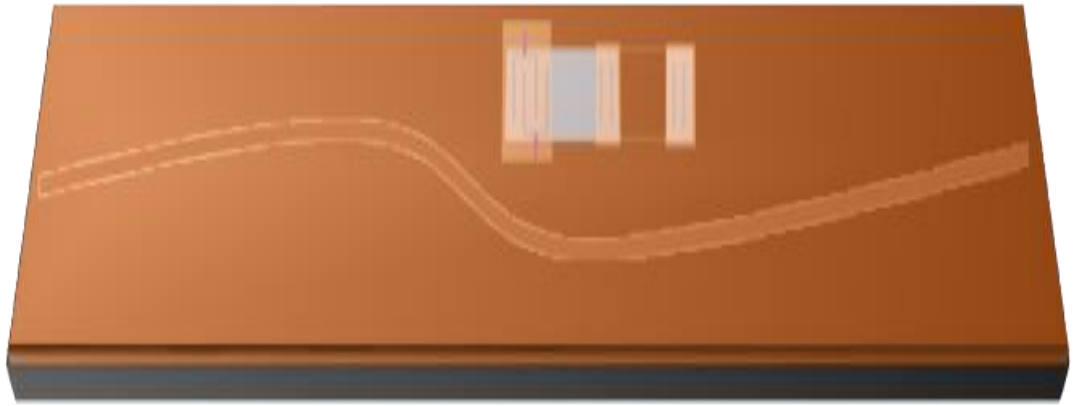


Technology #2: Improved Polymer / Metal / Polymer Liners as Compared to Commercially Available Liners.

Sensor / Material Integration : "Intelligent Pipelines"

Optical Fiber Integrated Alloys :
Structural and Corrosion Monitoring





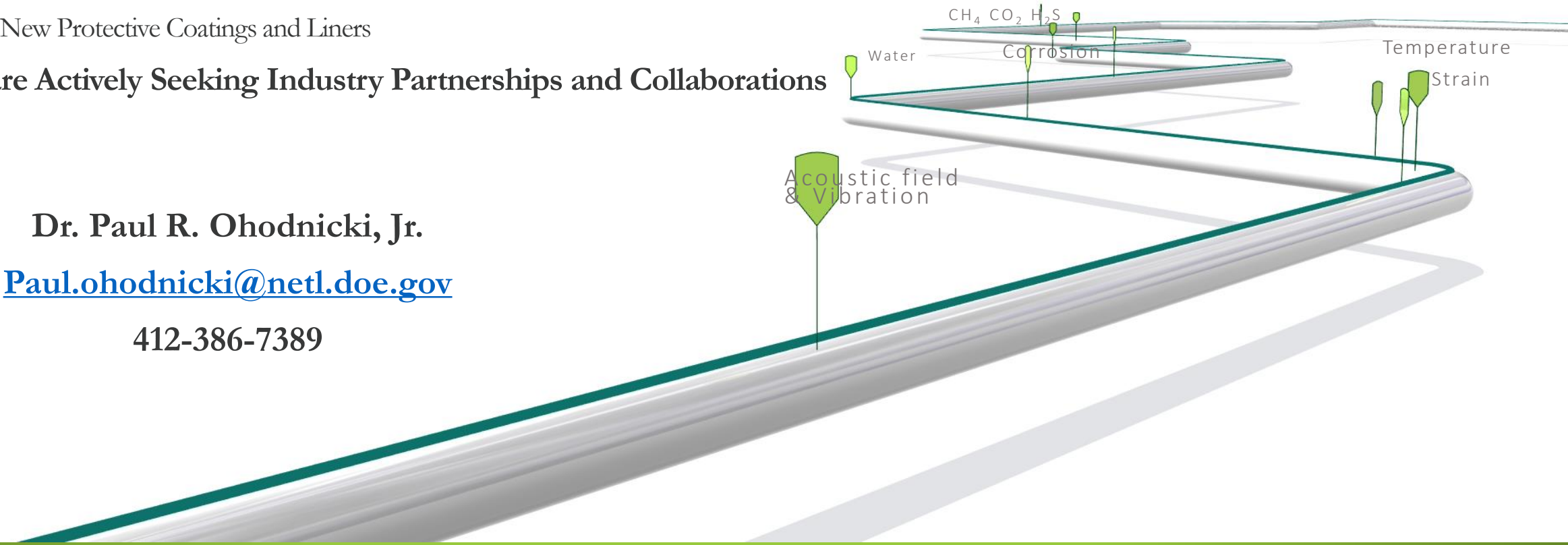
Sensor Integrated Coatings and Liners :
Intelligent Protection Systems

Efforts to Integrate these New Technologies are Beginning to Initiate in the Upcoming Project Year : April 1st.

The Ultimate Goal of the Program is to Bring the Technologies Together to Realize the Vision of "Intelligent Pipelines" through Sensor-Infused Pipeline Materials.

Summary and Key Take-Aways

- **NETL R&IC Has an Established Program in New Technology Development for Midstream**
- **Goal = Enabling a Vision of an "Intelligent Pipeline" Enabled by Advanced Technologies**
  - Geospatial Data Analytics
  - Advanced Embedded Sensors
  - New Protective Coatings and Liners
- **We are Actively Seeking Industry Partnerships and Collaborations**



Dr. Paul R. Ohodnicki, Jr.

Paul.ohodnicki@netl.doe.gov

412-386-7389