METHANE LEAK DETECTION TECHNOLOGIES TECHNICAL WORKSHOP

DOE-NARUC NATURAL GAS INFRASTRUCTURE MODERNIZATION PARTNERSHIP

SEPT. 18 – 19, 2018

2018

Local Distribution Company Efforts to Detect and Repair Leaks

Christina Sames
Vice President, Operations & Engineering
American Gas Association

There is nothing more important to America's natural gas utilities than the safety of the customers we serve and the communities in which we operate.

"AGA and its member companies are committed to promoting positive safety cultures among their employees throughout the natural gas distribution industry. All employees, as well as contractors and suppliers providing services to AGA members, are expected to place the highest priority on employee, customer, public and pipeline safety."

— Excerpt from AGA Safety Culture Statement

NATURAL GAS

AGA

- Founded in 1918
- Represents local energy companies – Those that deliver clean natural gas to homes and businesses
- 95% of natural gas customers in the U.S. receive their gas from AGA members

AGA
American Gas Association

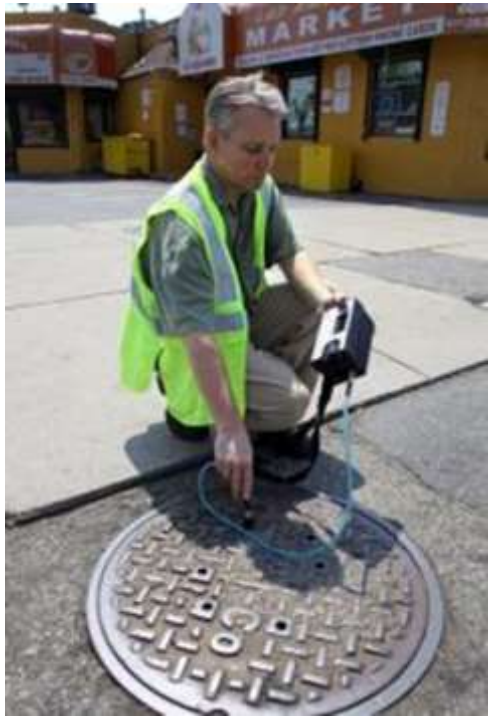
Vegetation Surveys

Pre-leak survey regulations. Can no longer be the primary leak survey method:

- **Visual observation to detect abnormal or unusual growth.**
- **Oxygen starvation and drying out effect of a natural gas leak causes vegetation in area of gas leak to die or become abnormal.**

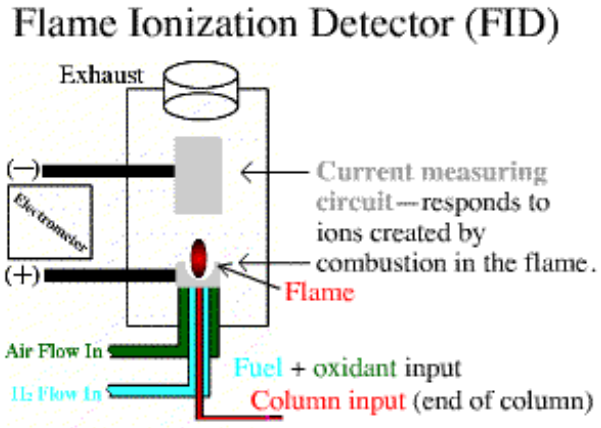
Combustible Gas Indicator

- **Measures small concentrations of combustible gases with catalytic (hot wire)**
- **Intrinsically safe (can be operated in a gaseous environment and will not ignite that gas)**
- **Can be used indoors**
- **Special filters can eliminate false readings such as gasoline vapors. But, marsh gas and natural gas cannot be differentiated with the filter. Ethane Detector is needed**



Pinpointing

- Bar Hole - An opening made by driving a bar rod through the soil and/or paving for purpose of testing subsurface atmosphere with gas detection instruments.
- Areas where gas readings are highest are often considered location of below ground leak.
- Technicians trained to consider gas migration, which is utilized when classifying leaks.



Hydrogen Flame Ionization (FI)

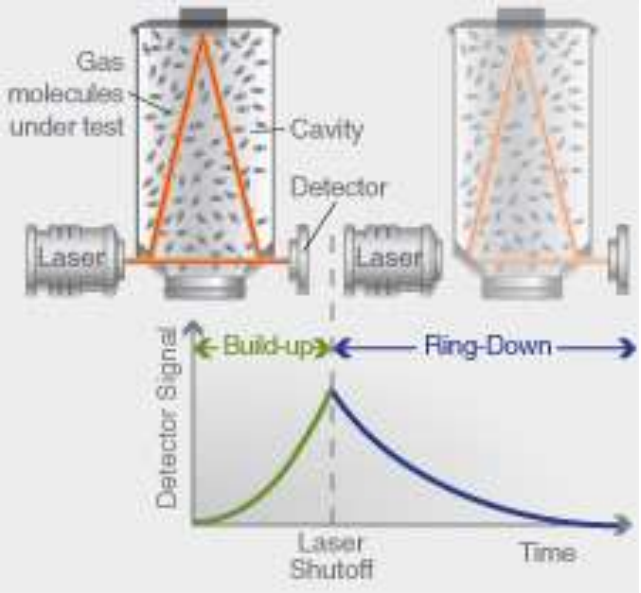
- Intake sample of air and analyze air inside the unit.
  - Air sample must be at least 10% oxygen
  - Flame is fueled by hydrogen
  - Capable of measuring hydrocarbons in air as low as 1 PPM

Optical Methane Detector (OMD)

- **Uses infrared (IR) light & optical detector to detect methane down to 1 ppm**
- **When OMD passes through natural gas, methane in plume absorbs some of the IR light reaching the detector.**
- **Decrease in light converted to ppm & transmitted to display panel**
- **Faster speeds can be used in mobile unit vehicle**

Multiple Platforms

Multiple FI and OMD platforms are being used.



Cavity Ring Down Spectroscopy (CRDS)

Increased sensitivity to IR absorption

Ref: https://www.picarro.com/technology/cavity_ring_down_spectroscopy

Detection Levels

	Percent Gas in Air	Percent LEL	PPM	PPB	Combustible Gas Indicator	Flame Ionization Detector	Mobile InfraRed Optical Detector	InfraRed Optical Detector	Laser Detector	Picarro - Cavity Ring-Down Spectroscopy
	100				CGI Upper Limit			DP-IR Upper limit		
UEL	15		150,000	150,000,000						
			100,000	100,000,000					RMLD Upper Limit	
LEL	5	100	50,000	50,000,000						
	4	80								
	3	60								
	2	40								
Detectable by Smell	1	20	10,000	10,000,000		FID Upper limit				
			200				OMD Upper limit			
	0.005	0.1	50	50,000	Typical CGI Lower Limit					
	0.001	0.02	10	10,000		Typical FID alarm setpoint				
			5	5,000					RMLD Lower Limit	
	0.0001		1	1,000		FID Lower limit	OMD lower limit (@ 25 MPH)	DP-IR Lower limit		
	0.0000001		0.001	1						CRDS lower limit
	0	0	0	0						

Natural Gas Systems:

Leaks on Larger Transmission Lines

Welding –

- Cut out section that may no longer be fit for service and install new line
- Install/weld a repair sleeve (steel/composite)

Distribution Pipe Repair

Plastic

- **Squeeze off, cut out and either join new pipe with coupling or fusion (note: there are a variety of fusion techniques)**
- **Clamps**

Cast iron

- **Repair clamps**
- **Liners/seals**

Cast iron or steel to plastic

- **Need a transition fitting**

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TOP WORK PLACES 2018

The Washington Post

Christina Sames

Vice President, Operations & Engineering

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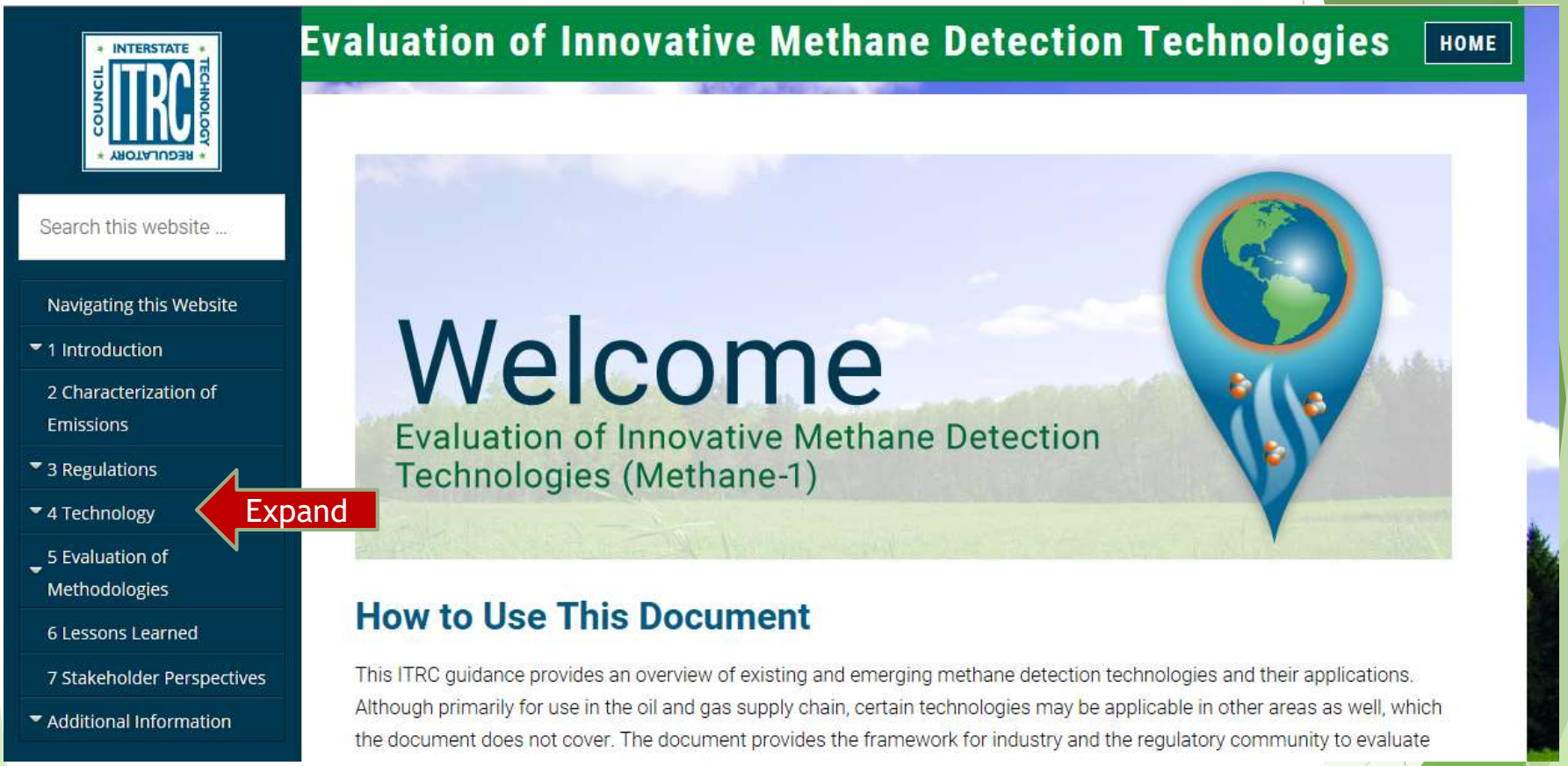
100 YEARS

Evaluation of Innovative Methane Detection Technologies

Guidance for Evaluating Methane Detection Technologies for a Variety of Applications, including Regulatory Requirements

www.itrcweb.org


Evaluation of Innovative Methane Detection Technologies
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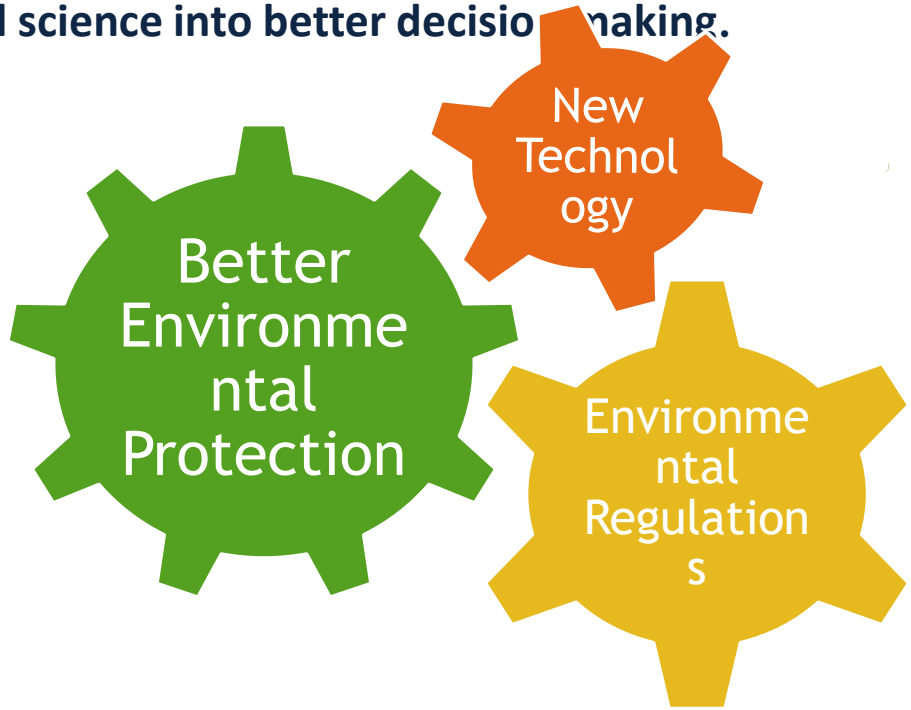
Welcome
Evaluation of Innovative Methane Detection Technologies (Methane-1)
How to Use This Document
This ITRC guidance provides an overview of existing and emerging methane detection technologies and their applications. Although primarily for use in the oil and gas supply chain, certain technologies may be applicable in other areas as well, which the document does not cover. The document provides the framework for industry and the regulatory community to evaluate

Outline

1. What Is ITRC?
2. Context & Challenge for Methane Detection Technology Evaluation
3. Characterization of Oil & Gas Emissions and Sources
4. Methane & Leak Detection Regulations
5. Technologies Overview
6. Evaluation Guidelines and Principles
7. Lessons Learned
8. Example Evaluation Scenarios
9. Stakeholder Perspectives

What is ITRC?

The Interstate Technology & Regulatory Council (ITRC) is a state-led coalition working to advance the use of innovative environmental technologies and approaches. ITRC's work translates good science into better decisio naking.



Evaluation of Innovative Methane Detection Technologies

- 60+ individuals representing State, Federal and International Regulators, Private Industry, Public Stakeholders, Academia and Others collaborated for over 2 years to produce technical-regulatory guidance document, which was published in September 2018 (ITRCweb.org)
- Provides a centralized reference for oil & gas methane emission sources, leak monitoring regulations, detection technologies, evaluation guidelines and principles, and relevant case studies summaries/links

Context

- Federal, state and international regulations addressing methane from oil and gas
- New detection technologies and applications being developed and introduced into the market

- No standard methodology or guidelines to evaluate performance and equivalence of new or innovative methane detection technologies to existing approved technologies or methods

The Challenge…

- How to evaluate and compare various methane/leak detection and measurement technologies?
- What are the important questions and considerations to help meet specific regulatory requirements or needs for various segments of the oil and gas supply chain?
- How does it all tie together?

  (Emission Sources + Regulations + Technologies + Evaluation Methods)

The Resource: Evaluation of Innovative Methane Detection Technology Tech-Reg Document

- Characterizes various methane emission sources along the entire oil and gas supply chain
- Summarizes existing and proposed methane and leak detection regulations for each segment of the oil and gas supply chain, including regulations that allow for approval of alternative detection technologies
- Identifies regulatory barriers and opportunities to the use of new or innovative methane detection technologies

The Resource: Evaluation of Innovative Methane Detection Technology Tech-Reg Document

- Overview of existing and emerging methane detection technologies and their applications
- Guidance regarding performance characteristics and parameters to consider in technology evaluation
- Provides a starting point and framework for evaluation of detection technologies

Oil & Natural Gas Supply Chain

Production & Processing

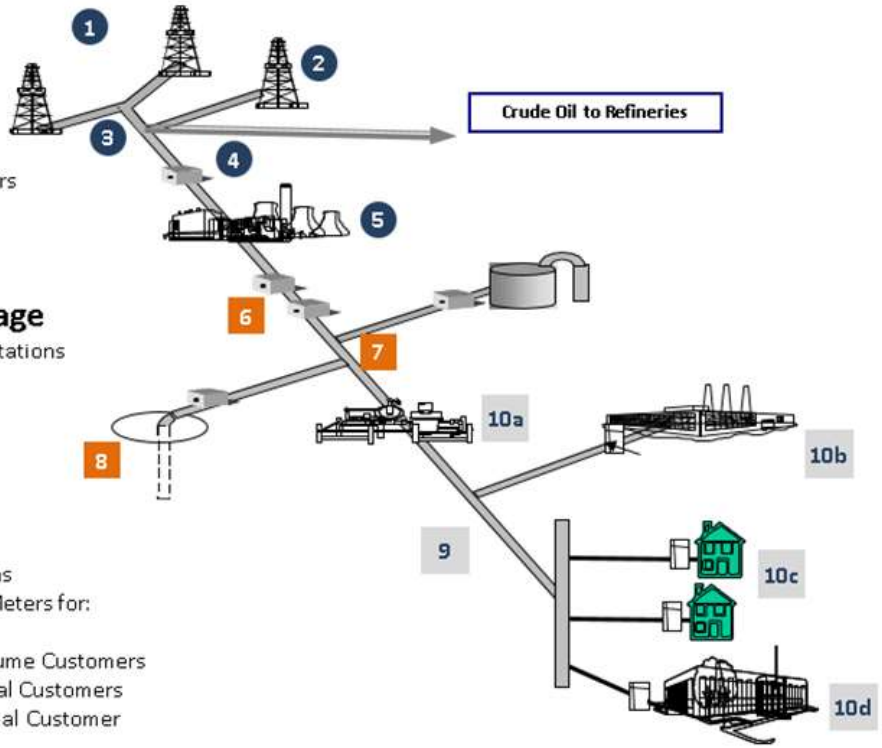
1. Drilling and Well Completion
2. Producing Wells
3. Gathering Lines
4. Gathering and Boosting Compressors
5. Gas Processing Plant

Transmission & Storage

6. Transmission Compressor Stations
7. Transmission Pipeline
8. Underground Storage

Distribution

9. Distribution Mains
10. Regulators and Meters for:
    a. City Gate
    b. Large Volume Customers
    c. Residential Customers
    d. Commercial Customer



Source: Adapted from American Gas Association and EPA Natural Gas STAR Program

Different Types of Methane Regulations & Oversight

- Environmental Protection & Resource Conservation
  - Environmental Protection Agency (EPA)
  - Bureau of Land Management (BLM)
  - State and Tribal Environmental and Oil & Gas Oversight Agencies
- Operational & Public Safety
  - Pipeline and Hazardous Materials Safety Administration (PHMSA) of the U.S. Department of Transportation (DOT)
- Safety and Just and Fair Utility Rates
  - State Public Utility Commissions

Regulations & Allowable Technologies

- Environmental Protection & Resource Conservation
  - EPA Method 21
  - Optical Gas Imaging (OGI)
  - Entities which allow alternative Methods/Technologies
    - EPA – NSPS OOOOa; Subpart W
    - BLM – Waste Prevention Rule
    - State Agencies – CO, PA, CA* (*transmission/distribution/storage only)
    - Canada – Federal & Provincial (Alberta)

- Operational & Public Safety
  - "Leak detector equipment" (any equipment capable of detecting leaks in gas distribution and transmission systems) – PHMSA

Regulatory Barriers & Considerations

- Pathway to approval for alternative technologies
  - Regulatory allowance for alternative technologies
  - Clearly defined review criteria & approval requirements
- Regulatory Considerations
  - Commercial availability & maturity of technology
  - Leak detection program vs. technology
  - Capabilities, reliabilities and limitations of technology or program
  - Equivalency criteria
  - Enforceability
  - Alternative technology pilot program

Technologies Summary (Classification Scheme)

Consideration	Response
Primary Data Type	Quantitative vs. Qualitative
Result Type	Yes/No vs. Value
Detection Range	% or ppm or grams/hour, etc.
Measurement Temporal Distribution	Seconds, Minutes, etc.
Size of Device	Small, Handheld, Large,
Deployment Method	Fixed, Walking, Vehicle Path, etc.
Environmental Limitations	Humidity, Temp, Contaminants, etc.
Maturity	Mature vs. Developing
Specificity to Methane	Nonspecific/Specific & Low/High

General Technology Categories

Optical Gas Imaging (OGI)
Flame Ionization Detector (FID)
Tunable Diode Laser
High Flow Dilution Sampler
Catalytic Combustion
Metal Oxide
Gas Chromatography (GC)
Mass Spectrometry (MS)
Printed Nanotubes
Tunable Laser (closed path)
Etalon
Fourier Transform Infrared (FTIR)

Technology Evaluation

- How to evaluate the performance of new or innovative leak detection systems?
- Primary or ultimate objective is leak or emissions detection but for what purpose or need?
- Clarify and define specific system goals or requirements
  - Evaluation is dependent on a clear understanding of the desired goals or requirements to be achieved
  - Objectives should be performance based and not place limits on types of technology systems or platforms
  - Develop system objective statement and metrics

Leak Detection System Primary Objective Examples

Achieve compliance with a regulation

Determine emission rates

Meet emissions reduction target

Assess if emission reductions equivalent to another system/technology

Locate high emitting sources

Technology Evaluation

Example primary objective:

Achieve Compliance with a Regulation. The system will detect leaks for repair at well sites/well pads equivalent to or better than that achieved by completing semi-annual OGI in order to comply with NSPS OOOOa fugitive emissions requirements.

Evaluation Objective – Questions to Consider

- Are cost objectives mandatory for successful system performance?
  - System may need to meet cost-effectiveness metrics such as cost per site or cost per methane reduced per site to be considered suitable for widespread deployment
- Are there any regulatory requirements or barriers?
  - Mandate to use specific technology(ies) or no option for approval of new technologies
  - Must measure methane and VOCs
  - Criteria for obtaining approval or determining equivalence of a new technology not clearly defined

Define Metric Types for Evaluation

- Most system objectives can be classified into one of three categories for performance defining metrics:
  - Quantify emission rates and reductions
  - Identify emission source
  - Ambient concentration
- The objective should be expressed as a quantifiable, testable metric that describes the primary goals, target sites, and acceptable limitations of the system

Metric Type Example 1:

Emission Reductions. The system will achieve equivalent or better emission reductions at compressor/gathering stations than prescribed regulatory technologies (OGI; Method 21) and work practices.

Equivalency is defined as percent of annual emissions mitigated at the company/basin-level. In addition to the system's ability to detect leaks, it must be evaluated as part of a work practice that includes the emissions threshold and time to repair detected leaks.

Metric Type Example 2:

Emission Source. The system will detect, locate, and quantify emission sources at well pads under a range of climate conditions for a specific geography.

Emission sources ≥ 6 scf/hour must be located within 1 meter spatial accuracy and their emission rate quantified to ±30% within 24 hours. Sources should be identified as intentional, unintentional, or offsite with less than a 5% error of misclassifying intentional or offsite sources as onsite, unintentional.

The system must perform successfully 80% of the annual hours with a maximum of 1 week to detect emissions.

Metric Type Example 3:

Emission Concentration. The system will signal when fence line methane concentrations exceed an actionable level.

The system must have a 95% probability of signaling within 4 hours of elevated concentration during precipitation-free conditions of -20 to 120 ^{0}F and <10 mph wind speed.

Table 5. Summarizing Examples of Technology/Applications
Source: ITRC Methane Team.

Technology	Primary Data Type	Result Type	Detection Range (low to high) - Represents Typical Sensitivity of the Technology	Specificity to Methane/ Interference	Other Benefits	Measurement Temporal Resolution	Size (small, handheld, large)	Typical Deployment Method (walking, vehicle path, or fixed location)	Environmental Limitations (humidity, temperature, etc.)	Calibration Procedure	Maturity (developing, newly available, mature)	Miscellaneous
Pellistor (Catalytic Bead)	quantitative	quantitative (concentration)	500 ppm-5%	nonspecific/high	low cost, widely used or readily available	seconds	small	walking, fixed	humidity, temperature, contaminants	calibration gas; weeks to months	mature	See text
Metal Oxide Semi-conductor (MOS)	quantitative	quantitative (concentration)	50 ppm - 1%	nonspecific/high	low cost, widely used & readily available	seconds	small	walking, fixed	humidity, temperature, contaminants	calibration gas; frequent and self-zeroing	mature	See text
Flame Ionization Detector (FID)	quantitative	quantitative (concentration)	5 ppm (low)	nonspecific/high	widely used & readily available	seconds	handheld	walking, fixed	humidity, temperature, contaminants	calibration gas; frequent	mature	See text

Technology Equivalency

- Regulations may include an option for use of an approved alternative technology or program
- Data and information must be presented to demonstrate an alternative is equivalent or better than a default/prescribed technology at achieving target metrics
- Equivalency demonstration can be classified into two groups:
  1. Equivalent assessment of individual emission sources
  2. Equivalent reduction of aggregate emissions

Equivalent Assessment of Individual Emission Sources

- This assessment can be included in the concentration or emission source categories
- An alternative technology must demonstrate equivalent detection, quantification, or localization of individual emission sources of a similar type, concentration, emission rate, and/or gas composition
- Examples:
  - NSPS OOOOa definition of OGI, which specifies that OGI equipment "must be capable of imaging a gas that is half methane, half propane at a concentration of 10,000 ppm at a flow rate of ≤60g/hr from a quarter inch diameter orifice"
  - PHMSA requirement that any equipment capable of detecting leaks in gas distribution or transmission systems may be used

Design Elements & Protocols for Evaluating Equivalency

- Once the leak detection system objectives and testable metrics have been defined, evaluation protocols for assessing these metrics should be developed.
- Each objectives category (identify, quantify/reduce, concentration) has a different set of general approaches that can be used to evaluate the objectives, which include:
  - Laboratory Testing
  - Field Testing
  - Field Trial
  - Side-by-Side Testing
  - Modeling

Design Elements & Protocols for Evaluating Equivalency

- Laboratory Testing
  - Testing under controlled conditions to assess performance criteria such as minimum detection limit, precision, response time, interference from other compounds, and the effect of conditions such as temperature and humidity.
  - Has the advantage of being relatively low cost and better able to test defined conditions such as specific ambient temperature.
  - May not be ideal for assessing how a system will perform in the field especially for locating or quantifying emissions due to difficulty in replicating complex, diverse atmospheric conditions.
  - May be useful for screening of systems.

Design Elements & Protocols for Evaluating Equivalency

- Field Testing (Controlled Releases)
  - Ideal for systems with emission source objectives because they can assess the accuracy of source quantification and/or localization under realistic meteorological conditions.
  - Should use controlled releases that are of similar emission rates and release points as targeted sources.

Design Elements & Protocols for Evaluating Equivalency

- Field Trial
  - Conducted at actual operating facility or facilities.
  - Has the advantage of incorporating realistic conditions including the human element of leak detection and repair into the evaluation process.
  - Can include controlled releases by intentionally releasing emissions from O&G equipment.

Design Elements & Protocols for Evaluating Equivalency

- Side-by-Side Testing
  - Controlled Statistical Field Survey
  - Specifically compares the performance of one technology against another technology, typically one that is a generally accepted practice.
  - Intended to establish the performance characteristics of a new method or technology against established Method 21 or OGI leak survey methods to confirm that the new system in whole meets the requirements of the end user, regulations, and the market place.

Design Elements & Protocols for Evaluating Equivalency

- Modeling
  - Highly valuable for evaluating emission reduction objectives due to the probabilistic nature of emission rates.
  - Computer-based modeling, coupled with empirical validation of model accuracy, is a potential solution to rigorously evaluate application efficacy under the most likely encountered meteorological and site conditions.
  - Fugitive Emissions Abatement Simulation Toolkit (FEAST) model

Lessons Learned

- Methane detection technologies are moving to quantitative, continuously-recorded, data-intensive systems
- Cost-benefit analyses, required for USEPA rule-making, will require a replacement methane detection technology to be “equivalent” to an existing system
- Detection technology testing or evaluation protocols may have certain environmental limitations, which in turn may mean a new technology is approved only for certain applications or geographical areas
- There will be renewed opportunities for researchers, academics, industry, regulators, and interest groups to improve the methane detection technologies as well as the related regulations and the evaluation methodologies that link specific technologies to specific regulatory requirements

Stakeholder Perspectives

- Stakeholders support technologies to monitor emissions of methane to prevent harm to human health and the environment
  - Safety issues relating to oil and gas production and transmission activities
  - Abandoned wells and/or lines
  - Underground storage facilities
  - Offshore wells (and other issues outside the scope of this document)

Thank you!

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Proactive Approach to Quality Audit and Control Programs

Presented By:

Paul D. Wehnert

About Heath Consultants Incorporated

- Established in 1933
- 3rd generation family/Certified Women's Business Enterprise by WBENC.
- Over 1,700 employees
- Manufacturer of leak detection and locating products
- Provide contract field service, leak detection, locating, corrosion and meter services

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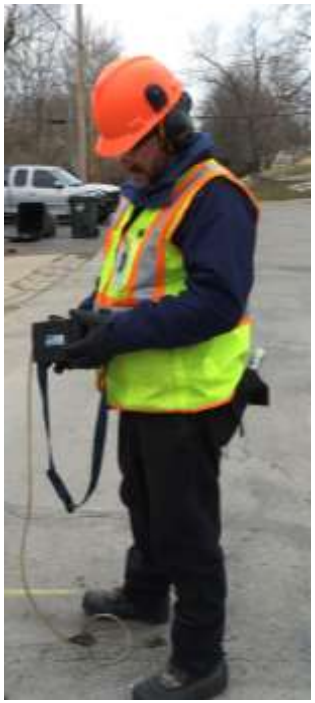
Regulatory Requirements

- DOT Regulation 192.723 - Distribution Systems: Leakage Survey
- DOT Regulation 192.706 - Transmission Lines: Leakage Survey



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Remote Methane Leak Detector (RMLD®)

- **Revolutionary Technology**
  - Parts per million meter (ppm-m)
  - Nominal distance of up to 100 feet
  - Instantaneous response
  - Built-in Bluetooth
  - Survey quickly and efficiently
- **Rugged Design**
  - Intrinsically Safe Rating
  - Tunable Diode Laser Absorption Spectroscopy
  - Reliability in inclement weather (snow, rain, humidity, dry heat)
  - Internal calibration check cell

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Detecto Pak-Infrared (DP-IR ™)

- **High sensitivity sensor**
  - Parts per million meter (ppm)
  - Instantaneous response
- **Infrared Controlled Interference Polarization**
  - Detects only methane gas
  - Will not false alarm on other hydrocarbon gases
- **Rugged Design**
  - Easy to use interface
  - Built in self-test/zero functions
  - Internal calibration system
  - Eliminates the need for gas cylinders and refill systems

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Optical Methane Detector (OMD™)

- **High sensitivity sensor**
  - Parts per million meter (ppm)
  - Instantaneous response
- **Mobile Platform**
  - Survey quickly and efficiently
  - Simple Configuration (easy install)
- **Rugged Design**
  - Reliability during inclement weather (-20º F to +110º)
  - Internal calibration check cell

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ABB MobileGuard™

- **High sensitivity sensor**
  - Parts per billion meter (ppb)
  - Instantaneous response
- **Mobile Platform**
  - Geo-located measurements
  - Survey quickly and efficiently
  - Simple Configuration (easy install)
- **Leak Detection Software**
  - Easy to use interface
  - Real-time plotting of leak Indications
  - Real-time gas discrimination
  - GIS compatible

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Manual Technician's Map *(Old Way)*

- Leaks recorded on paper and filed
- Hard to verify results
- Manual billing and time keeping
- Slow communication
- Difficult to audit
- Prove you were there

Manual Technician's Map

Current Audit Forms

Tagging

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Automated Solutions on Tablet/Phone

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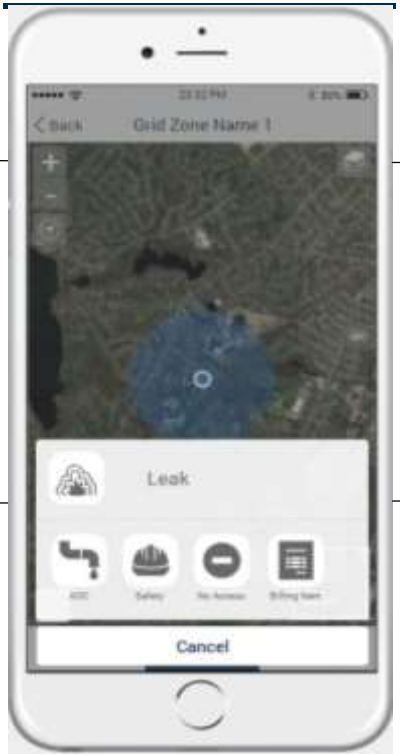
Automated Solutions on Tablet/Phone with instruments



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Automated Solutions

- Paperless System
- Mobilization
- Reliable
- Accountable
- Map Integration
- Bluetooth Enabled
- Data Portability
- Reports
- Web Based
- Easy to Use - Unobtrusive

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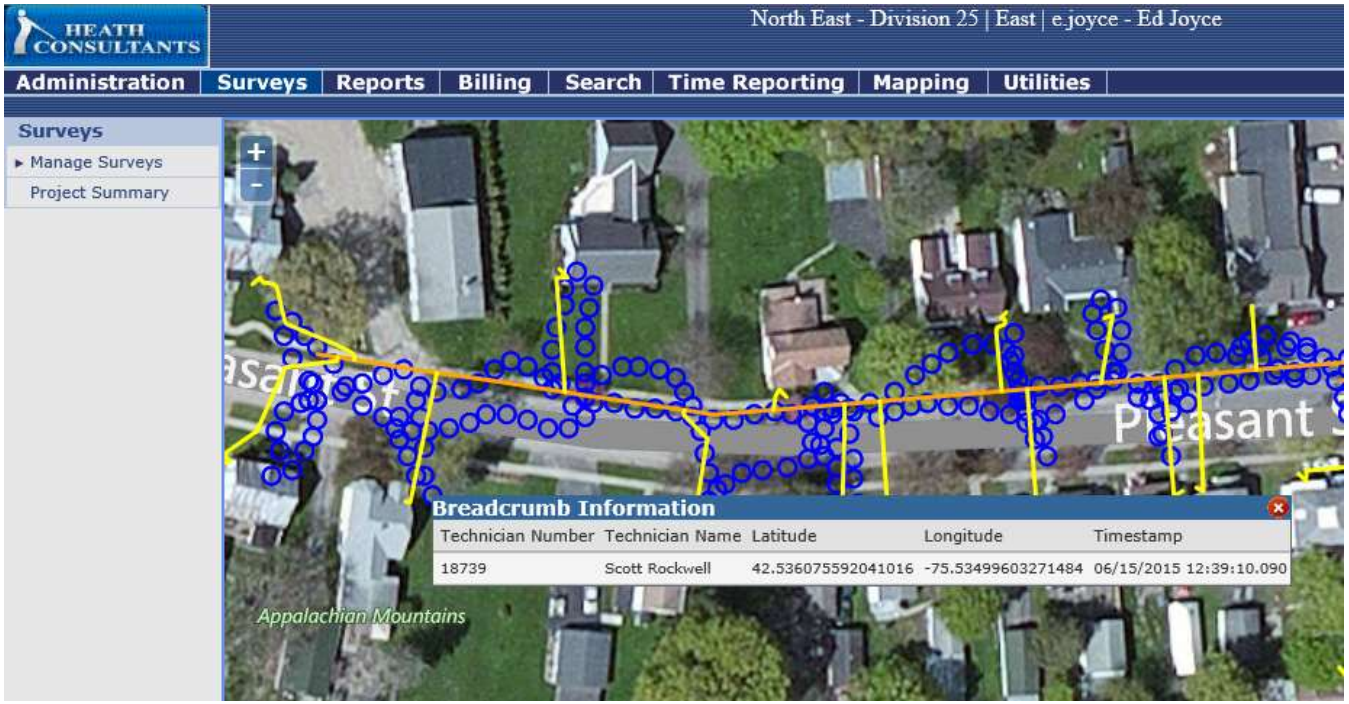
Automated Breadcrumb Trail



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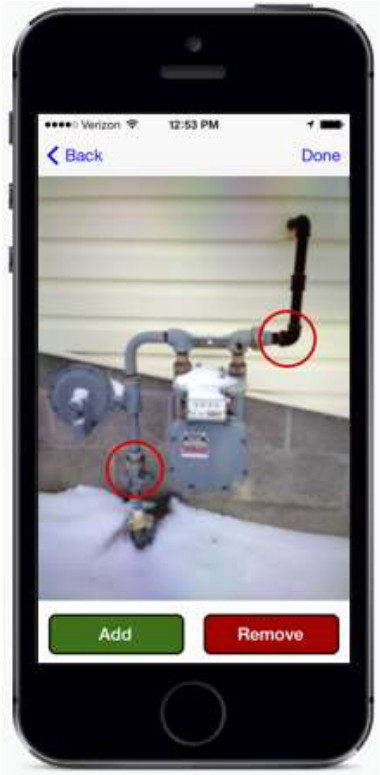
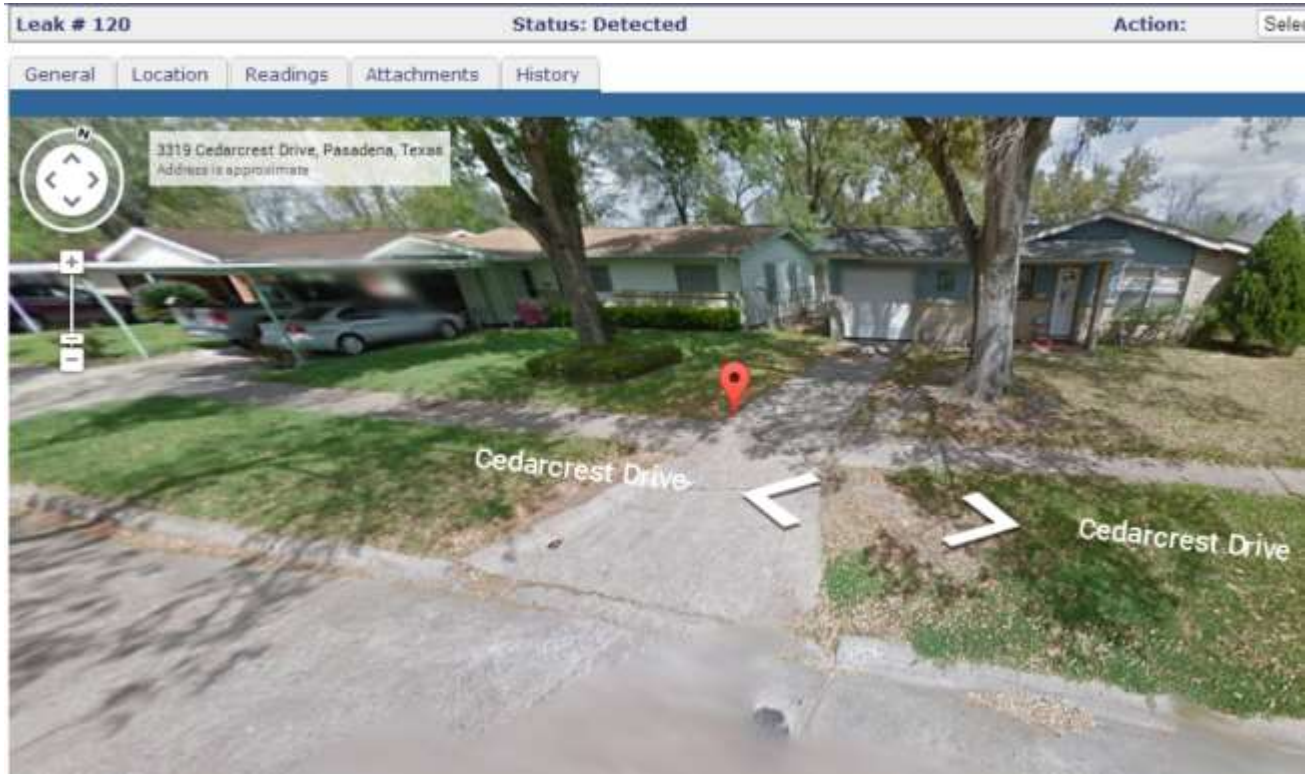
Meter Leak Pin Screenshot



Surface Leak Pin Shot



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Any Questions?

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Applying New Technology to the Gas Industry

Safety, Integrity, Reliability, Operational Efficiency, and the Environment

> Daniel LeFevers
Director, State and Consumer Programs
September, 2018

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GTI Overview

Serving the Industry Since 1941

- Independent, not-for-profit established by the natural gas industry
- GTI tackles tough energy challenges turning raw technology into practical solutions
- Downhole to the burner tip including energy conversion technologies
- LDC Collaborative Research via:

OTD Operations Technology Development

UTD Utilization Technology Development

ETP Emerging Technology Program

OTD Member Companies

gti

Select Emerging & Near-Term Solutions

REDUCE RISK, INCREASE SAFETY, MANAGE COSTS

OPW Breakaway Fitting

Reduce the risk of incident when meter set assemblies and other aboveground pipe are impacted by vehicles, snow, and ice.

3M Locatable Plastic Pipe

Passive tags installed by the PE pipe manufacturer. Replaces tracer wire, no continuity required.

ORFEUS HDD Obstacle Avoidance

Ground-penetrating radar based system for horizontal drilling obstacle avoidance. Addressing steps to bring to the U.S. market.

Excavation Encroachment Notific

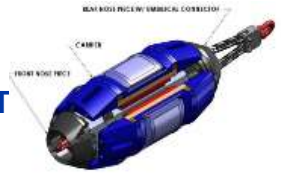
Reduce risk of third-party damage from excavation and ag equipment. GIS-based real-time tracking. Currently rolling out 150 unit demo with PG&E and others.

Lorax Integrated Intelligent Safety System (IISS)

Mitigate risk of gas leaks d party damage on commercial, multi-family, and small industrial service lines.

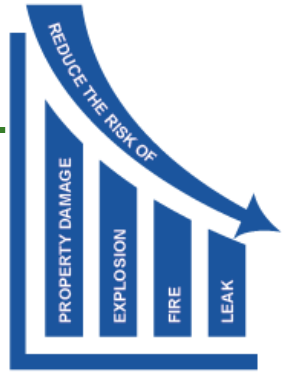
Quest Integrated Small Diameter EMAT

Address need for inspection tool for smaller diameter (e.g., 8”) pipe. Tool, electronics, software integration completed. Ready for field test during 2018.



Meter Breakaway – Shut off Device

Vehicular Impacts and Falling Snow and Ice



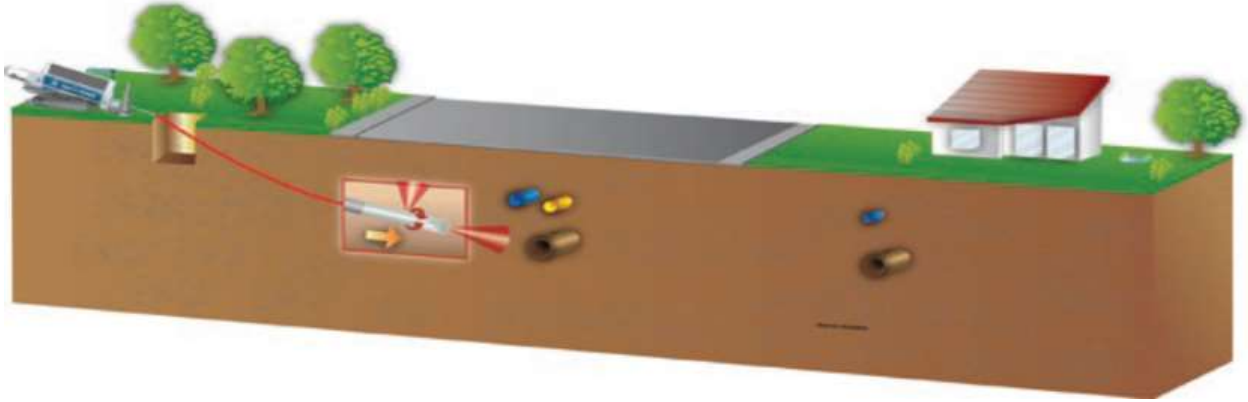
- Breakaway disconnect/shutoff can be easily installed to protect meter sets and other above ground piping.
- Reduce risk from vehicle collision, seismic events, falling ice & snow, etc.
- Commercially available by fourth quarter 2018

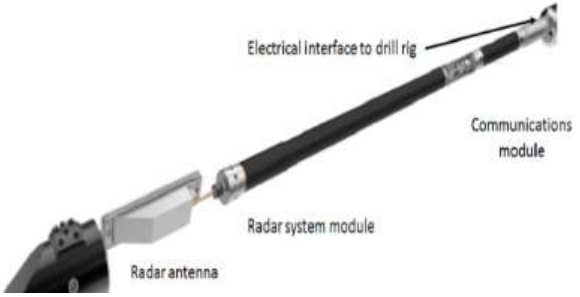
Benefits

- The breakaway fitting will reduce the risk of a major leak, fire, explosion, and property damage caused by out side forces impacting and damaging the MSA.
- The implementation of a breakaway fitting will result in a safer meter set assembly for homeowners, and will make for safer delivery of natural gas.

Obstacle Detection System for Directional Drilling

- ORFEUS – “Operational Radar For Every drill string Under the Street”.
- ORFEUS project to enhance the technology that provides real-time obstacle detection to increase the safety margins of trenchless (HDD) utility installations.
- Conducted a demonstration of the capabilities of the pre-commercial ORFEUS system in April 2017.
- Continuing research in 2018 and 2019 to further improve product leading to commercialization in 2020

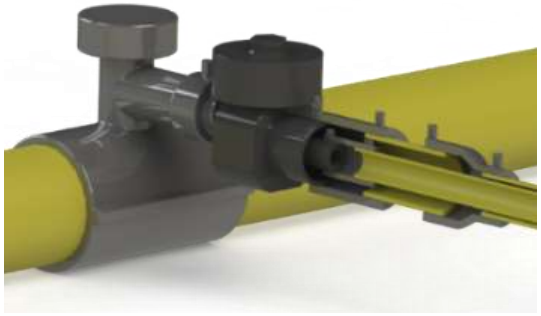




Lorax Integrated Intelligent Safety System (IISS)
Excavation Damage and other Risks

- **Developing an Integrated Intelligent Safety System (IISS)** (Lorax Valve) to mitigate the risk of gas leaks due to third party damage on commercial, multi-family, and small industrial service lines by shutting off the flow of gas.
- Intelligent safety shutoff device that will shut off the flow of gas in the event of line or meter set damage or failure.
- Will trip even with small pin-hole size leak
- Can be activated remotely by operator, fire, methane, or water sensor
- Continuing lab and field pilot evaluations

Very small leak



Benefits

- 100% Mechanical
- Detects very small to catastrophic leaks
- IoT capable
- Full control above ground
- Will halt the flow of ALL gas (no EFV bypass)
- Fire plug at riser

Intrinsically Locatable Technology for Plastic Piping

Locatable Plastic Pipe

Addresses a critical pain point for gas industry

- Significant improvement to worker & area safety
- Higher life expectancy
- Higher productivity in installation

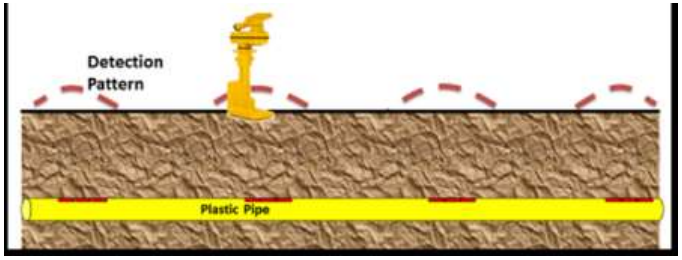
Robust

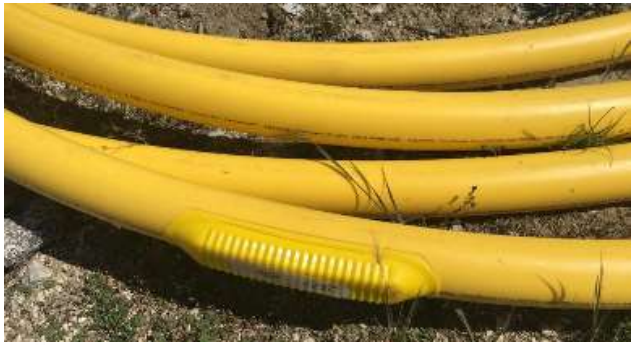
- Continuity not required, if a cluster of tags is removed, the other sections continue to function uninterrupted.
- Does not provide a path for lightning
- Corrosion resistant, maintenance free

Simple

- Replaces tracer wire, access points and connections
- Reduced complexity of locate – No transmitter connection needed
- Utility identification by frequency

On Pipe Attachment





Trials and testing with 3M continue
Goal to have product available to market in 2019

Intrinsically Locatable PE Pipe – Utility Installations

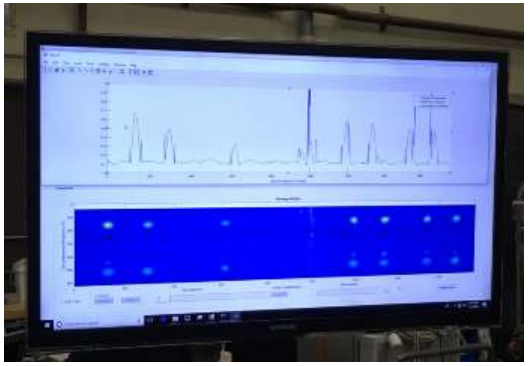
Excavation Encroachment Notification

Excavation Damage Prevention

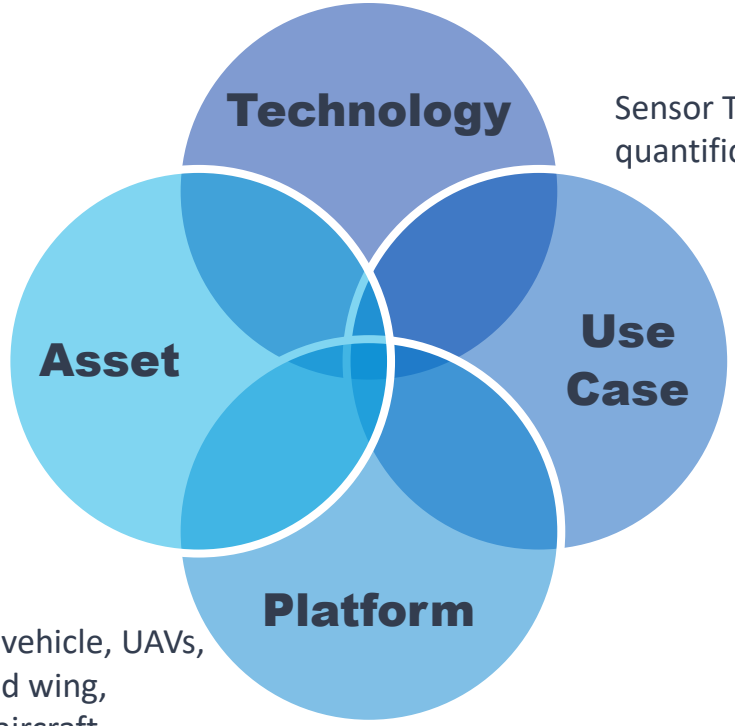
- Currently executing a 150-device Pilot Project in the PG&E and SoCal service territory
- Identify/prevent risk of excavation damage to buried gas facilities by:
  - Characterizing excavators' behavior by analyzing and transferring data from excavators to cloud-based GIS,
  - Increasing awareness of construction equipment activity
- Excavator activity is tracked and movements are characterized using machine learning algorithms in real-time using a GIS-based platform to alert operators and Utility stakeholders
- Next Steps: Continue improving the platform, enhancing machine learning and discussions with commercializers

EMAT Sensor for Small-Diameter and Unpiggable Pipes Internal Inspection

- **Sponsors: DOT/PHMSA and OTD**
- **Objective and Value**
  - Build an Electro-Magnetic Acoustic Transducer (EMAT) sensor to detect flaws and quantify cracks in metallic pipes
  - Inspect and assess small-diameter (8-inch) and unpiggable pipes
  - Implement the tool into a commercial line of inspection systems
- **Status/Next Steps**
  - Phase 2 is complete - developed a tethered sensor integrated with an external computer for full-scale pipe tests in controlled conditions
  - Phase 3 started in April 2018 - complete the tool with internal power and data management for a field-ready integrated unit
  - Evaluate the tool in ILI inspection at utility sites



Remote Gas Sensing and Leak Detection



Sensor Type, detection, quantification, measurement

Pipelines (transmission, distribution), above ground facilities, customer meters

Leak survey, monitoring, investigation, first responder, emergency response, GHG reporting

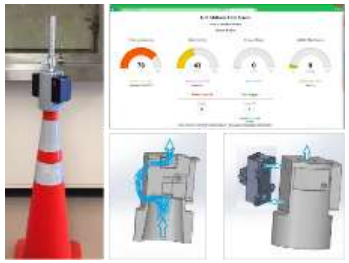
Hand-held, vehicle, UAVs, drones, fixed wing, helicopter, aircraft

Leak Detection and Monitoring

TECHNOLOGY DEVELOPMENT AND EVALUATION

Field Tool for Improved Leak Measurement and Classification

Methane concentration does not tell the whole story. Utilities need a repeatable method to compare the leak rate and prioritize Class 2 & 3 leaks. Simultaneously measures CH_4 concentration, air flow, temperature, and humidity for improved quantification of leak classification.

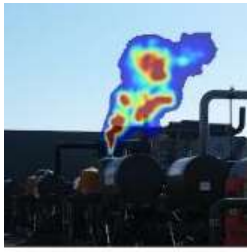


Robots for Methane Detection

Having a remotely operated robot-based methane detection system can provide a safer method for investigating a leak when the potential for high/explosive methane concentrations exist inside of a structure. Knowing the methane concentrations profile within a building provides better knowledge about the leak event and allows for a more effective and efficient utility response. The project is developing a remotely operated robot based methane detection unit to reduce worker exposure to potentially hazardous scenarios.

Evaluating Gas Imaging Technologies

Gas imaging cameras are a tool that allows for the safe detection and identification of leaks as well as enable the quantification of leak flow rate, resulting in increased safety for customers as well as utility employees along with the quantification of environmental benefits associated with leak repair and/or pipe replacement programs. The project will investigate using gas imaging cameras for identifying and detecting leaks on buried piping systems as well as other gas facilities.



Leak Detection and Monitoring

Drone Based Methane Detection
With advancements in this space, methane detection systems are moving from hand held devices to mobile platforms such as vehicles and UAVs. Several off-the-shelf UAV based methane systems are currently on the market, however, their applicability to distribution use cases is uncertain. In particular, most systems have focused on identifying large point leaks and may not have the sensitivity for use on distribution leaks. This project will be a Phase 1 feasibility study and technology evaluation.

Methane Monitoring Tools For Utilities and First Responders
Network of remote sensors connect wirelessly for full situational awareness via phone or tablet. Provides information about natural gas concentration at multiple points at a leak site. Initial field testing underway on two form factors: (1) First responder use case and (2) Utility measurement use case (semi-permanent longer-range wireless access for utilities to assess and monitor leaks over time).

Unmanned Aircraft Systems (UAS) in the Gas Industry

- Unmanned Aircraft Systems (UAS) or Drones
  - Can be equipped with many different sensors:
    - Thermal leak detection
    - Methane sensors
    - Photography
    - LiDAR

- Can be used for various purposes

UAS in the Gas Industry

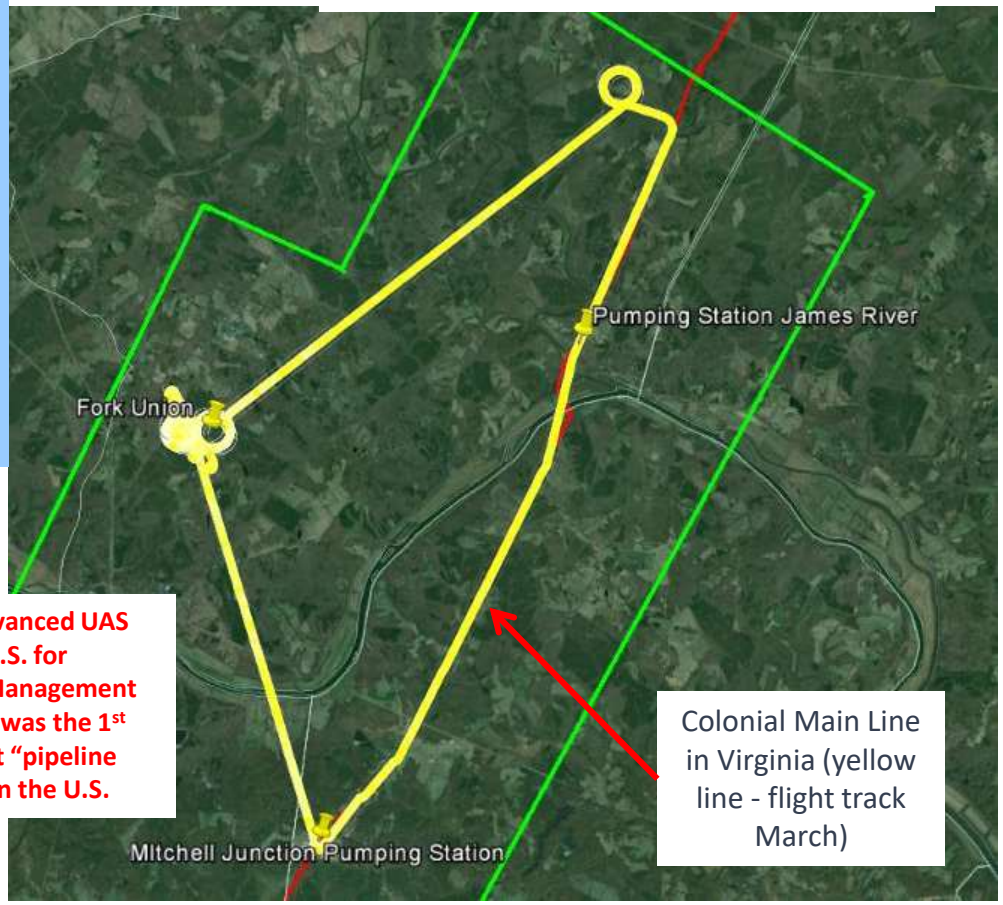
- Many benefits of using UAS
  - Safer than conventional aircraft and inspection practices
  - Faster
  - More versatile
  - Less costly
  - More environmentally friendly
  - Higher Precision Flight Profiles
  - Multi-mission capability

The Plan

- Funding to date was for Test Flights
- Add Applications
- Add Sensors
- Add Aircraft
- Extend Test Range
- Add natural gas transmission lines

Safely, effectively and in full compliance with all laws & regulations

UAV Project
First Flight on Corridor: March 17, 2016



Colonial Main Line in Virginia (yellow line - flight track March)

1) **This is the most advanced UAS Test Range in the U.S. for Pipeline Integrity Management**
2) **The flight in March was the 1st beyond line of sight "pipeline patrol drone test" in the U.S.**

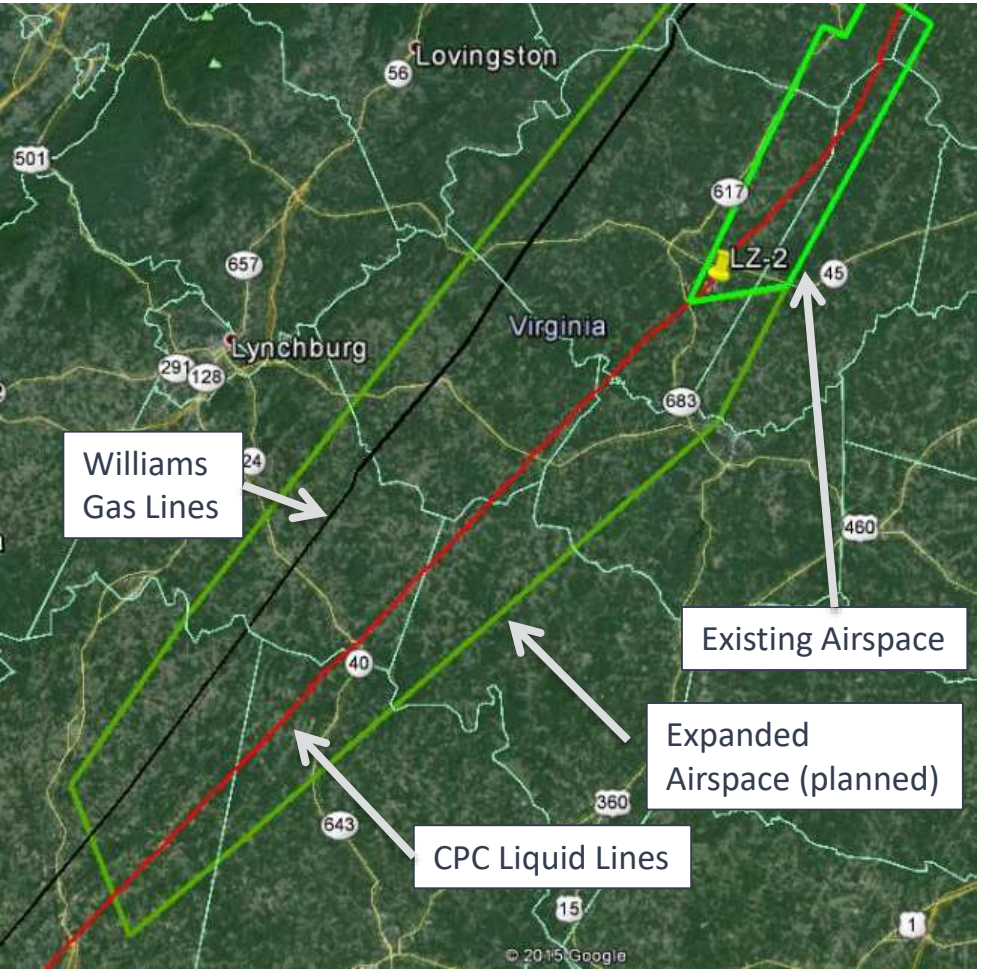
Buckingham COA

- Test Site COA
- RS-16 UAS™
- 185 Square Miles
- 3,000 ft ceiling

> **Pipeline: 27+ mi**

- 1M Barrels/Day
- Part of 5,500 mile network

A



Airspace Development Plan

> Extend airspace south to cover ~100 miles of CPC Lines (liquids)

> Extend airspace west to cover ~100 miles of Williams gas lines

> Total Area: increases from 185 to 1,850 sq. mi.

> Goals:

- Develop & demonstrate ability to fly 100 miles of corridor
- Add gas transmission lines
- Attract other users to reduce cost

> Governor McAuliffe's Office is considering investment in facilities & infrastructure to support this program

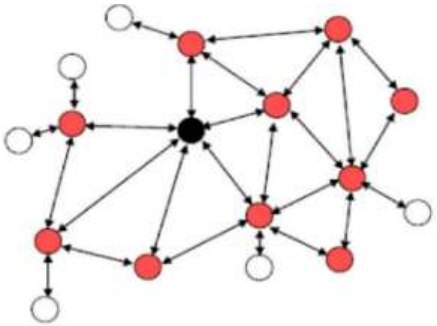
> Electric company in area is considering participation as are other industry groups

Remote Gas Sensing and Monitoring

- System and devices to remotely monitor methane during emergency gas leak situations
  - Tool for utility personnel and first responders
  - Mesh network of devices can be placed around a home(s) or confined space
  - Transmit real-time concentration to give personnel rapid situational awareness
  - Negotiating agreement with commercializer

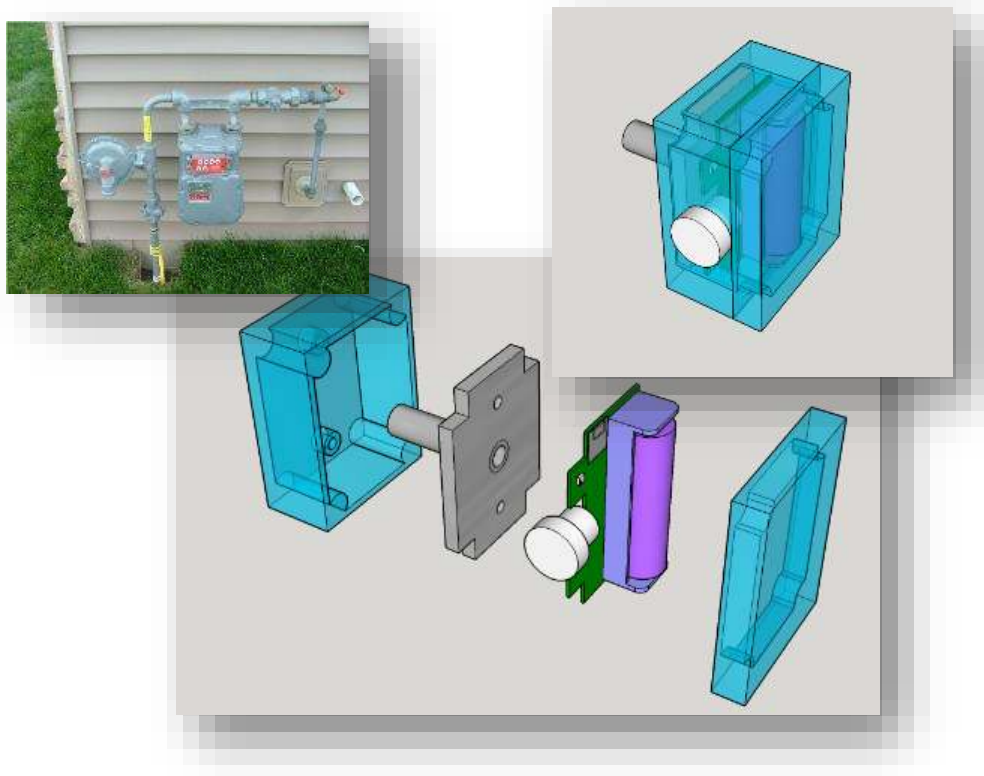
Methane Sensing for 1st Responders

- A multi-sensor tool for leak site investigation.
  - Wireless sensor nodes measure CH4, temperature, and humidity.
  - Mesh network of 6 sensor nodes with 50’ node-node spacing indoors with obstructions; range 100’ outdoors.
  - Each sensor node serves a webpage via Wi-Fi that contains the data from all of the sensor nodes.
  - A mobile device adjacent to any sensor node can access webpage.



Exploring IoT Application: Remote Pressure Sensing

- Examine current IoT offerings with regard to monitoring applications for gas utilities
- Multi-year remote pressure monitoring
  - Star network topology
  - Single AA size battery
  - 8 year runtime without EH
  - 24 readings / 1 send per day
- Energy harvesting
  - solar / vibration / thermal



Turning Raw Technology into Practical Solutions

www.gastechnology.org | @gastechnology

Daniel LeFevers
GTI
Director of State and Consumer Programs

daniel.lefevers@gastechnology.org - 847-544-3458

SENSIT Technologies

Innovative Detection Solutions

Utility – Industrial – HVAC - Fire

All products designed, manufactured, and serviced at our facility in Valparaiso, Indiana, USA

All products designed, manufactured, and serviced from our facility in Valparaiso, Indiana, USA

Global supplier of detection technologies and solutions since 1980

Brands include: Sensit, Trak-It, Gas-Trac, Smart Cal and Ultra-Trac.

100 Employees

We serve the natural gas, propane, fire service, telecom, HVAC and industrial markets

ISO 9001:2008 certified company

Gas Detection Products

Innovation • Solutions • Service

SENSIT Vehicle Methane Detector (VMD)

Fast, efficient, and accurate

Leak Surveys

SENSIT VMD

– Vehicle Methane Detector

- Vehicle mounted leak survey instrument
- Methane selective
- Open Path Infrared
- Logs survey information
- Streams data via Bluetooth to tablet mounted in cab
- Maps GPS coordinates via Google Earth

SENSIT Technologies

VMD Features

- Instantaneous response for quicker leak pinpointing
- Sensitivity to 1 ppm
- Simple calibration via calibration cell
- Rugged design for all weather usage
- Optional protective VMD Shield

SENSIT Technologies

Tablet Operation

- Data transmission via Bluetooth
- Touch screen operation
- Adjustable alarm points
- Tablet displays:
  - Gas Concentration
  - GPS location
  - Detection alarms
- Waterproof tablet

SENSIT Technologies

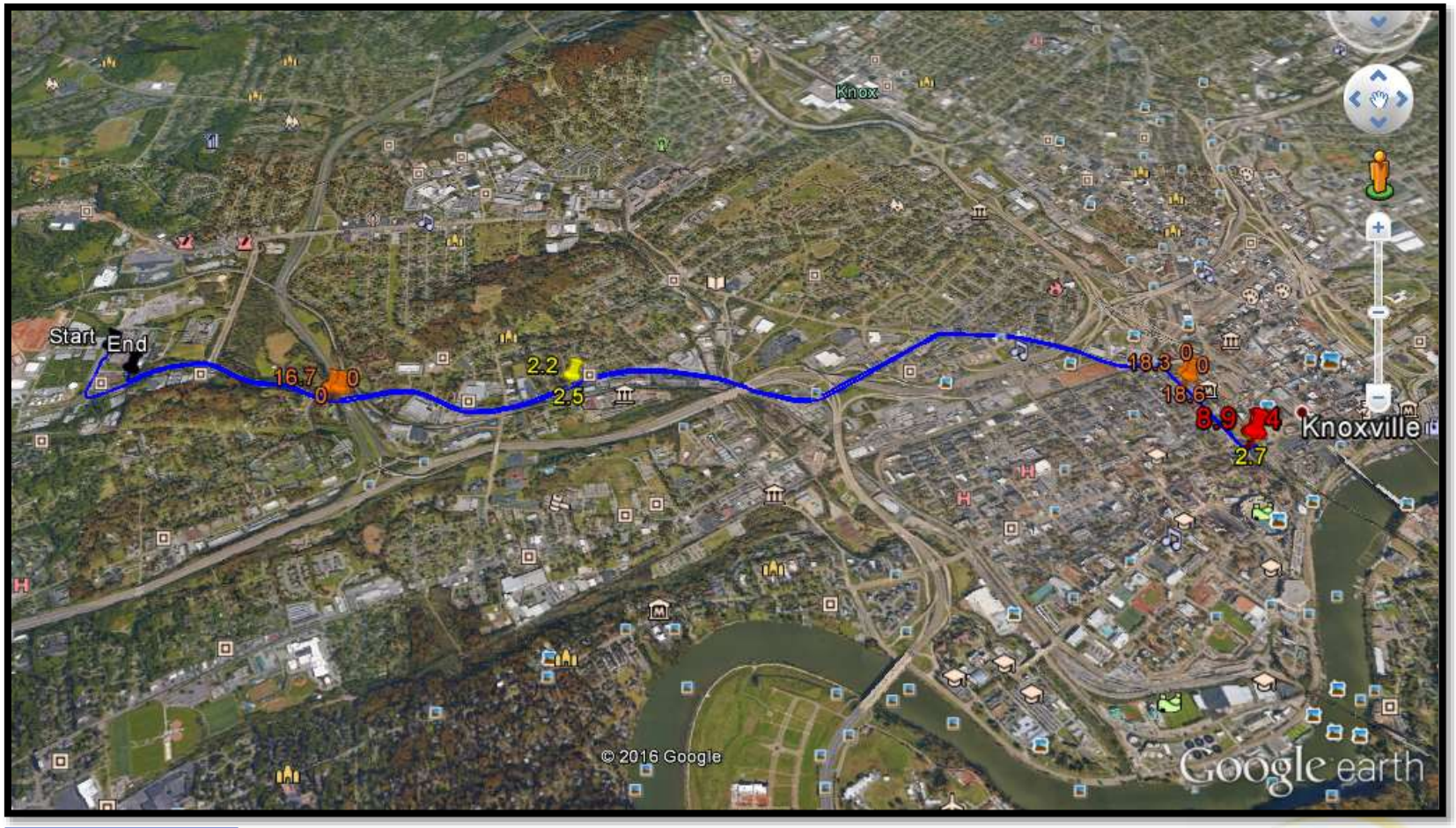
Mounting and Installation

- Simple installation
- Adapts to cars, trucks, ATVs
- Adjustable bar height for easy deployment, transport
- No cables through firewall
- 3 to 8' path length (5' is typical for trucks)
- Integrates with SENSIT PMD vacuum system

SENSIT Technologies

SENSIT VMD

- Integrates with Google Earth



VMD Knox.kml

SENSIT Technologies

SENSIT VMD

- Integrates with Google Earth

SENSIT Technologies

VMD Photos


Ready for surveying


Van installation w/Shield


VMD installed on ATV with Shield


VMD w/PMD Vacuum system


Survey bar up for travel


VMD shipping case

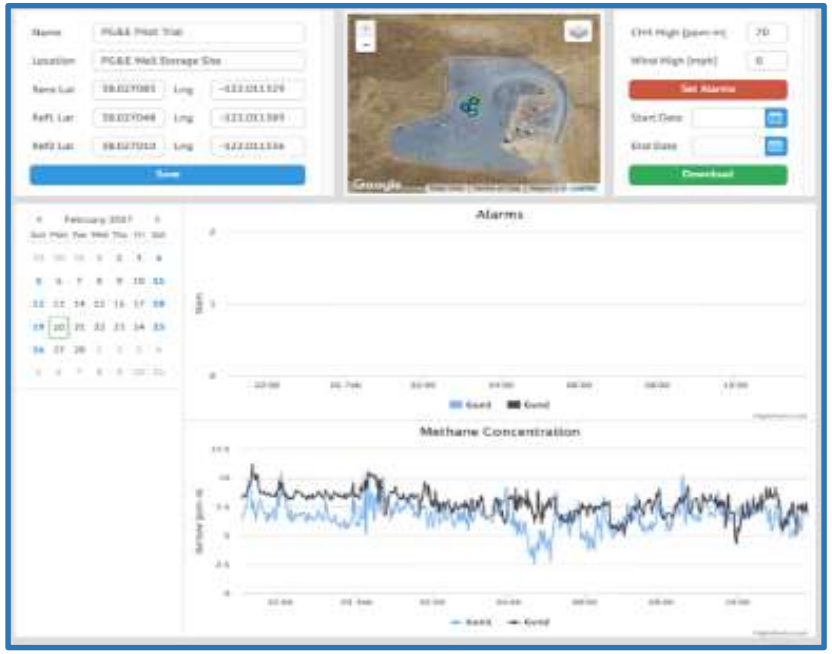
SENSIT Technologies

New Products from SENSIT

SENSIT Technologies

Fixed Point Laser Methane Gas Monitor – The Gas-Trac FPL

- Methane selective
- Single or dual gun with 100’ detection range
- Solar powered with built-in rechargeable battery
- Wireless communication to secure server
- Continuous datalogging
- Simple report generation
- Includes anemometer (wind direction, speed)
- Remote monitoring dashboard (below)



SENSIT Technologies

Hand-Held Laser Methane Gas Detector

Gas-Trac LZ30

- Methane selective
- 100’ detection range
- Adjustable alarms
  - vibration, visual, audible
- 5 ppm sensitivity
- Integrated Cal cell
- Weighs less than a pound

SENSIT Technologies

SENSIT Technologies

Innovative Detection Solutions

Utility – Industrial – HVAC - Fire

Discussion, Q&A

www.gasleaksensors.com

Fiber Optic Sensing Association
Connect and Protect

Advancing Pipeline Safety with Fiber Optic Sensing

NARUC Natural Gas Infrastructure Infrastructure Modernization Partnership

Mark Uncapher

FOSA Director

muncapher@fiberopticsensing.org

September 19, 2018

Boston, Ma

What is FOSA?

- The Fiber Optic Sensing Association ("FOSA") is a non-profit industry association formed in 2017 in Washington D.C.
- Provides North American education on the benefits of distributed fiber optic sensing technology, including through:
  - Webinars
  - Videos
  - White papers
  - Developing standardized industry practices
  - Public policy advocacy
- Membership is open to companies globally who make, install, support and use distributed/quasi-distributed fiber optic sensors.

How Does It Work? – general concept

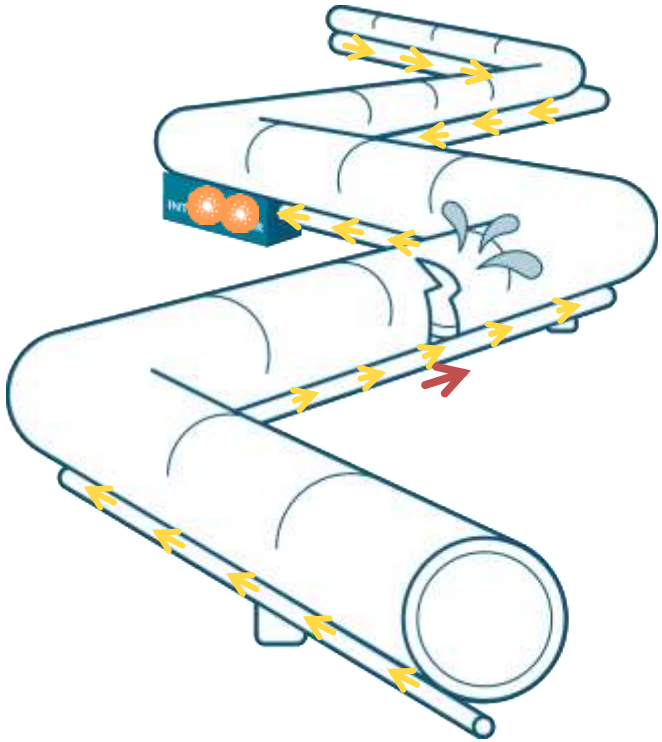
The phenomenon used to measure vibration, temperature or strain in a fiber optic cable relies on the interaction between a laser light and the glass in an optical fiber.

When light travels through a transparent media, the main pulse travels forwards, but a small fraction is back-scattered through interaction with the glass. This changes at every point along the cable in accordance with the local environment.

Different backscatter processes can be used to extract relevant information.

That backscatter signal can be exploited by different technologies to understand the external environment– strain, temperature, vibration, etc.

The end data can be used to understand the environment at every point along the fiber and act on the information.



What is Distributed Fiber Optic Sensing?

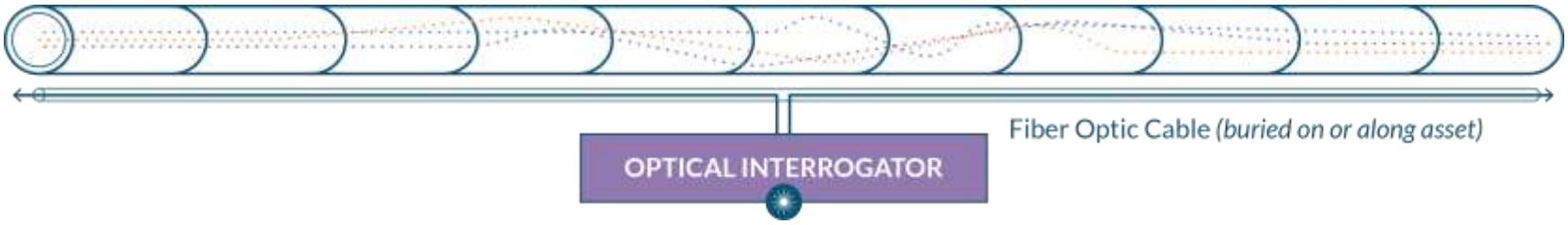
DTS — Temperature

DAS — Vibration

DSS — Strain

- Monitoring of fiber optic cables from a single location via pulsed laser light
- 24/7 Continuous Monitoring – over long continuous distances
- 1,000's of sensing points – high resolution with meter size localization potential

- Passive sensor: No power along asset
- Monitors temperature, strain and/or vibration
- Multiple applications possible in a single system
- Upgradeable technology - without replacing sensor



Fiber Optic Sensing Applications

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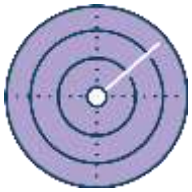
Pipeline Condition Monitoring

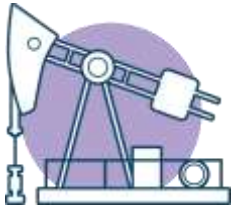
Pipeline Heat Trace Monitoring



Third Party Intrusion/Security

Geo-Technics

Transport Monitoring



Oil & Gas In-Well Monitoring

Industrial Process Monitoring

Structural Health Monitoring

Power Cable Monitoring

Improving Pipeline Safety

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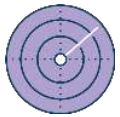
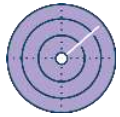




	Pipeline Condition Monitoring	Pipeline ROW Monitoring	Pipeline Geo-Technics	Pipeline Process Monitoring	Structural Health Monitoring	Pipeline Trace Heat Monitoring
DAS	Single Phase Detection Mixed Phase Leak Detection Subsea Leak Detection	Pipeline ROW Intrusion Hot Tap Theft Prevention Valve (Theft) Operation Perimeter security Subsea Pipeline Monitoring	Earthquake Detection Rock Fall Monitoring	Slack line monitoring Slug Profiling Pig tracking		
DTS	Gas / Liquid Leak Detection Mixed Phase Leak Detection		Soil Erosion			Pipeline Heat Trace Monitoring
DSS			Soil Erosion Subsidence Monitoring Land Slip Monitoring		Pipeline Deformation / Hoop Strain	

Key benefits / pipeline safety applications

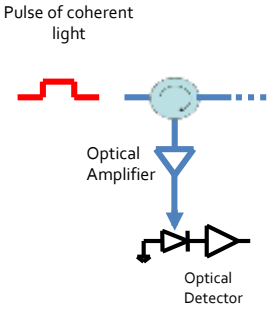
- **Reliable** – Ruggedized interrogator, simple fiber optic sensing cable, little to go wrong
- **Safe** – passive sensor along pipeline, often dielectric, electricity only used at interrogator point / block valves
- **Secure** – buried, affixed, or aerially installed, tampering is immediately evident
- **Economical** – cost per sensing location is lowest on market, single fiber becomes thousands of sensing points
- **Scalable** – multiple technologies or applications on a single cable

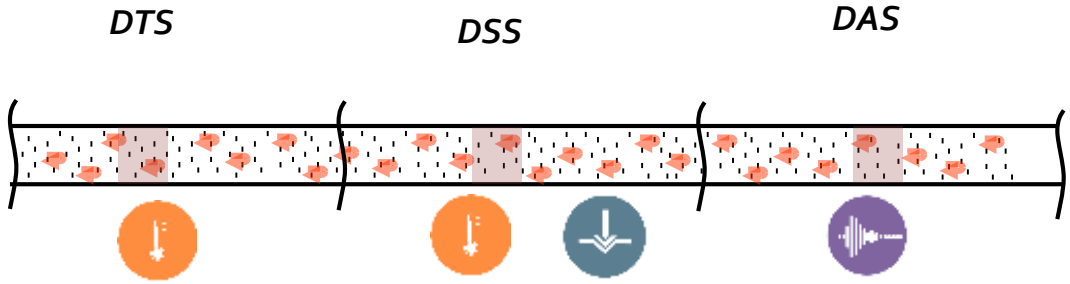





Pipeline Condition Monitoring	Pipeline ROW Monitoring	Pipeline Geo-Technics	Pipeline Process Monitoring	Structural Health Monitoring	Pipeline Heat Trace Monitoring
Single Phase Detection Mixed Phase Leak Detection Subsea Leak Detection	Pipeline ROW Intrusion Hot Tap Theft Prevention Valve (Theft) Detection Perimeter security Subsea Pipeline Monitoring	Earthquake Detection Soil Erosion Monitoring Subsidence Monitoring Land Slide Monitoring	Slack line monitoring Slug Profiling Pig tracking	Pipeline Deformation / Hoop Strain	Pipeline Heat Trace Monitoring

Signals extractable from a fiber



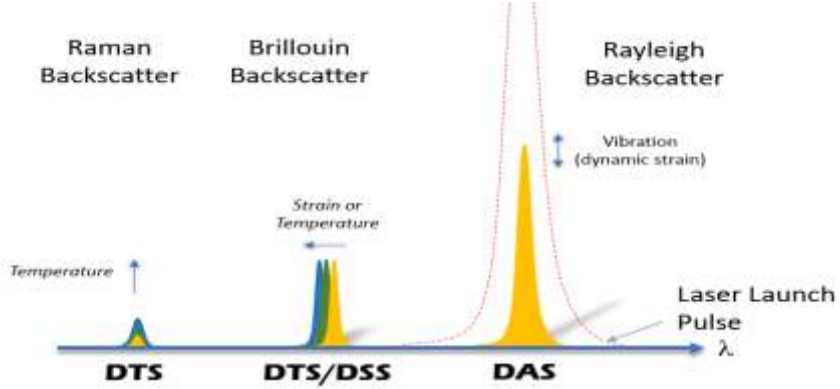


Mechanism: Raman Backscatter
Signal: Thermally Excited Molecules
Responds to: Heat

Mechanism: Brillouin Backscatter
Signal: Thermally Excited Vibrations
Responds to: Heat, Strain

Mechanism: Rayleigh Backscatter
Signal: Dynamic Molecular Position
Responds to: Vibration

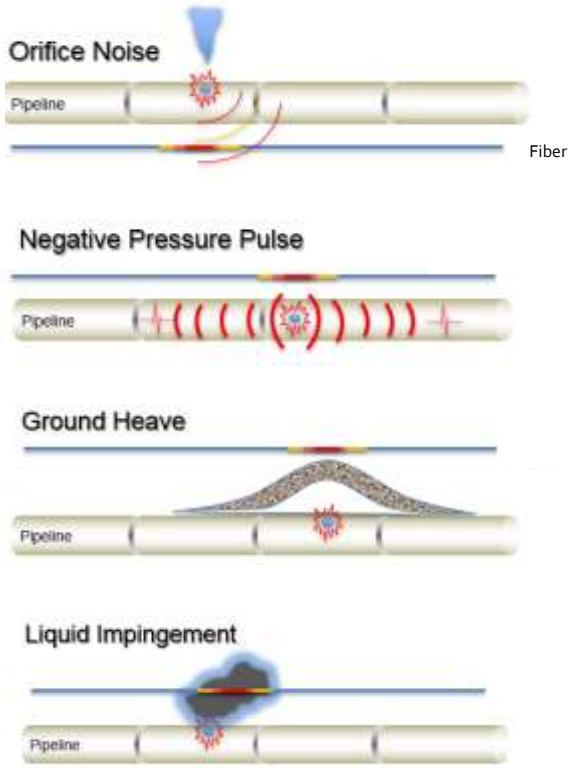
Note: shown figuratively – separate fibers / devices required for each technique



Brillouin based DTS / DSS is often combined in a single DSTS device

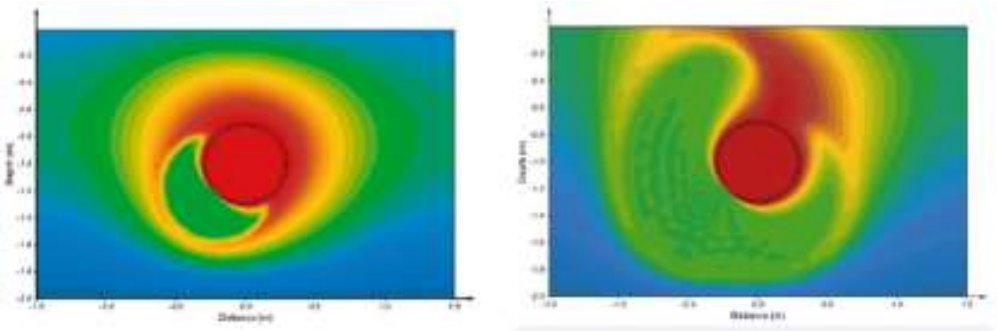
Enhancing Leak Detection with Acoustics / Strain

- **Multiple Acoustic & Vibrations** leak signals are available
  - **Orifice Noise** from a leak in the pipe
  - **Negative Pressure Pulse** propagating in Pipe
  - **Ground Heave** / Displacement from a gas leak
  - Leaking **liquid impingement** on the cable
- **Key Metrics**
  - **Reliability** - comparable to CPM systems (Computational Pipeline Monitoring)
  - **Sensitivity** – Total spilled volume typically measured in barrels / tens of barrels (liquid)
    - Speed of detection – typically measured in seconds to minutes
    - Size of leaks detected – typically measured in litres per min
  - **Accuracy** – typically will not relay leak rates, but leak locations accurate to ~ ±10m
  - **Robustness** – Requires additional work to function during transient conditions but possible – or can operate in a reduced manner
- **Other Key Benefits**
  - Multiphase detection
    - Techniques are independent of flow conditions
  - Above Ground & Below Ground Leak Detection
    - Taped fiber to pipe important for avoidance of wind noise
  - Robust solution for sub sea leak detection



Enhancing Leak Detection with Temperature

- Some leaks are associated with abnormal local temperature changes
  - Small/ insipient leaks introduce local temperature changes (detection limit < 0.1% of flow – order of magnitude better than conventional CPM or Mass/Volume balance systems)
  - Thermal leak shows "signature pattern" that can be distinguished from surrounding conditions
  - Independent from leak size
- Distributed temperature sensing with dedicated alarming algorithm provides efficient leak detection



Example of cold spot (gas leak) propagating around a pipeline

Comparison to Internal Solutions

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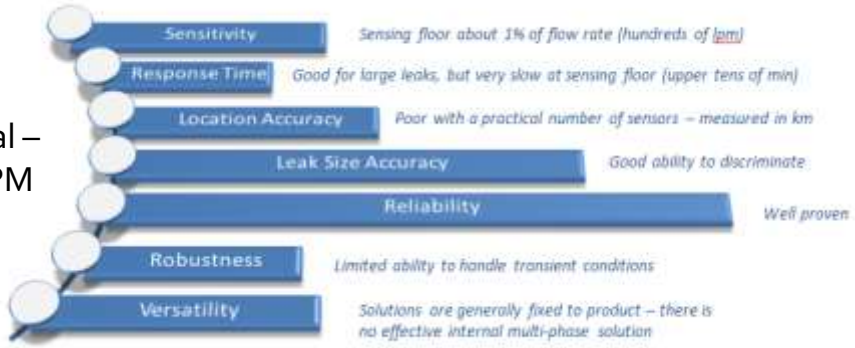
Note: External solutions currently unsupported by a standard or RP

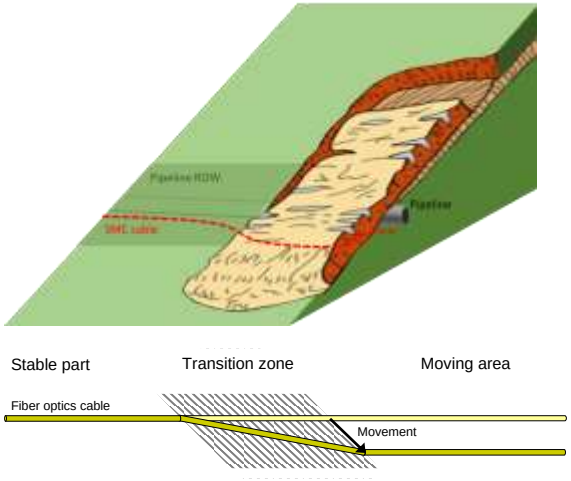
Internal – e.g. CPM



External Fiber Optic Sensing Solutions

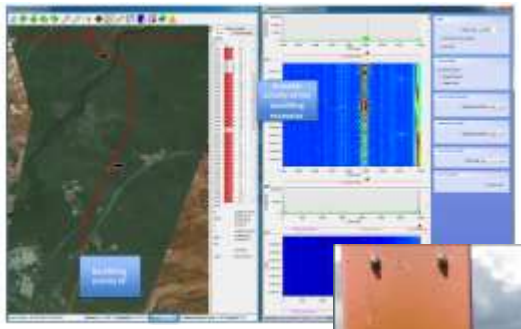
Geohazard Monitoring

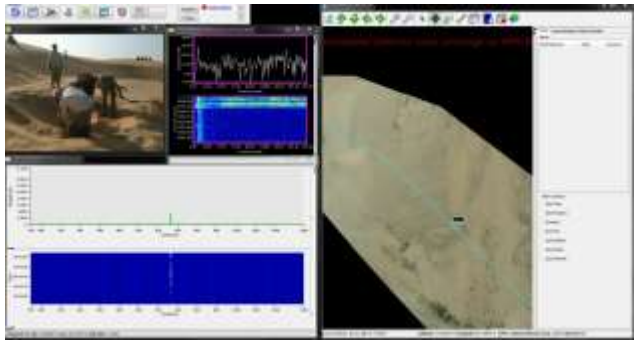
- Ground movement (landslide), subsidence and soil erosion may impact pipeline integrity.
  - Distributed strain sensing provides information on landslide and subsidence
  - Abnormal temperature variations provide information on soil erosion
  - Dedicated strain sensing cable in the pipeline vicinity
- Additional pipeline deformation (strain sensing) monitoring provides information of the geohazard impacts on the asset itself.
- Early signs of growing geohazard can help taking mitigation actions in view of preventing major failure of the pipeline.

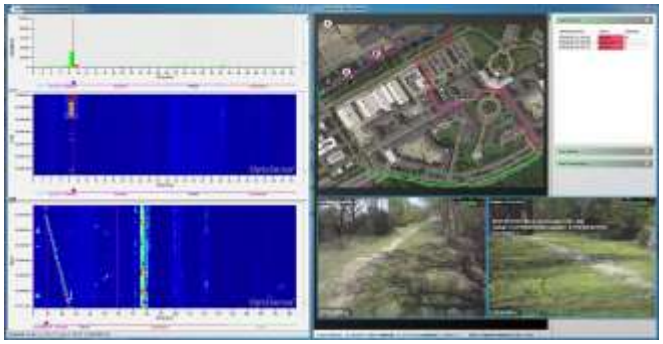


ROW Intrusion Detection Capabilities

- Fiber Optic Sensing is widely used for Pipeline Hazard Prevention:
  - Accidental Damage Prevention (e.g. Backhoe)
  - Hot Tap Attempt Prevention (digging / drilling / increased activity)
  - Block Valve Security (Fence / Buried)
  - Product Theft / Illegal Valve Detection (hot tap operation)
  - Pattern of Life Surveillance
  - Online forensics
- Adaptable to a wide range of environments

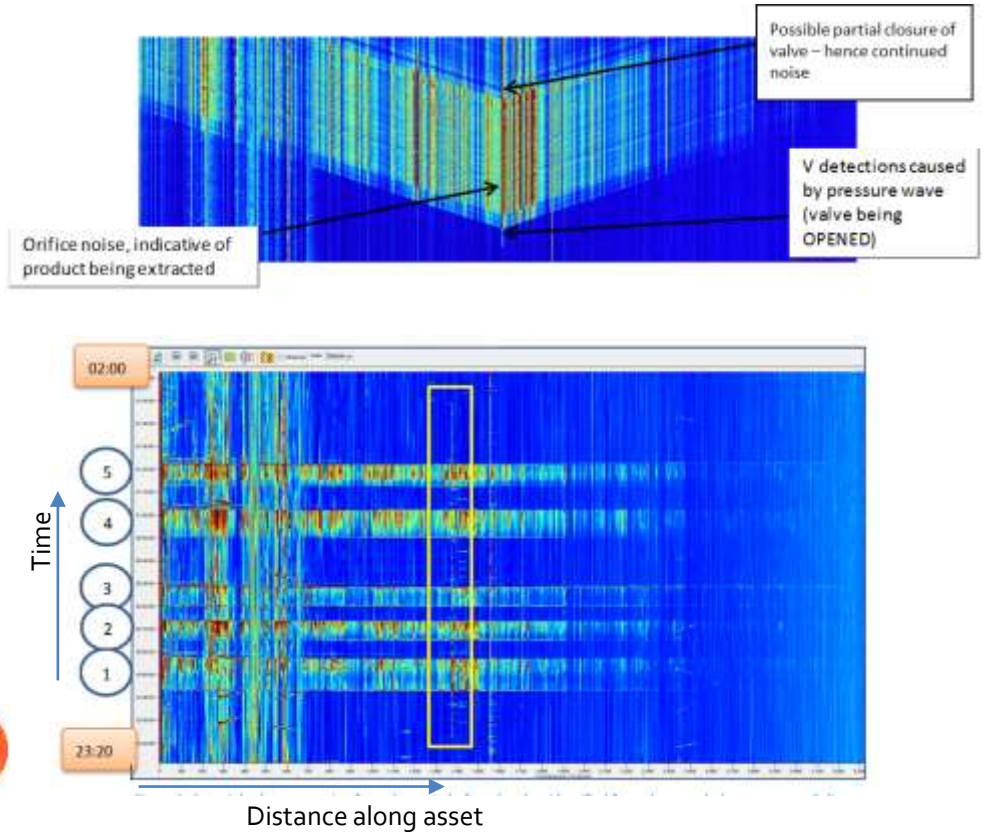






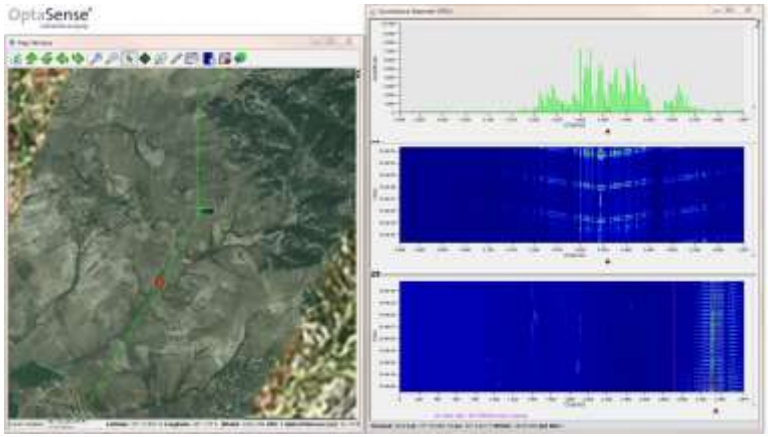
Refined Product Theft

- Latin American client with a known theft problem on a refined product line - identified from mass balance
- Thefts were observed with a regular pattern – middle of the night
- Monitoring system temporarily hooked up for a week's surveillance
- 1st night – system alerts to operation of illegal valve (not one known to client) and identifies approximate position – activity repeated 5 times – each corresponding to ~1 tanker load
- Client heads to approximate location and is guided in by system to location with 10m accuracy

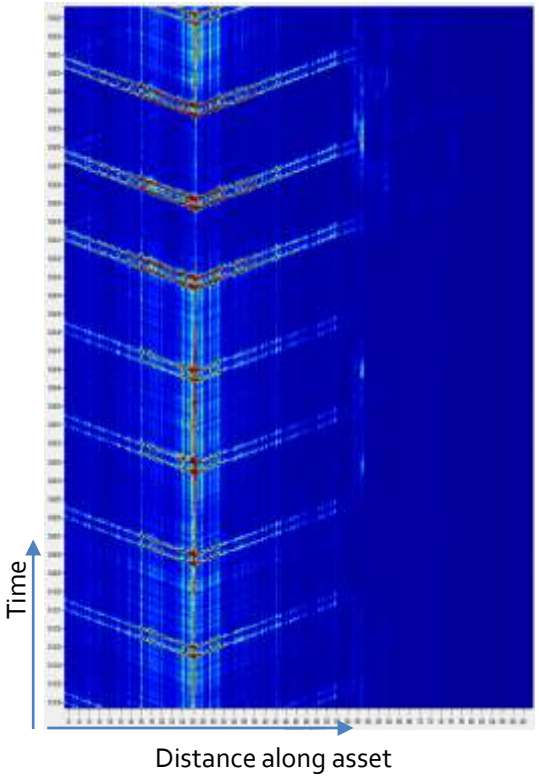


Pig Tracking– Case Study

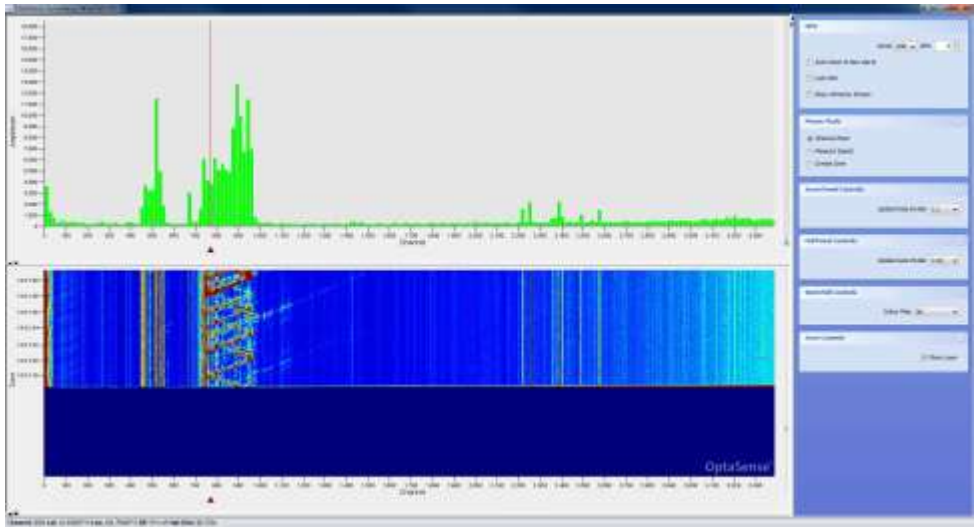
Pigs Unlimited

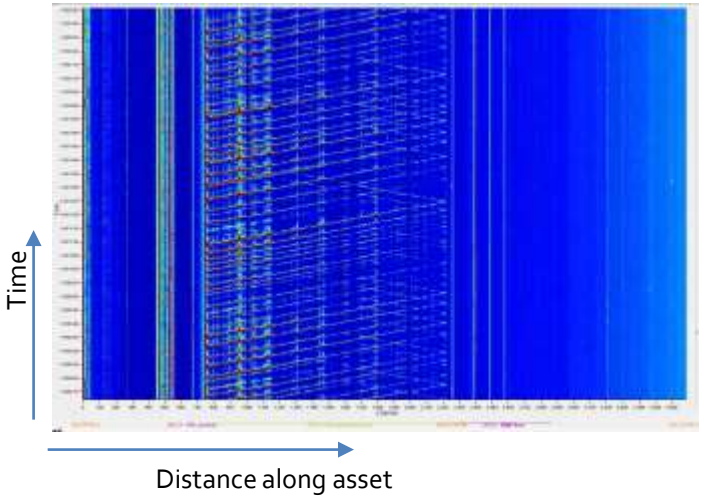


The interaction of a cleaning pig / scraper with the side walls and butt welds creates a moving series of pressure pulses – long used for very precise PIG location



Slack Line Monitoring





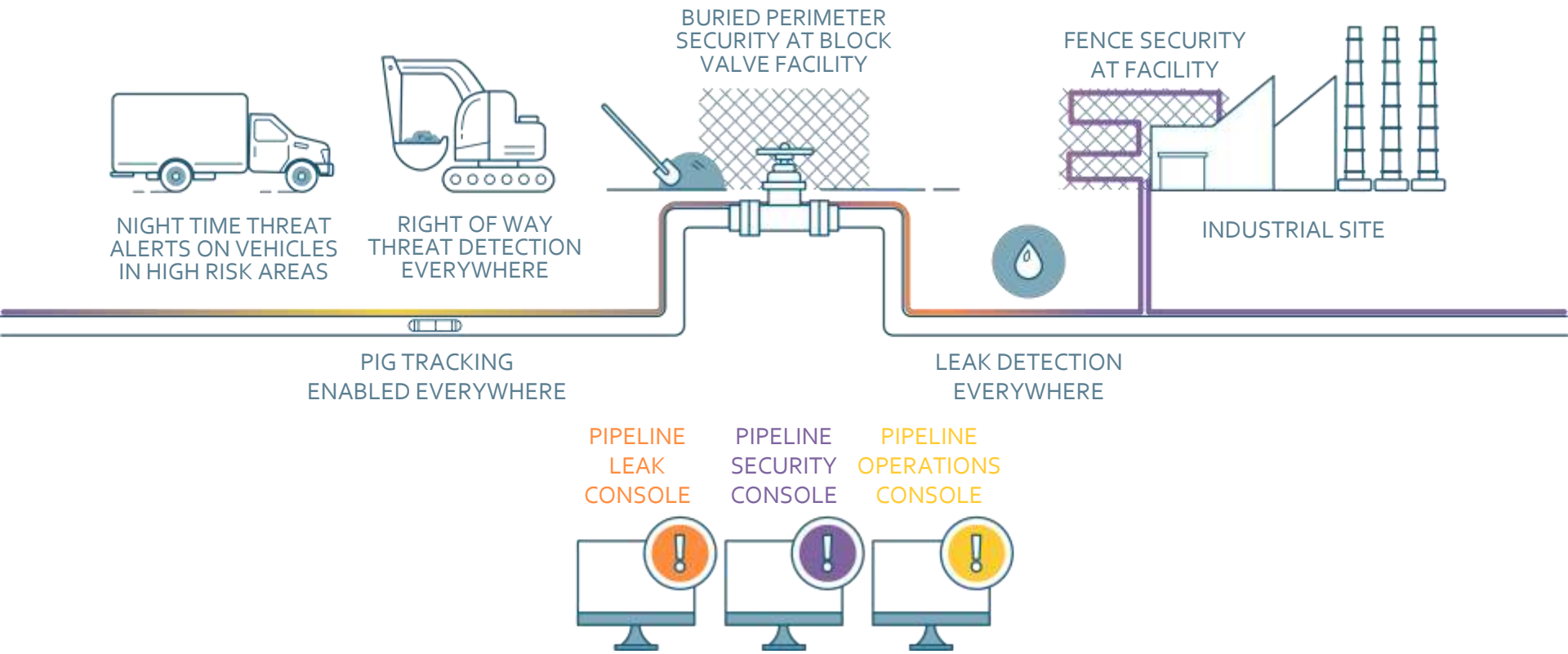
Slack lines create a low frequency transient signal (essentially a Negative Pressure Pulse) which transit exactly like those of the Pig or the leak identifier – directly related to flow conditions, the effects can propagate many miles – fiber sensing provides a mechanism to effect a feedback control loop

Pipeline Trace Heating Monitoring

- In some particular cases (heavy oil, bitumen sand, sulfur etc), fluid must be maintained at temperature above environmental temperature to guarantee low viscosity
  - Use of thermally insulated pipeline
  - In combination with heating elements
- Distributed temperature monitoring along the pipeline is used as:
  - Hot spot detection (overheating, destruction of heating elements)
  - Cold spot detection (blockage, malfunctioning heating system)
  - Optimization of heating power (sufficient heating over full pipeline length)
- Need for absolute temperature data

Thermally Insulated Pipe

Multiple Modalities: Individually Configured Zones



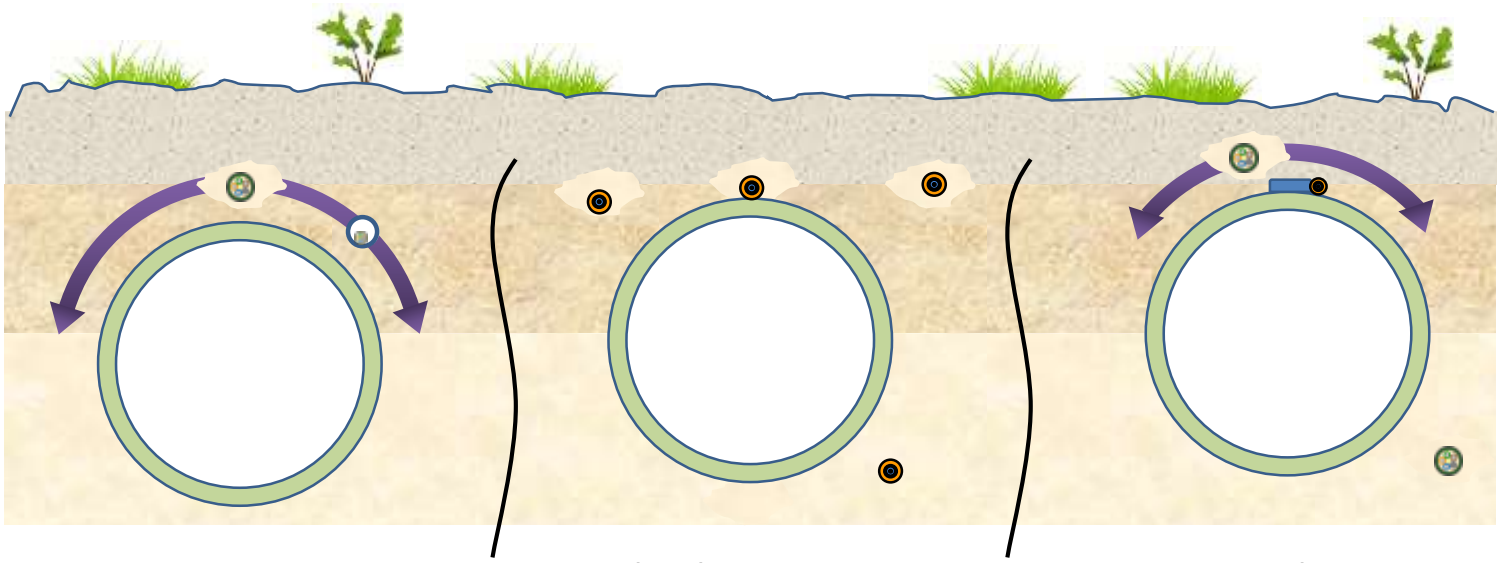
Getting the fiber in the same trench

FERC

Utility Products Magazine

- Direct Buried Cable
  - Armored cable placed directly into the pipe trench, e.g. partially backfill, place cable – complete backfill
  - Good coupling and position orientation
  - Pauses to pipeline operation for splicing operation – cable in ~5-10km reels
- Cable In Conduit
  - HDPE Conduit placed directly into the pipe trench, e.g. partially backfill, place conduit – complete backfill
  - Unarmored Cable blown through conduit once backfill complete
  - Less disturbance to pipeline lay
  - Less well coupled but compensated for by lack of armor
  - Not suited to all measurement types (retards temperature measurement)
- Retrofit
  - Currently difficult…
  - Being addressed by both Government and Industrial R&D funding

Optimizing the position for various techniques



DAS / Acoustic / Vibration Sensing

- *Optimum location for ROW Monitoring – upper half of pipeline, 0.5-1.0m below surface*
- *Optimum location for leak – minimum offset from pipe 0.3-0.5m*
- *Similar for armored / ducted cable*
- *Sand screening to protect cable*

DSS / Strain Sensing

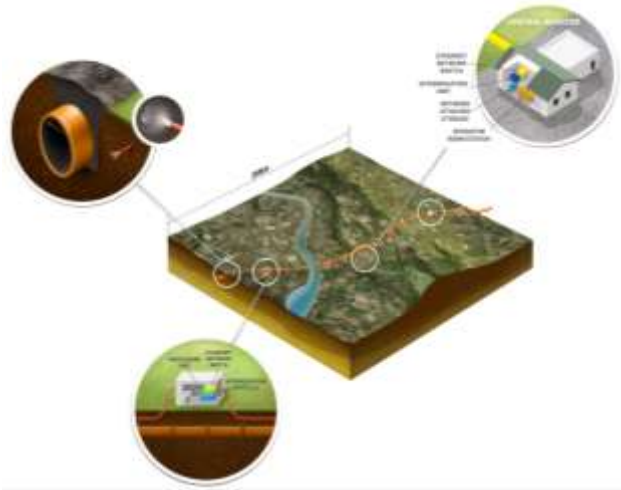
- *Strain measurement delivered WHERE the fiber is:*
- *n soil close to pipe (~1m) – picks up soil strain*
- *at pipe bottom picks up soil sagging / lift*
- *strapped to pipe picks up strain coupled to pipe*

DTS / Temperature Sensing

- *Liquid leak applications – at pipe bottom (gravity spill) – 15-30cm*
- *Gas leak applications – above pipe (Joule Thompson cooling) – 15-30cm*
- *Trace Heat Monitoring – strapped to pipe / heating element*

What are the Benefits?

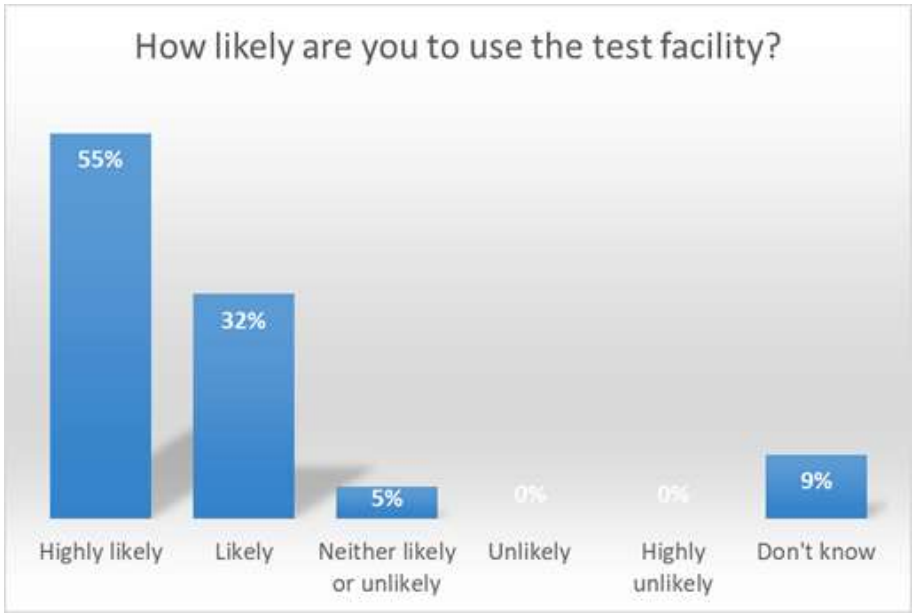
- Long reach – spans greater than 50 miles (80 km) possible
- Quick scan – entire length scanned in seconds – real time reporting
- High spatial resolution – thousands of sensing points, detect every few feet
- Precise event location detection – know quickly and accurately when problems occur
- All dielectric – centrally powered, no risk of sparking
- Almost zero maintenance
- Add additional fiber to the sensor cable – built-in communications capability along rights-of-way / broadband delivery

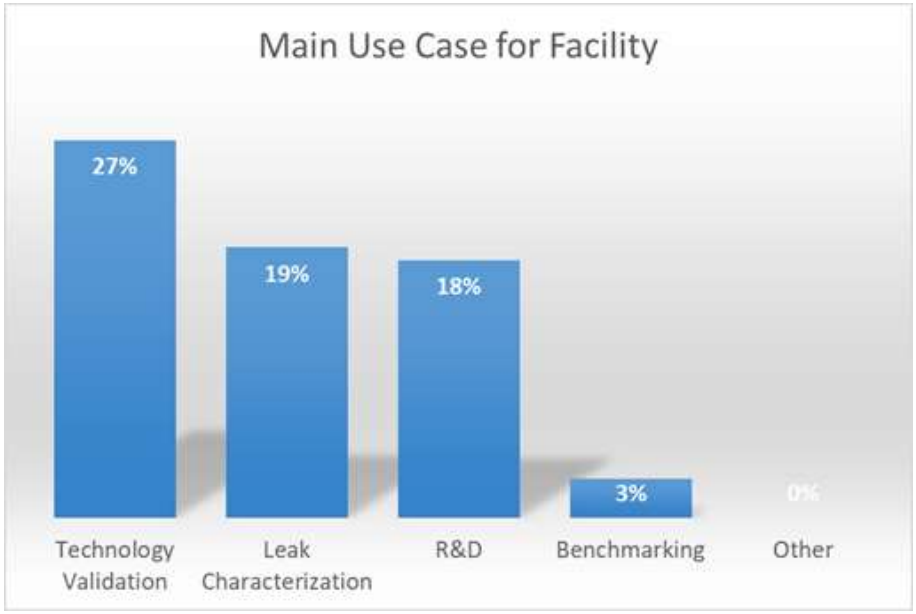


Per sensing point, there is no more economical way to monitor lengthy, critical assets

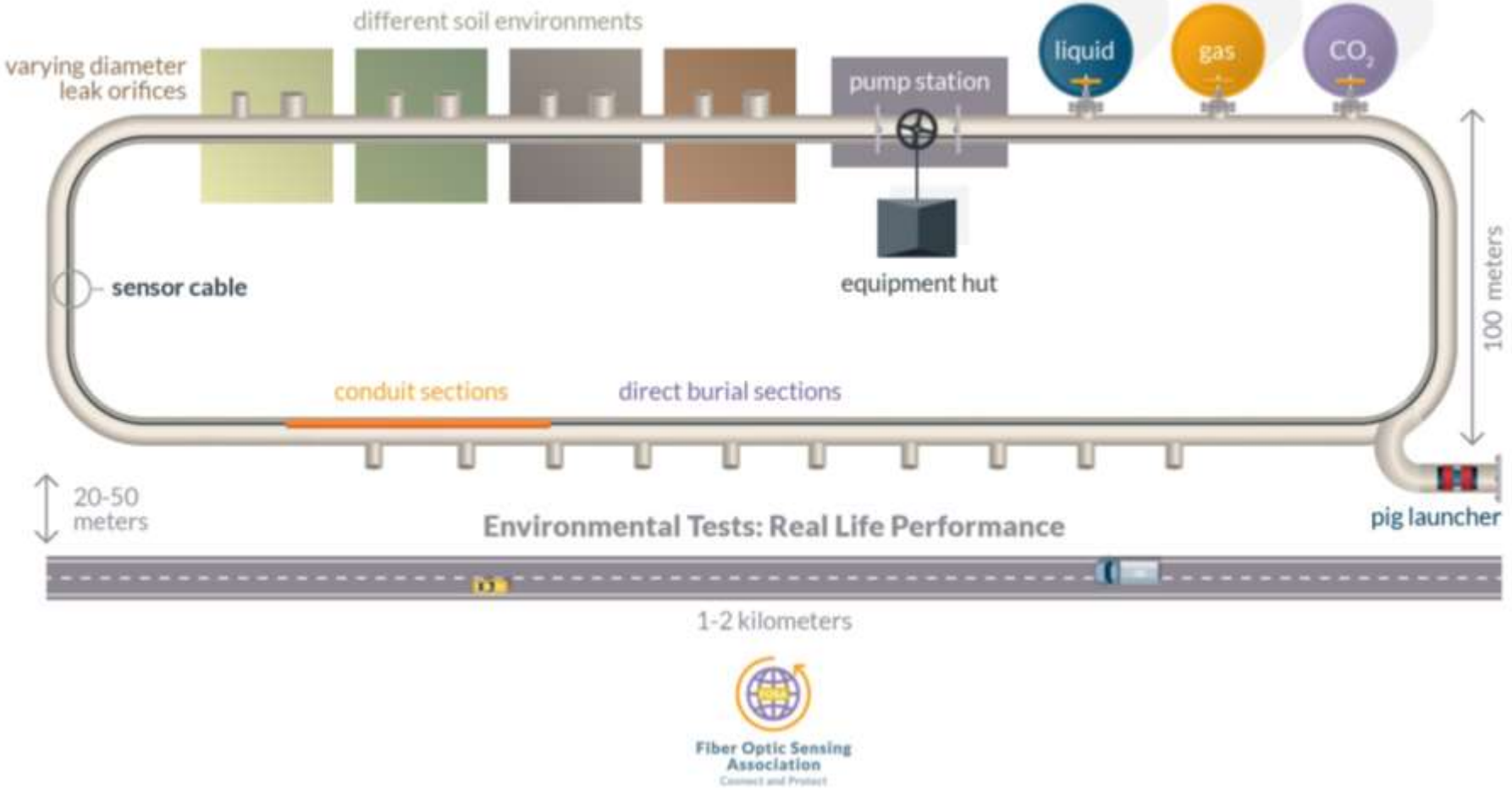
U.S. Pipeline Safety Test Facility – Survey

Would you use it…and how?

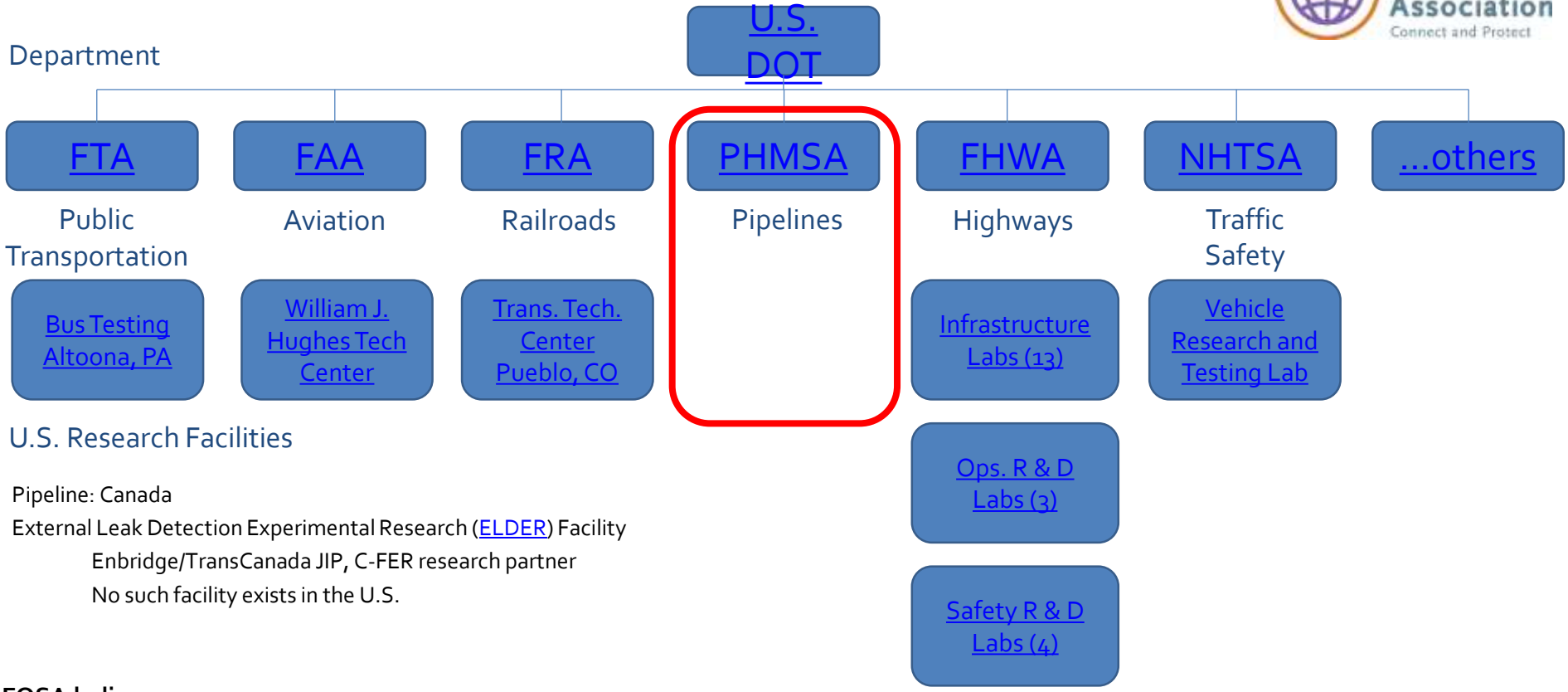




Proposed Pipeline Safety Test Facility



Precedent for U.S. Pipeline Safety Test Facility



Pipeline: Canada

External Leak Detection Experimental Research (ELDER) Facility

Enbridge/TransCanada JIP, C-FER research partner

No such facility exists in the U.S.

FOSA believes

The time is right to raise awareness of the need for a national-scale external testing facility for pipelines

Such a facility would be a great use of public or public/private funds to enhance pipeline safety and improve efficiency

FOSA Members with Sensing Products

Fiber Optic Sensing Association
Connect and Protect

adelos

AP SENSING advanced photonic

ASYMMETRIC

FOtech SOLUTIONS

OptaSense® a QinetiQ company

AP SENSING advanced photonic

LIOS TECHNOLOGY

omnisens Securing asset integrity

OZ OPTICS LIMITED

LIOS TECHNOLOGY

omnisens Securing asset integrity

OZ OPTICS LIMITED

YouTube

Fiber Optic Sensing Association

Connect and Protect

Thank You – Questions?

Visit our website at **fiberopticsensing.org**

NATURAL GAS INFRASTRUCTURE
MODERNIZATION PARTNERSHIP
TECHNICAL WORKSHOP ON METHANE
EMISSIONS MANAGEMENT
TECHNOLOGIES

FLIR and OGI (Optical Gas Imaging)

SEPTEMBER 2018

The World's Sixth Sense

FLIR will be the **world's sixth sense**, improving the way we live by bringing innovative **sensing technologies** into daily life.

FLIR Technology will help keep our world safe and aware, **our environment clean and preserved**, our communities healthy and entertained, and our economies efficient and productive.

FLIR at a Glance

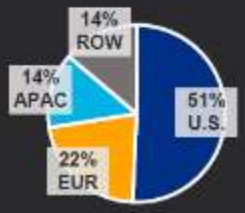
Revenue: $1.7B

Did You Know?

- FLIR ITS sensors analyze over 250,000 road intersections worldwide
- Raymarine instruments were selected to outfit all U.S. Coast Guard craft
- FLIR is 1 of only 3 companies in the U.S. that produces military-grade laser crystals
- FLIR security solutions will be core to the Safe City initiative of a major city in the U.S. Northeast
- FLIR gained #1 market share in Firefighting thermal cameras within two years of entering market

FLIR Metrics

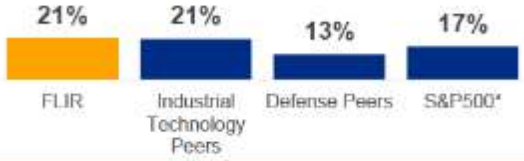
Geographic Revenue



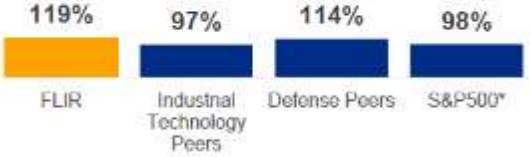
52%	Adj. Gross Margin
$241M	Free Cash Flow
16%	ROIC

FLIR vs. Peers

Adj Operating Margins



Free Cash Flow Conversion



Patents per Employee

Who is FLIR?

US Based Company (OR)

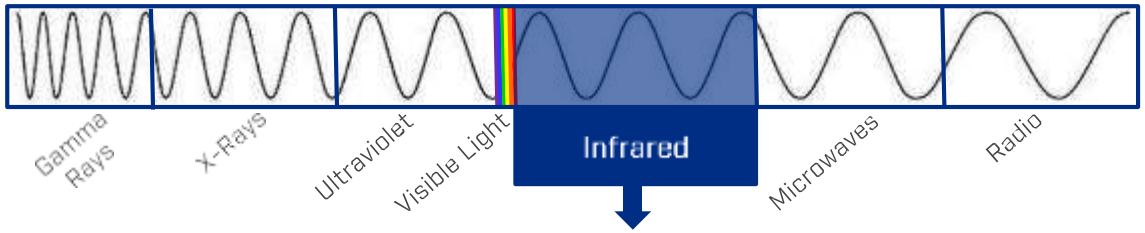
50 Years of IR Experience

Pioneers of OGI

Vertically Integrated Organization

What We Do

Leveraging an Area of the Electromagnetic Energy Spectrum



To Develop Imaging Solutions That Enhance People's Perception

See in Total Darkness

See Through Obscurants

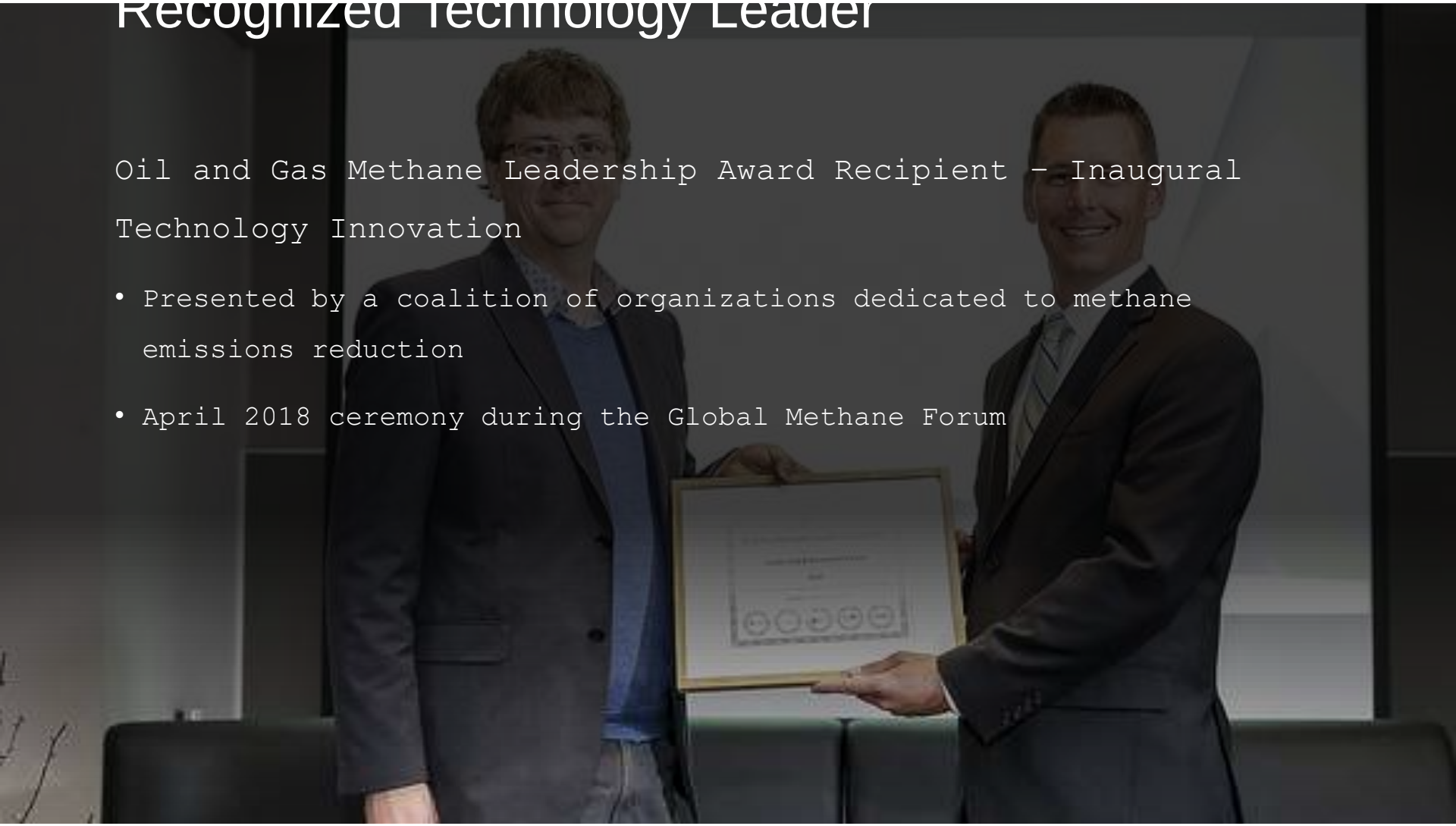
Measure Temperature

Visualize Emissions

Accurately Detect People &

FLIR

Recognized Technology Leader



Oil and Gas Methane Leadership Award Recipient – Inaugural Technology Innovation

- Presented by a coalition of organizations dedicated to methane emissions reduction
- April 2018 ceremony during the Global Methane Forum

OPTICAL GAS IMAGING (OGI)

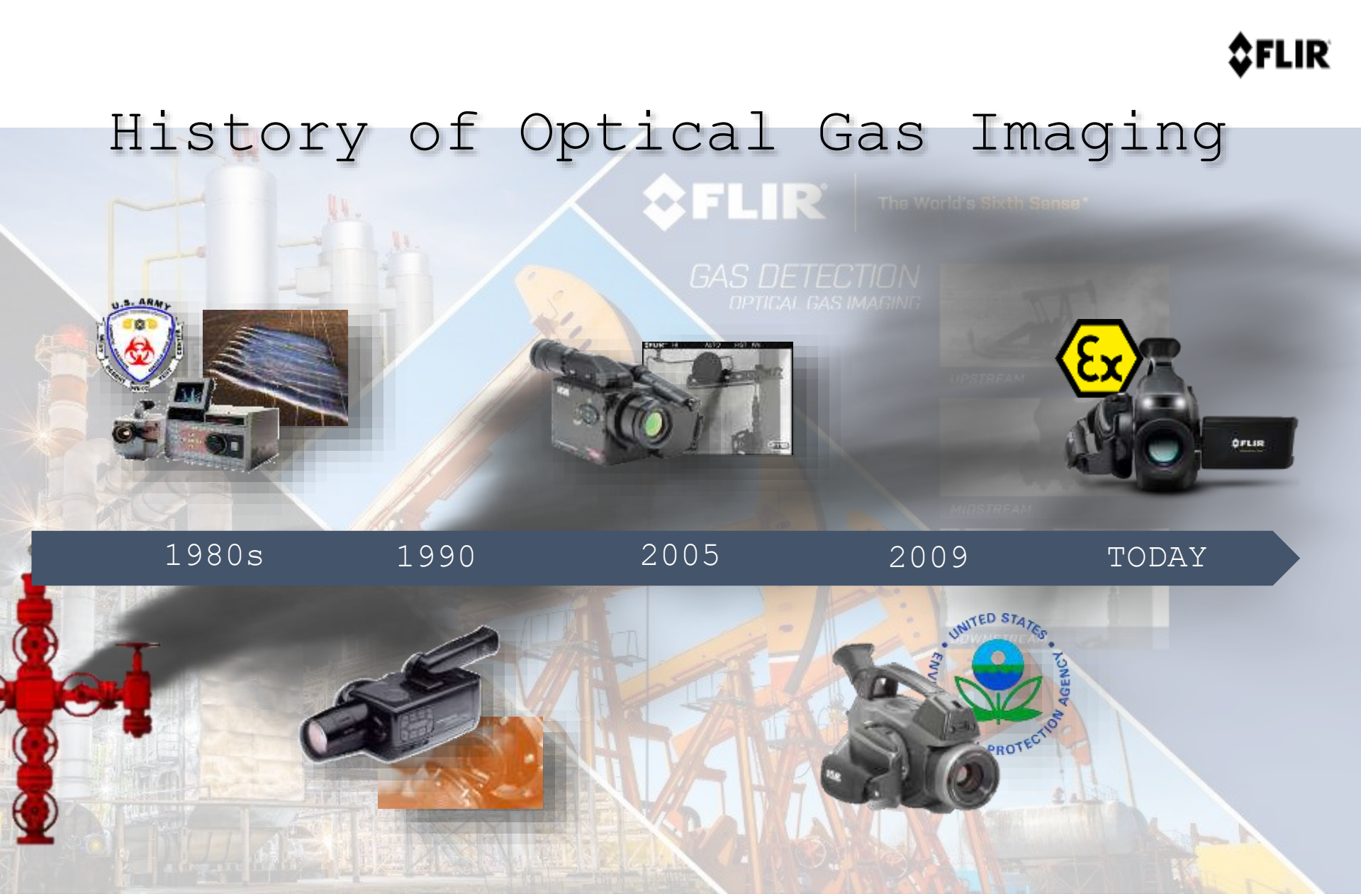
EFFECTIVE

- Find leaks fast & safely
- Visual evidence of leaks

EFFICIENT

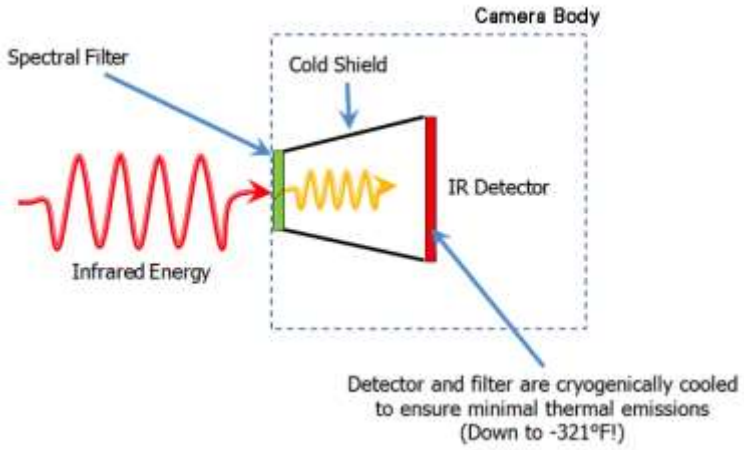
- 9 times faster than M21
- High ROI for producers

History of Optical Gas Imaging

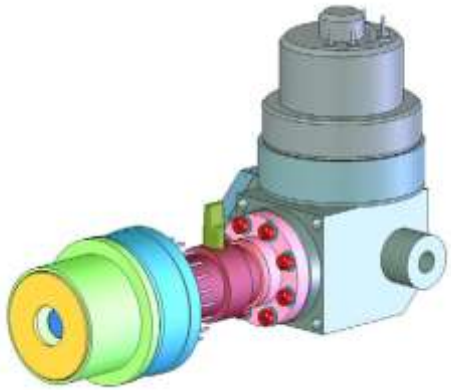


How Does Optical Gas Imaging Work?

SPECTRAL FILTERING

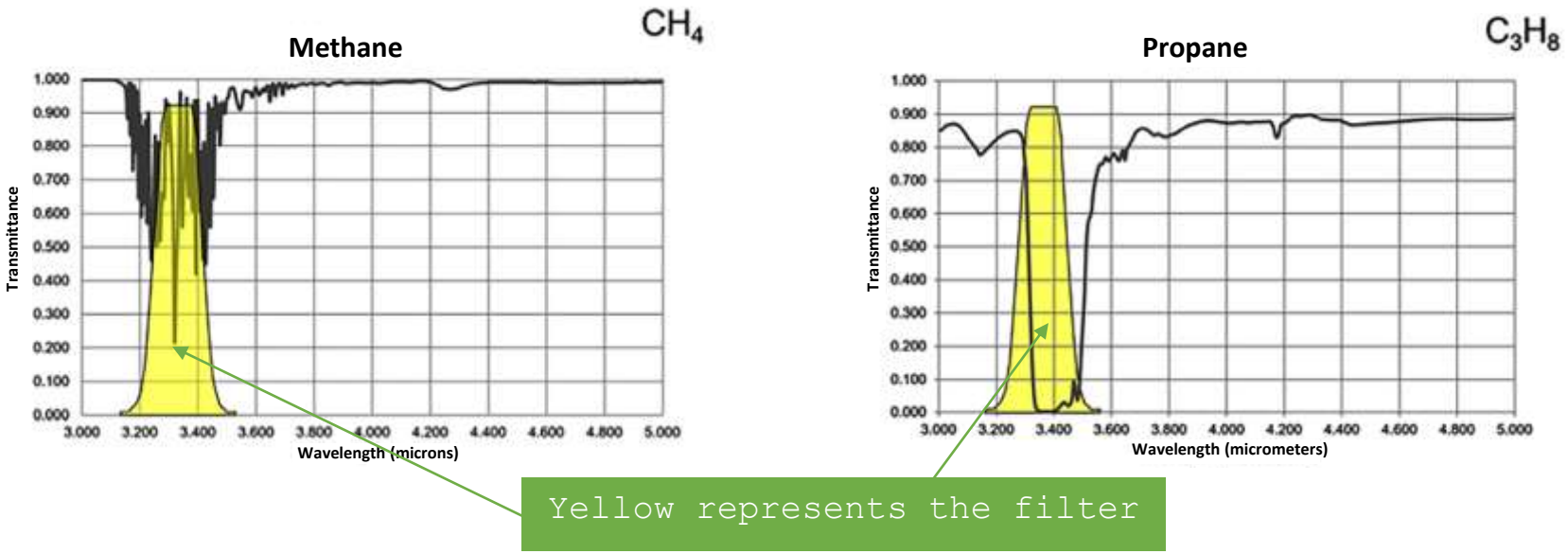


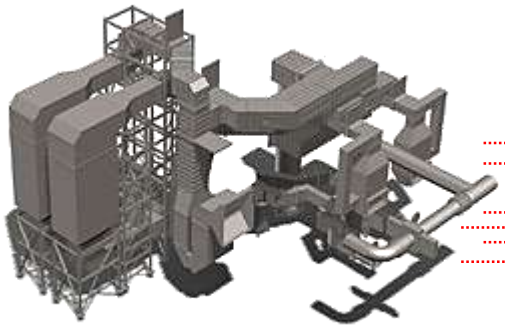
CLOSED CYCLE COOLER

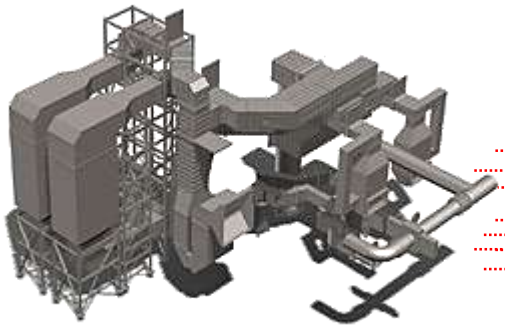


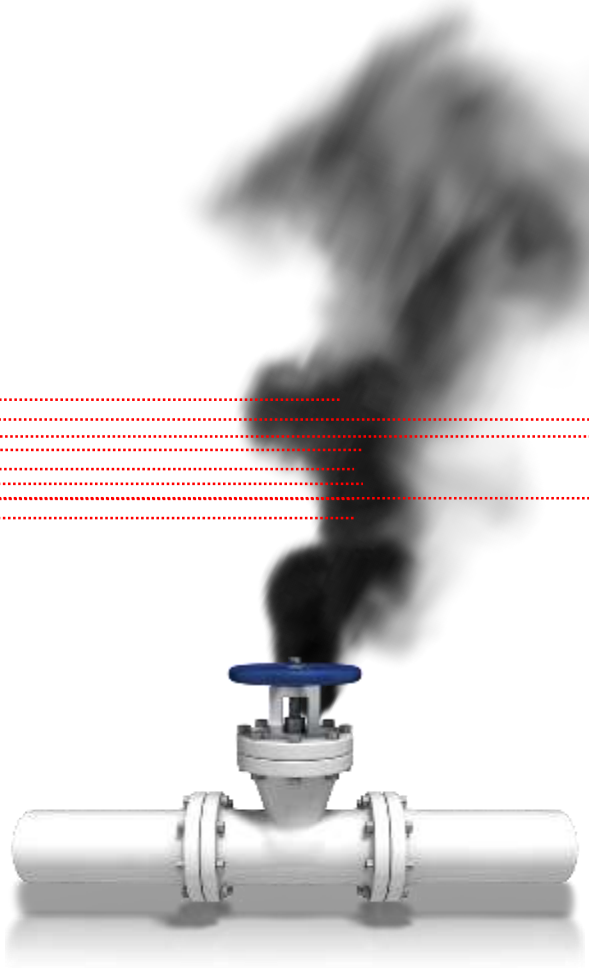
Infrared Absorption Characteristics

MORE THAN 400 GAS COMPOUNDS CAN BE DETECTED, INCLUDING









US OGI Regulations Timeline

2005

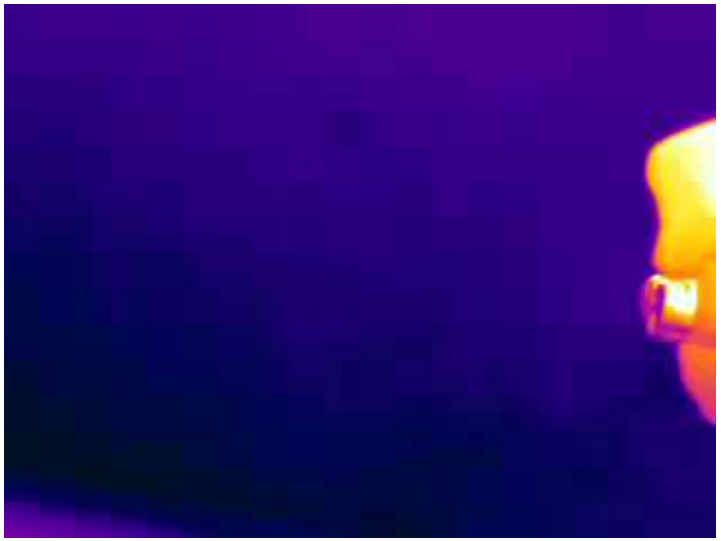
- May 2005: FLIR introduces the world's first commercial Optical Gas Imager, the GasFindIR
- Dec 2008: Mandatory GHG Rule finalized
- Dec 2009: EPA's Alternative Work Practice (AWP) for Method 21 is promulgated
- Nov 2010: Subpart W final rule signed
- Aug 2012: NSPS (New Source Performance Standard) Final Rule
- June 2016: BLM final Rule
- Nov 2016: EPA OOOOa final rule
- June 2017: EPA OOOOa inspections must be completed, repaired and re-inspected

2018

Examples of Optical Gas Imaging

Sensitive enough to see the small leaks….

BUTANE LIGHTER



HAND SANITIZER

Safety Issues

When using Method 21, the operator often must surround themselves with both hydrocarbon and VOC plumes in order for their instrument to register a reading.

Natural Gas Upstream

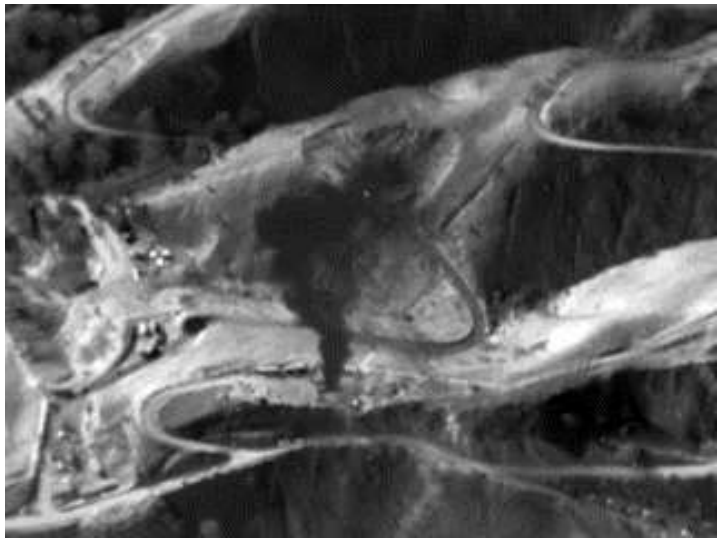
PUMP JACK

WELL HEAD

Natural Gas Storage

LEAKING TANK

ALISO CANYON LEAK

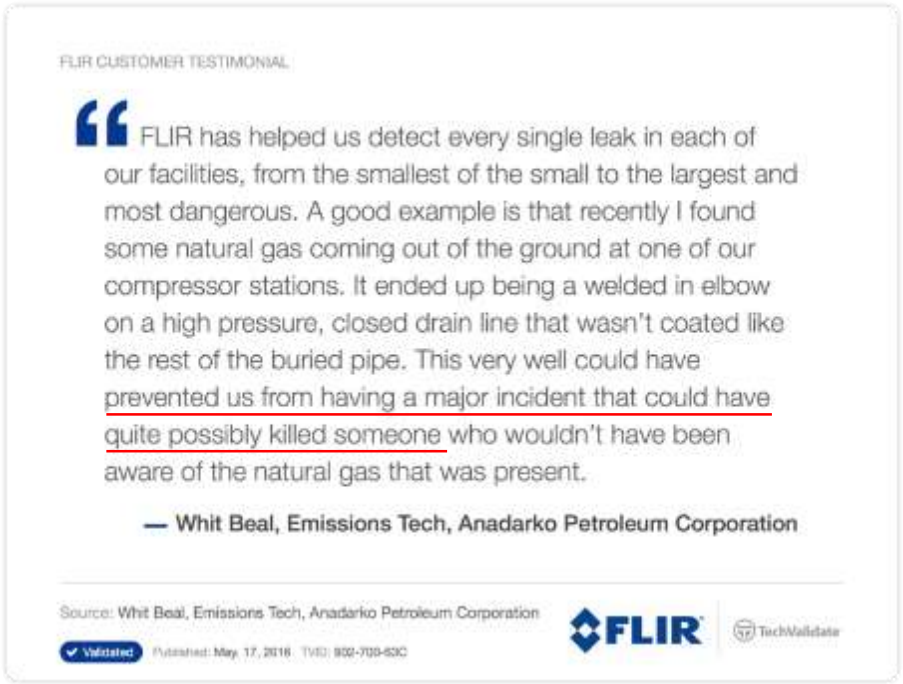


Downstream – Gas Station Leaks

GAS STATION PUMP

GROUND HOLE COVER AT GAS STATION

OGI – An $\mathcal{E}^2$ Solution



FLIR CUSTOMER TESTIMONIAL

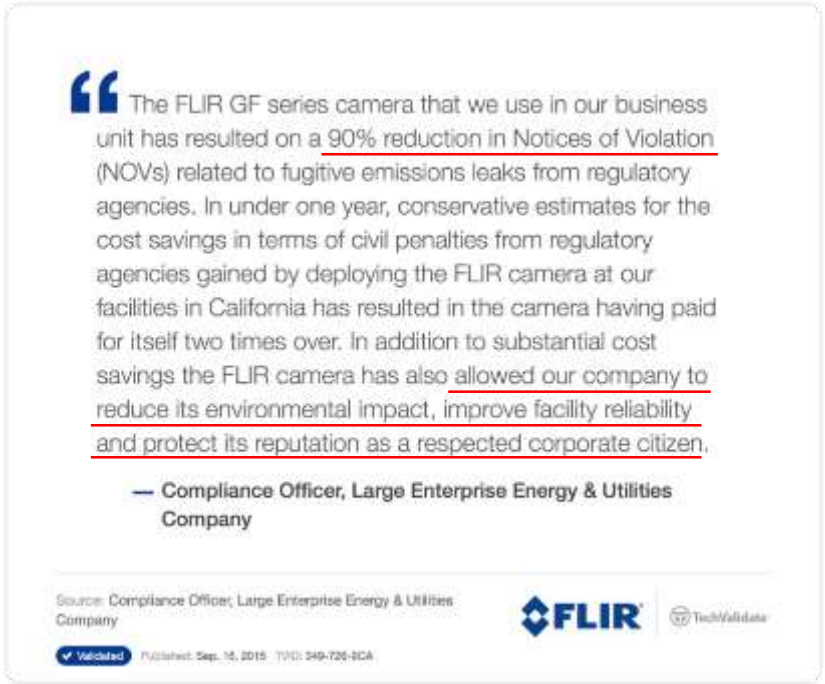
"FLIR has helped us detect every single leak in each of our facilities, from the smallest of the small to the largest and most dangerous. A good example is that recently I found some natural gas coming out of the ground at one of our compressor stations. It ended up being a welded in elbow on a high pressure, closed drain line that wasn't coated like the rest of the buried pipe. This very well could have prevented us from having a major incident that could have quite possibly killed someone who wouldn't have been aware of the natural gas that was present.

— Whit Beal, Emissions Tech, Anadarko Petroleum Corporation

Source: Whit Beal, Emissions Tech, Anadarko Petroleum Corporation

Validated Published: May. 17, 2016 TVID: 902-709-63C

FLIR TechValidate



"The FLIR GF series camera that we use in our business unit has resulted on a 90% reduction in Notices of Violation (NOVs) related to fugitive emissions leaks from regulatory agencies. In under one year, conservative estimates for the cost savings in terms of civil penalties from regulatory agencies gained by deploying the FLIR camera at our facilities in California has resulted in the camera having paid for itself two times over. In addition to substantial cost savings the FLIR camera has also allowed our company to reduce its environmental impact, improve facility reliability and protect its reputation as a respected corporate citizen.

— Compliance Officer, Large Enterprise Energy & Utilities Company

Source: Compliance Officer, Large Enterprise Energy & Utilities Company

Validated Published: Sep. 16, 2015 TVID: 349-726-8CA

FLIR TechValidate

Producer Return On Investment

*The cumulative gas savings realized by the program has exceeded **$5,000,000** in the past 6 years, which has more than covered the overall program costs. This includes the Optical Gas Imaging equipment and associated operators, along with all repairs and maintenance, including labor and parts.*

Statoil – FLIR is a win, win, win

Thank You

Craig O'Neill

Global Business Development Manager
Optical Gas Imaging

Phone: 800-224-6003
Email: craig.oneill@flir.com

urban}intelligence

PLAN FOR WHAT'S NEXT

Urbint is a company of **technologists** and **AI experts** with one goal -

To help make communities more resilient.

Our Partner - Energy Impact Partners

The world's leading coalition of utilities investing a new energy future

urb|int

Threats.

In 2015, a **weld between two gas pipes** cracked open, leading to a large explosion. The weld was weakened by the pipes sagging into soil undermined by a **sewer leak** that was known for 8 years.

In 2006, a **gas line** was cut by a plumber causing a house to fill with gas and explode. The gas line was cut because it **cross bored a sewer line** – the plumber was running an augur through.

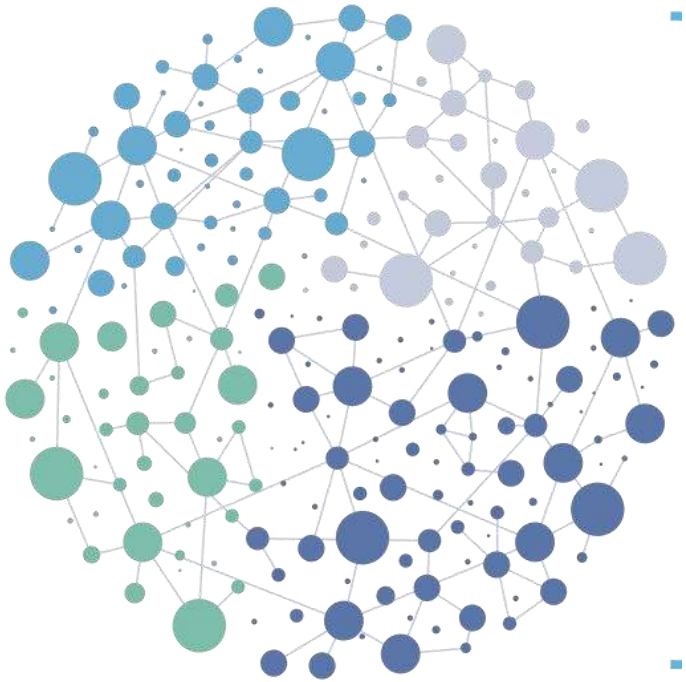
In 2010, a **plastic gas main** ruptured; two hours later an explosion leveled a nearby house. The main ruptured after a **third party excavated** to avoid an inactive steel pipe and instead hit the plastic main identified by the utility.

In 2018, a cracked **cast iron main**, leaked gas into a house which subsequently exploded. The main, amongst thousands of miles scheduled to be replaced by 2023, had already caused **two nearby incidents** in the days leading up to the explosion.

Risk is understood by looking backwards

System specific….

- Inspections
- Historical Leak Surveys
- Repairs
- Material
- Age

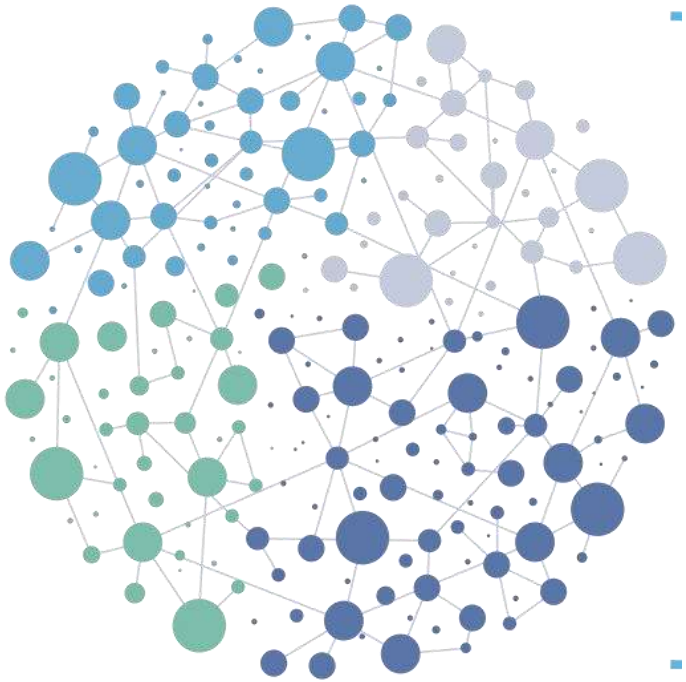


Knowing your **vulnerabilities** makes you a **compliant** organization.

Understanding your **threats** will make you a **safe** organization.

Accounting For Real World Threats

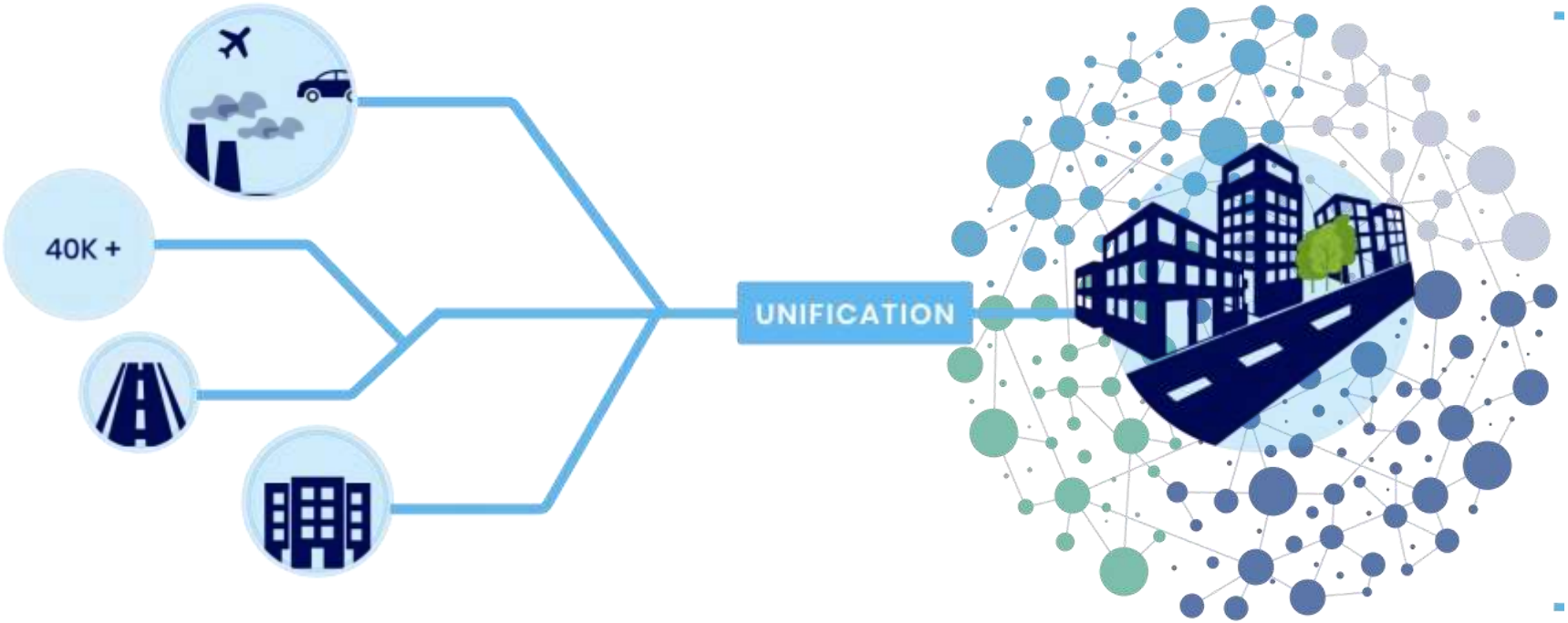
- Soil
- Flooding
- Weather
- Pollution
- Co-located infrastructure
- Uran factors
- Topology/elevation



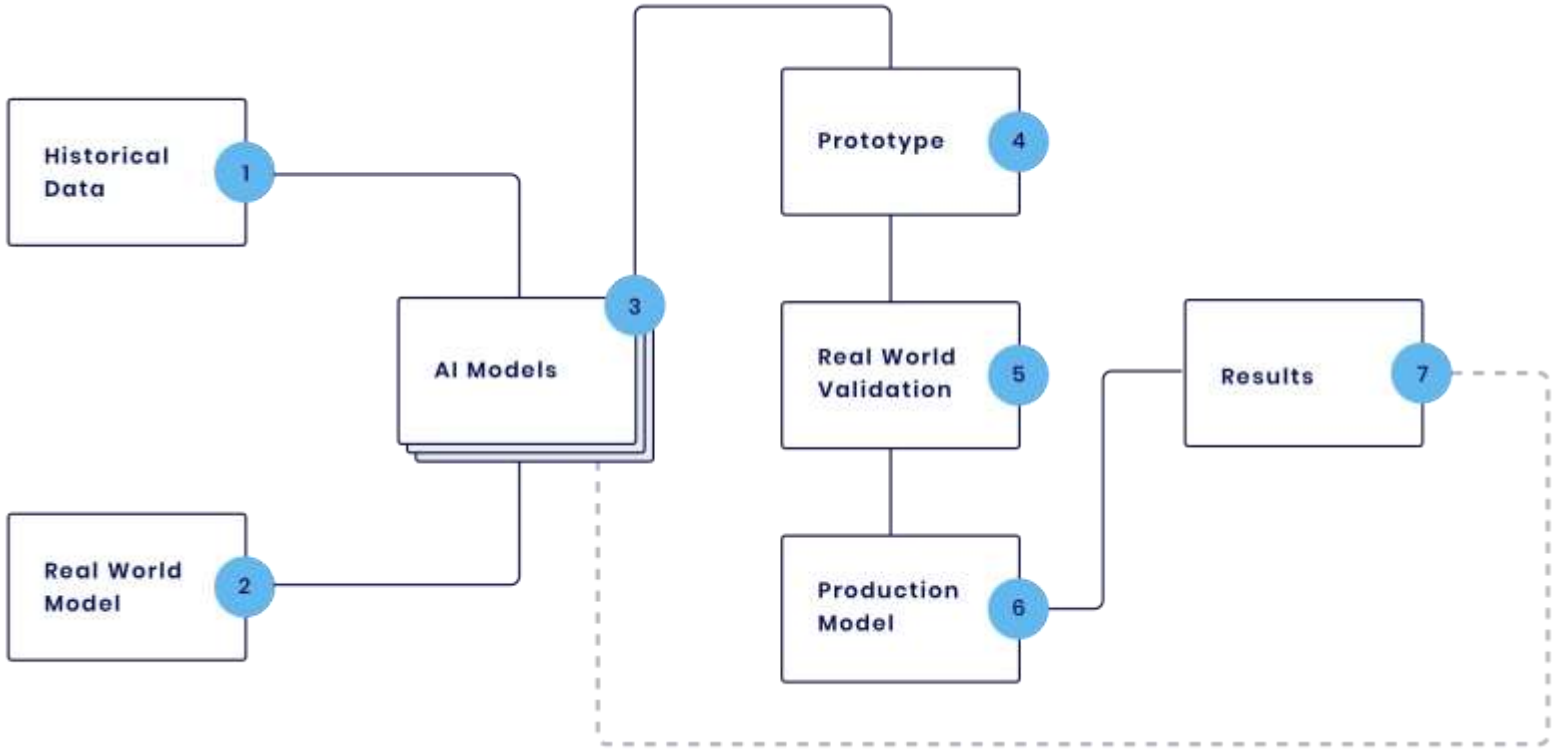
Modelling the Real World.

Linked and Computed Data

Graph Database

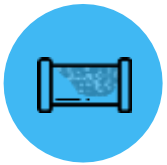


Training Artificial Intelligence.



Causes of Methane Leaks

Accounting for Gas Utility Risk



- Cross bores
- Excavation Damages
- Corrosion
- Weather
- Co-located infrastructure

Case Study - Goal

GOAL: Predict severe levels of corrosion

Utility's data:

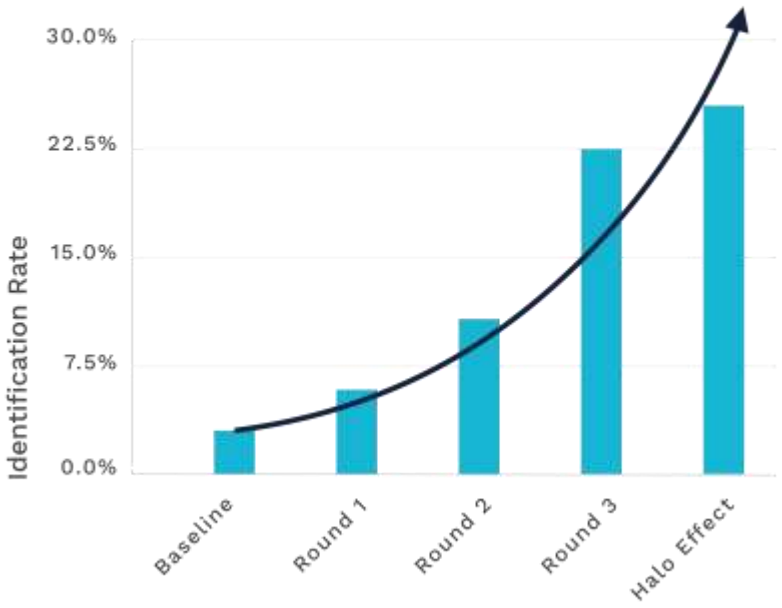
- Gas service addresses
- Historical inspection data and service replacements

Urbint's data:

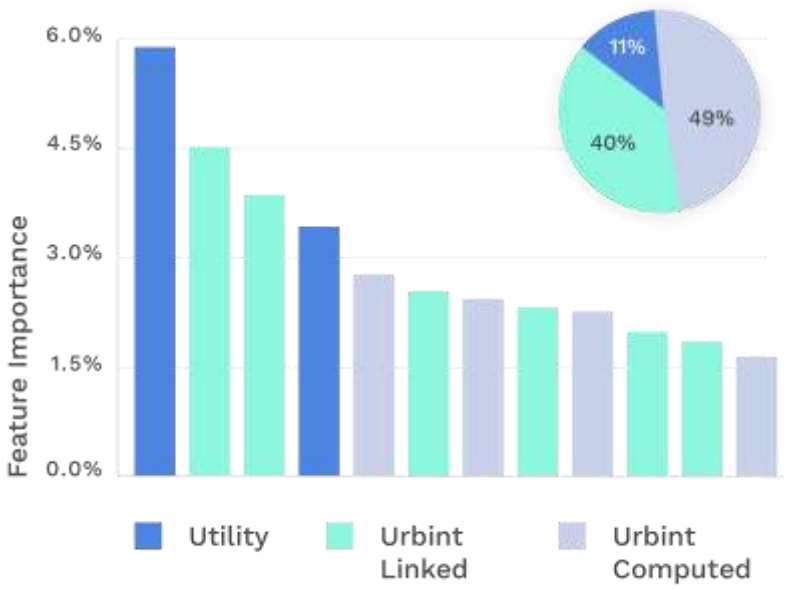
- Property profiles
- Building attributes
- Ownership information
- Geographical information
- Event data (permits, violations, etc.)
- Proprietary algorithms (Pollution Effect, Coastal Effect, Building Impact, Weather)

Case Study - Results

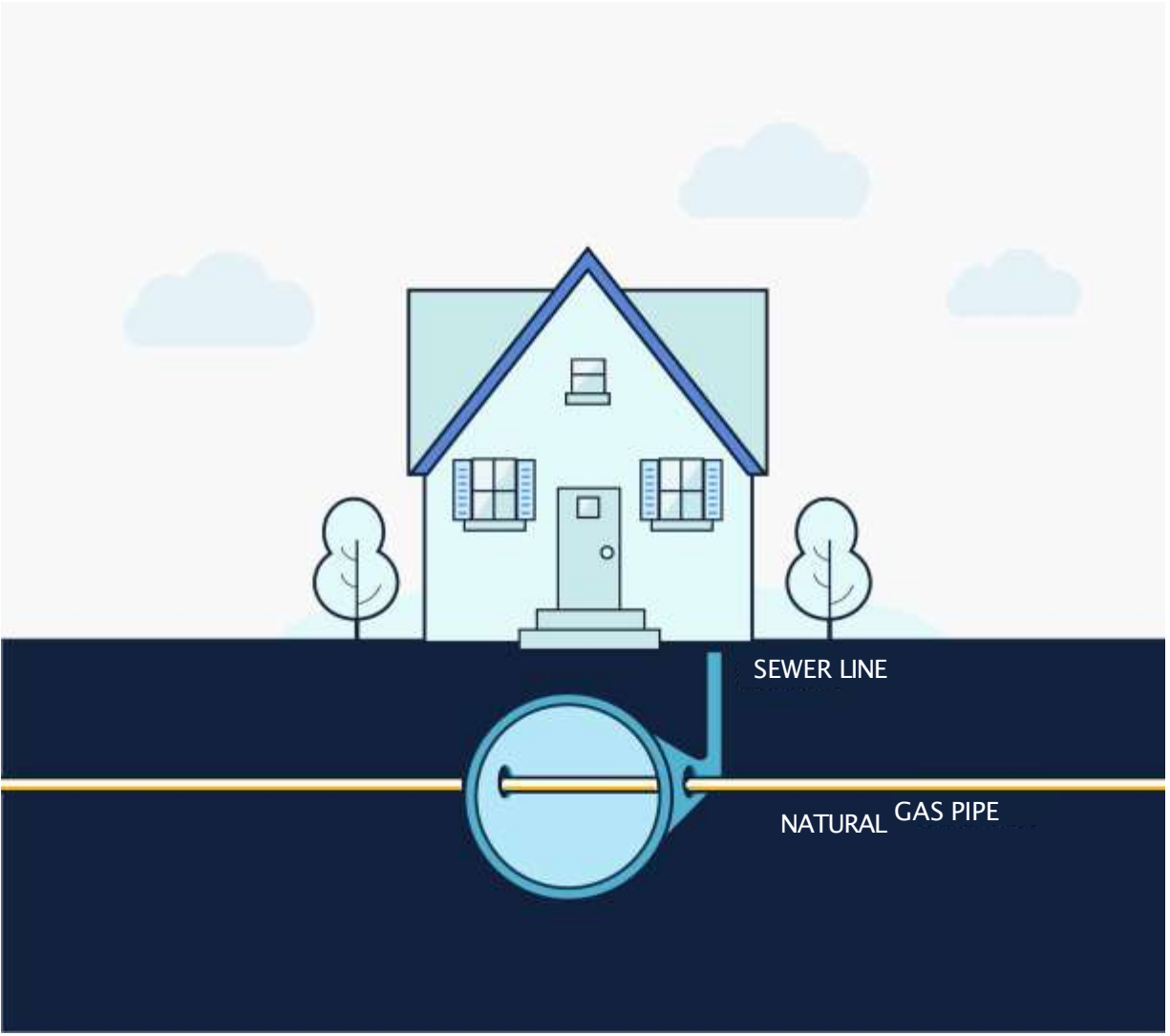
8x lift on identification of **at-risk** assets



Urbint features provided 89% of predictive indicators



Use Cases.



Cross Bores.

Dangerous

One accident a year attributable to cross bores ('02–'15)

Costly

Inspection crew, video QC, and digging expenses add up

Uncertain

In many communities the sewer lines are not all known

Cross Bores

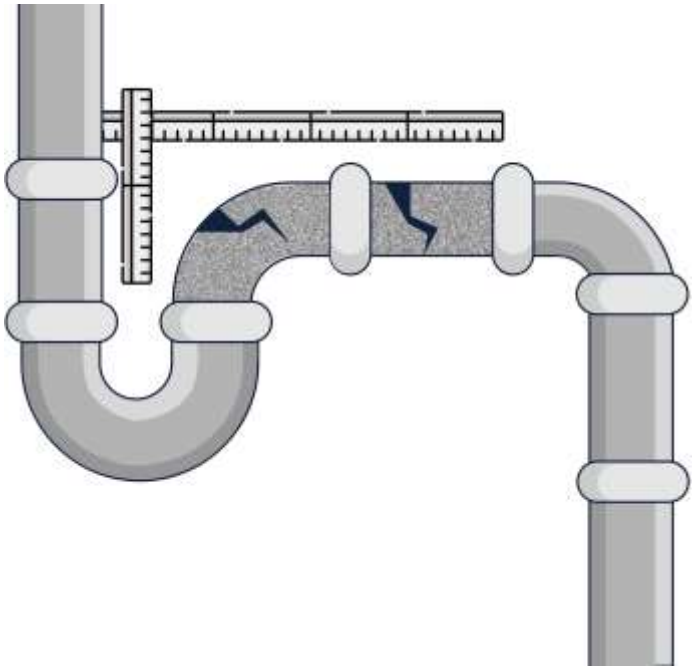
Models to identify cross bores, prioritize inspections, and improve QC

Utility's data:

- Asset locations
- Asset characteristics
- Historical inspection data

Urbint's data:

- Topology
- Permits
- Roads
- Sewer laterals
- Property attributes
- Building attributes



Corrosion

- One of the most common causes of service line leaks
- 2,440 corrosion *leaks* in services
  were repaired last year in your territory
- Severe corrosion is more expensive to remediate

Corrosion

Models to predict corrosion levels and optimize inspections / surveys

Utility's data:

- Asset locations
- Asset characteristics
- Historical inspection data

Urbint's data:

- Topology
- Electric Transmission
- Permits
- Roads
- Soil resistivity
- Weather
- Vegetation
- Land use

Damage Prevention.

Miscommunication

1in 5 excavation leaks avoidable during locate

Trust

2in 5 excavation leaks associated with excavators

Damage Prevention

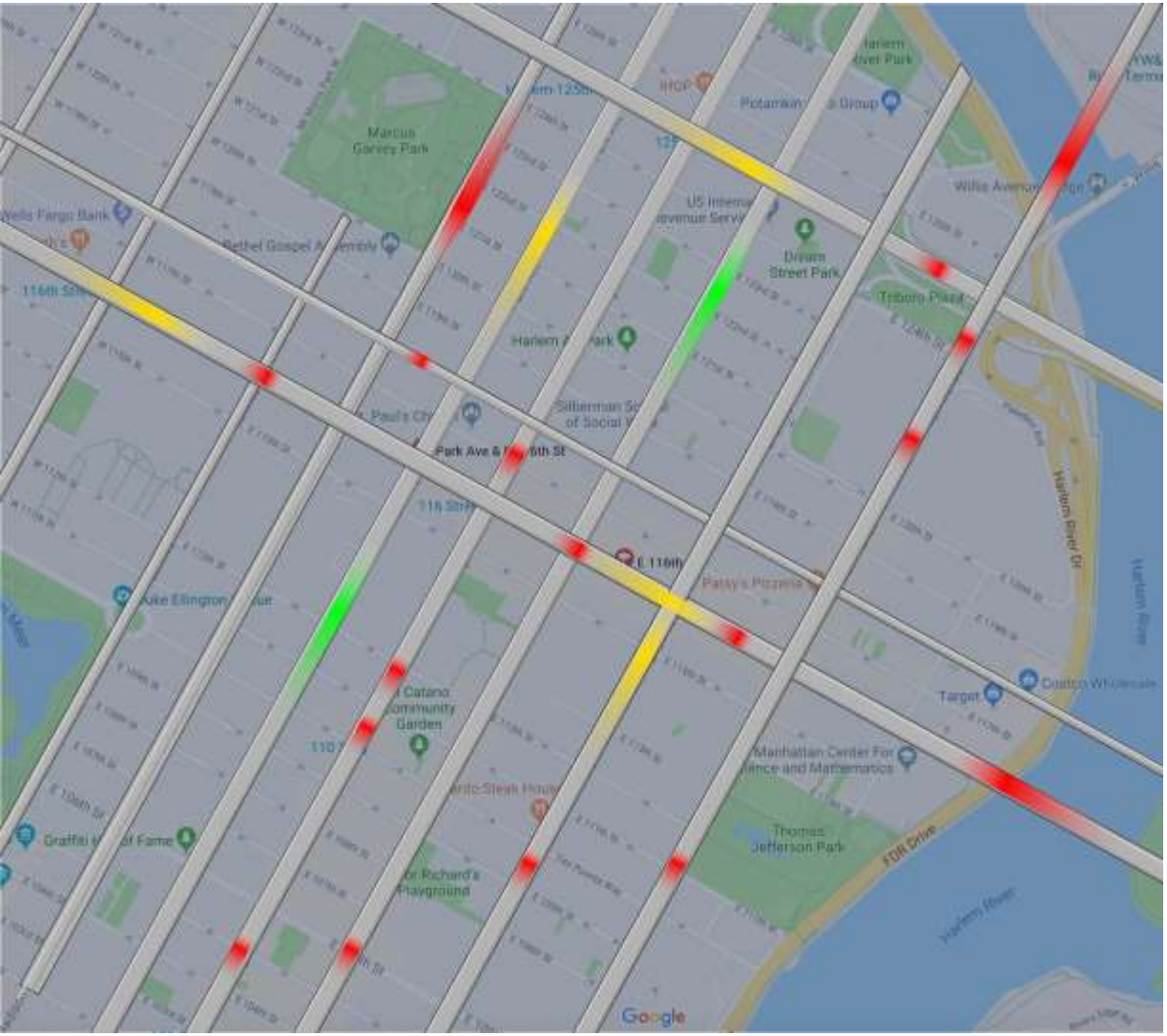
Technology to prevent mislocates and models to identify conditions susceptible to contractor error

Utility's data:

- Asset locations
- Asset characteristics
- Damage event data

Urbint's data:

- Freezes
- Permits
- Roads
- Weather
- Property attributes
- Topology



Main Replacement.

Vulnerable

Cast iron, bare steel, and early plastic mains have known vulnerabilities

Priorities

Thousands of miles are vulnerable with limited funds each year

Main Replacement Prioritization

Models to identify threats to pipe health, estimate cost implications from external factors, and schedule main replacement programs

Utility's data:

- Asset locations
- Asset characteristics
- Leak history

Urbint's data:

- Colocated infrastructure
- Permits
- Roads
- Weather
- Property attributes
- Building attributes
- Topology
- Soil characteristics

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Leak Survey and Emissions Data Collection via Surveyor Vehicle

Aaron Van Pelt – Senior Director, Product Development & Innovation

Picarro, Inc.
Santa Clara, CA

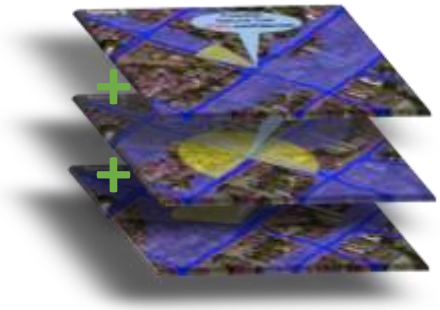
September 19, 2018
Massachuse6s Dept. of Public Utilities
Boston, MA

Supported by the National Association of Regulatory Utility Commissioners &
U.S. Department of Energy Natural Gas Infrastructure Modernization Partnership

An introduction…

- Picarro's mobile leak detection technology allow natural gas leak plume data to be collected at a speed and scale not previously possible
- Picarro's advances in "Big Data" Analytics allow better-informed conclusions to be drawn from that data and action taken
- Methane data can be collected once and used for multiple applications:
  - Leak Survey
  - Emissions Quantification / Reduction
  - DIMP Initiatives

Data Collection



Data Management

Decision Support

Picarro's Advanced Leak Detection (ALD) Technique

US Patents covering Picarro's so5ware, data analytics & hardware specific to natural gas applications:
14 issued: (9,719,879. 9,645,039 B1. 9,696,245. 9,618,417. 9,606,029. 9,599,597. 9,599,529. 9,557,240. 9,500,556. 9,482,591. 9,470,517. 9,322,735. 9,310,346. 9,274,031)
3 pending: (15/088885. 14/534022. 14/326195)

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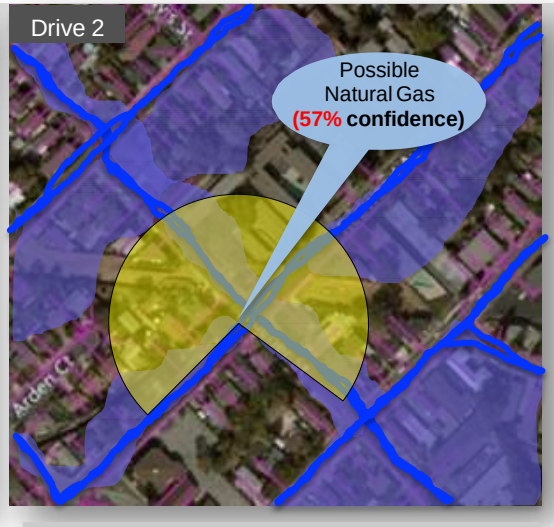
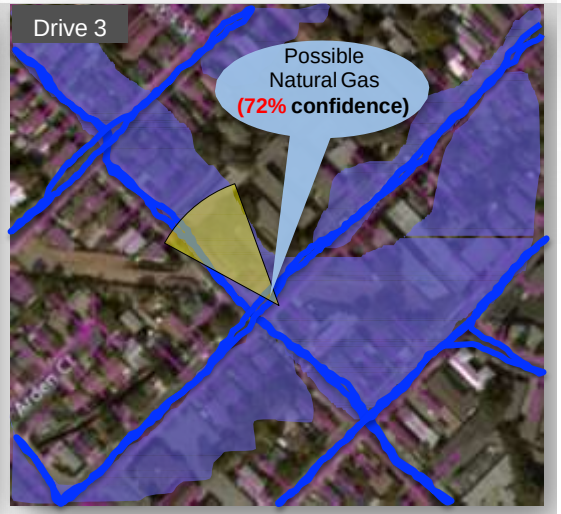
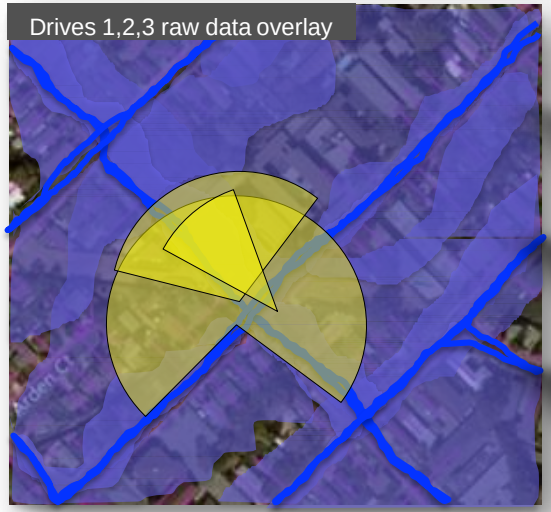
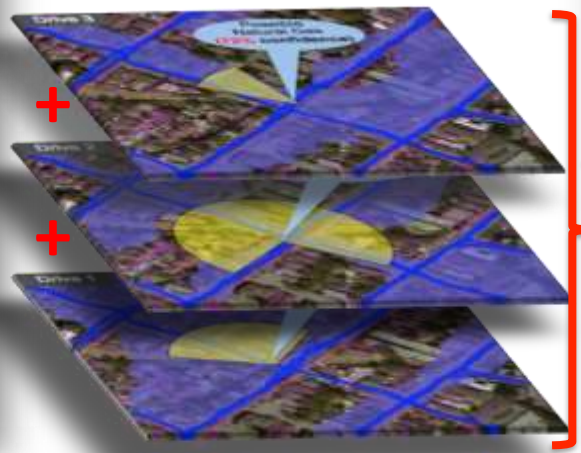
Data from multiple drives is processed by analytics to improve leak location, coverage & source attribution

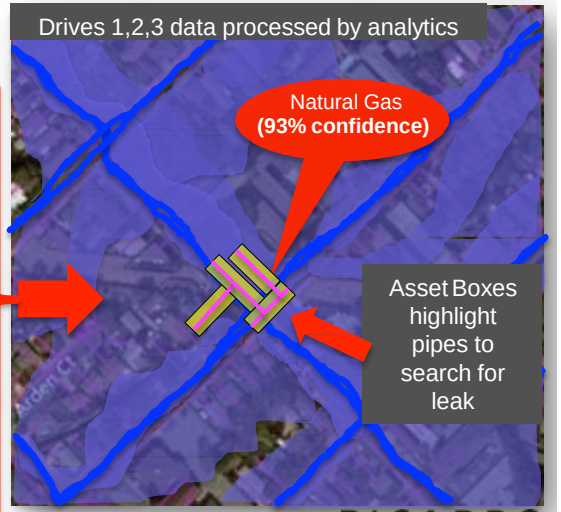






Ethane source attribution, **search areas** & **Field of View** combined by analytics over multiple drives





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Labor Efficiencies: targeted follow-up assignments

Typical Leak Survey Results – Targeting Investigations Efficiently

"Gap" (area not covered by Picarro FOV™ Coverage Area requiring foot survey)

Assets associated with a leak indication requiring investigation

Typical 90% FOV™ coverage example

PorTolio of Analytical Solutions

Suite of configurable & customizable analysis modules to address each customer requirement

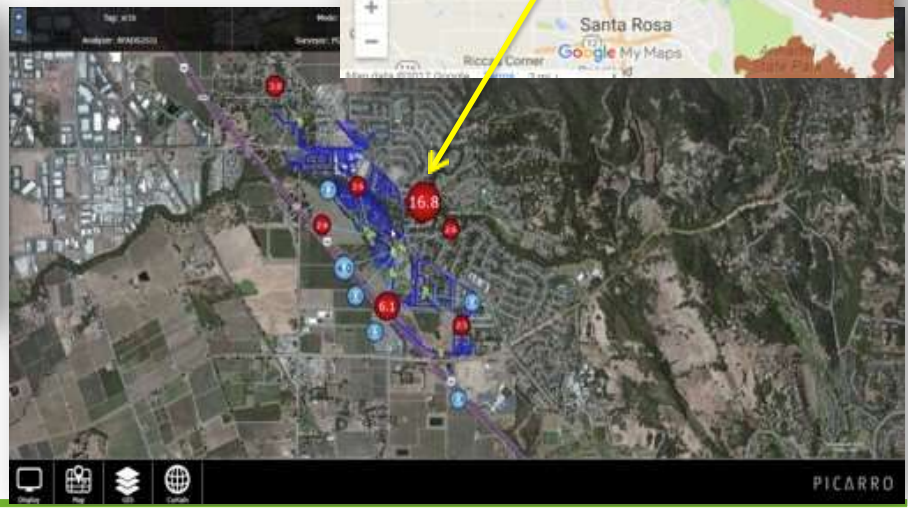
Rapid, Large-Area Emergency Survey

- Picarro's system has been used after events including:
  - Earthquakes
  - Tornadoes
  - Hurricanes & Floods
  - Wildfires
  - Over-Pressurization
  - Gas Odorant Loss

Emergency survey a`er Napa earthquake, PG&E

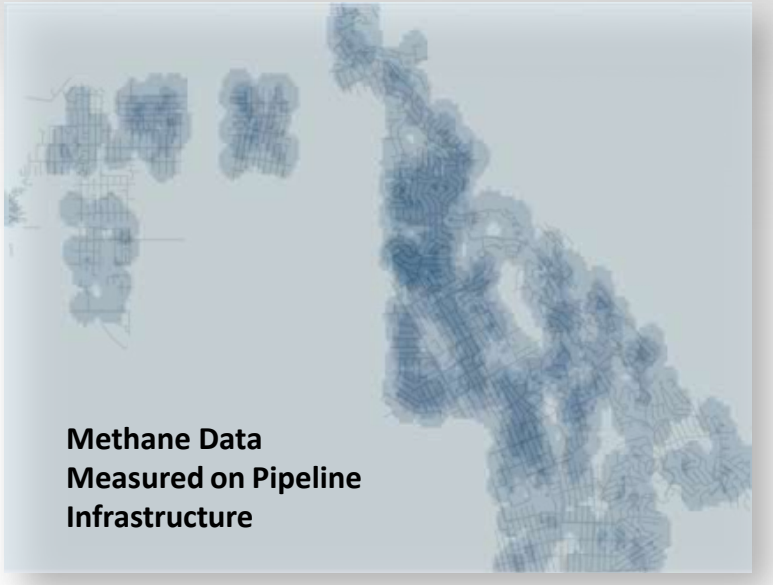
Emergency survey a`er Sonoma wildfires, PG&E

Emergency survey a`er Harvey & tornadoes (Centerpoint Energy, TX)

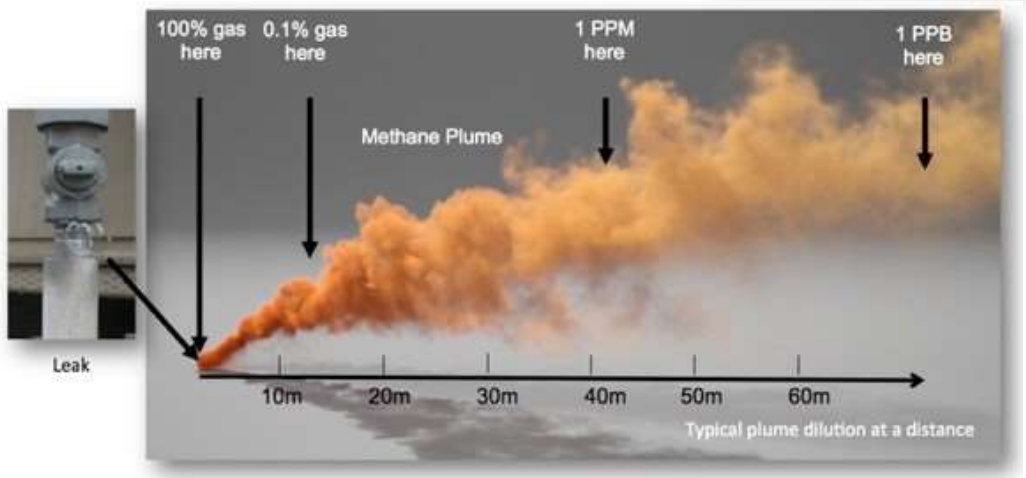


What's Different about Methane Data

- Measuring methane data provides a "live" snapshot of the current state of pipelines
- There are qualities of methane plumes (shape/size/flux etc.) that we can measure that correlate to the risk, size and type of the leak that created the plume



Methane Data Measured on Pipeline Infrastructure



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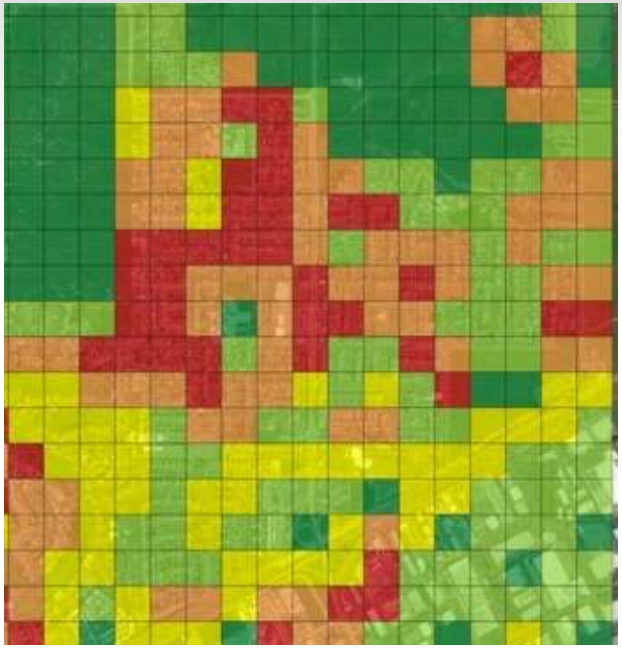
Risk Ranking Analytics

- Leak plumes have characteristics we can measure relating to leak grade
- Indications are risk-ranked in bins based on potential of being priority leaks
- Percentile bins are:
  - top 10%
  - top 25%
  - top 50%
  - bottom 50%
- Analytics settings can be tailored to specific Utility goals:
  - Budget optimization
  - Maximize risk reduction
- Settings can be adjusted to favor detection of below-ground Grade 1&2 leaks, with less sensitivity to above-ground and Grade 3 leaks
- Machine learning algorithm continuously improves over time

- Color indicates risk rank prediction
- Number indicates final leak grade

PG&E's Risk-Based Compliance Survey Framework

- PG&E is working with Picarro to develop a predictive leak model to explore the concept of risk-based leak survey
- Evaluating a model that predicts the number of leaks per map area using:
  - Historical below-ground leak data
  - Mobile survey (methane) data
  - Current PG&E DIMP model risk scores per map

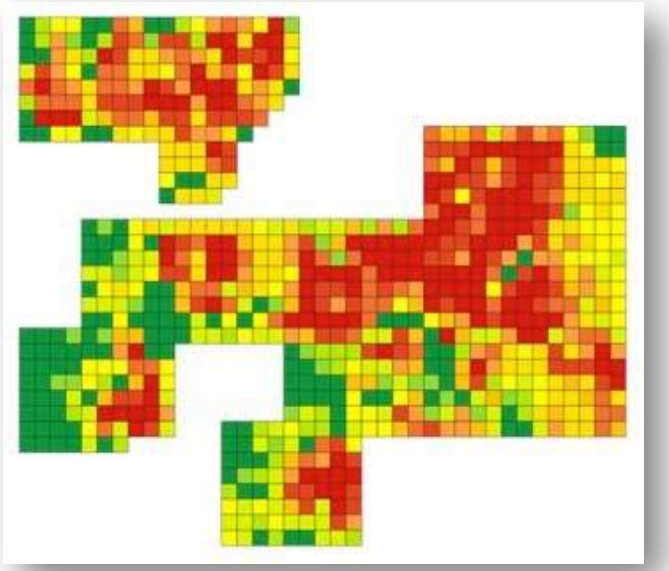


- **Motivation:**
- PG&E wants to focus leak surveys on the areas with potentially more leaks
- Risk-based survey will identify areas with higher probability of leaks and accelerate the surveys of these areas
- Areas to be surveyed will be prioritized independently of the time interval since previous survey

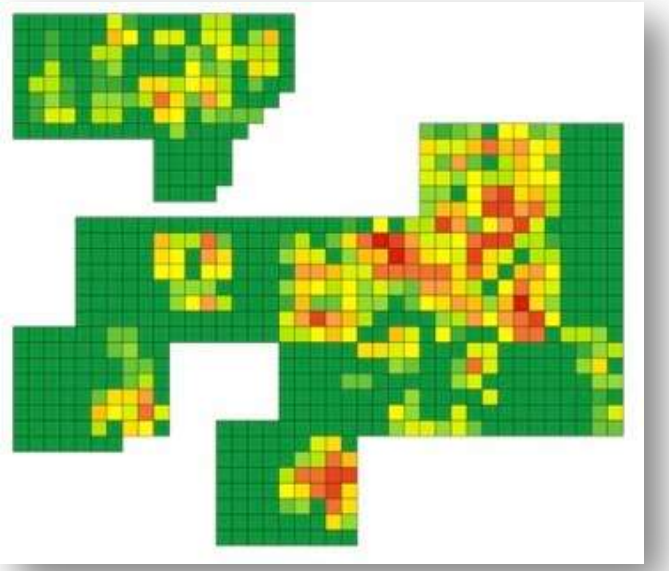
Forecasting (for Leak Survey)

- Forecast annual O&M and labor due to leak survey & leak repair activities
- Provides projected number of Picarro leak indications to inform labor allocation
- Enables more efficient scheduling of Picarro leak investigations

Predicted total leaks (above & below ground)
(**Highest leak survey cost**)



Predicted below-ground leaks
(**Highest O&M repair cost**)



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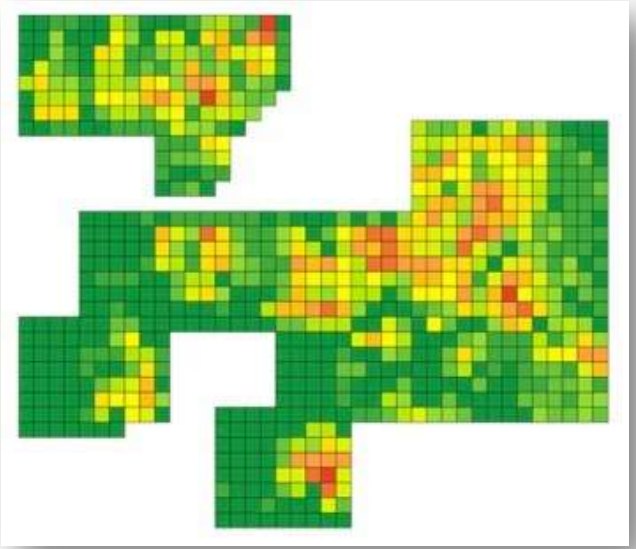
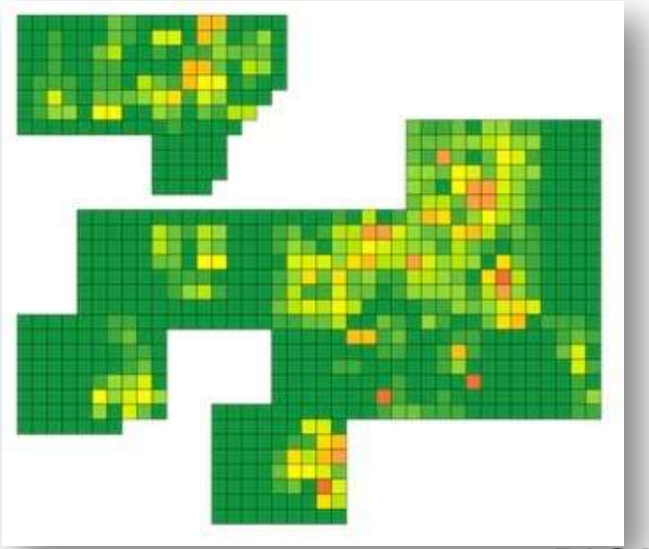
Risk Mapping (Analysis of System Risk)

- Provides high-level visualization of system risk
- Visualization of system risk helps support risk management, asset management, & capital prioritization decisions
- Allows mapping of
  - highest-risk areas to identify areas with highest likelihood of hazardous leaks
  - areas most likely to have below-ground leaks that could migrate especially in winter months

Most potential hazardous leaks (grade 1 & 2)
(**Highest overall risk**)



Highest-emitting potential leaks (high leak rate)
(**Highest migration risk**)



Emissions Quantification & Leak Density Estimation Analytics

- Using methane data, Picarro's analytics estimate leak density & emissions of pipe segments rather than identifying individual leaks
  - Significant emissions reduction by identifying pipe segments with highest leak density for repair/replacement
  - Significant O&M cost avoidance by identifying pipe segments with highest leak density for capital replacement
- Better informs targeted emissions & risk reduction programs

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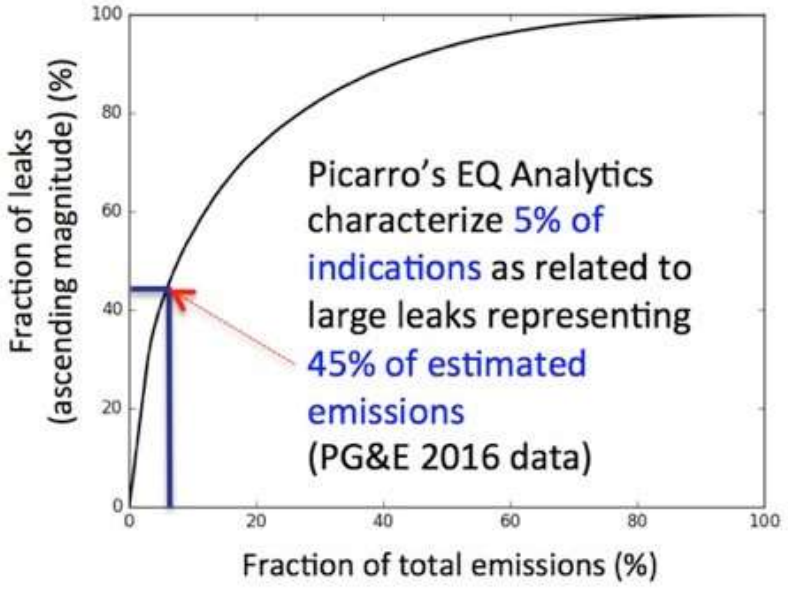
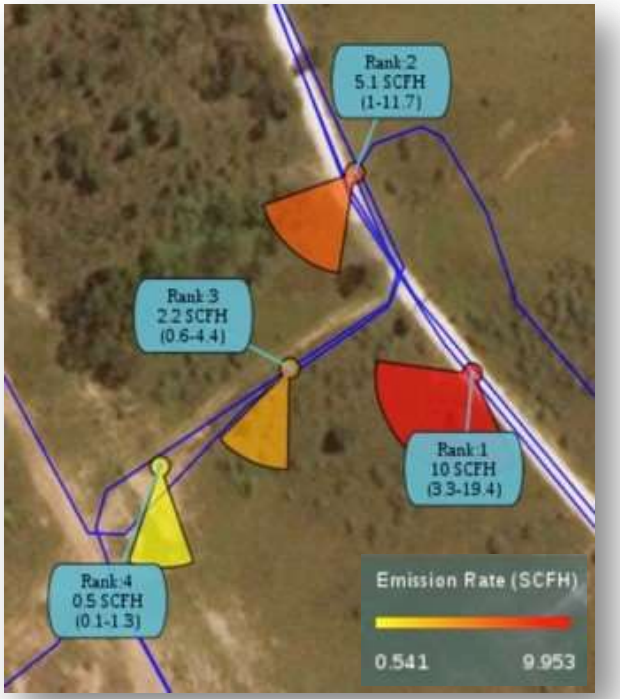
Emissions Quantification (EQ) Analytics

- PG&E using EQ capability for methane emissions reduction & compliance with California Leakage Abatement Ruling (SB-1371)
- 2017-18 project to locate "super emitters" for repair (leak rates >10 cubic feet per hour)
- 2018: PG&E began "super emitter survey" of 100% of their network – expect to be complete by year end



Emissions Quantification Example



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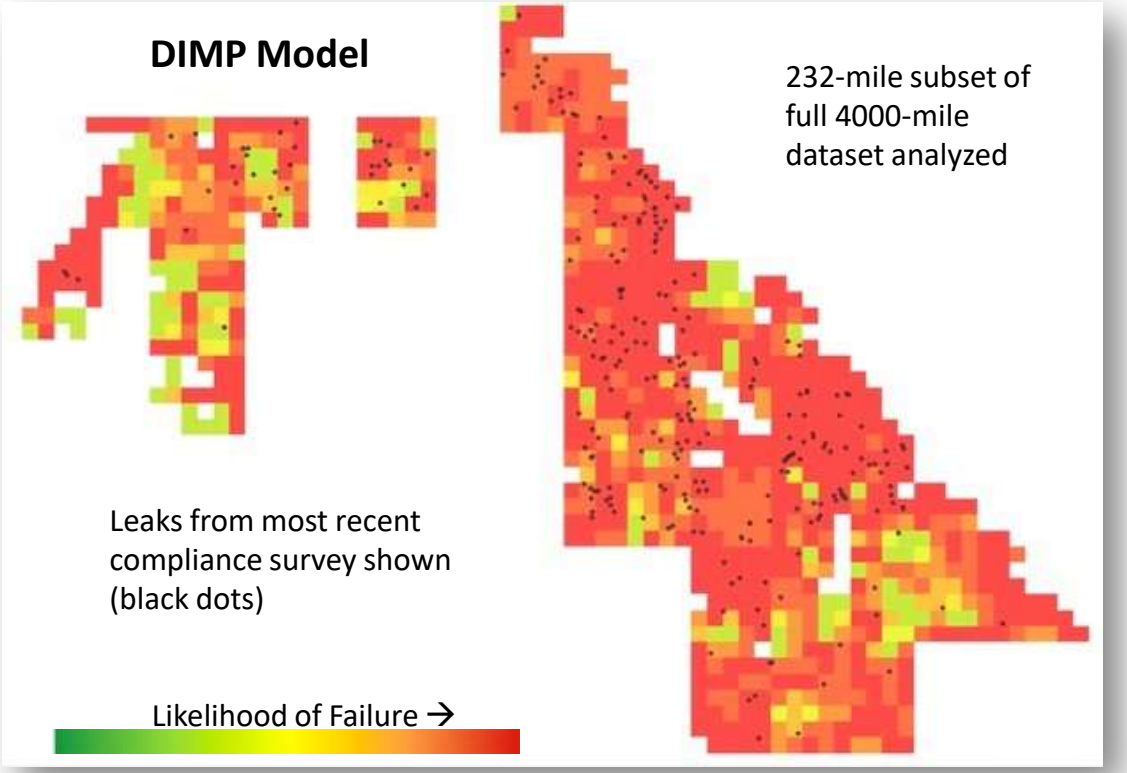
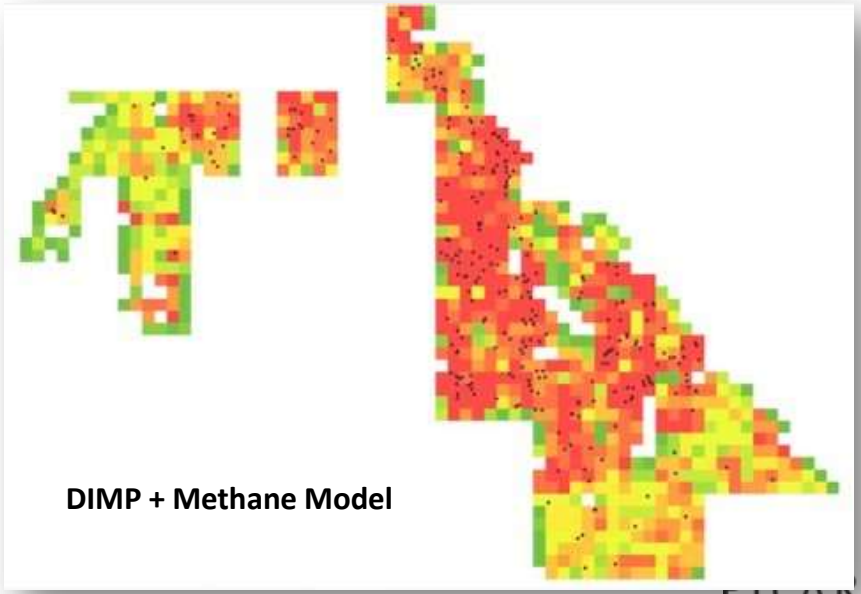
Current Existing DIMP Models

- Use **DIMP model** to define the **top 1% of highest risk grid cells** for **replacement** across an example dataset of 4000 miles of pipe:
  - The top 1% of grid cells defined by the **DIMP model** contain **60** below-ground leaks



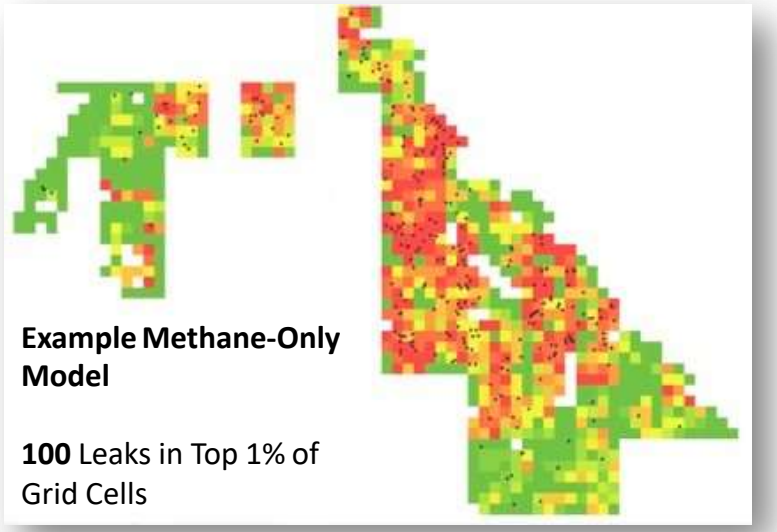
Improving DIMP Model: Combined Picarro Methane Data + DIMP Model

- **Combine the DIMP model** and the **Picarro mobile methane model**
- Adding mobile **methane** data provides a more accurate view into the riskiest areas identified by the DIMP model
  - The top 1% of grid cells defined by the **DIMP + methane** model contain **165** below-ground leaks
  - Number of leaks removed by pipe replacement **increases by 2.75x** compared to the DIMP-only model
  - **Leaks** found **confirm** DIMP + methane data model is more **accurate**
  - Many areas that DIMP model deemed **high LoF** became **low Lof** since they actually have **low methane emissions**
  - Some areas that DIMP model deemed **low LoF** actually have **high methane emissions** and became **high LoF**



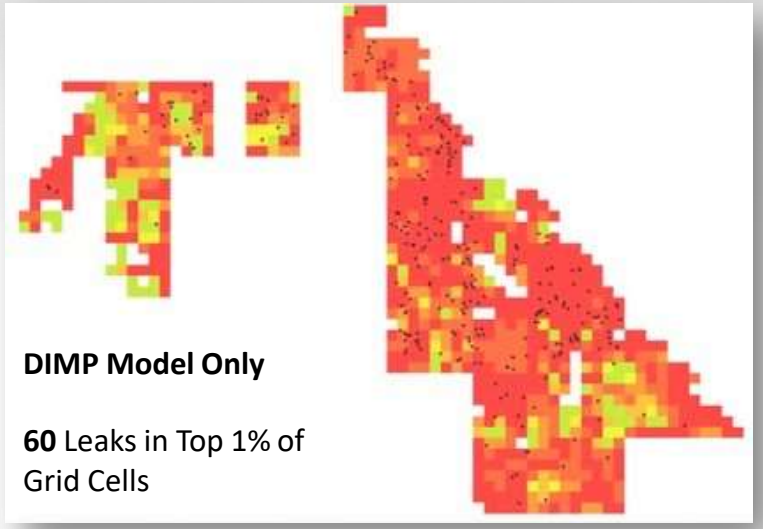
Pipe Replacement

- Models compared: leaks removed assuming pipe replacement done in the top 1% highest-risk grid cells in 4000mi data set
- Capital prioritization efficiencies are realized



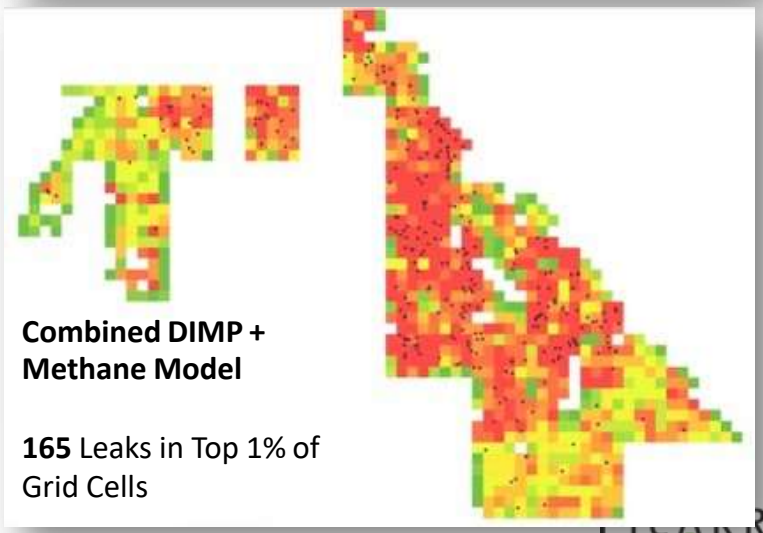
Example Methane-Only Model

100 Leaks in Top 1% of Grid Cells



DIMP Model Only

60 Leaks in Top 1% of Grid Cells



Combined DIMP + Methane Model

165 Leaks in Top 1% of Grid Cells

Example of Pipe Replacement Application with DIMP + Methane Model

- Collect mobile methane emissions data on the 10% riskiest areas identified by the DIMP model. Use methane data to augment the DIMP model to define the top 1% for replacement.
  - Assume the number of leaks removed by better identification of pipe replacement projects increases by 2.75x (using DIMP + methane model)

- Applying this logic to a hypothetical large utility with 25,000 miles of main:
  - 656 additional leaks are removed by capital dollars via pipe replacement
  - These leaks would incur O&M expense to repair if found by leak survey or odor calls
  - Typical O&M repair cost of $3,000 per below-ground leak
  - Results in $1.96M O&M cost avoidance of future O&M expense

	Top 1% by DIMP Model	Top 1% by DIMP + methane model	**Difference**
Number of Leaks	375	1031	**+ 656**
O&M Avoidance	$1.13M	$3.09M	**+ $1.96M**