

# LongPath Technologies, Inc.

Scalable, Quantitative & Continuous  
Methane Emissions Monitoring

OMB

October 15, 2021



LongPath Technologies was founded by a team of engineers and atmospheric scientists to bring the best new technologies and methodologies to bear on the issue of methane loss from the oil and gas supply chain.

Mitigation of CH<sub>4</sub> emissions from oil and gas requires rapid action across all facilities  
**Regional continuous monitoring with right thresholds of detection**



The goals of methane detection are 1) to find and fix emissions quickly and 2) to provide direct measurement of emissions, whether for valuation of RSG and ESG metrics or regulatory purposes. To accomplish either, real-time emissions detection is needed, across all sites, and, due to the fat-tailed distribution of problematic emitters, continuously through time. Lastly, the right thresholds of detection are needed to be able to dynamically address both mitigation and emissions quantification needs.

# Continuous Monitoring Matters

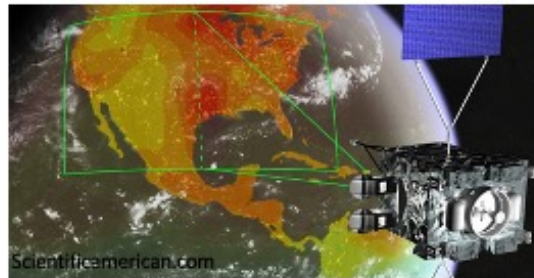
## *Spot check approaches*

- Emissions from O&G are fat-tailed: a small portion of large leaks cause most emissions
- Inspections and aircraft can locate large leaks, but suffer sparse coverage (no temporal context; miss / misinterpret intermittency)
- Satellite methods provide intermittent coverage at coarse resolution

### Current approach



### Aircraft & satellite platforms



This presentation briefly covers two important aspects of methane detection: first, why continuous monitoring is critical, and second, why the ability to quantify emissions with an appropriate threshold of detection is important.

Emissions from oil and gas operations are fat tailed, meaning that a few large and unpredictable fugitive events cause the bulk of overall emissions. The infrequent, unpredictable, and sometimes intermittent nature of these emissions means that spot-check approaches to monitoring or measurement would need to occur with extremely high frequency to be effective.

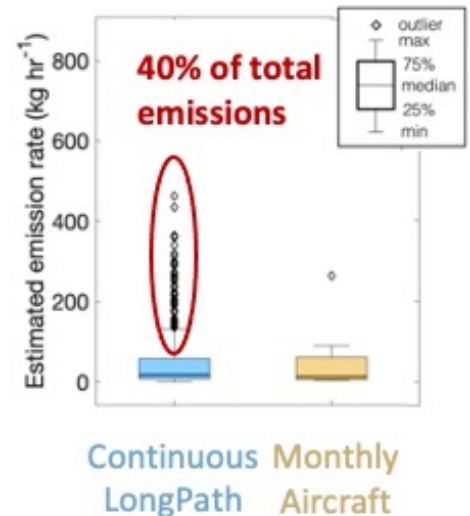
OGI visits and aircraft and satellite fly-bys can locate large leaks, but they lack the temporal context that can help operators diagnose issues. In particular, snapshot-in-time approaches can either miss or misinterpret intermittent events.



# Continuous Monitoring Matters

## Act on most important emissions quickly

- Emissions follow log-normal (“fat tail”) distribution
- **40-80% of emissions from 10-20% of leaks**
- Many large emissions can be intermittent
- Continuous monitoring finds intermittent emissions as they occur ☑ actionable



## Necessary for shifting regulations from:

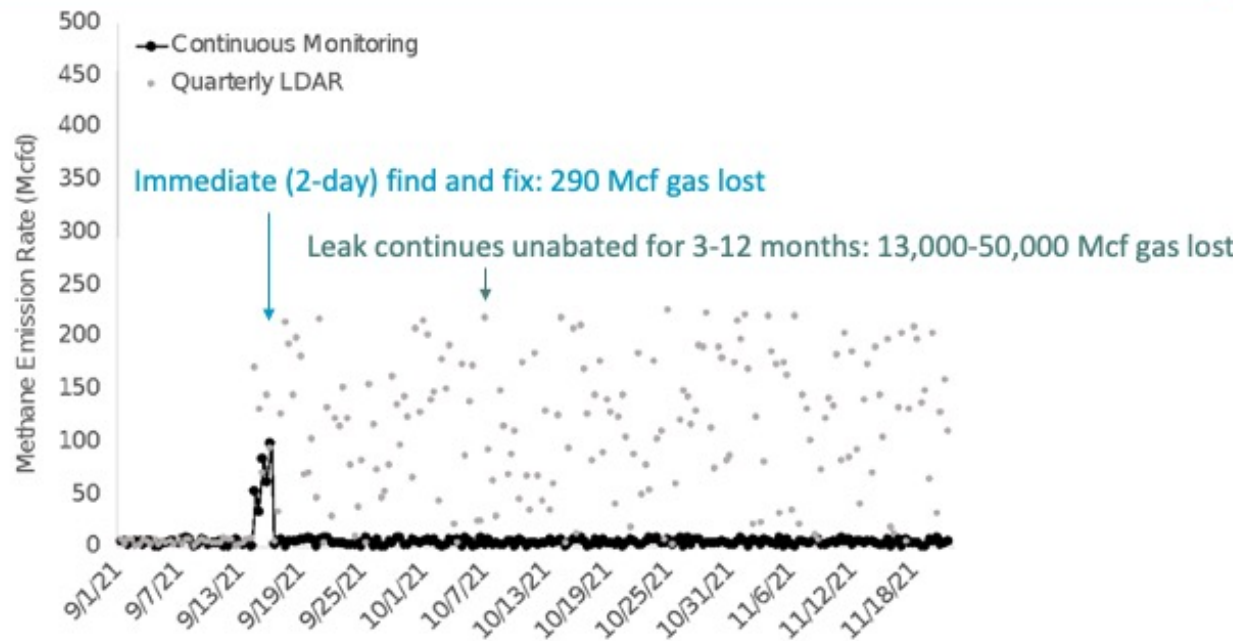
- Prescriptive to performance-based
- Estimated to measured

**\*\*Alden et al., ES&T (2020)**

A year-long continuous monitoring study at an underground natural gas storage facility, performed by this team, proves out this concept: 40% of total emissions came from 10% of emission events. Even very frequent aircraft fly-bys only managed to detect one of these events.

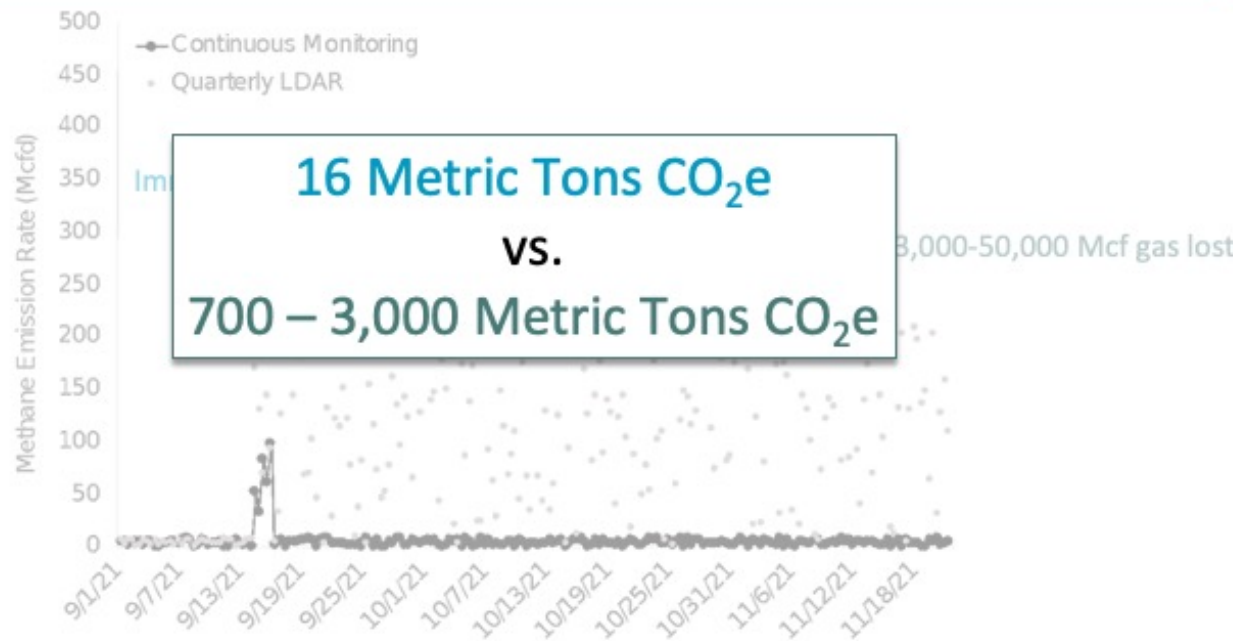
Simply put, continuous monitoring is the check engine light for the oil field -- it allows us to use the 80/20 rule to our advantage and solve the biggest piece of the emissions pie by using the lowest-cost and easiest-to-integrate methods out there.

# Continuous Monitoring Matters



The simulated (modeled, not measured) data shown here is based on real emission events that have been found and fixed using LongPath Technologies continuous monitoring. Here you can see that a simulated fugitive event began on 9/16. Using continuous monitoring equipment, the emission would immediately (within hours to days) be identified as being abnormal, and a field crew would be able to fix the problematic equipment within 2 days. The black line shows that, using continuous monitoring, emissions would return immediately to the baseline value. The gray dots show what would have happened if the malfunction had not been detected until a routine quarterly or annual LDAR visit.

# Continuous Monitoring Matters



The difference in gas lost equates to thousands of metric tons of CO<sub>2</sub>e. Given that continuous monitoring technologies are widely commercially available, there is no reason that this should not be the de facto modality for saving industry money and saving society the impacts of emissions. Aircraft fly-bys, satellite sweeps, mobile methane monitors and routine or even highly frequent OGI visits would have resulted in massive gas losses compared with continuous monitoring.

# Detection Thresholds Matter

**“Super Emitter” Threshold<sup>1</sup> = 26 kg/hr**  
**Regulated Vent Limits = 12 - 14 kg/hr**

<b>Monitoring Platform</b>	<b>Mcf/day</b>	<b>kg/hr</b>
Satellite <sup>2</sup>	130	100
Flyover <sup>2*</sup>	45	35
LongPath <sup>3</sup>	0.2	0.2

Blind tests and field data demonstrate LongPath’s ability to identify emissions across the spectrum, from small emissions to large leaks and vents

<sup>1</sup>Zavala-Araiza et al., Nature Communications (201

<sup>2</sup>Presentations at CH<sub>4</sub> Connections, November 20

<sup>3</sup>Field testing & Alden, et al., Env. Sci. & Technol. (201

\*Lower limits have been recently published with low wind speed

In addition to continuity of measurements, it is critically important to consider a technology’s threshold for emissions detection. The scientific literature defines very large unintended emissions, or super-emitter events, as greater than or equal to 26 kg/hr. Several major platforms for methane detection have detection thresholds that are not sensitive enough to see even these large events, much less offer a nuanced view of total emissions and how they change through time.

Blind tests and field data demonstrate LongPath’s ability to identify emissions across the spectrum, from small to large leaks and vents.



Mitigation of CH<sub>4</sub> emissions from oil and gas requires rapid action across all facilities  
**Regional continuous monitoring with right thresholds of detection**



In summary, to provide the maximum cost savings and societal benefit, emissions monitoring should be everywhere, all the time, and with the right thresholds of detection.



# LongPath Technologies, Inc.



- LongPath's solution is based on Nobel Prize-winning laser technology
- Jointly developed by the University of Colorado and NIST
- Recipient of multiple ARPA-E grants
- Only blind-test validated & peer review published continuous monitoring solution
- Monitoring 200+ square miles by end of 2021
- Poised for rapid scaling in 2022



LongPath Technologies serves this need in a networked fashion that offers high-value monitoring to the industry for a very low cost.

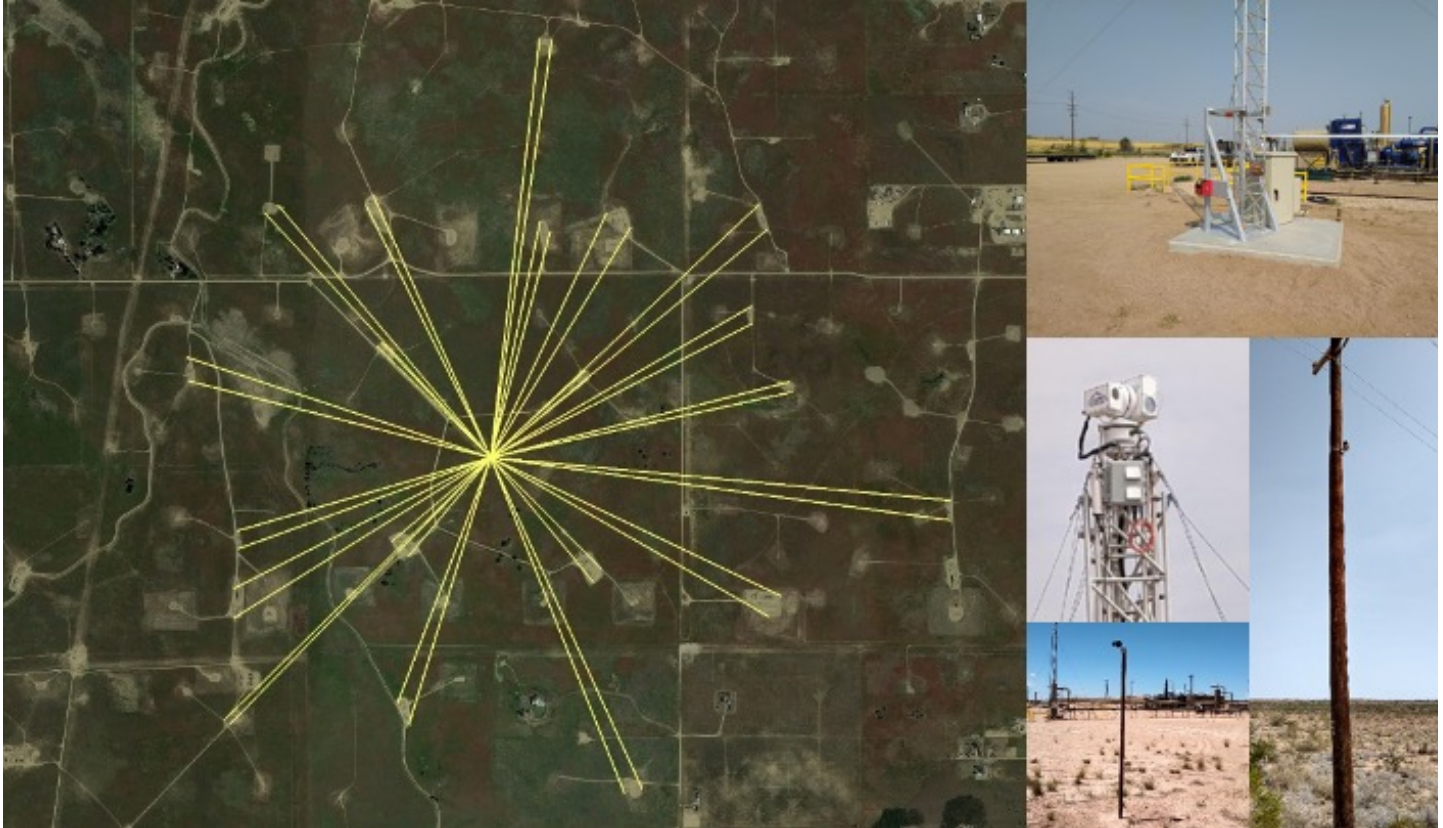
Our solution is based on Nobel Prize winning Dual Frequency Comb Laser Spectroscopy that was jointly developed by the University of Colorado and NIST, coupled with inversion algorithms jointly developed by the University of Colorado and NOAA.

We are the recipients of multiple Department of Energy ARPA-E grants, first to develop the tech and later to commercialize and scale.

We are the only continuous monitoring solution that has published our blind-validation testing results in the peer reviewed literature. This means that there will be no surprises when it comes time for regulatory approvals and demonstrating quality control of monitoring and data.

LongPath is out in the field with multiple E&P partners, with monitoring of over 180 facilities by the end of 2021.

We are poised for rapid scaling in 2022, both in terms of our financial backing and our production capabilities.



LongPath Technologies uses a single centralized node to deploy a laser spectrometer on a small tower. All power and communications occur at that one location.

The laser is a dual frequency comb spectrometer, which gives part per billion precision measurements of the open atmosphere, currently up to distances of over 2.5 miles and growing.

At each facility that we monitor, we post small retroreflective mirrors that are passive and require no power, communications or maintenance.

These retroreflectors can be placed on existing infrastructure, or on small hydrovaced poles on the periphery of pads.

At the end of the day, what is delivered to the customer is continuous, time resolved, real-time emission rates on a facility-by-facility basis. Also included is a smart automatic alerting system to notify the operator if problematic emissions do occur.

# Why LongPath?

## 1) Continuous

- Emissions events reported to operator in real-time

## 2) Quantitative (Mcf/d)

- Detects events <6 scfh at distance of 1 mile
- Quantify emissions reductions / confirm low emissions

## 3) Scalable

- Networked coverage of facilities 2.5+ miles away
- Lowest cost maintenance-free continuous monitoring platform
- 60 to 240 measurements for the cost of one flyover visit

## 4) Automatic Alerts

- Automatic email & text notification of leak detection in real-time
- Dynamic statistically determined threshold for each facility
- Real-time data via dashboard, Mongo Data Base, RSS feed

## 5) Lifetime Maintenance

- System hardware and software is owned and maintained by LongPath
- LongPath coordinates all installation and communications

The key differentiators of LongPath from other technologies are the following:

First, what the system delivers is time resolved emission rates, not concentration. This means that the operator does not need to perform any complicated interpretation of the data – gas losses can be directly compared to gas production.

Second, the emission rates are quantified, which means that emissions reductions and the confirmation of low emissions can be measured.

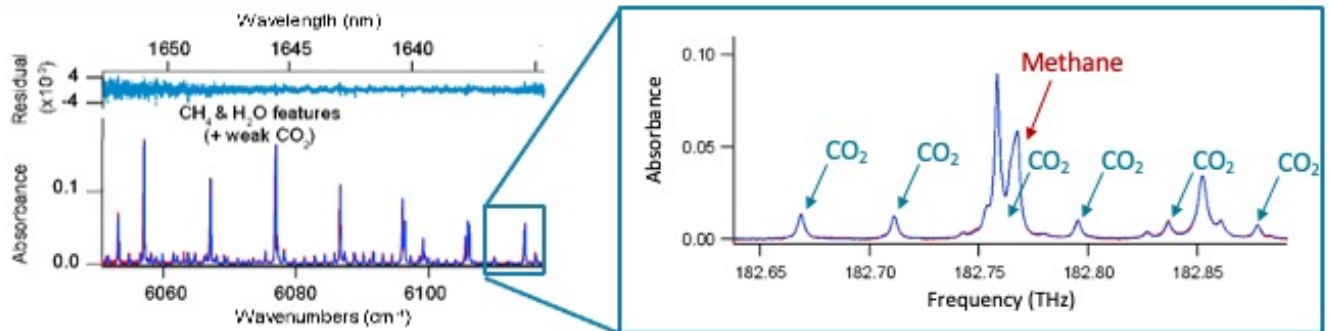
Third, the solution is highly scalable. We are creating a network of coverage so that all operators can benefit from a low cost point of entry into continuous monitoring. For example, dozens to hundreds of quantified rates, from tens of thousands of continuous measurements, can be obtained for the cost of one flyover visit.

Fourth, we provide automated real-time streaming of data to the customer, with automated alerts and no false positives to date with dynamic alert thresholds.

Finally, we install and maintain everything, including cellular communications, and because of the lifetime covered maintenance for the customer, we are by far the lowest cost solution on the market.



# Dual Frequency Comb Sensor



**Frequency comb: 50,000+ wavelengths of eye-safe infrared light**

**Senses unique pattern of absorption by quantum energy level transitions in molecules**

**Same frequency comb technology in optical clocks at NIST**

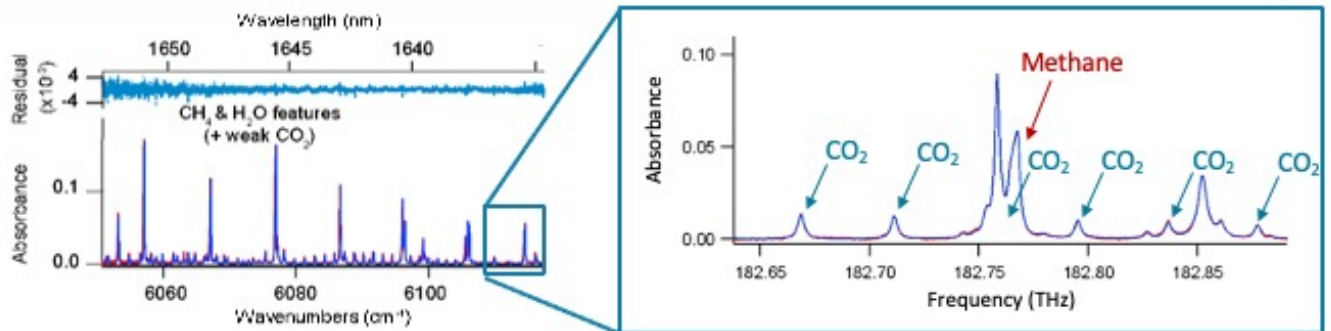
This slide demonstrates how frequency comb technology, originally the recipient of a Nobel Prize, and later developed out by our team for rugged and remote use in the field, provides unprecedented precision and stability for methane sensing.

Frequency combs emit tens of thousands of different wavelengths of eye-safe infrared light. All elements of the laser are low-cost and easy to procure, because the technology is based on telecom industry fiber materials.

The laser senses unique patterns of absorption, leading to extremely precise, direct measurement of methane, water vapor and carbon dioxide.



# Dual Frequency Comb Sensor



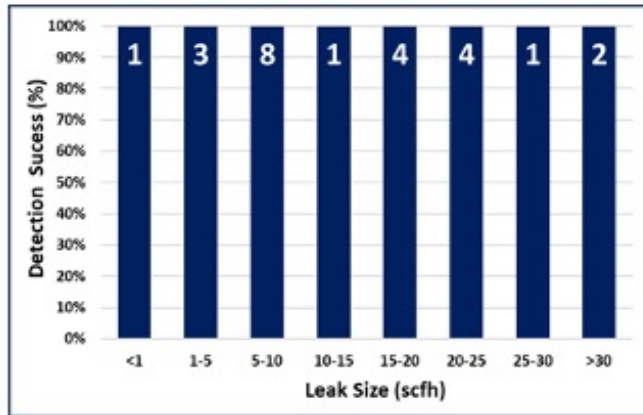
- Never drifts, never needs calibration
- No cross-species interference
- No sensor aging, or water vapor degradation, etc.
- Telecom optical fibers and components w/ 7+ yr. lifetime

This means that the sensor never drifts and never needs calibration. It can remain in the field for many years with no degradation.

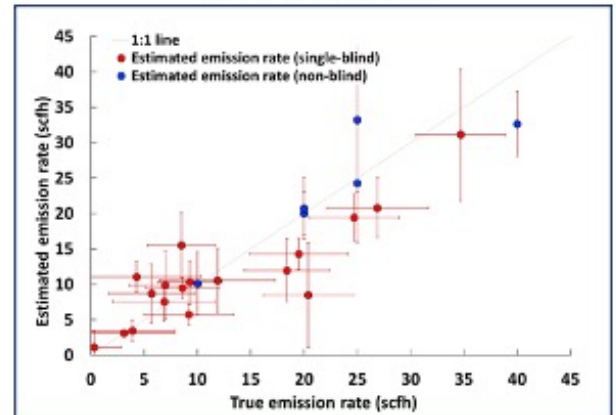
This also means that there is no cross-species interference – water vapor is measured directly, and so it does not produce interference signals in the ways that, for example, metal oxide sensors must contend with.

# Blind METEC 3<sup>rd</sup> Party Validation

**Detection**



**Quantification**



## Two rounds METEC blind testing

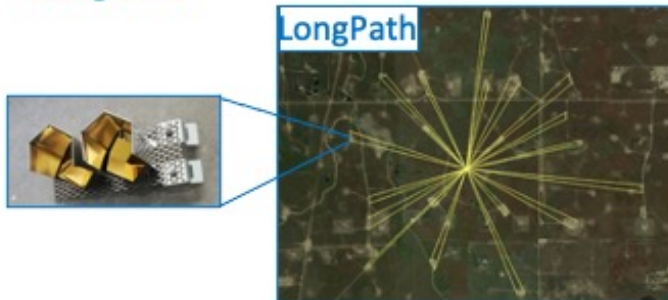
- 30+ leak scenarios
- 100% True Positives and 100% True Negatives

Alden, et al., *Env. Sci. & Technol.* (2019)  
Coburn, et al., *submitted*

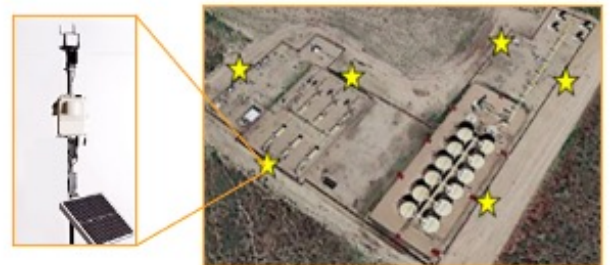
We have published blind validation testing results in the peer reviewed literature, demonstrating the detection and quantification capabilities of the system as robust and verified.

# LongPath Scalable Solution

## LongPath



## Point Sensors



**1 LongPath system** does the work of 80+ point sensors (each with own comms, calibration & maintenance)

**1000 LongPath sensors** to cover entire Permian, 7+ year lifetime

The way that we deploy this laser means that the already low cost of the laser is spread across many many facilities, enabling a highly scalable solution in a "network" of coverage. Each single laser system does the work of 80+ point sensors. There is only one point for power and communications with our system, and the tower can provide societal co-benefits such as broadband networking support for rural communities.

It would only take 1000 LongPath sensor to cover the entirety of the Permian Basin – the cost and logistics of this would be a tiny drop in the bucket for oil and gas.

## Low, Predictable Cost to Implement/Maintain



	LongPath		Laser-based Point		Metal Oxide Point	
Calibration	✓	Never	✓	Never	✗	Yes
Sensor Aging	✓	Never	✓	Never	✗	12-24 month life
H2O interference	✓	No		Minimal	✗	Yes
Peer-review Blind-test	✓	Yes		--		--



Very well-positioned for EPA acceptance

This slide demonstrates in table format how LongPath compares with point sensors. Any continuous monitoring system will provide high value to the oil field, but the calibration, sensor aging, water interference and proven nature of LongPath make it very well positioned for a smooth transition to regulatory support.



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Peer-review Blind-test	✓	Yes		--		--
Daily cost per facility (over 2 yr deployment)		<\$22/day		>\$60/day		\$23/day



Includes install, maintenance, final OGI leak locate

Finally, the cost of the LongPath system is the lowest total cost of ownership on the market. Furthermore, the all-in costs include final leak locate with an OGI camera, making this solution extremely actionable and easy to integrate into current work practice for the industry.

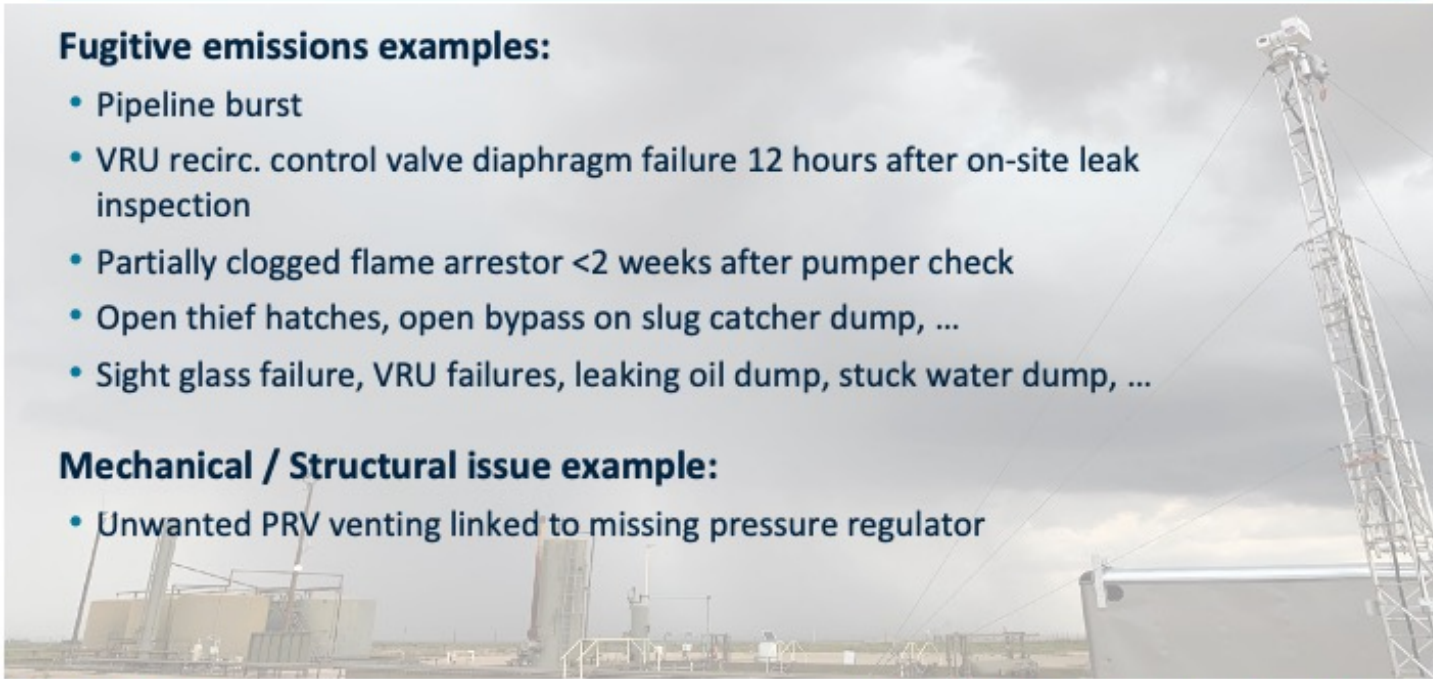
# Examples of Emissions Found & Fixed

## Fugitive emissions examples:

- Pipeline burst
- VRU recirc. control valve diaphragm failure 12 hours after on-site leak inspection
- Partially clogged flame arrestor <2 weeks after pumper check
- Open thief hatches, open bypass on slug catcher dump, ...
- Sight glass failure, VRU failures, leaking oil dump, stuck water dump, ...

## Mechanical / Structural issue example:

- Unwanted PRV venting linked to missing pressure regulator



This slide shows a few examples of the kinds of emissions – both fugitive and structural – that LongPath has been able to mitigate.

# Permian/Anadarko Pilots Emissions Examples



## Fugitive emissions examples:

- Pipeline burst
- VRU
- insp
- Par
- Op
- Sight glass failure, VRU failures, leaking oil dump, stuck water dump, ...

**Demonstrated win-win:**  
**LPT provides the best overall gas loss reductions**  
**and costs are largely offset by gas savings**

## Mechanical / Structural issue example:

- Unwanted PRV venting linked to missing pressure regulator

In short, LongPath provides the best overall gas loss reductions, with its networked coverage of continuous and sensitive detection threshold monitoring, and the monitoring costs are largely offset by the gas savings provided to the customer.

# Methane is Not an individual Operator Issue...

## It is an Industry- & Society-Wide Issue...

The New York Times

*Here Are America's Top Methane Emitters.  
Some Will Surprise You.*



LongPath Technologies

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Oil & Gas companies have struggled to find cost efficient methods to detect emissions and pin-point the sources. It is not a company-to-company issue, it is an industry-wide and society-wide issue that requires a holistic and networked approach.

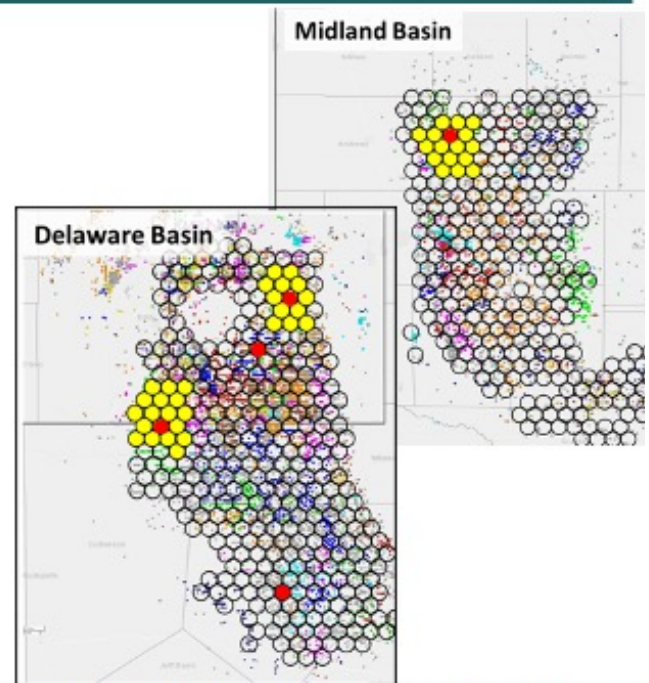


# Methane is Not an individual Operator Issue...

**It is an Industry- & Society-Wide Issue...**

## **LongPath offers a Basin-wide Approach**

- Telecom-style network for Continuous Monitoring
- Full Solution to enable LDAR by Exception



LongPath offers basin-wide solutions to this issue, allowing industry, regulators and other stakeholders to work together in support of a monitoring network that can provide a win-win to all parties.