UAV Based Open Optical Path Sensing – TDLAS

Detecting Leaks & Quantifying using UAV Based TDLAS Data

FIRMATEK

Firmatek's Simple Approach

We specialize in advanced geo-spatial mapping and engineering solutions for the solid waste industry, using drones as our primary data collection method.

After analyzing available sensor options, we chose TDLAS and collaborated with manufacturers to align workflows with mapping methodologies.

With background in 3D mapping, applied a fundamental mapping style approach like how we would fly our other payloads.

Our goal is to provide clear, accurate, and detailed insight for managing landfill emissions.

Firmatek's Timeline

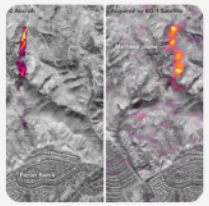
2022

About 10 flights, continuing improvement of data collection

Learning Curve

2023

Participated in EREF controlled release study



Controlled Release

2024

Adopted Purway sensor, for gimbal mounted more dynamic sensor.

Purway Sensor

2024

Conducted well over 200 methane detection flights utilizing TDLAS

200+ Flights

2021

PRESENT

First TDLAS Sensor

2021

Began R&D to utilize TDLAS for Leak Detection

Launched as Leak Detection Service

2023

About 40 flights, continuing improvement of data collection

30 Flights

2023

Expanding interest in new technology resulted in more industry leaders to consider

Continued Growth + Leaning

2024 -

2024 EREF Controlled Release, 3 research projects with industry stake holders & Academia. More internal/external R&D.

Tunable Diode Laser Absorption Spectroscopy

How TDLAS Works:

Tunable Diode Laser Absorption Spectroscopy (TDLAS) technology works by emitting a laser beam at a specific wavelength that corresponds to the absorption characteristics of the target gas. As the laser passes through the air, gas molecules absorb a portion of the light. The amount of light absorbed is directly related to the gas concentration. By analyzing the returning light, the sensor accurately measures the concentration of gases, such as methane.

Variations in Naming:

- Differences reflect setup types, such as **closed-path** (point measurement) vs. **open-path** (column measurement)
- Measuring the absorption of light through particles

Proven Technology:

- **TDLAS** has been used for over 60 years.
- It is widely known as a reliable and accurate method for spectrochemical analysis.

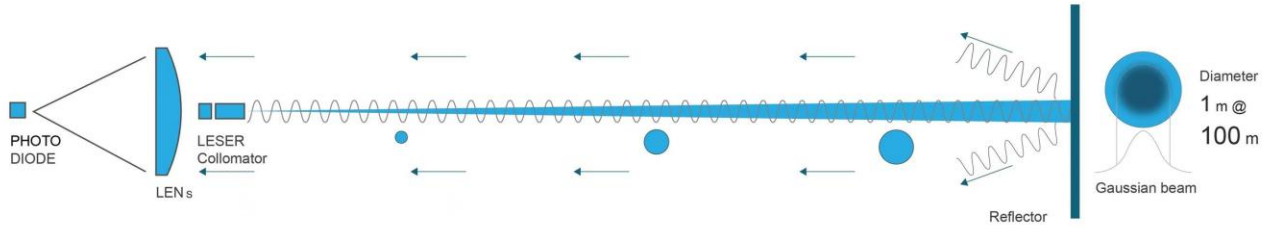


Figure Provided by Purway Innovation Technology Company

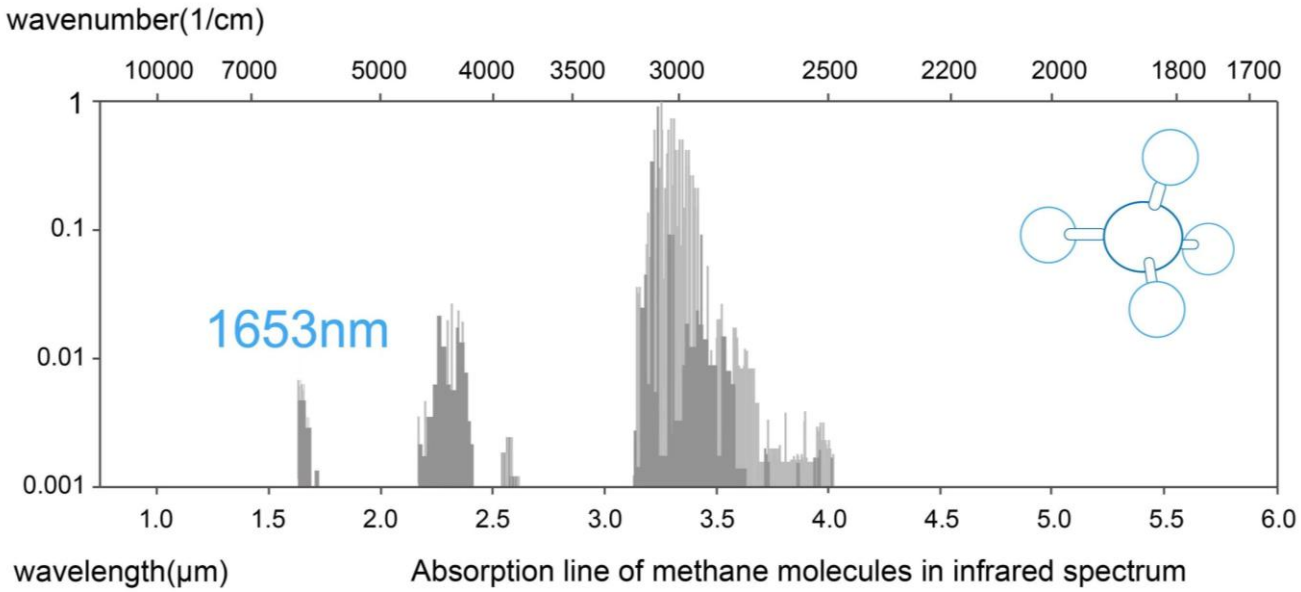


Figure Provided by Purway Innovation Technology Company

Bird’s Eye View of TDLAS In-Action

TDLAS & Method-21

Column vs. Point Measurement:

- TDLAS = column-integrated measurements (ppm·m) over a distance
- NSPS/SEM requires point-specific measurements (hits = 500+ppm) at the surface vs column measurement

Regulatory Misalignment:

- SEM regulations require – 5-10cm above ground surface
- TDLAS operates at higher altitudes, which does not meet this proximity requirement

No Standardized Protocol for TDLAS:

- No standardized approach currently in place for TDLAS for SEM compliance under NSPS

Susceptibility to Atmospheric Variables:

- Environmental & Atmospheric variables are thought to influence data, How? Solutions to mitigate?

Example of "Ground Truthing" Readings

Atmospheric/ Environmental & Other Variable Conditions

Data Collection Optimization:

- Optimize data collection with flight line spacing, orientation, condensing data collection windows
- Less Atmospheric variation with shortened data collection timeframe

Enhancing Detection Consistency:

- Log weather data from multiple sources
- Collaborations with Republic Services & Flux Labs improved detection accuracy and explored leak quantification
- Applying wind corrections and atmospheric adjustments to enhance data precision

Topography Challenges:

- R&D on flight altitude to mitigate connectivity issues
- DSM terrain follow, must be accurate elevation data
- Laser Altimeter

Example of Drone-Mounted Anemometer

Operational Limitations

Wind Limitations:

- 30mph UAV operating limit

Chemical Interference:

- Haven’t specifically tested chemical interference
- Can distinguish heavy gases that are not CH4 (SNR)

Snow Cover:

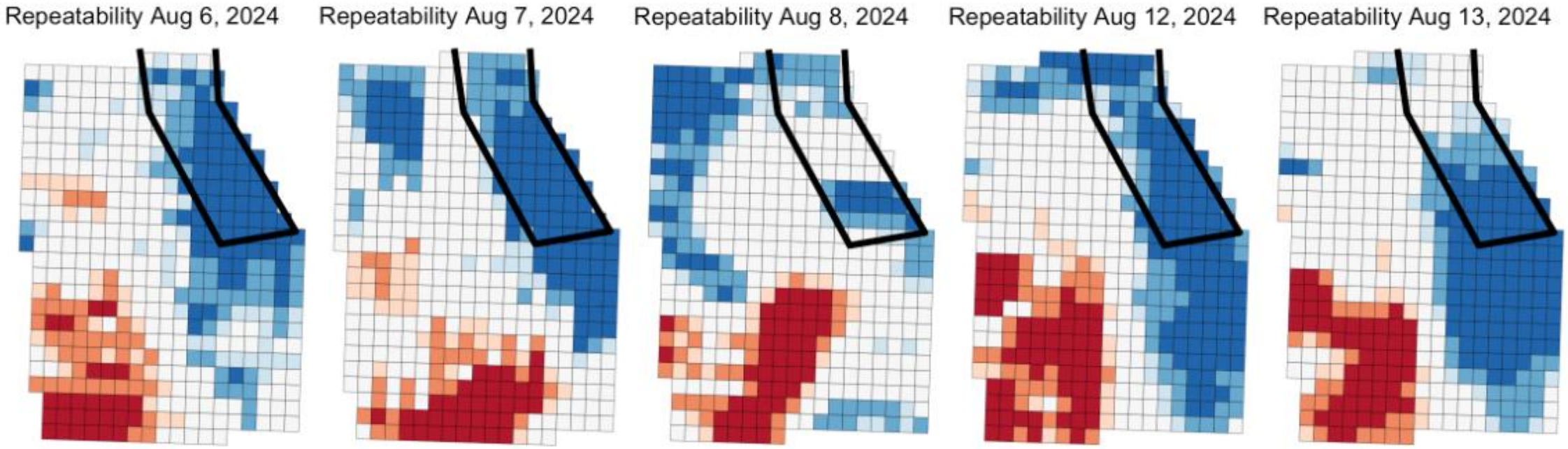
- Haven’t specifically tested
- Reasonable to believe laser would scatter

Coverage Capability:

- Capable of flying 400+ acres in 8hrs

Example of snow-covered landfill.

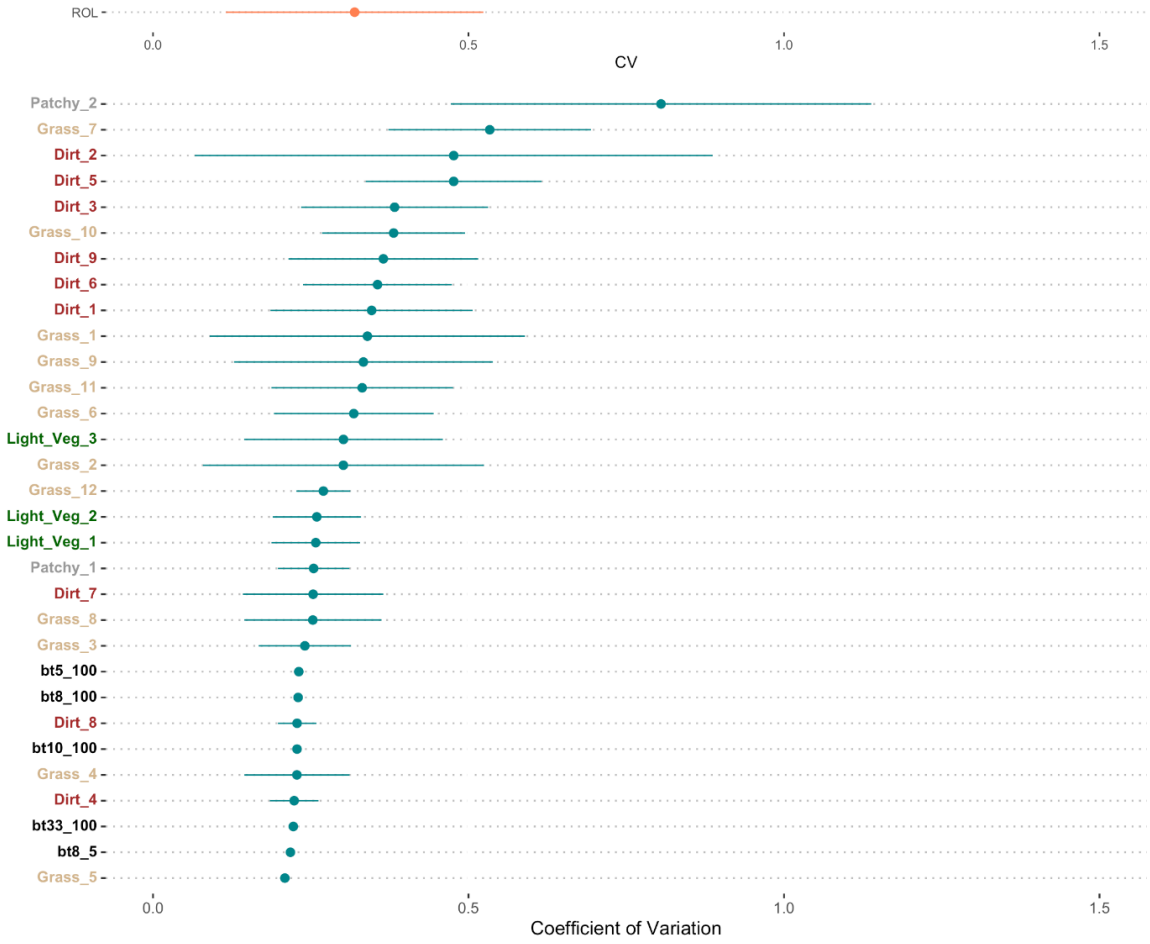
Column Data Repeatability



Consistent Measurements:

- Very repeatable results day after day in same areas
- Consistent highs & lows

Column Data Consistency



Coefficient of Variation between Surface Types

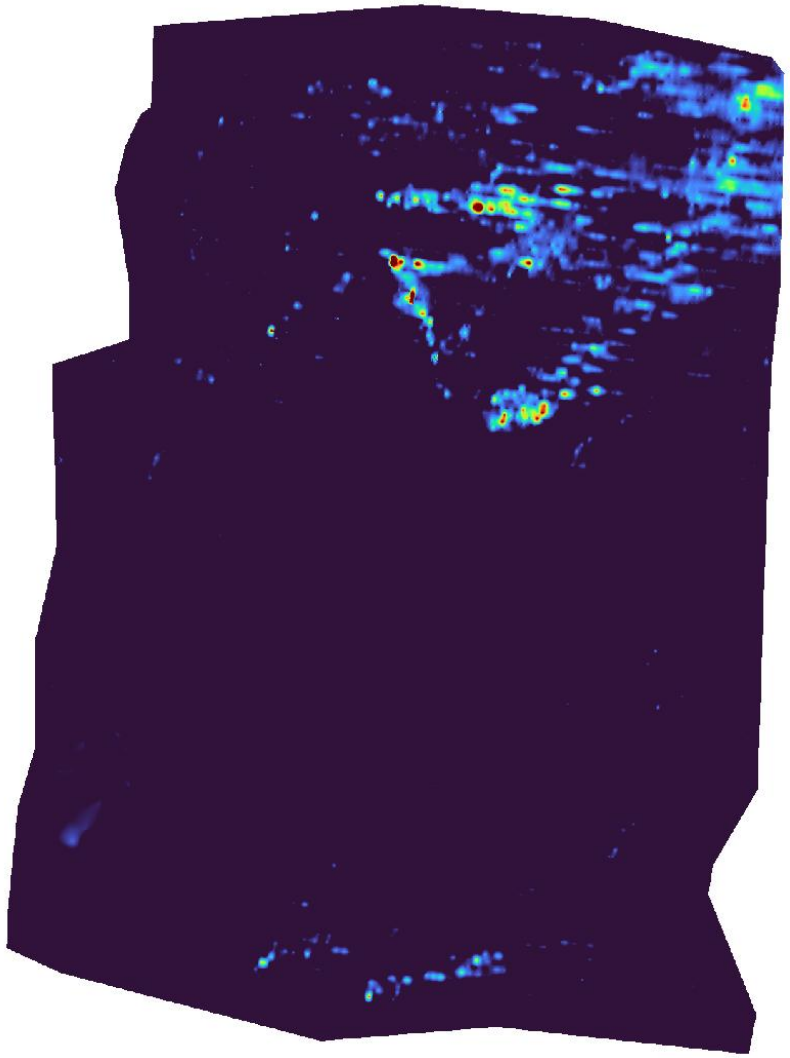
Improved Sensor Consistency:

- Purway TDLAS sensors have proved to be very consistent
- Testing is indicative of a low coefficient of variation between target surface types
- Include anti-false alarm features, enhancing detection reliability

Efficacy of TDLAS Detection:

- Advancements in TDLAS tech provides greater precision filtering out inaccurate signals
- Enhanced data transparency and higher sampling rates contribute to more informed decision-making, leading to improved detection efficacy.

Actionable Data for Site Operators & Managers



Example of Interpolated Methane Data Map_Post (TDLAS) Collection

Leak/Plume Mapping:

- Provide detailed maps of leak locations for efficient repair
- Total site coverage vs “walkable” areas
- Ability to see effects of high release rates vs low release rates (is there a plume?)

Actionable Data for Site Operators & Managers

Precise LDAR Solutions (Leak Detection and Repair):

- Locate leaks and monitor until mitigation efforts are complete
- A sizable portion of leaks we detect are from erosion or areas of weak cover material not only gas system infrastructure
- Provide Lat/Long location of leaks with imagery or inspection footage if necessary
- Distinguish between high-concentration and dispersed leaks for prioritization

Example of Live Feed of Measurements comparing to SEM – 26,929ppm

Take Aways & Next Steps

We've applied our expertise to optimize data collection and improve detection accuracy while overcoming operational challenges. Partnering with industry and scientific experts, we will continue refining our approach to deliver effective, affordable solutions for methane leak detection and quantification.

Moving forward, the focus should be targeting leaks with higher release rates, which contribute more to emissions than smaller, high-concentration leaks. This strategic shift will maximize our impact on reducing methane emissions.