Active Sensing of Greenhouse Gases:
airborne demonstration and spaceborne discussion

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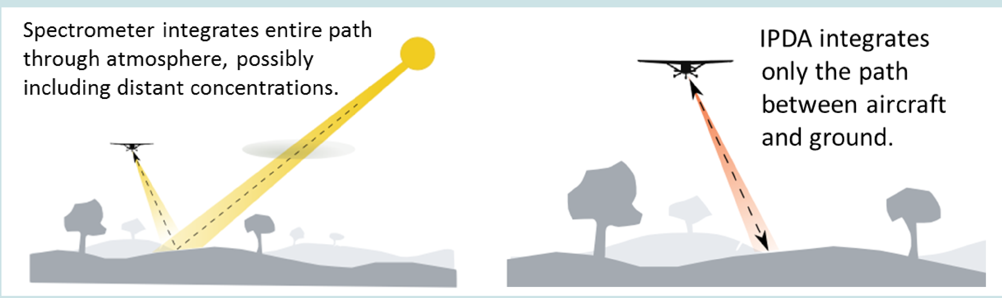
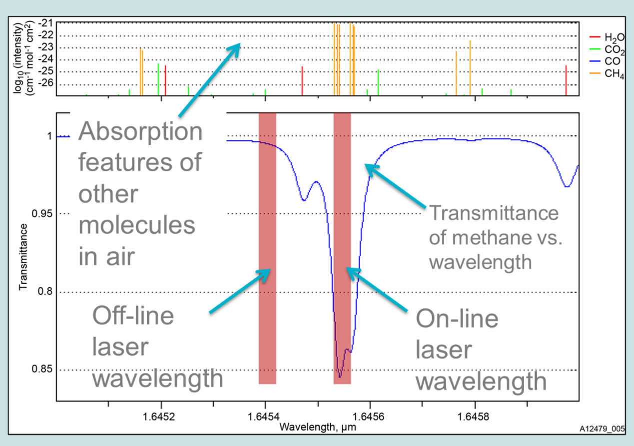
Methane Monitor IPDA Lidar

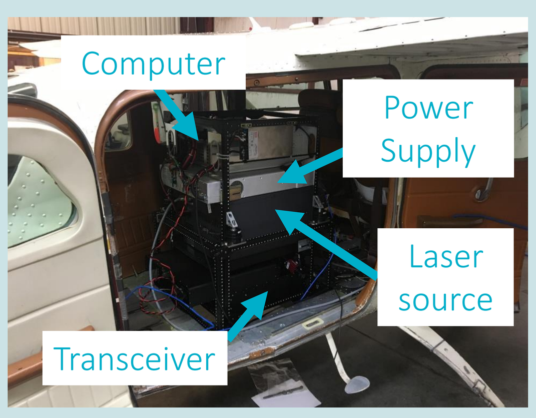
Methane Monitor is an Integrated Path Differential Absorption (IPDA) lidar that measures methane total column density above the ground.



- Two lasers form a pulse pair: on-line is absorbed by methane, off-line is absorbed less by methane
- The difference in intensity is used in Beer-Lambert law to calculate the absorption coefficient and derive the column concentration
- Pulse intensities measured at transmission and return and normalized for wavelength jitter



- Vibration isolated rack installed above camera port
- Weight: 240 lbs
- Power: 650 W
- Rack Size: 20"x20"x32"

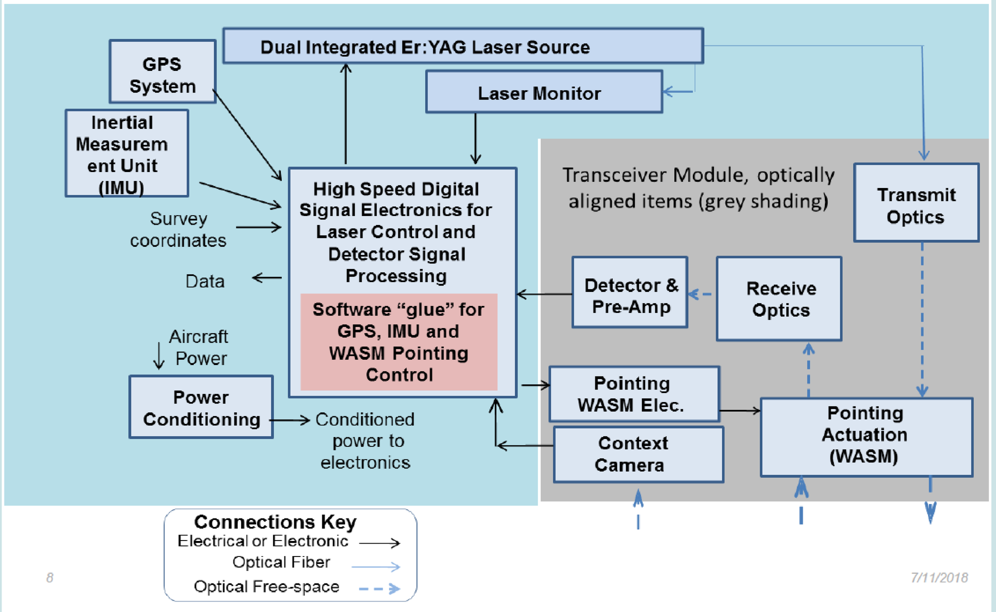


Parameter	Performance
Operating Wavelengths	1645.4 (off) 1645.55 nm (on)
Sensing Swath	Up to 400 m (¼ mile)
Altitude	800-1800 m (2.6-6 kft) AGL
Methane Emission Rate Detection Threshold	50-100 SCFH* (1-2 kg/hr) depending on wind speed
Spatial Resolution	~3 m
Geo-location Accuracy	1-5 m depending on altitude
CH_4 Error	50-60 ppm-m

*standard cubic feet per hour

Laser requirements

- Line-width: keeping the on-line light within the absorption band in a high-vibration environment
- Pulse energy >500 uJ
- Pulse pairs at 10 kHz
- Line Width ~1.5GHz (Methane, 4.5GHz)



Methane Monitor System Block Diagram

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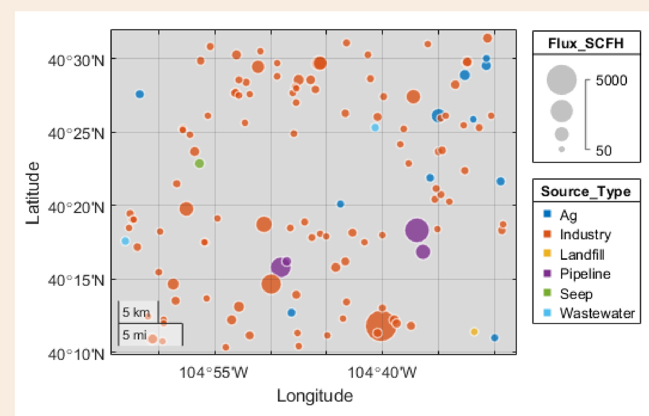
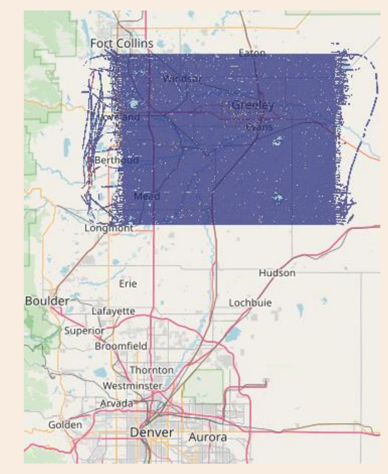
Denver-Julesburg Basin Demo

Survey Summary

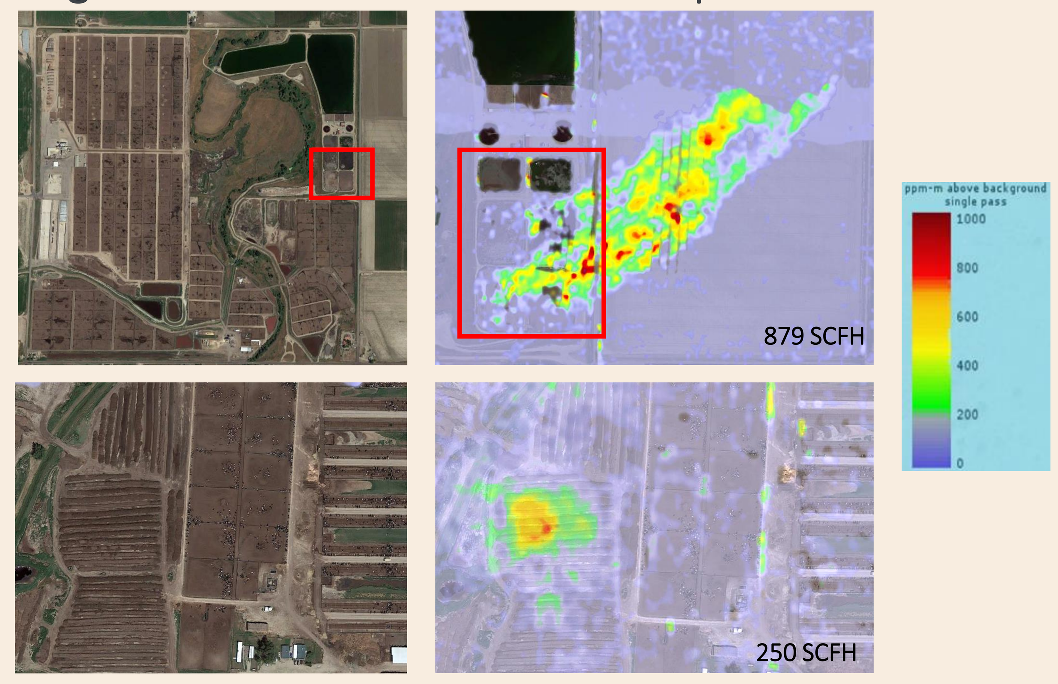
- Front Range: region north of Denver, CO
- 720 sq. mi. of survey data collected in ~8 days
- Identified 127 methane emissions
- Average emission: 274 SCFH (5 kg/hr)
- Estimated total flux: 35,000 SCFH per 720 mi² (647 kg/hr per 1864 km²)
- All estimated fluxes are preliminary



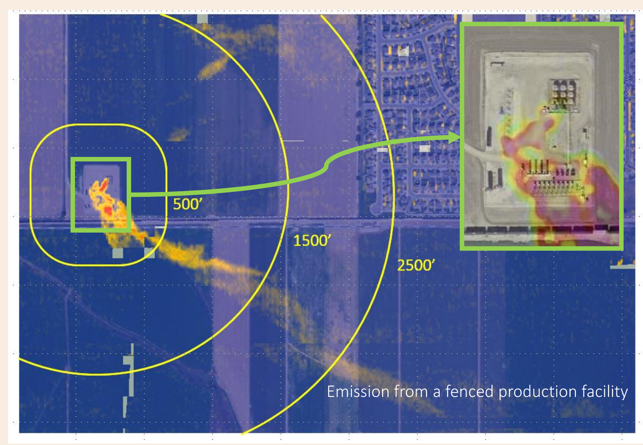


6 different source types: Industry (primarily O&G facilities) (108), Agriculture (11), Pipeline (4), Wastewater (2), Seep (1), Landfill (1)

Agricultural Waste Emissions Examples



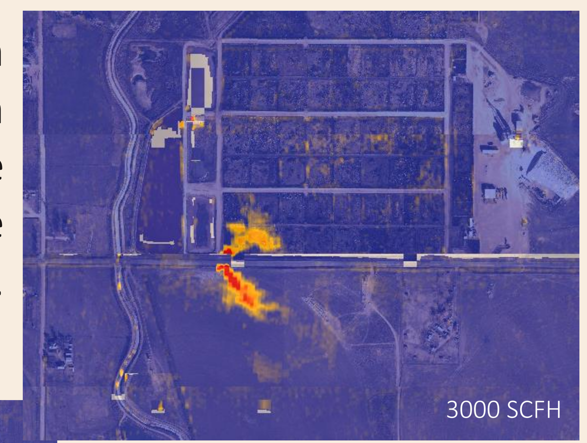
Facility Emissions



Plume shapes can change dramatically with wind. Large oil and gas emissions can be seen close to residential areas.

Distribution Fugitive Emissions (Broken Pipes)

Ground verification revealed a broken distribution pipe emitting near a large **cattle** operation.



Ground verification revealed a broken distribution pipe emitting near recently closed **biogas** operation.

High spatial resolution measurements are critical for source identification.

Acknowledging PHMSA R&D support via 2013 and 2015 BAAs: DTPH5613T000004, DTPH5615T00016 and internal BAE Systems research and development funding through the Active Sensing Technology Initiative.

Discussion

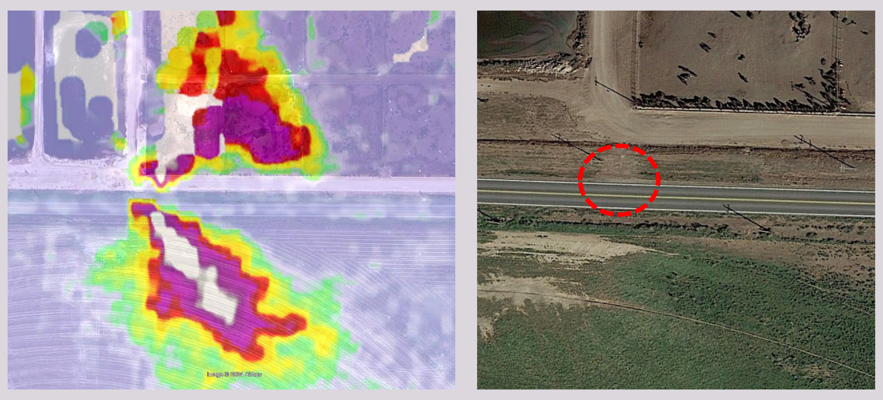
Case Studies

Suspected 6 years of leaking

- Source located near an operator's equipment yard and along an irrigation ditch
- Google Earth historical imagery reveals dead vegetation for 6 years prior to leak detection
- Leak rate ~2,000-3,000 SCFH
- >300 ft diameter dead patch

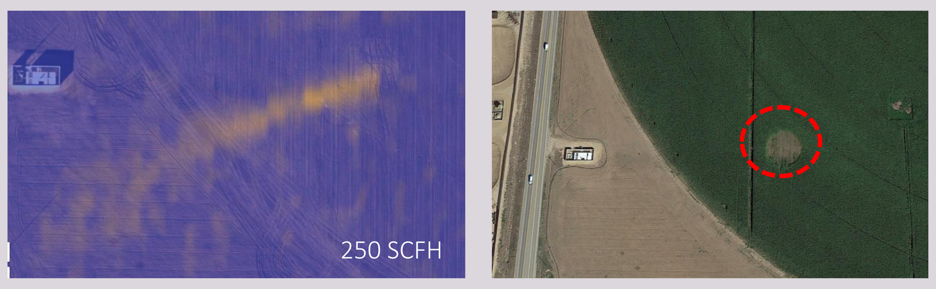
Could have been cows

- A broken pipe near a cattle operation could easily be misidentified in large-GSD satellites or narrow-swath airborne instruments
- Leak had likely persisted for >6 months



Small but important

Area mapping revealed leaks that had been missed by ground inspection. Fugitive emissions can also be a safety concern for fires or explosions.



How can Active Sensing support the IWGGMS Community?

Airborne Active Sensing for Calibration and Validation

While the BAE Systems' Methane Monitor instrument was initially developed to find pipeline leaks, such high spatial resolution measurements could be useful for supporting calibration and validation efforts for future and ongoing CH4 satellite missions.

Advantages

- High precision measurements (fewer assumptions tied to radiative transfer models, clouds, sun angle, or other atmospheric priors
- Independent retrieval for validating passive retrievals
- Context-informed source identification

Challenges

- Coverage and revisit
- Flux estimate still highly dependent on wind
- Column height not 1:1 at nominal altitudes

What challenges could spaceborne active sensing solve or support?

BAE Systems partners with scientists to pursue PI-led and nontraditional missions. Let's connect!

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