



Next-Generation Laser-Based Natural Gas Leak Detection

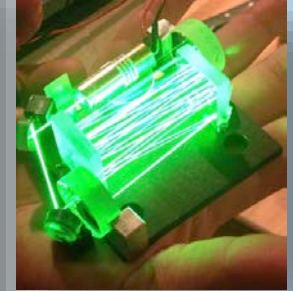
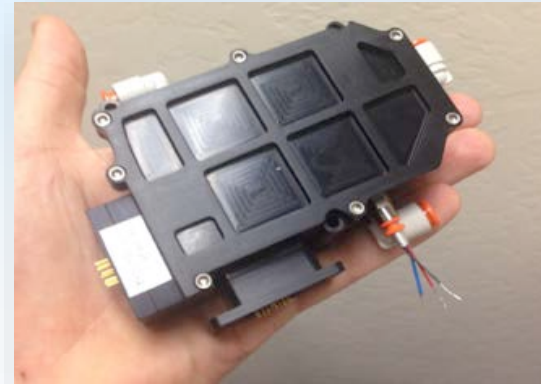
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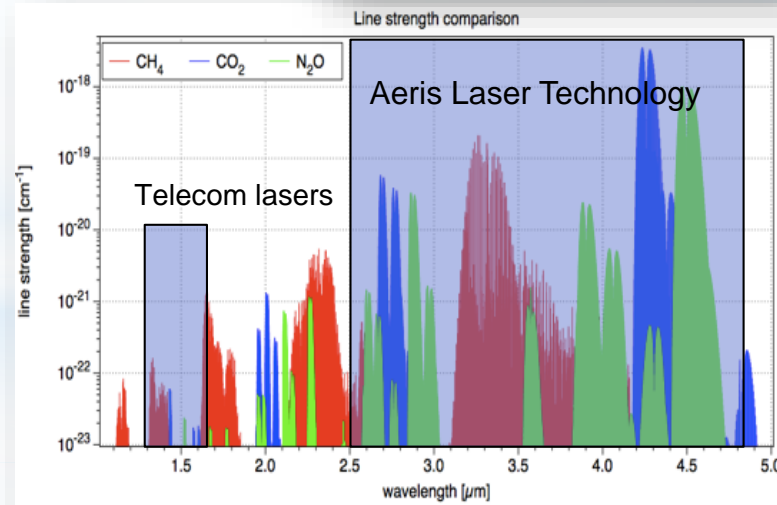
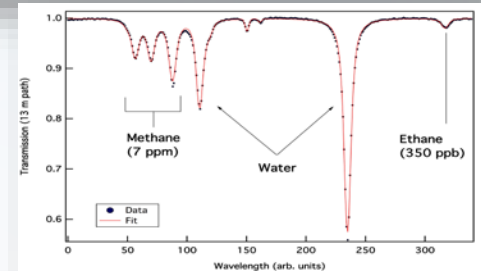
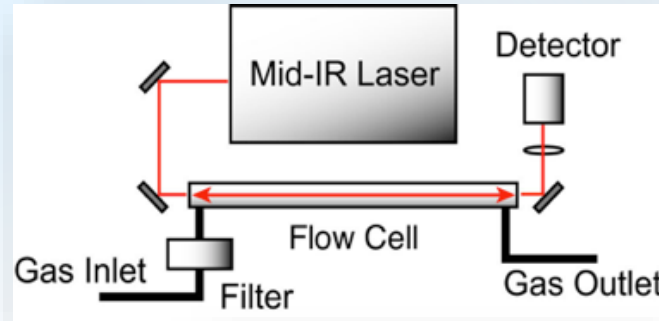
Aeris Miniature Laser-Based Sensor Platform: MIRA

- MIRA: Worlds smallest ultrasensitive laser-based gas sensor platform
 - Laser *Absorption* Spectroscopy provides sensitive, accurate measurements
 - *1ppb/s* sensitivity
 - 10x smaller, lighter instruments (MIRA Pico shown below)
 - Mid-IR operation accesses more species
- Unique, Patent Pending multipass cell
 - Robust, state-of-the-art monolithic design requires no alignment or regular servicing
- Proprietary Custom Electronics, Software
 - 50 years tribal knowledge in a cc sized board
- 5-20x Lower power consumption and 2-10x lower cost than competing products



Core Technology: Mid-IR laser absorption spectroscopy

- *Direct absorption* is measured as the laser wavelength is rapidly tuned
- Simple, general, robust and proven approach
- Middle infrared = much stronger absorption
 - 200x for CH₄, 8,000x CO₂, 32,000x for N₂O
- Discrete, unique “fingerprints” in the MIR eliminate cross sensitivity
- *Only optical sensor with simultaneous ethane and methane at 1ppb/s!*



Natural Gas Leak Detection

Make Natural Gas Green Again!

- Natural gas has largely replaced reductions in coal over last 20 years
- CH₄ 80x more potent than CO₂ in 20 yrs
 - Each 1.25% that leaks *doubles the carbon footprint*
 - Estimates are that leaks are between 1.5-8%, making NG worse than coal!
- Aeris measures CH₄, H₂O, and C₂H₆
 - C₂H₆ (2-10% of NG) : **discrimination of thermo- vs biogenic sources**
- Many Potential Embodiments
 - *In-situ autonomous, mobile, handheld, airborne/UAV*



Natural Gas Leak Detection: Applications

- Fixed, autonomous monitoring

- *Wellpads: (1,000,000+ wells)*
- *Compressor stations (1500 turbine + 10,000's recip)*
- *Storage facilities: e.g. Aliso Canyon*



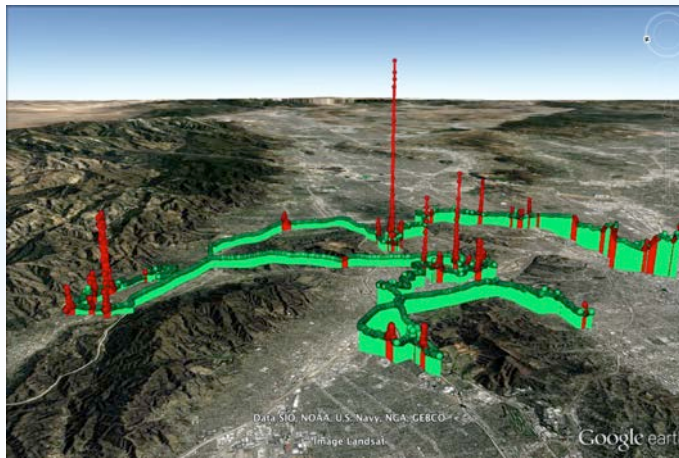
- Handheld

- 1000x more sensitive than NDIR, no consumables
- Worlds only trace handheld simultaneous ethane/methane



- Mobile: Pipeline, Utilities

- GPS data combined with sensor data provides leak MAPS



- Airborne: UAV, conv. aircraft

- Unique size/weight

Natural Gas Leak Detection: Ethane and source attribution

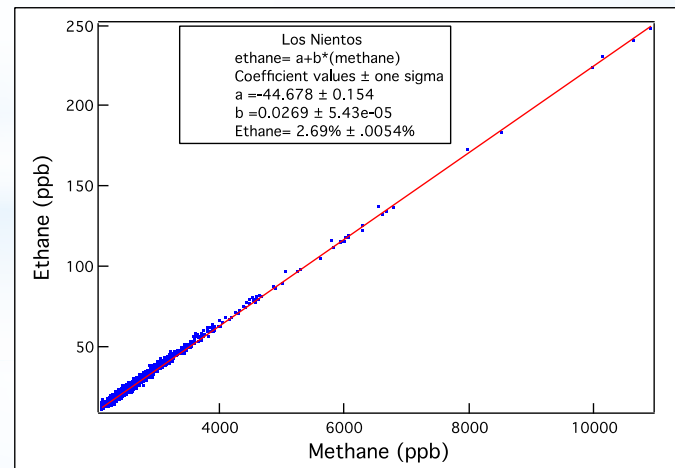
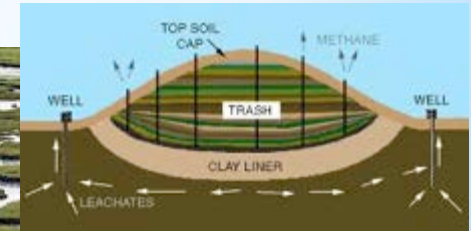
- Ethane is typically 2-5% of the NG stream
- No Ethane in ambient air
- Ethane is not produced in biological systems
- Biogenic methane sources:
 - Permafrost, bogs, landfills, livestock, sewage plants
- Isotope approaches less accurate, more ambiguous
 - Isotope ratios for C, H (D), can overlap over wide range-
- If ethane and methane correlate, source is fossil fuel!
- **Aeris has unmatched 1ppb ethane sensitivity! Enables accurate $C_2H_6:CH_4$**



-OR-

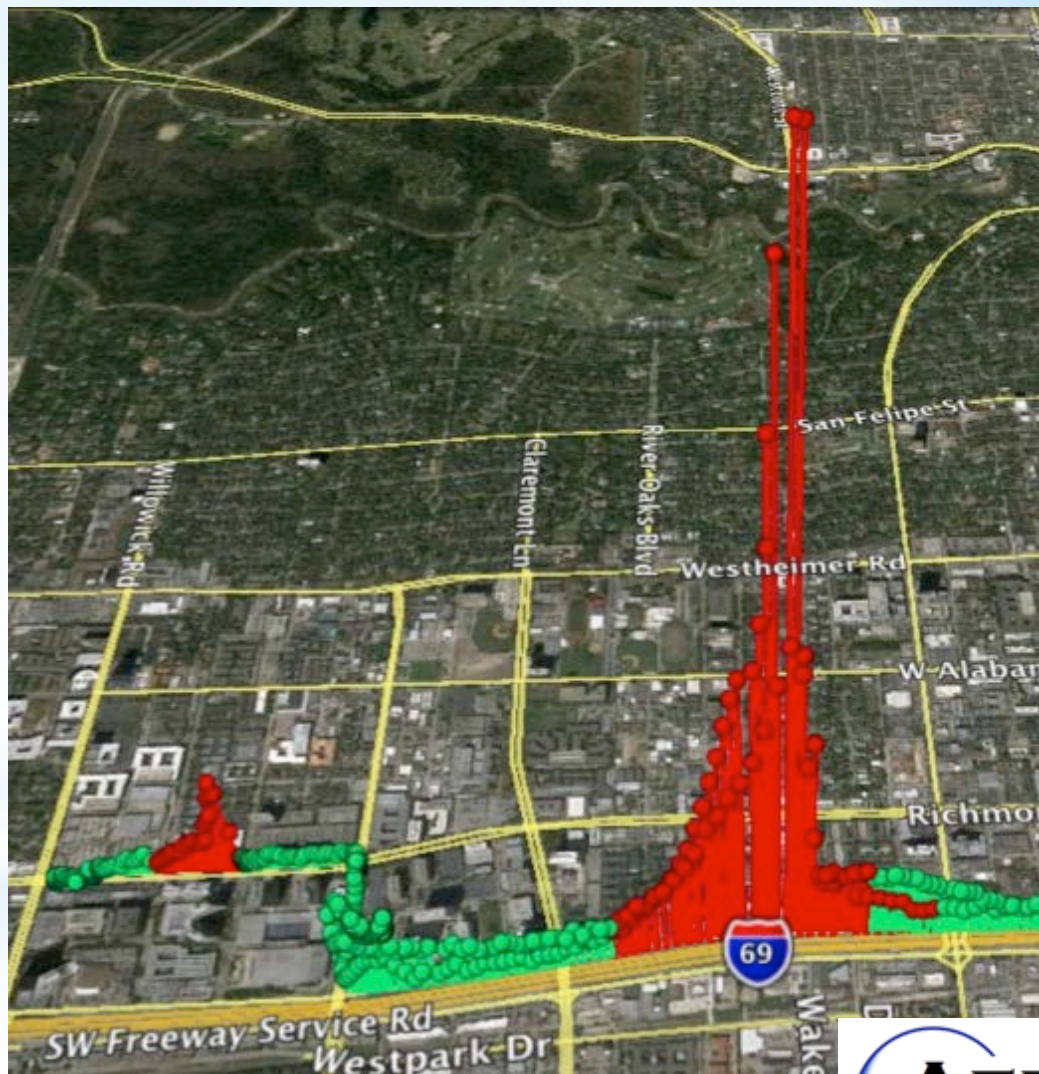


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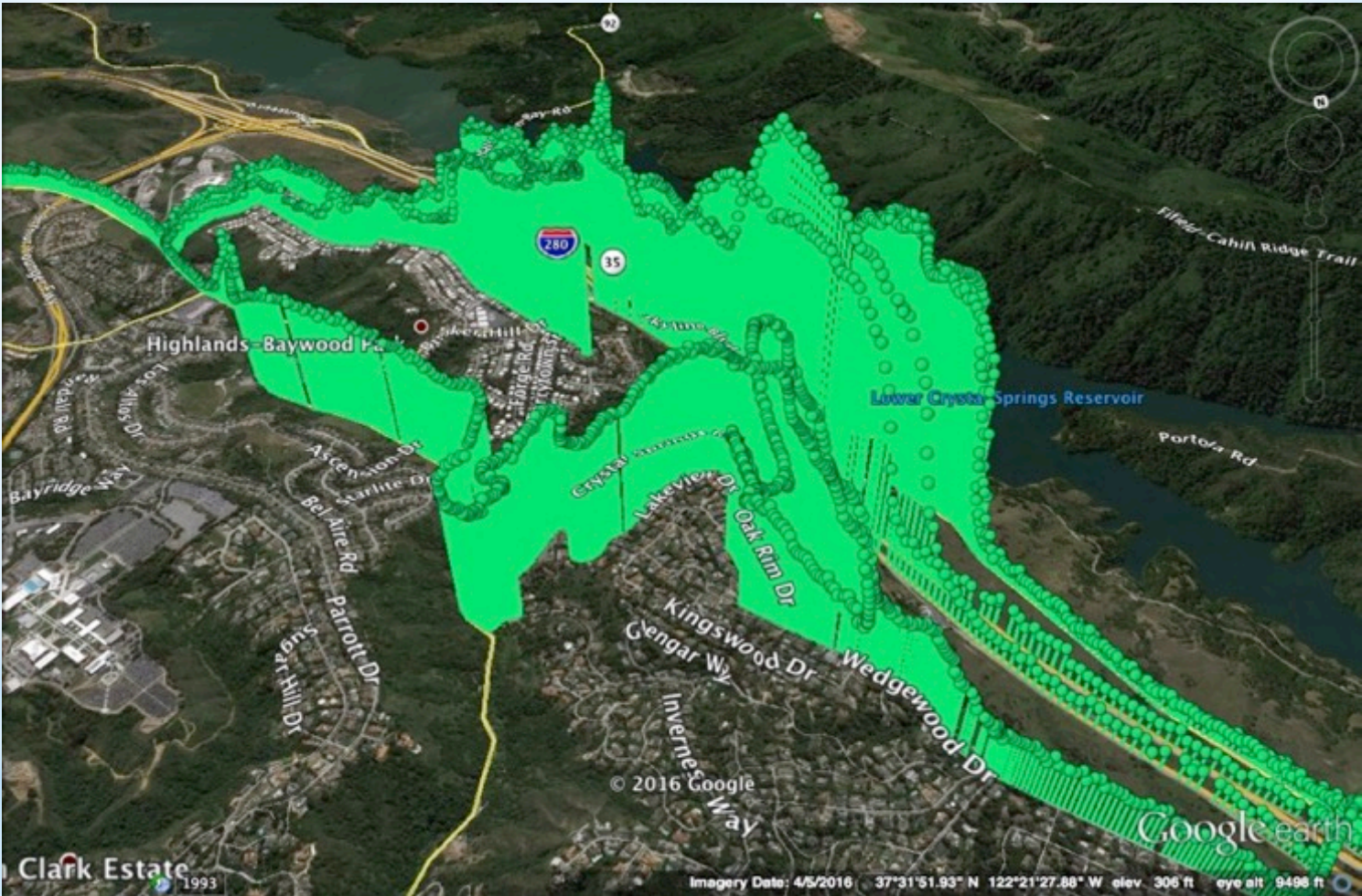


MIRA Pico Mobile LDS: Mobile Leak Detection w/GPS

- Simultaneous gas detection and GPS enables “maps” of leaks
- CH₄ only = **Green**,
CH₄+C₂H₆ = **Red = leak!**
- Persistence of leaks on multiple passes indicates leaks vs passing motorcycles, etc.
- Deployed in multiple service vehicles, a citywide map of leaks is obtained over a period of time

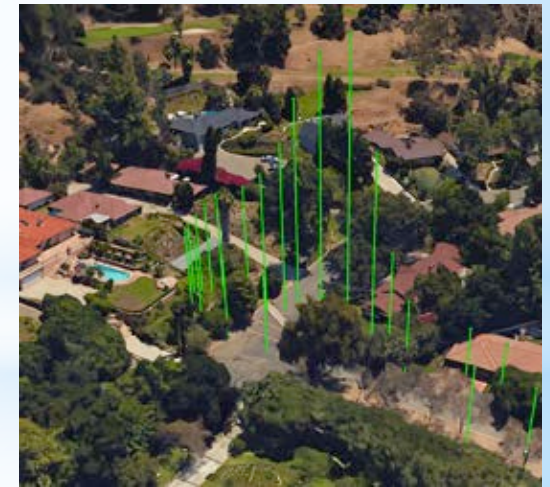
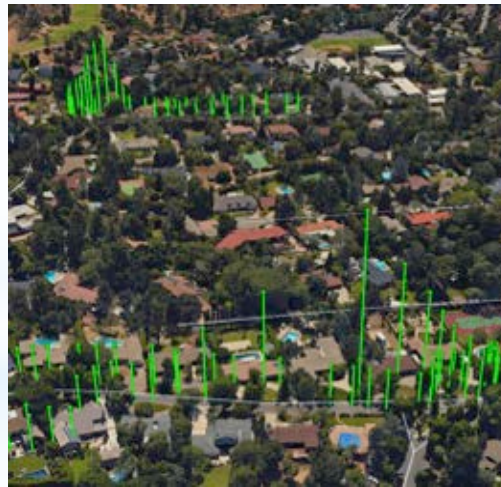


MIRA Pico Mobile: Ox Mountain Landfill Gas (Biogenic!)



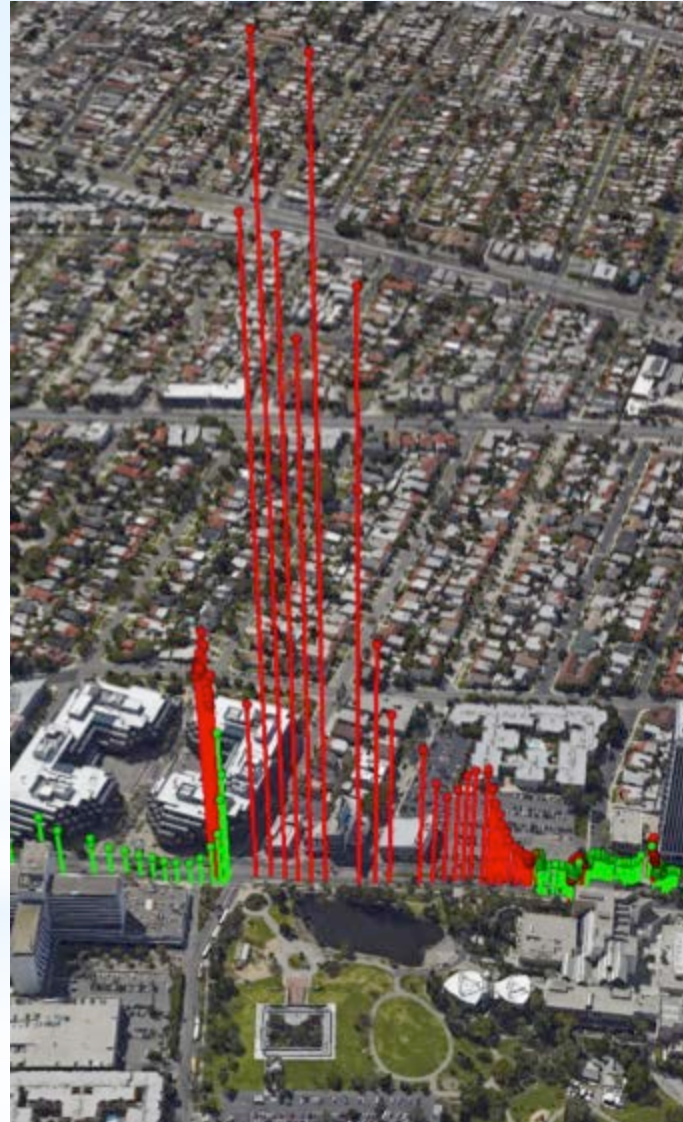
MIRA Pico Mobile LDS: Biogenic Sewer Gas

- Elevated methane (green) w/o ethane rules out natural gas as source
- Biogenic sewer gas
- Eliminates false alarms and unnecessary “leak surveys”



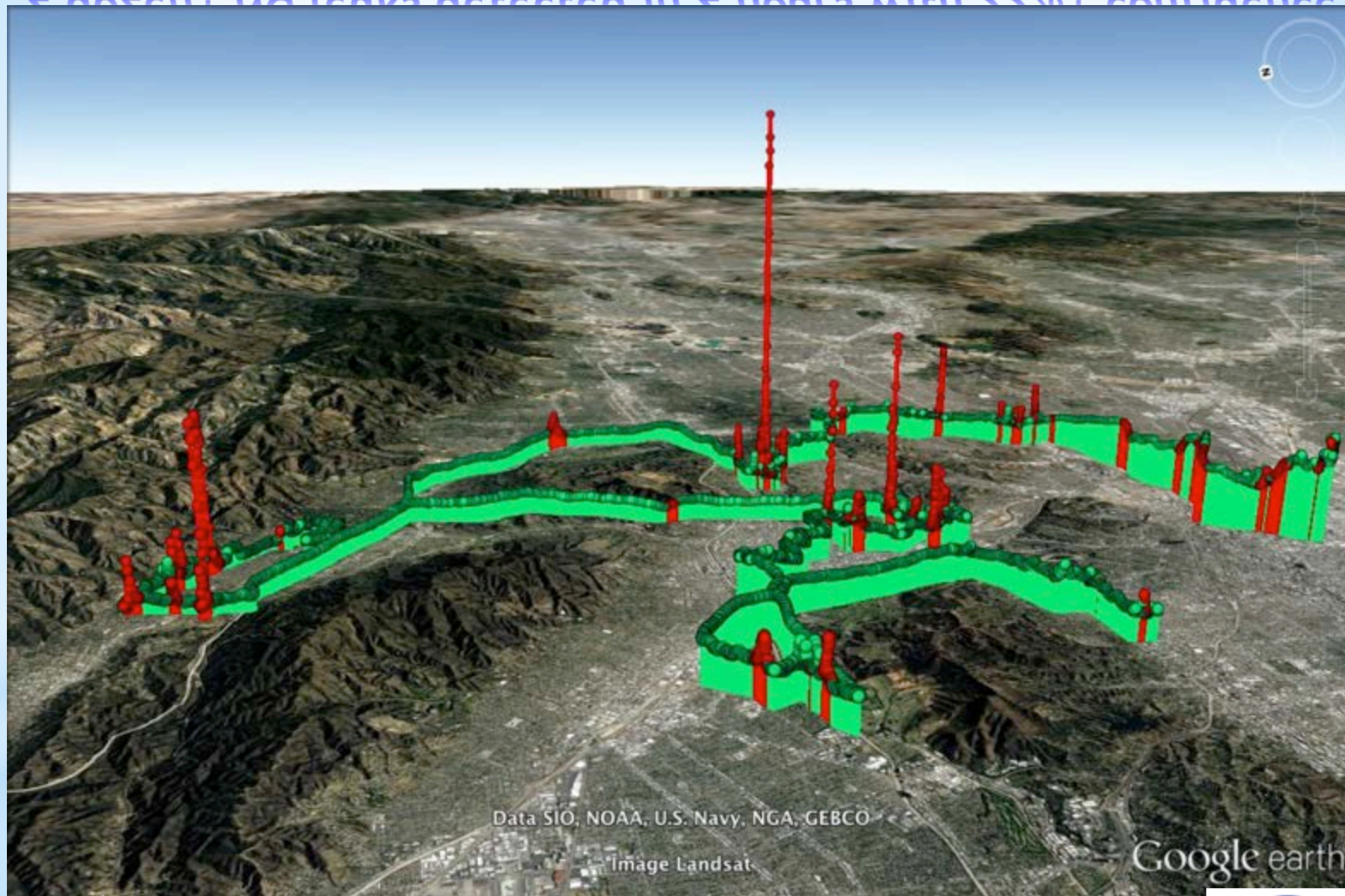
MIRA Pico Mobile: Natural oil seeps

- La Brea Tar Pits In West Los Angeles
- Presence of $\text{CH}_4 + \text{C}_2\text{H}_6$ at unique 1% level- Not Natural gas from utility!

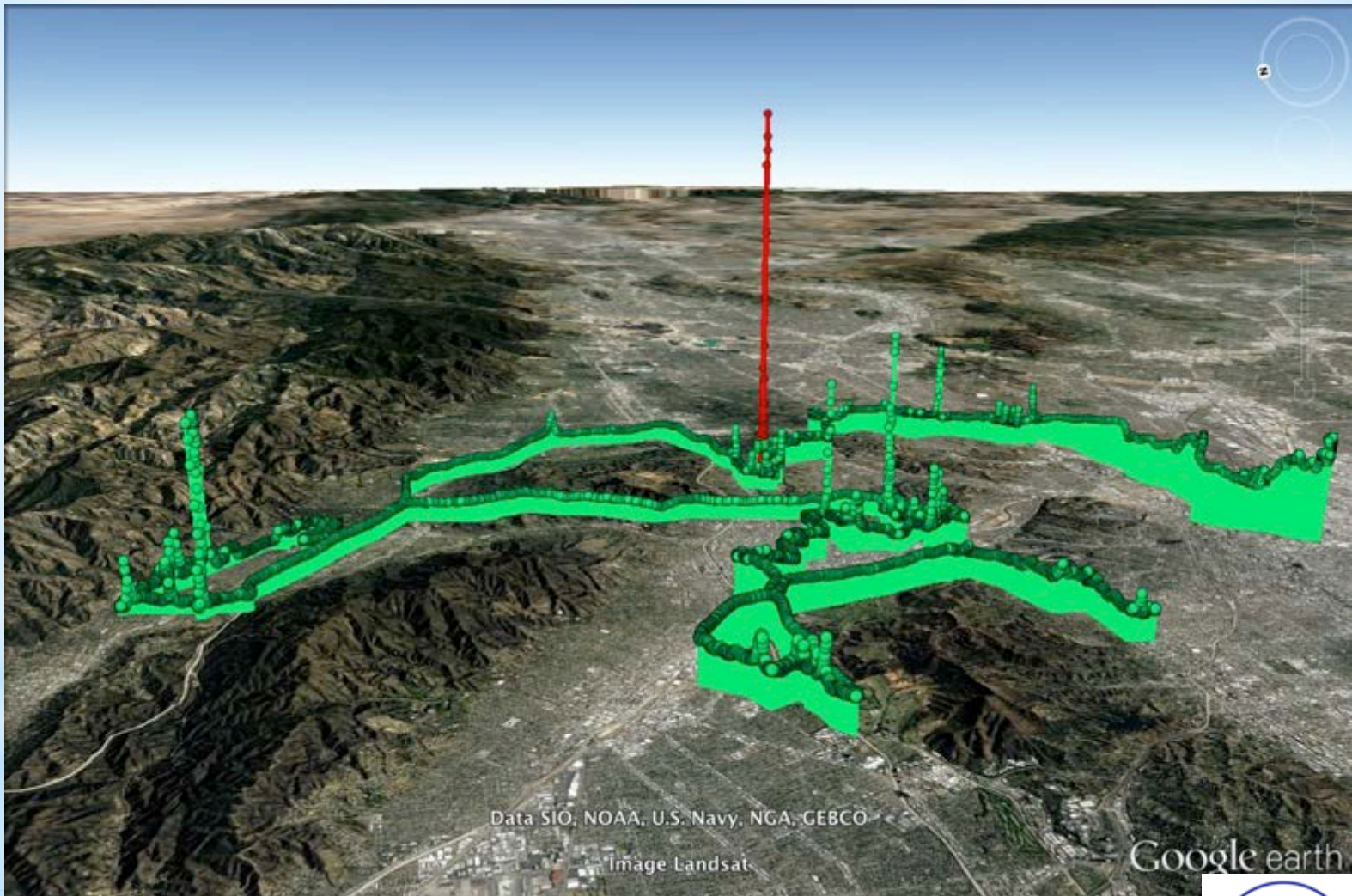


Aeris MIRA Pico Mobile LDS: Ethane+Methane= NG Leak

2 dozen+ NG leaks detected in 2 hours with 99%+ confidence



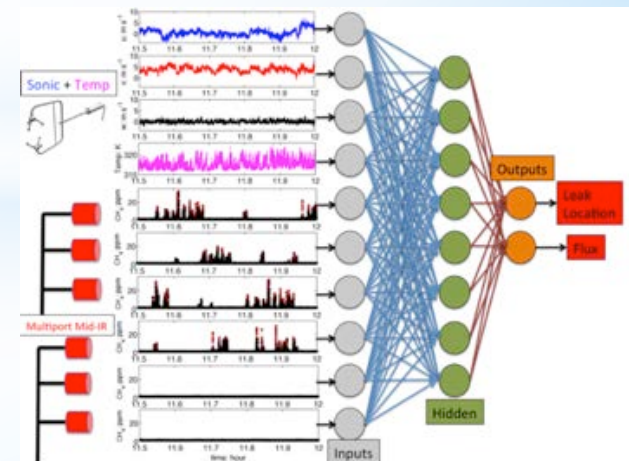
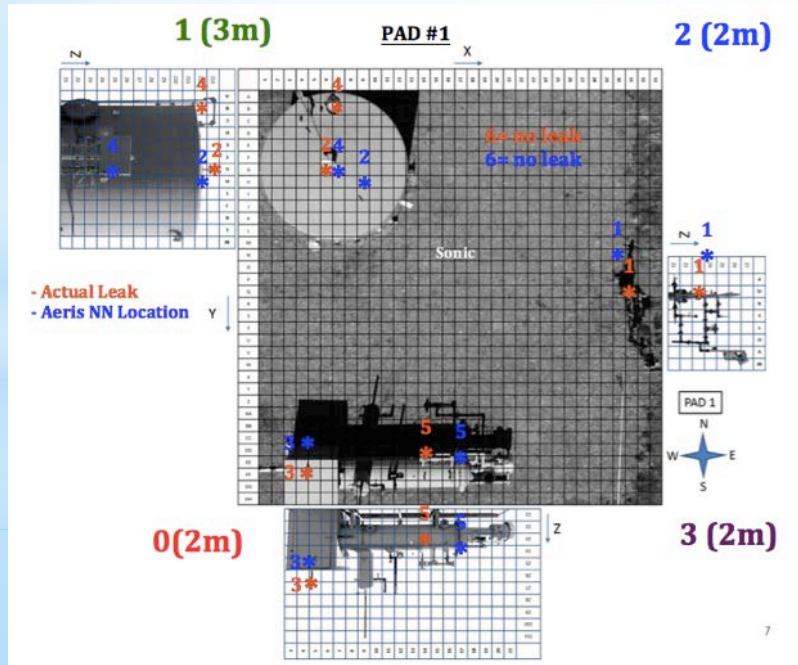
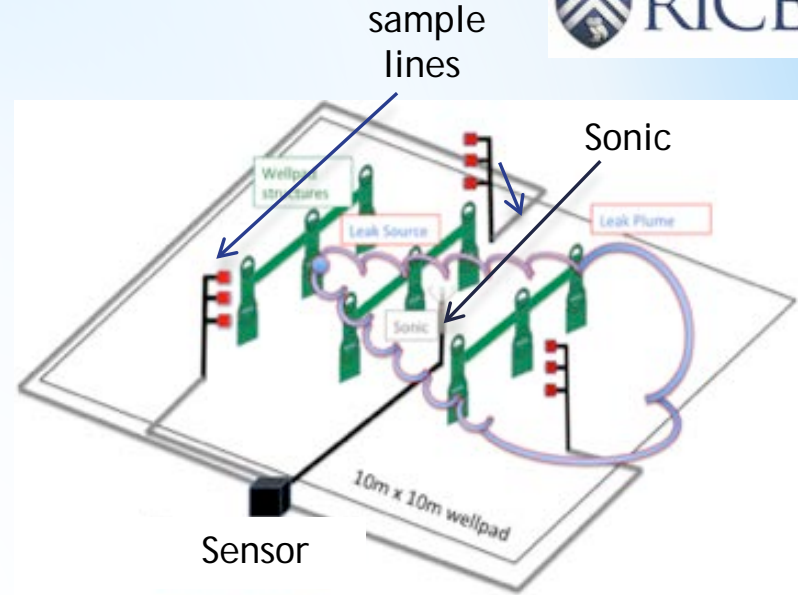
Aeris Pico Mobile LDS vs. Competition: Only 1 correlation detected (vs. 28 w/Aeris Pico Mobile LDS)



ARPA-E Project: "Autonomous, High Accuracy Natural Gas Leak Detection System"



- Autonomous determination of leak location and size at the wellpad :
 - New Aeris MIRA laser sensor
 - New, LANL developed neural-network analysis approach
- Initial Field tests at CSU support feasibility: leak location rapidly determined!



Aeris MIRA Leak Detection System: Summary

- Disruptive new, laser-based gas analyzer platform
 - 10-15x improvement over existing laser-based analyzers across critical metrics
 - Lower capital cost, lower total cost of ownership, unmatched C₂H₆ performance
 - Unique size/weight/power consumption enables new ways of thinking about leak detection
- New capabilities in fixed and mobile gas leak detection, wellpad monitoring
 - accurate maps of gas leaks “assembled” over time
 - urban and regional leaks in the distribution systems
 - Looking for interested Utility companies
 - *Initial wellpad testing of ARPA-E prototype system indicate rapid, unmatched au leak detection capability: 24/7/365 truly autonomous monitoring*