

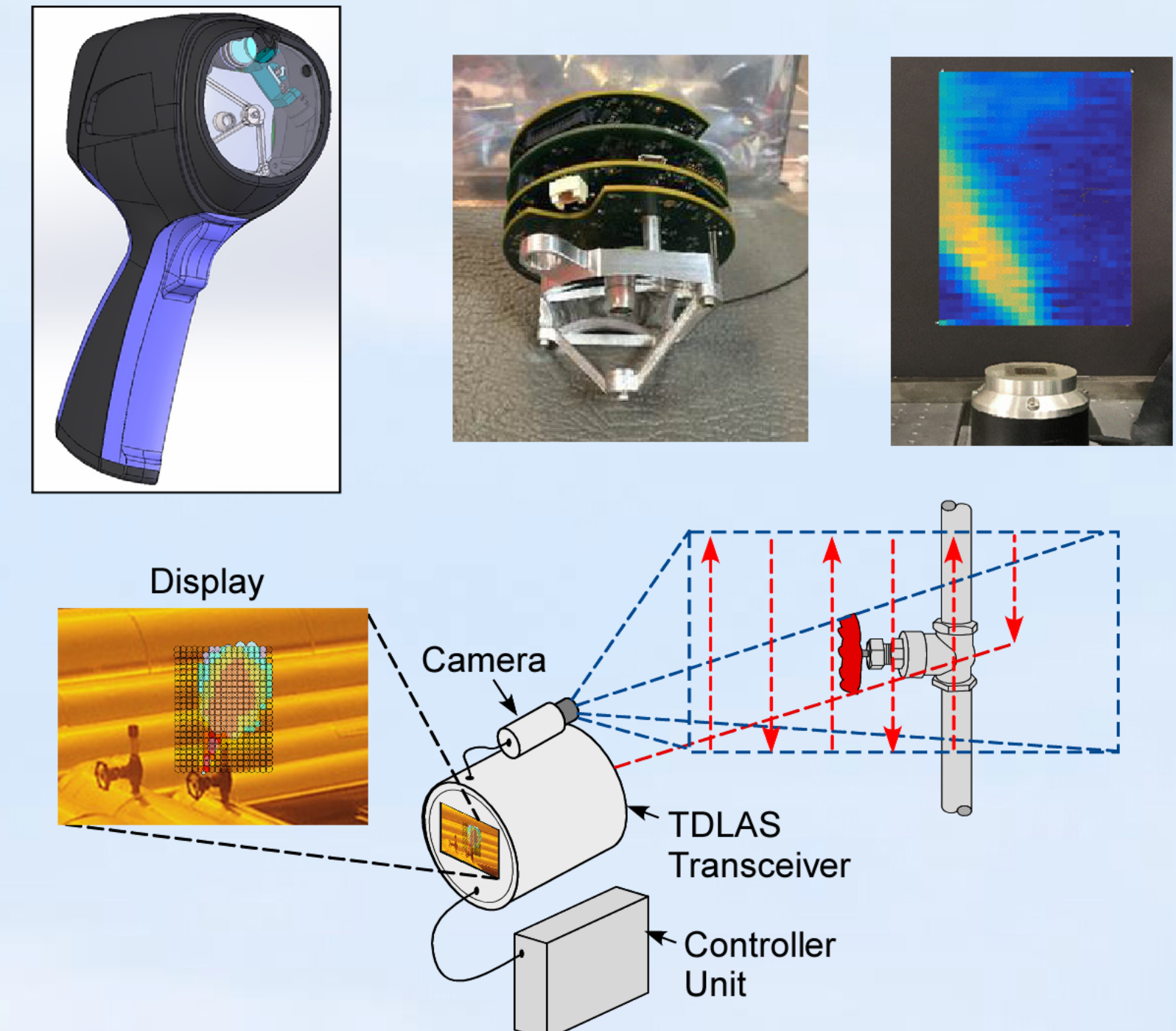
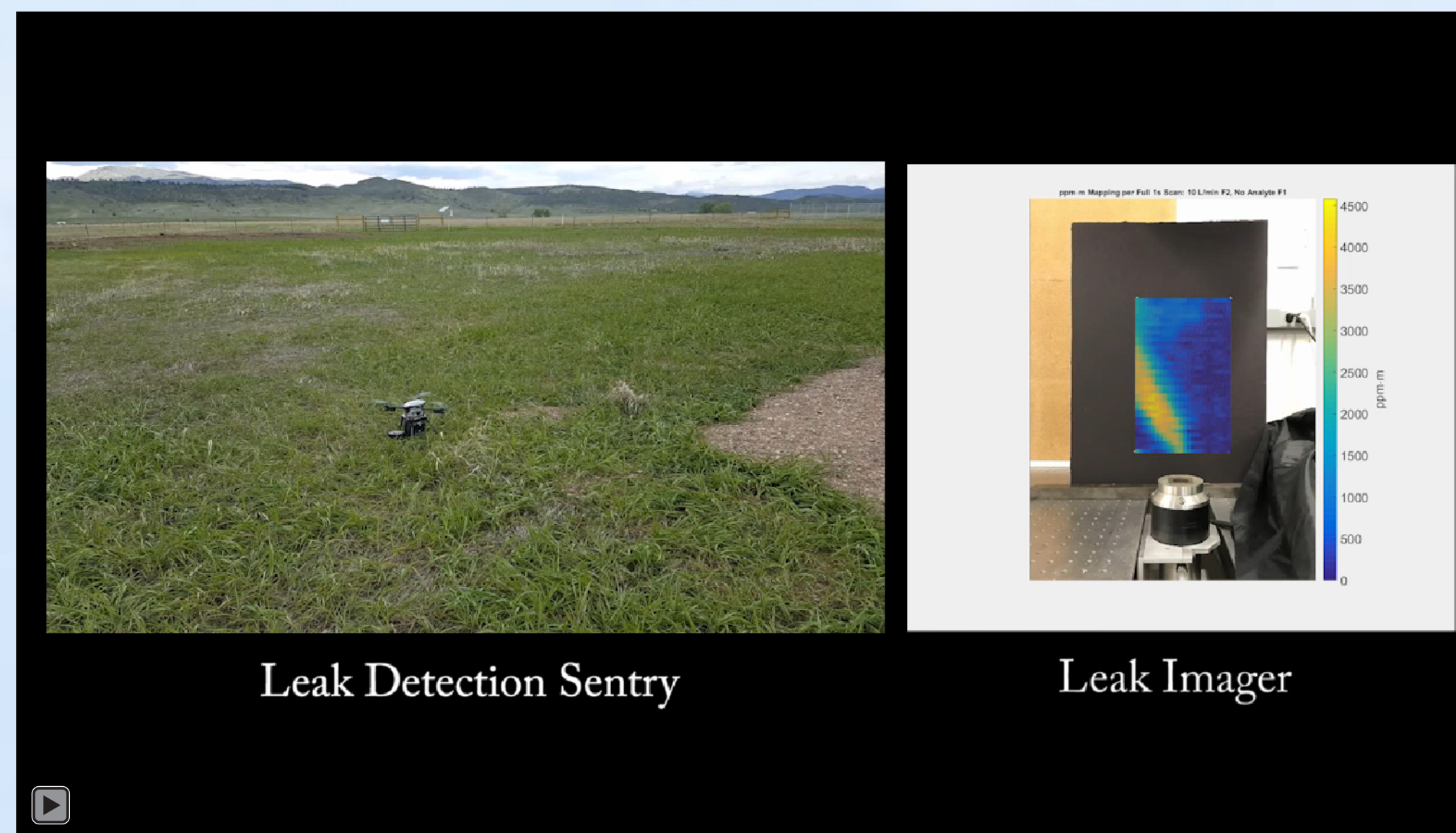
Laser-Based Sensors for Monitoring, Verification and Accounting (MVA) at Wellheads and Subsurface Storage Sites

Leak Detection Sentry



- Vehicle parked in garage with active RMLD™
- Continuous monitoring when parked
- Aerial surveys scheduled or triggered by leaks
- Solar powered charging station
- Self-centering docking platform

Hand-held Quantitative Gas Leak Imager



- Low-cost imager for leak detection and repair (LDAR)
- Hand-held quantitative detector
- Fast-scanning Backscatter Tunable Diode Laser Spectrometer
- Calibrated column-concentration (PPM-M) at each pixel
- Enables deducing emission rate

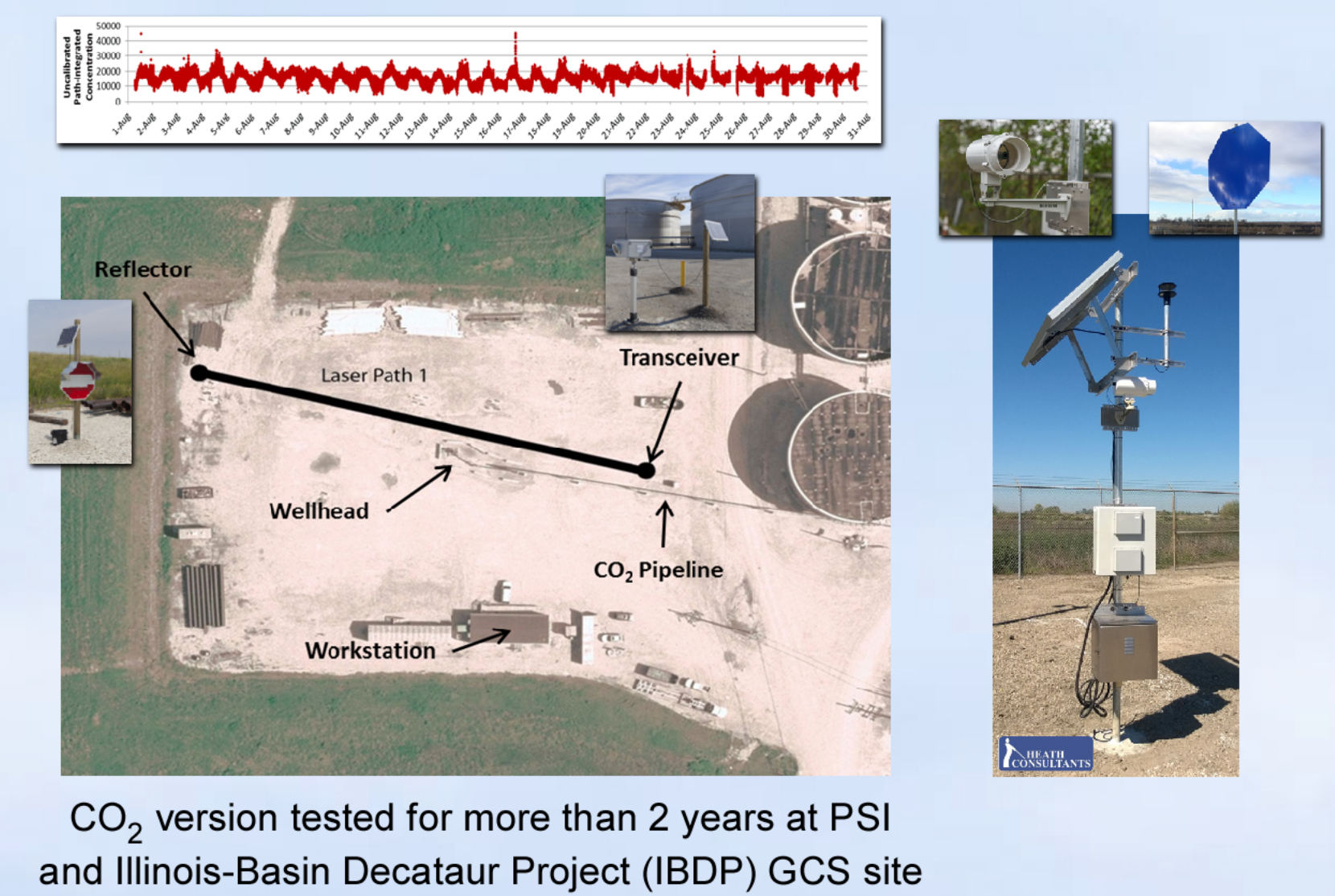
sUAS-Based Remote Leak Detection (RMLD-UAV)



Purpose	Natural Gas Leak Survey and Qualification
Technology	Methane detection via backscatter-laser spectrometer (RMLD™) adapted to PSI's small quadrotor UAS
Size	24" diameter, 9" depth
Weight	Approximately 3 lbs. with battery
Flight Range	Within visual sight (<2000 ft.) of base station
Survey Altitude	30 ft. typical
Endurance	30 min.
Wind	30 mph
Control	Hand-held GCS Optional computer for semi-autonomous flight with real-time waypoint updating Automated vertical launch and land
Lost Recovery	GCS locates after remote landing
Methane and GPS Data	Class 1 Bluetooth
Video Data	680 x 480, 5.8 GHz analog transmission
UAS Storage	System stows in 18" x 24" x 10" case

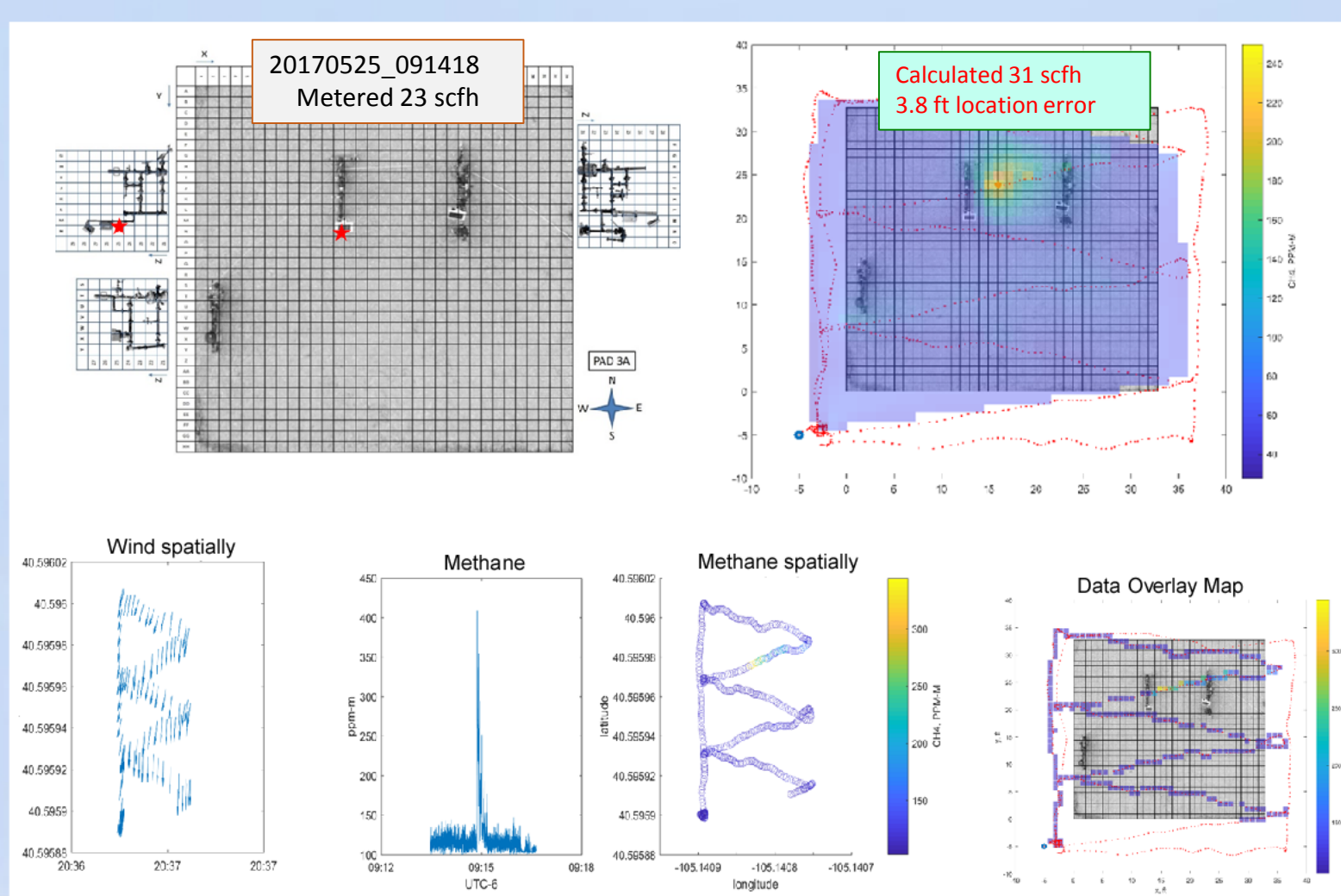
Remote Emission Monitor (REM) For wellheads and storage sites

- Permanent installation
- Open-path detection
- Continuous monitoring
- Real-time alarm notification
- AC or solar power
- CH₄, CO₂, other species



CO₂ version tested for more than 2 years at PSI and Illinois-Basin Decatur Project (IBDP) GCS site

Example Grid and Concentration Map Overlay



- Automated flight pattern control
- Dynamic in-flight pattern modification
- User-controlled or based on feedback from measured data
- Automated source localization via upwind projection and maximum density search

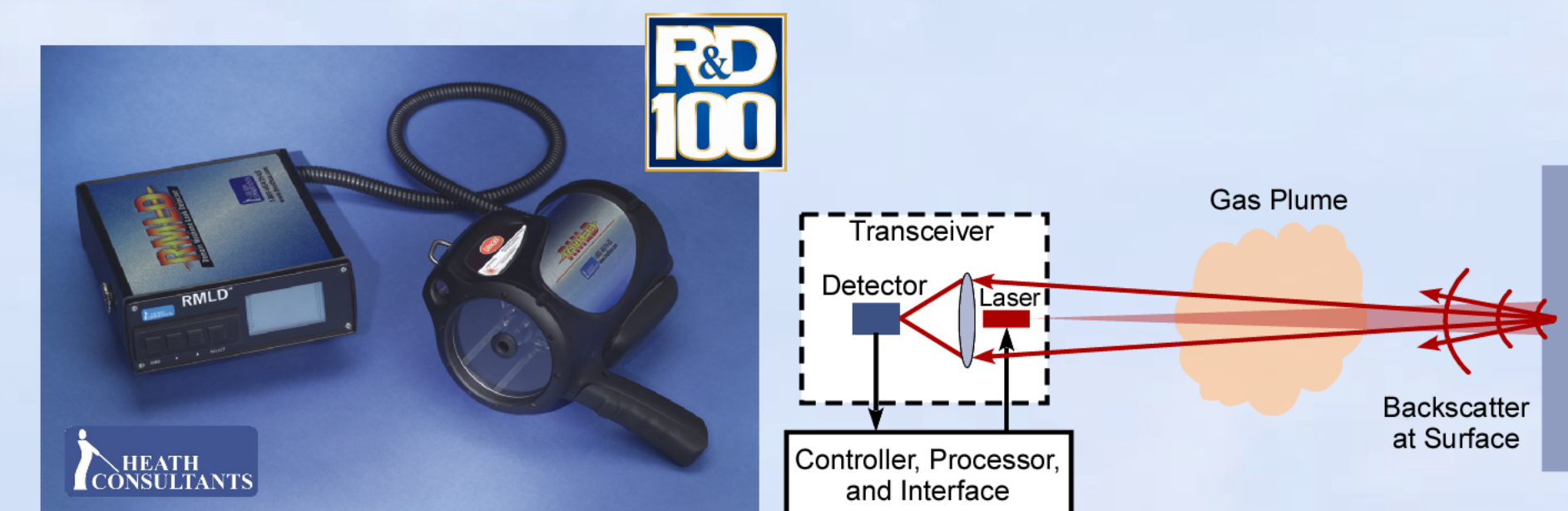
Leak Rate Measurement and Source Location



- Scans laser beam along a surface that a gas plume crosses
- Measures column-concentration versus position
- Deduce flux by integrating over position and multiplying by wind vector
- Configurable to stationary, mobile and flight platforms

Remote Methane Leak Detector (RMLD™)

- Rugged
- Reliable
- Accurate
- Thousands in use
- Introduced in 2005
- Measures methane column density (PPM-M) along laser path
- Standoff range 100 feet



Tunable Diode Laser Absorption Spectroscopy (TDLAS)

- **Selective:** little cross-species interference
- **Sensitive:** sub-ppm detection
- **Fast:** sub-second response time
- **Configurable:** point, open-path, or standoff
- **Non-Contact:** only beam interacts with sample
- **Quantitative:** percent to sub-ppm concentration
- **Multi-Species:** 2 or more gases capable

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