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Testing Next Generation LDAQ Technologies *Protocols And First Results*

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METEC$_{H_4}$

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arpa·e
CHANGING WHAT'S POSSIBLE

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METEC Goals

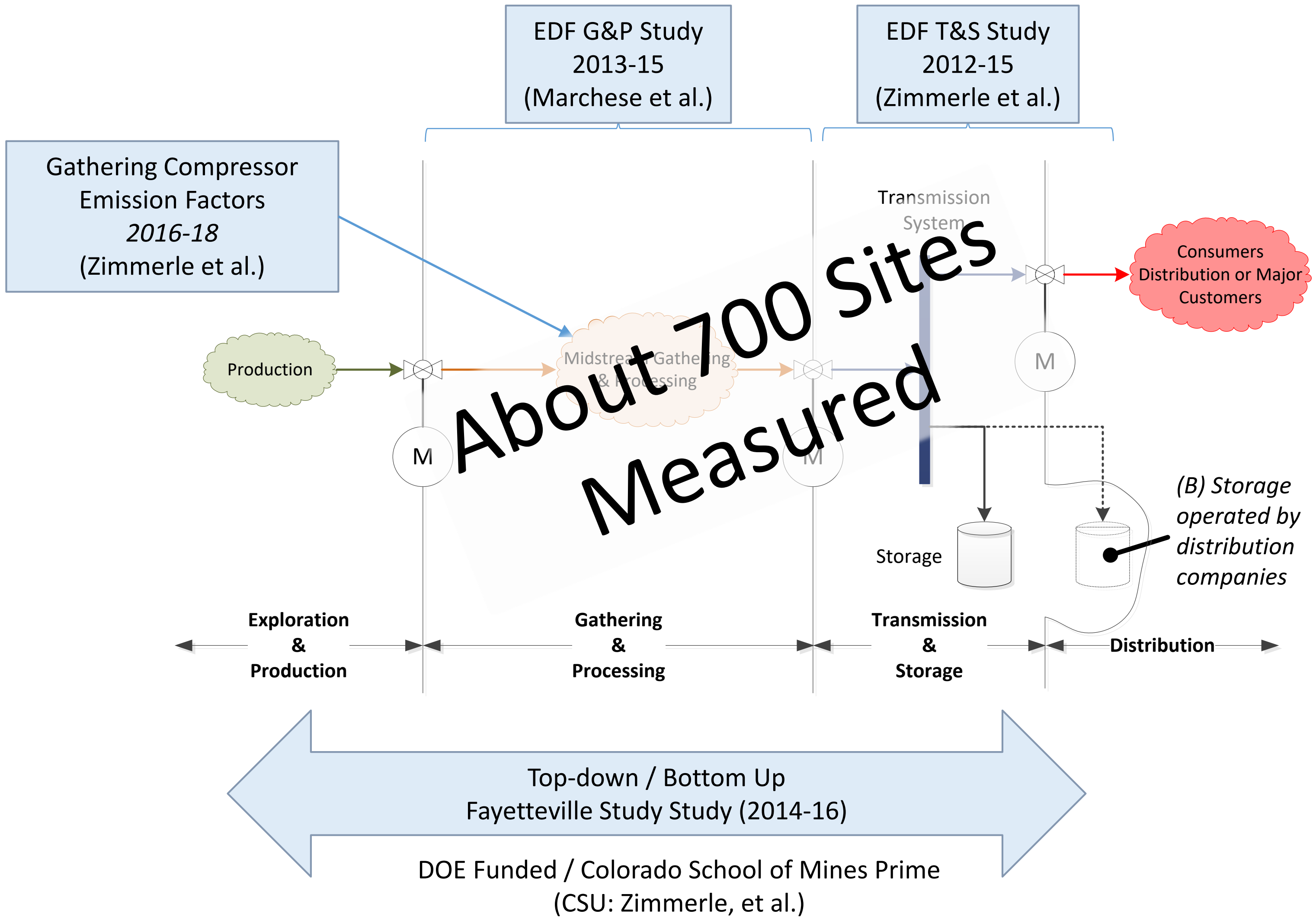
Goal #1: Gauge technical performance

- **Independent testing and validation** at a neutral venue to demonstrate technology and system performance
  - Two official rounds of testing (R1 and R2)
  - Opportunities for *ad hoc* testing

Goal #2: Engage stakeholder community

- Facilitate more effective hand-off and post-MONITOR field testing by developers and operators
  - Representative test site to engage stakeholders
  - Engage operators in design & construction of test site

CSU's Background in Methane Measurement



Papers: CSU & Partners

1. Subramanian, R. *et al.* Methane Emissions from Natural Gas Compressor Stations in the Transmission and Storage Sector: Measurements and Comparisons with the EPA Greenhouse Gas Reporting Program Protocol. *Environ. Sci. Technol.* **49,** 3252–3261 (2015).
2. Zimmerle, D. J. *et al.* Methane Emissions from the Natural Gas Transmission and Storage System in the United States. *Environ. Sci. Technol.* **49,** 9374–9383 (2015).
3. Mitchell, A. L. *et al.* Measurements of Methane Emissions from Natural Gas Gathering Facilities and Processing Plants: Measurement Results. *Environ. Sci. Technol.* **49,** 3219–3227 (2015).
4. Marchese, A. J. *et al.* Methane Emissions from United States Natural Gas Gathering and Processing. *Environ. Sci. Technol.* **49,** 10718–10727 (2015).
5. Bell, C. *et al.* Reconciliation of methane emission estimates from multiple measurement techniques at natural gas production pads. *Elem Sci Anth* (2017).
6. Vaughn, T. L. *et al.* Comparing facility-level methane emission rate estimates at natural gas gathering and boosting stations. *Elem Sci Anth* **5,** (2017).
7. Zimmerle, D. J. *et al.* Gathering pipeline methane emissions in Fayetteville shale pipelines and scoping guidelines for future pipeline measurement campaigns. *Elem Sci Anth* **5,** (2017).
8. Schwietzke, S. *et al.* Improved Mechanistic Understanding of Natural Gas Methane Emissions from Spatially Resolved Aircraft Measurements. *Environ. Sci. Technol.* (2017). doi:10.1021/acs.est.7b01810
9. Roscioli, J. R. *et al.* Measurements of methane emissions from natural gas gathering facilities and processing plants: measurement methods. *Atmos Meas Tech* **8,** 2017–2035 (2015).
10. Robertson, A. M. *et al.* Variation in Methane Emission Rates from Well Pads in Four Oil and Gas Basins with Contrasting Production Volumes and Compositions. *Environ. Sci. Technol.* (2017). doi:10.1021/acs.est.7b00571
11. Yacovitch, T. I. *et al.* Natural gas facility methane emissions: measurements by tracer flux ratio in two US natural gas producing basins. *Elem Sci Anth* **5,** (2017).

Pad 5

Context

Outlining a Potential Path To Equivalence

1. Establish a quantitative efficacy baseline for currently approved methods
2. Develop a technology-independent method to quantify equivalent emissions control and reduction
3. Develop a test & acceptance protocol for technology/method combinations.
4. *Stakeholder preparation for the regulatory and policy adoption cycle*

Possible to work in parallel on multiple steps

Outlining a Potential Path To Equivalence

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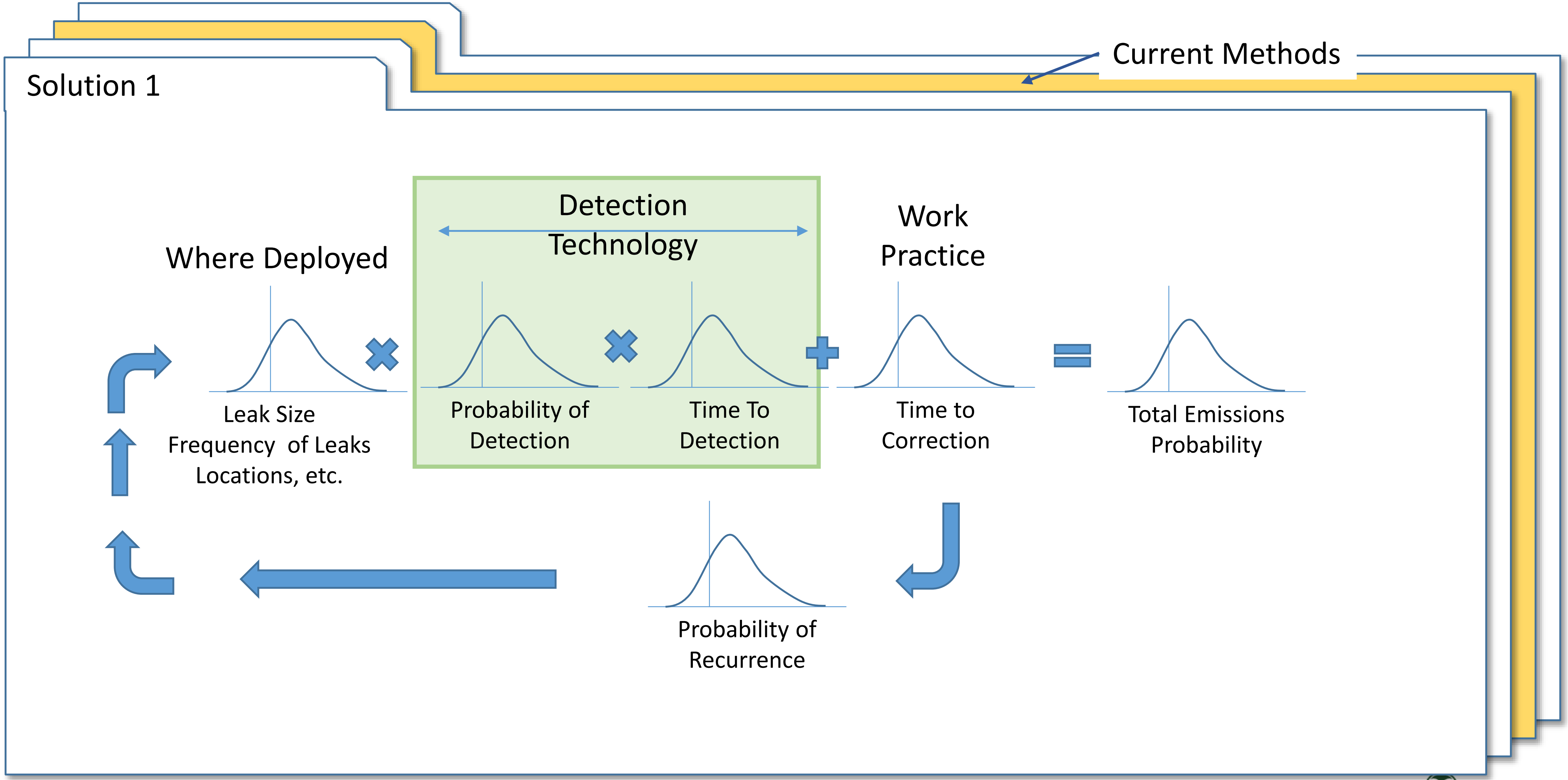
2) Define Equivalency: Assess Results in a Tech-independent Way

- Objective:
  - Develop method to understand performance of dramatically different methods
  - Build buy-in from stakeholders
- Concept:
  - Define deployment methods
  - Effectiveness testing aligned methods
  - Feed effectiveness metrics into software model
  - Merge with company/industry processes
    - e.g. response process after detections

Comparing Emissions Reduction Requires a Model



Shameless Advertising Alert:
OGI Baseline Study – Volunteer Your Teams!

Slots open on next test week:

- October 8 – 1 team
- October 9 – 3 teams
- October 10 – 3 teams
- October 12 – 2 teams

Additional testing:

- October 23-25
- One week Tues-Thurs in early November

- Invitation
  - Team: Experienced camera operator with own camera and protocol
  - Operator LDAR teams
  - Contractor teams
  - Regulators
- Recommend 2 days on site
  - 5-7 surveys over 2 days
- Sponsorship from
  - EPA
  - Environmental Partnership

What’s New in the Solution Approaches

Deployment Methods

Fixed | Scanning | Mobile | …

Sensor Technologies

Thermal | Chemical | Laser | Optical | …

Deployment Protocol

- Staff training
- Usage frequency
- Data integration
- Response thresholds

…

Existing types … new combinations

Other Testing Complexities

- Technology readiness level
- Detection & quantification versus detection only
- Probabilistic outputs
- Usable reporting

… there is a >70% probability of an emissions > 10 scfh in this volume

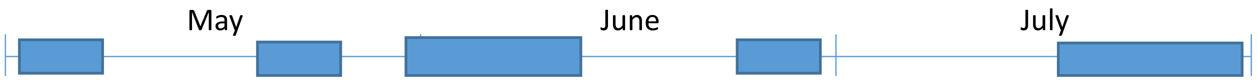
Current Protocols … Future Direction

Focus of R2 Test Protocols

<u>Deployment</u>

- Basin Survey
- Continuous Monitoring

<u>Repeatability</u>



<u>Technology Readiness</u>

- Graded complexity: A / B / C

Deployment Types

- **Basin Survey** → Solutions meant for assessing multiple sites
  - Solution: Rapidly screen sites with mobile unit. Typically a more expensive & sensitive system than permanent installs
  - Test Design
    - 1 week / multiple teams
    - Move between pads with different emissions scenarios “as fast as possible”
  - Deployment: Mobile to site / Mobile or stationary around the site
- **Continuous Monitoring** – Stationary Sensors
  - Solution: Permanently install inexpensive sensors that operate ≈24/7
  - Test Design
    - 2 weeks / multiple teams / larger METEC pads
    - Multiple hours per emission scenario
  - Deployment: Sensors at site / Sensor at a distance covering many sites

Technology Readiness

<u>3-Level Test Complexity</u>

A

- Single emission point per pad
- Steady emission rate

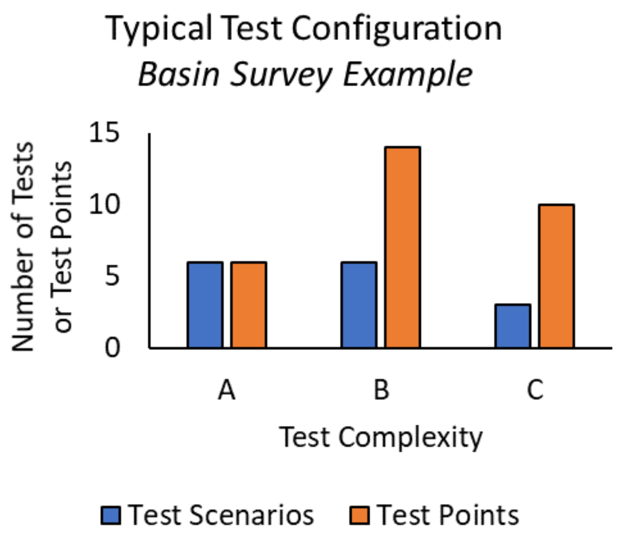
B

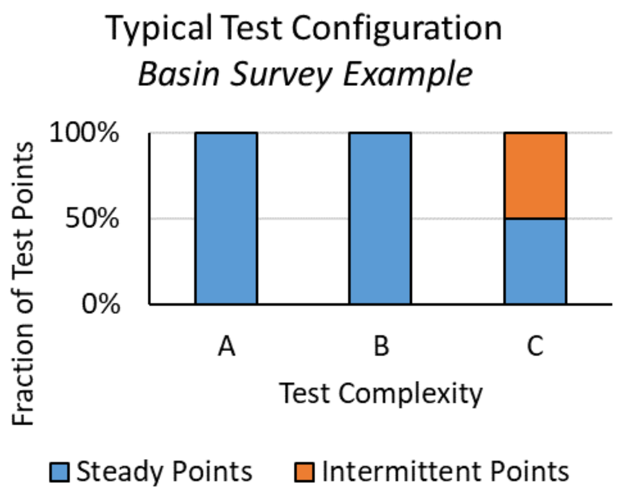
- Multiple emission points per pad
- Steady emission rate

C

- Multiple emission points per pad
- Steady, unsteady & intermittent rates

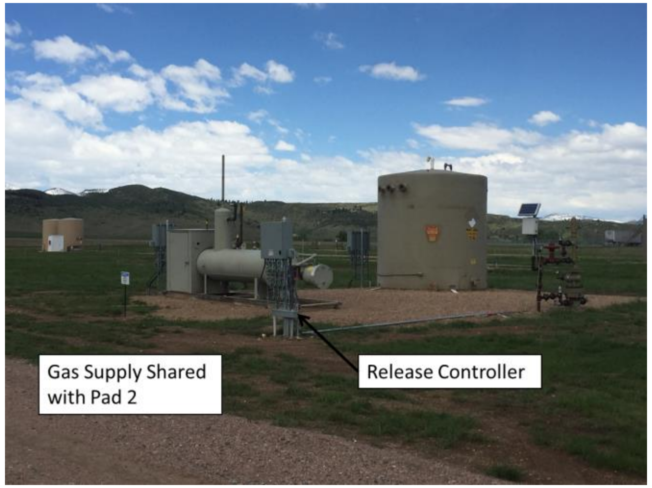
Increasing Realism





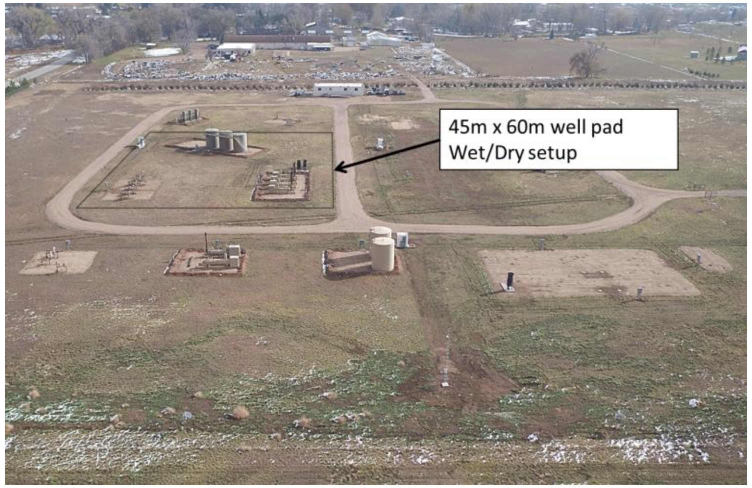
Site Complexity

Small



Medium

Large



Reporting

- Performers reported leaks on xyz grid
  - GPS coordinates for automated solutions
  - Human "lookup" for solutions without local GPS
- Performers varied on reporting speed
  - 7 MONITOR "full solutions"
    - 5 Tested and returned results: Bridger, CU, PSI, IBM, Rebellion
    - 1 Tested, report too late for presentation: Aeris
    - 1 Hasn't tested: PARC
  - 4 non-monitor did "formal single-blind R2 tests"
    - Reported results: Fluke, Gas Detection, Heath/REM
    - Tested, report to late for presentation: AlertPlus, Heath/REM
- @ METEC: Many additional tests that were not formal single-blind R2 tests

Recommend local-base GPS systems for future testing & *SCADA* integration

- Reporting time varied from 1 week to >3 months
- Typical time – several weeks

Detection "Grades"

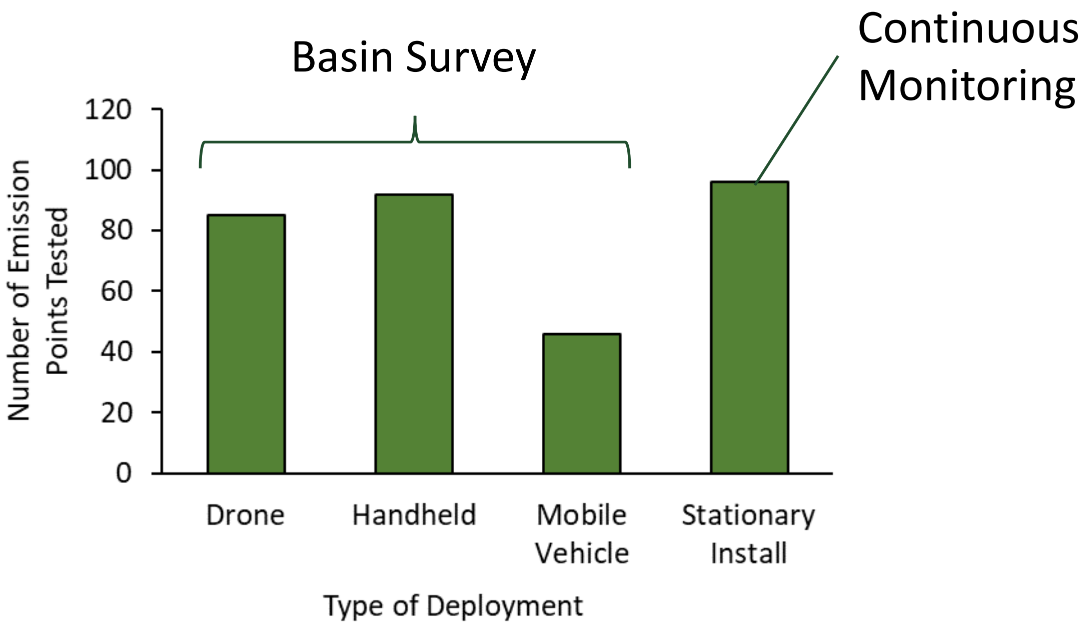
- Detected
  - Emission point reported on same equipment *unit* as an emission point: "Pad 4 / Wellhead 2"
  - 15% of difficulty "C" test points had two emitters close together: Detected if one reported.
- Same Group *(Important for some stationary solutions)*
  - Emission point reported on same *equipment group* as an emission point: "Pad 4 / Wellhead 2" but emission was on "Pad 4 / Wellhead 1"
- Not Detected
  - No reported point on same equipment or same group
- False Positive
  - Reported emission on equipment group with no emission point

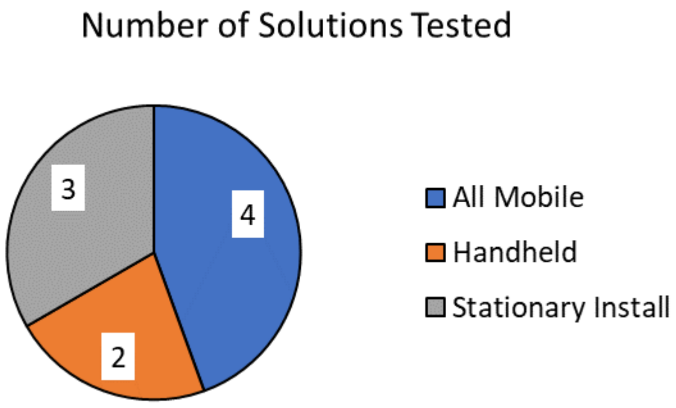
Not Covered in R2 Protocols

- Full complexity of emissions on real sites
  - Stochastic emission amounts, timing
  - Long-gaps between emission events
  - Operator interventions
- Weather → All tests are short (max 2 weeks), all in Colorado
- Site complexity → Well pads of low-to-moderate complexity
- Limited gas composition range may impact gas detection sensitivity
  - 86-88% methane / 10-12% ethane / market gas → used for automated tests
  - Methane only / unscented → used for handheld tests
- No hot backgrounds
- No exhaust plumes

Results

Who & How Many …



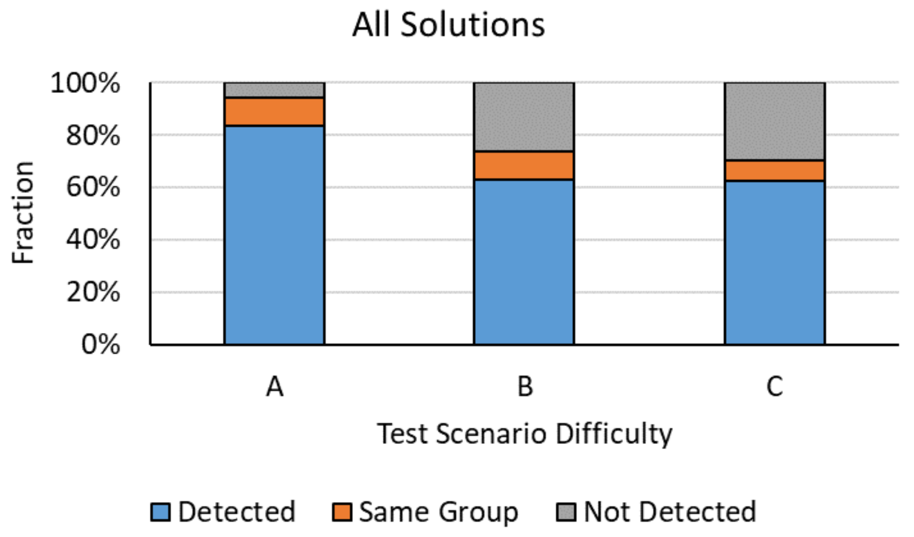


- Categories are “hazy”
  - Several levels of “mobility” / several degrees of “stationary”

Complex Scenarios Are Harder …

- Detection rates drop when multiple emission points are present

- Type of multi-point emissions has less impact than "if there are multiple points"



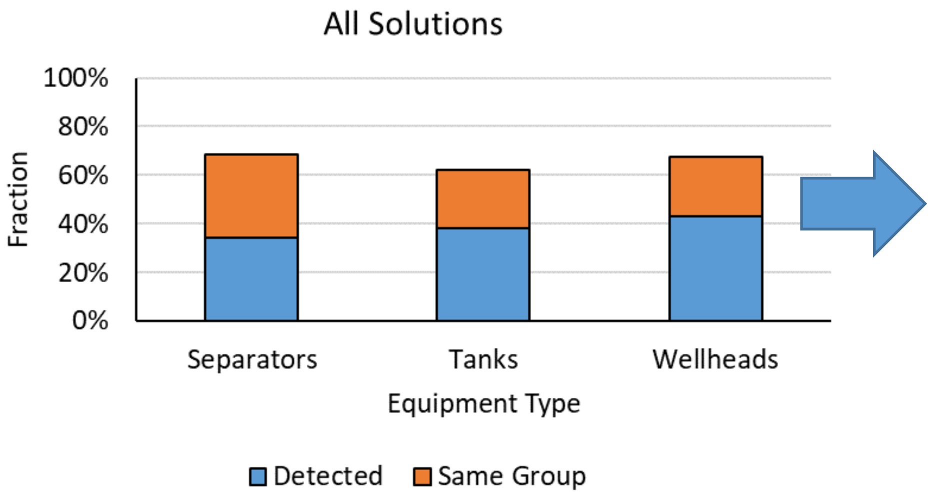
<u>3-Level Test Complexity</u>

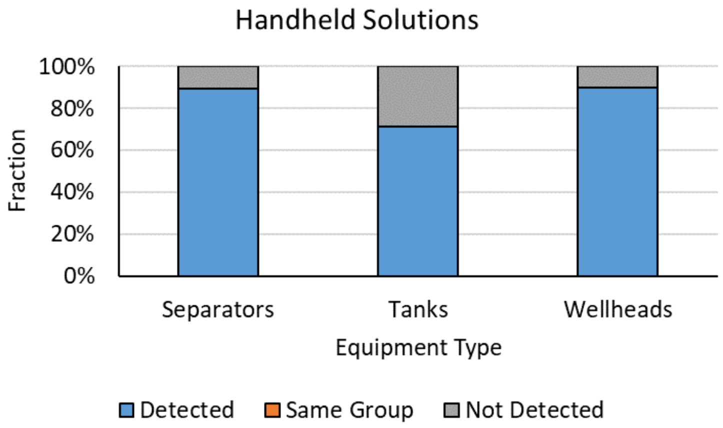
A – Single emission point per pad, Steady emission rate

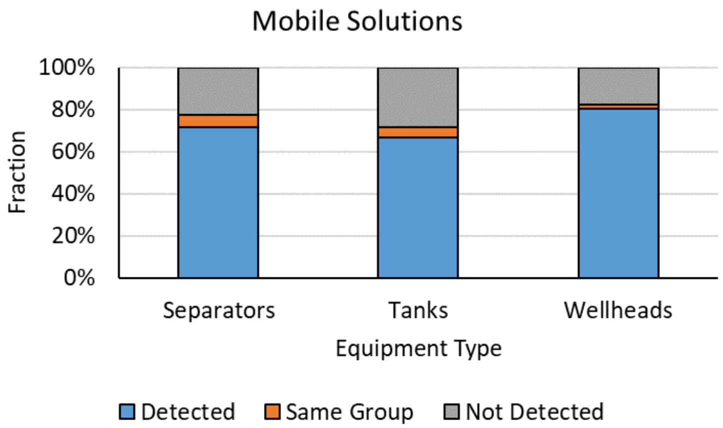
B – Multiple emission points per pad, Steady emission rate

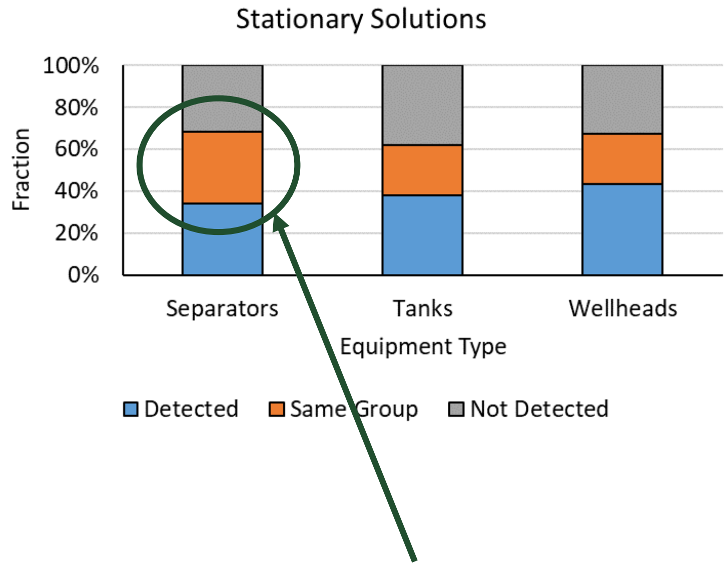
C – Multiple emission points per pad, Steady & intermittent rates

Large, closely spaced, equipment is harder …









Some stationary solutions *set up to only locate to equipment group*

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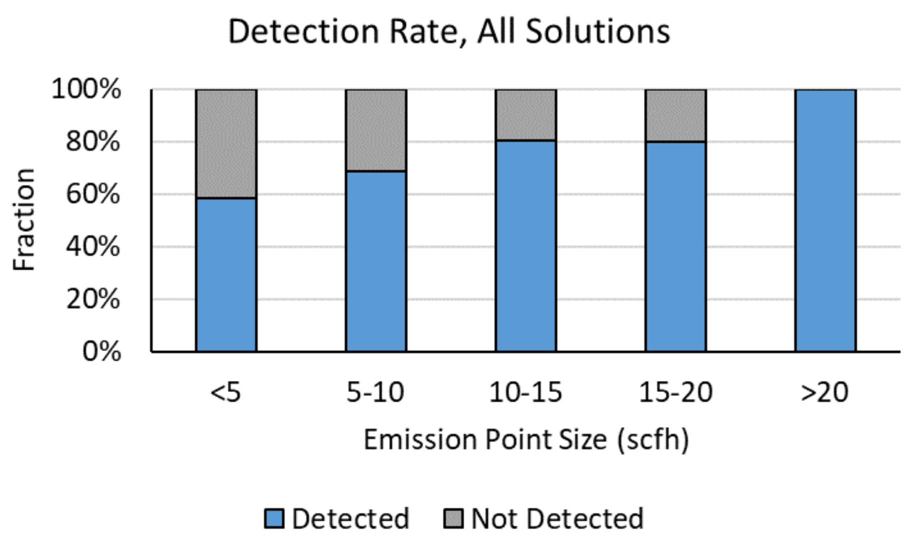
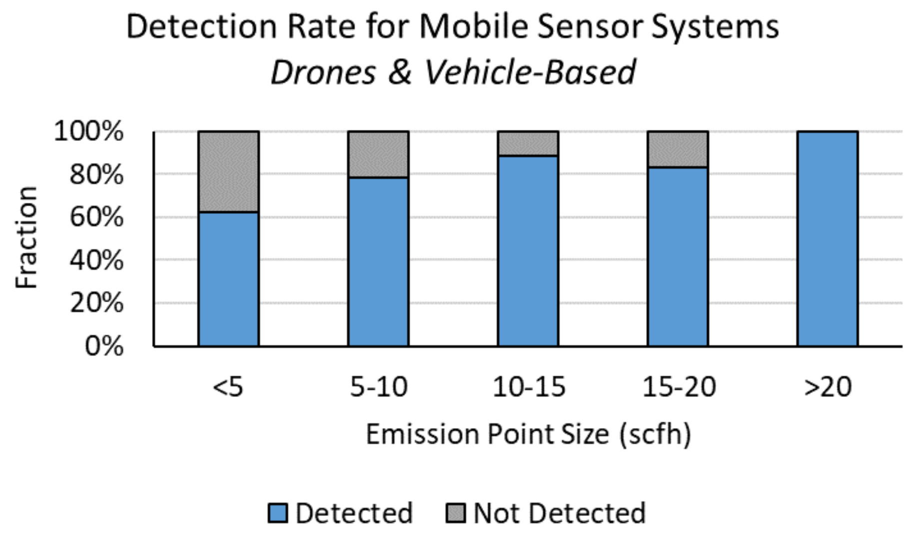
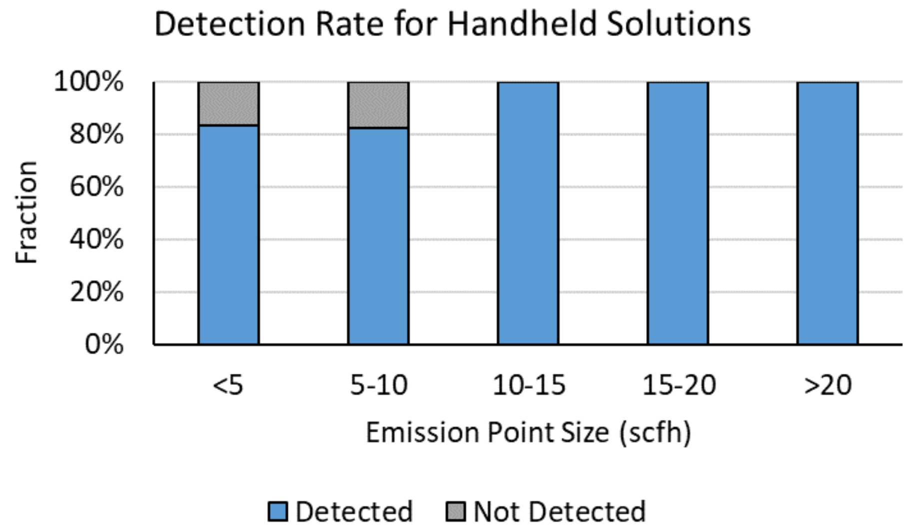
Smaller Leaks are Harder …

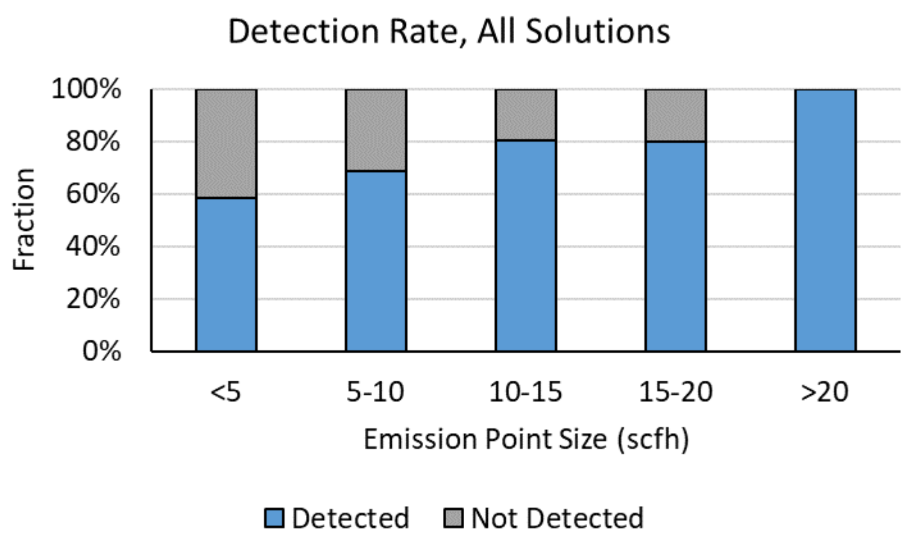


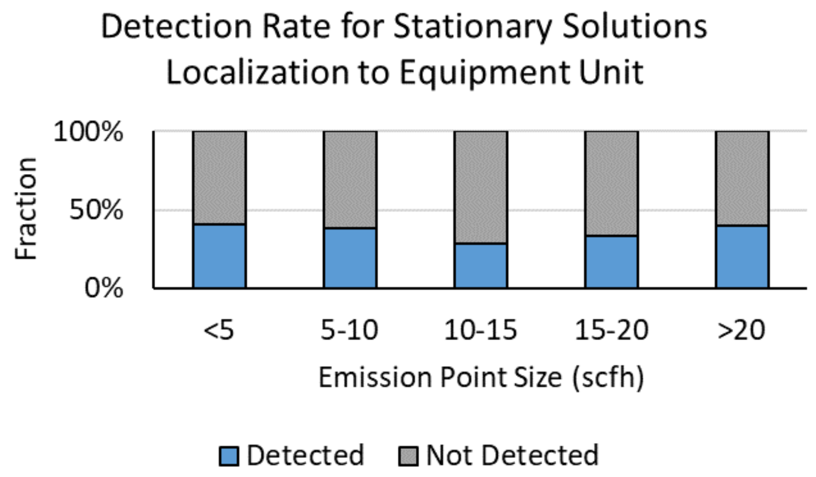


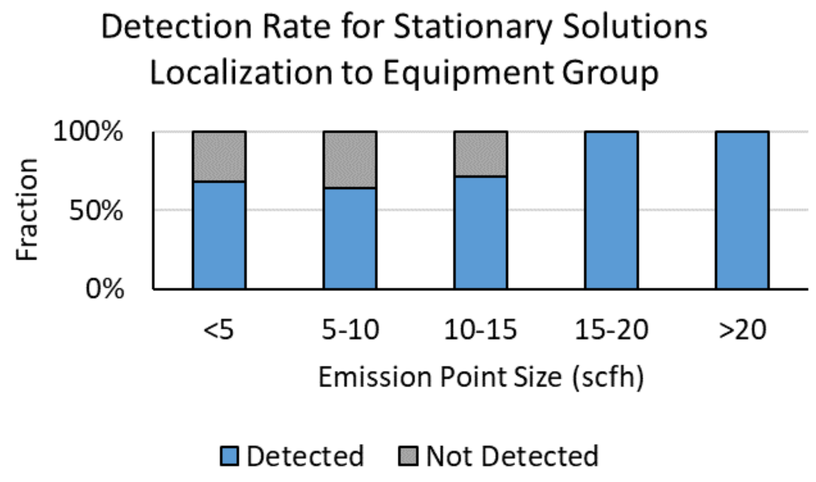


- Handheld solutions do better – but (in theory) require more labor
- Direct confirmation of results

Stationary Solutions – Identification Level

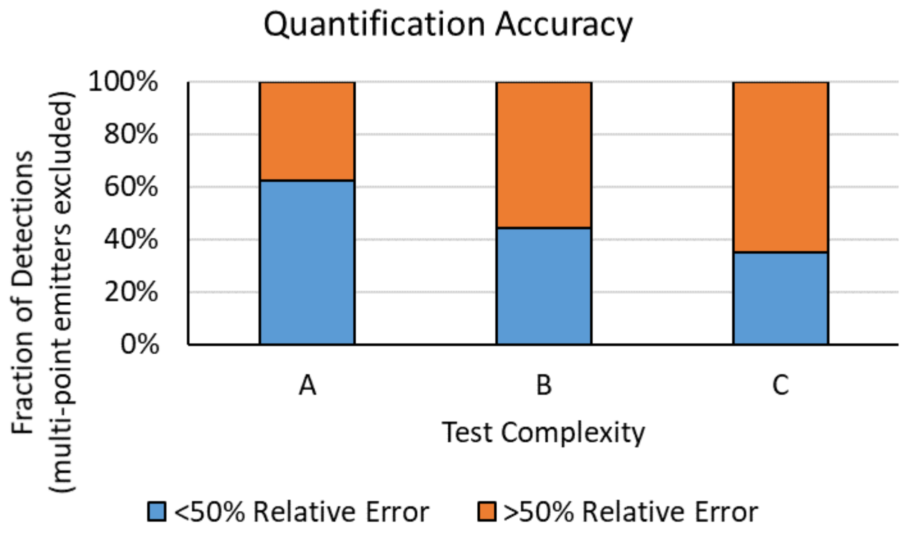


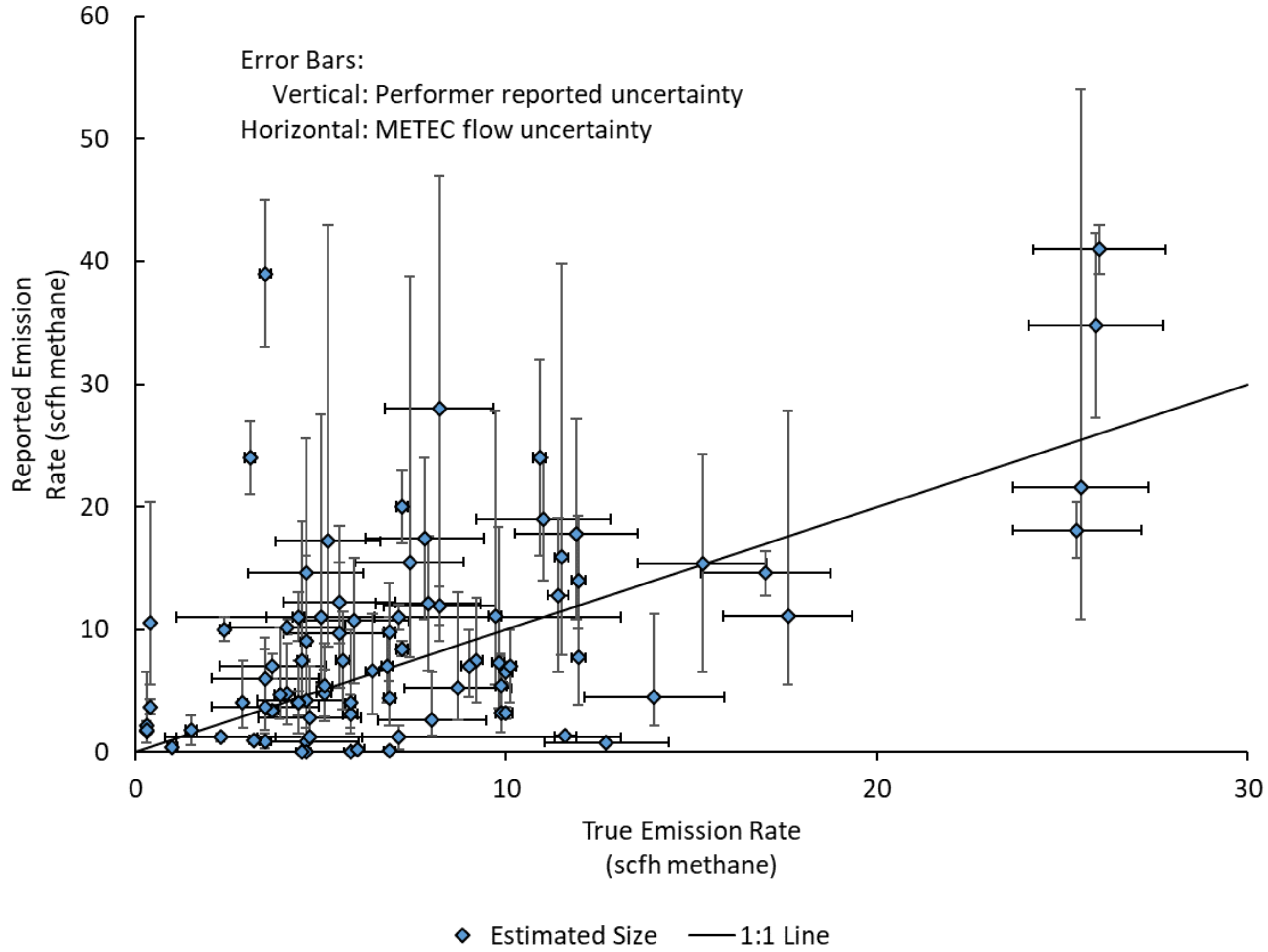




- Operate 24/7
- Detection is comparable to other solutions
- Localization is less precise

Quantification remains problematic



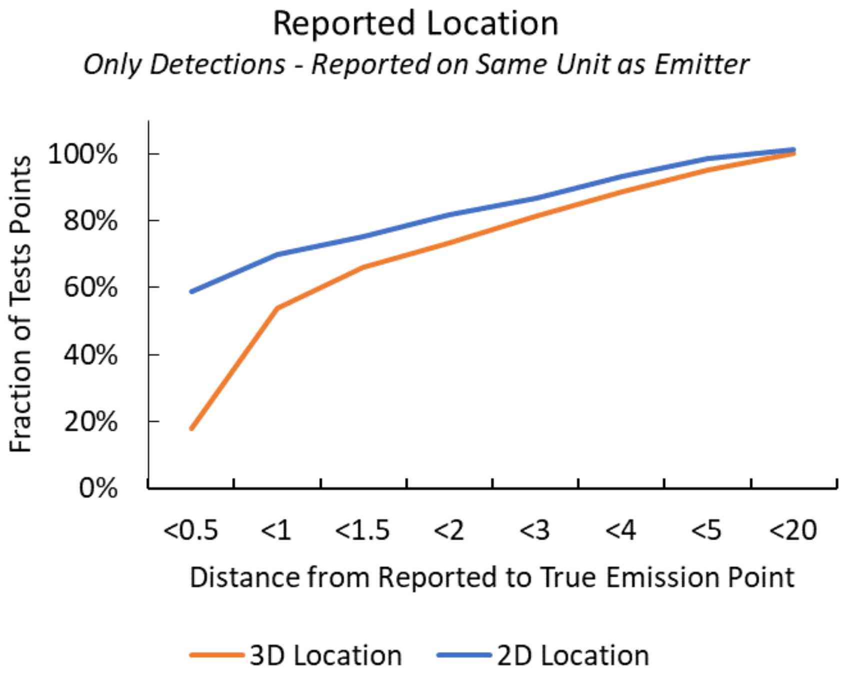


Single point emission locations
Detected emitters only

Localization … looks promising …

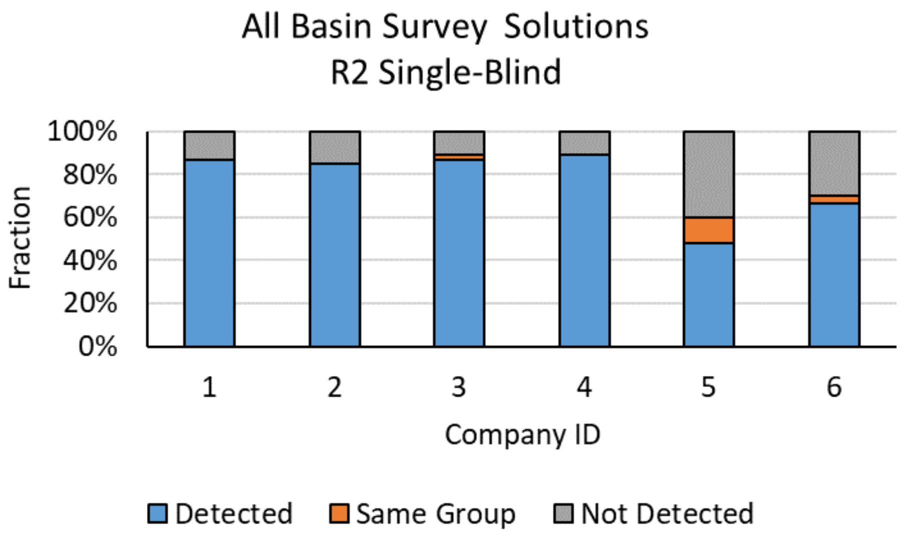
- 2D – 70% within 1 meter
- 3D – 54% within 1 meter

- Recommend automated capture of leak locations
  - In solution design
  - In SCADA tracking systems



Solution performance varies …

- *R2 protocol is a repeatable test*
  - Varying weather conditions … retests for weather allowed
  - No limit on time to turn in results
  - Sites / hour varies substantially
- Cost of solution must also be considered
  - Fully automated versus "operator plus tool"
- Most drone-based require pilot now, but moving toward automated flight paths



- Mobile vehicles, drones, and handheld
- Varying degrees of automation & human intervention

What Have We Learned?

- Testing – even in simplified METEC environment – distinguishes differences in performance

- Nuances challenge comparisons
  - Variation in deployment methods
  - Amount of human interaction with automated solutions → translates to cost
  - Amount of labor in post-measurement analysis → translates to cost

- Protocols are informative, but need more development
  - More repeat testing
  - Standardized reporting – with time limits
  - Tracking practical performance metrics: time/site, up-time, etc.

Future of Testing Protocols

Proposed "Testing Products"

1. Basin survey
2. Continuous monitoring
   - *Time to detection* must be measured

   Revisions & refinements of R2 protocols (with advisory input) [applies to 1 and 2]

3. Detection only variants — Basin & continuous monitoring modes for *detection only* solutions
4. Duration data product — Cost-reduced method to support long-term installs @ test site

Roundup Logisitcs

	Room 1: LSC 322 Tested R2 @ METEC	Room 2: LSC 324 Tested R2 @ METEC	Room 3: LSC 350A Ballroom No R2 METEC Test Results	Room 4: LSC 328-330 Tested R2 @ METEC
1:00 – 1:40	LongPath Technologies, Inc. – Basin Survey	Rebellion Photonics – Basin Survey	MIRICO Ltd.	
1:50 – 2:30	Fluke – Basin Survey	Heath Consultants, Inc. – Facility Monitoring	FLIR Systems, Inc.	
2:40 – 3:20	Gas Detection Services, LLC – Basin Survey	LaSen, Inc. – Basin Survey	United Electric Controls	Bridger Photonics – Basin Survey
3:30 – 4:10	Heath Consultants, Inc. – Basin Survey	Alert Plus, LLC – Facility Monitoring	MultiSensor Scientific	

Remember to fill out a feedback form!

Thank You

Contact

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