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COLORADO STATE UNIVERSITY

Advancing Development of Emission Detection

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Prime: CSU

PI - Daniel Zimmerle

PM – Wendy Hartzell

RS - Clay Bell → Ethan Emerson

Subawards:

University of Texas, Austin – David Allen, Arvind Ravikumar

Southern Methodist University – Kathleen Smits

What are ‘Next Gen’ LDAQ Solutions?

What Makes a Solution “Next Gen”?

Traditional Leak Detection

Close to each potential ‘leak interface’
Trained **surveyor** + sensor (camera)
Always a ‘**survey** method’
Inherently a **yes/no** result
Quantification as separate (optional) step

Next Generation

Emissions have been **transported by wind**
Greater automation/**autonomy** than traditional
Continuous & survey deployment methods
Stochastic result with uncertainty
May include estimated emission rate

Think: *Solutions* not *technologies or sensors …*

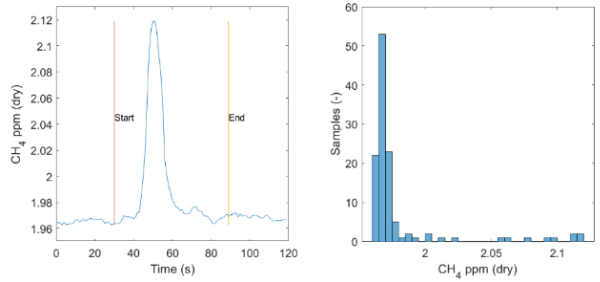
- Controlled & field testing should:
  - Utilize defined, replicable *single-blind* protocols
  - Test a solution *as it would be deployed*

Sensors

# of sensors / revision / power, etc.

Deployment

Locations / passes / speed / height / # of personnel …

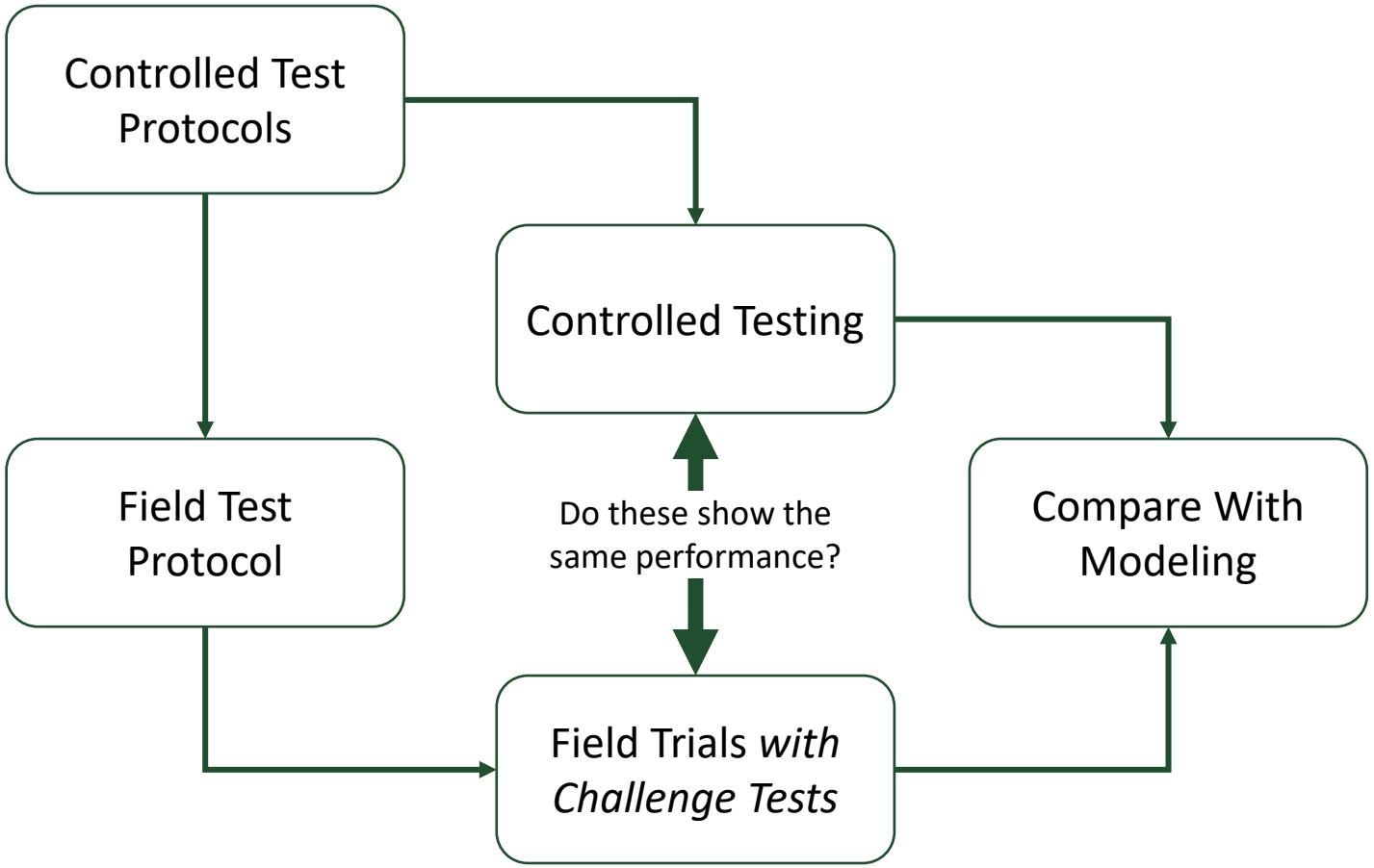


Analytics

Software revision / comms from site & to operator

- Test results should clearly state what/how/how many were deployed … results are only as valid as the test was representative

ADED: **A**dvancing **D**evelopment of **L**eak **D**etection



- Objectives:
  - Develop testing protocols
  - Show that controlled test results reflect field performance
  - Illustrate how results will be useful for modeling LDAR programs

https://energy.colostate.edu/metec/aded/

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Why Both Controlled & Field Testing

Controlled testing: No confusion about the 'true state' of the facility being screened

- Determine key parameters to evaluate effectiveness (i.e. "detection curve")
  - Classify reported detections: True positives vs false positives
  - Identification of false negatives (non-detects)
  - Determination of "time to detect"

Field testing: More realistic … but incomplete knowledge of 'true state' of facility

- More realistic environment to test *actual deployed behavior*
- Testing control is much more difficult
  - No ability to track everything that happens at the site … no foolproof 24/7 monitoring
  - Slow quantification (relative to solutions) with substantial uncertainty
  - Difficult to test efficiently – i.e. encounter a large number of emitters during testing

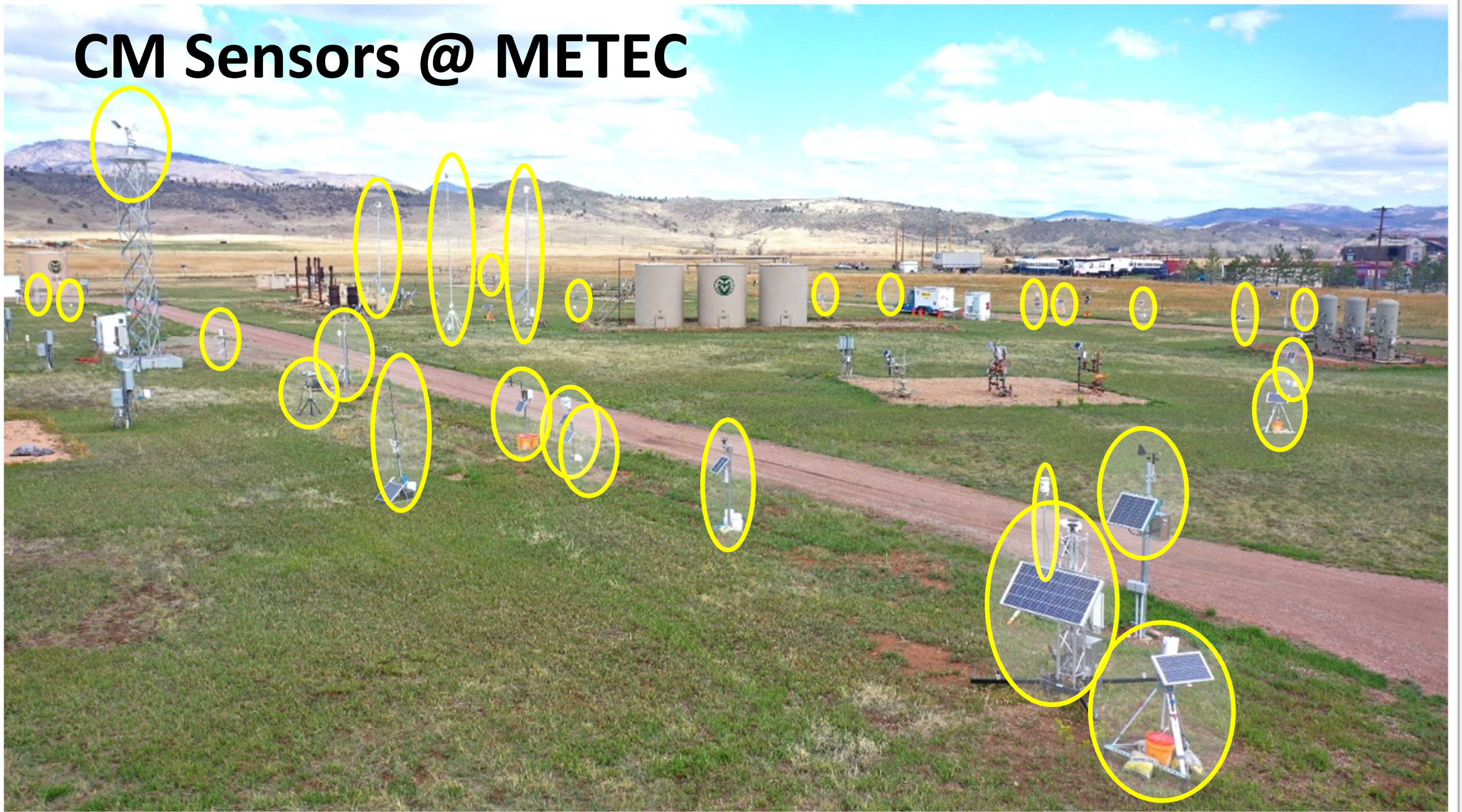
Controlled testing characterizes the solution … field testing qualifies the controlled testing protocol

Controlled Testing

What controlled testing has been conducted?

- Continuous monitoring protocol
  - 3 test programs at METEC
  - 10 solutions participated
- Survey protocol
  - 3 test runs
  - 6 solutions participated

CM Sensors @ METEC



Objectives of controlled test protocols:

- Evaluate *key performance parameters* of LDAQ solutions.
- Test sensitivity of the solution *as deployed*
  → Not an instrument test.
- Standard protocols: Test many unique solutions and produce *comparable results* broadly understood by stakeholder community.
- *Reproducible experimental methodology:* Compare newly tested solutions with previously tested solutions

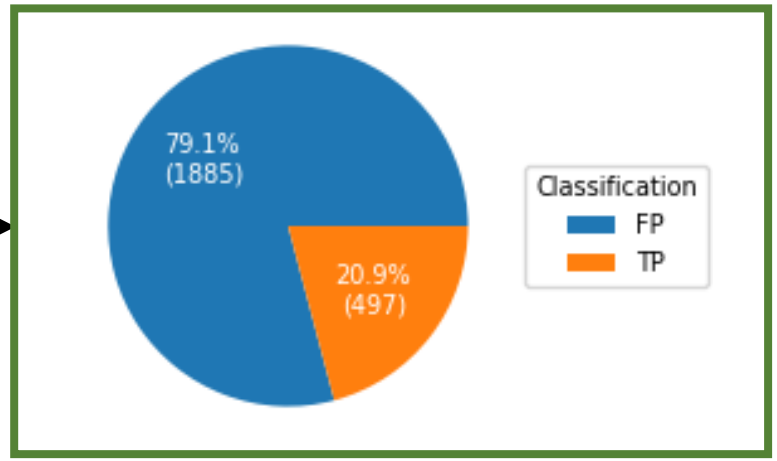
Protocols at: https://energy.colostate.edu/metec/aded/

Approximately 60 entities contributed to the protocol development

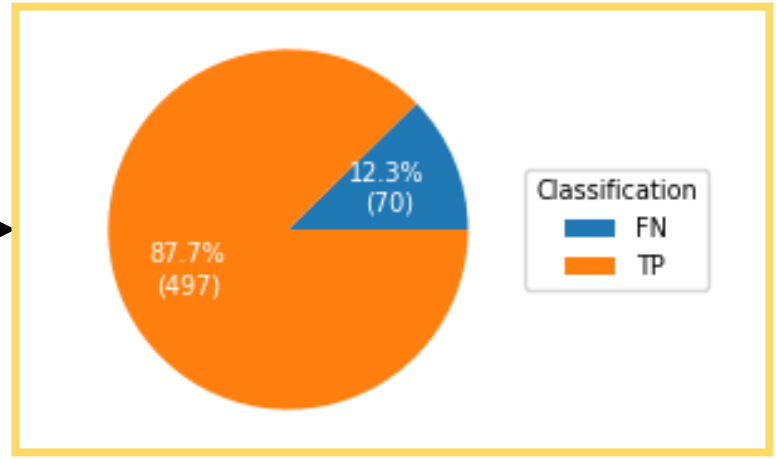
Classification of Detections

Solution Reported Emitter	Emitter Active on Facility: Yes	Emitter Active on Facility: No
Yes	True Positive (TP)	False Positive (FP)
No	False Negative (FN)	True Negative (TN)

Summary of reported emitters

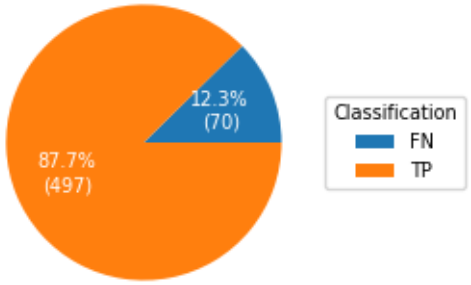


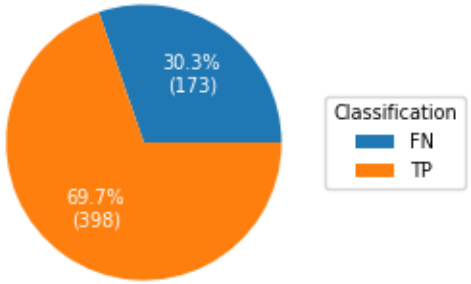
Summary of active emitters



Detections: Notify if Problems Occurs

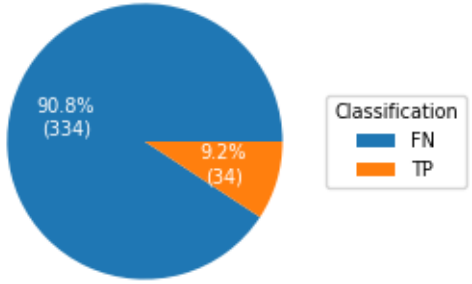
Better Performance

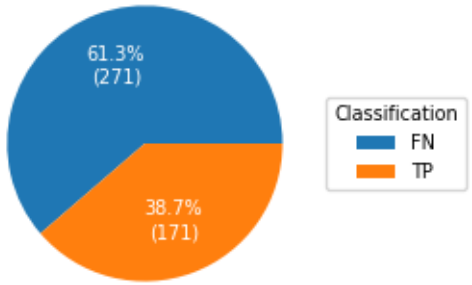




TP to FN Fraction

Worse Performance



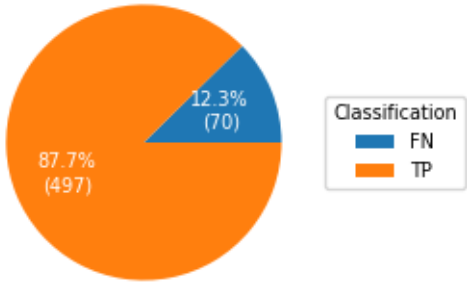


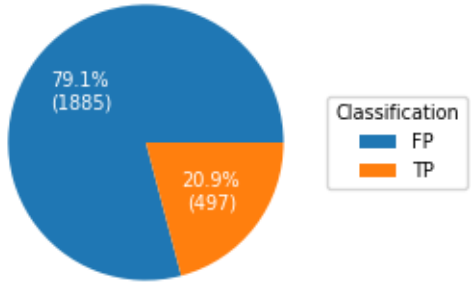
TP to FN Fraction

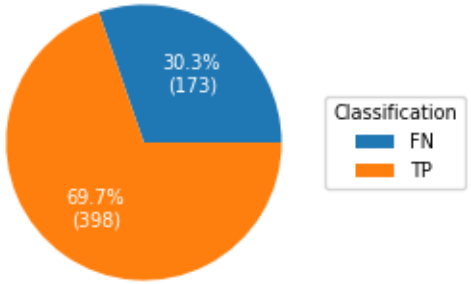
Results from 4 different continuous monitoring solutions testing at METEC for ADED project

Detections: Don’t Notify if No Problem

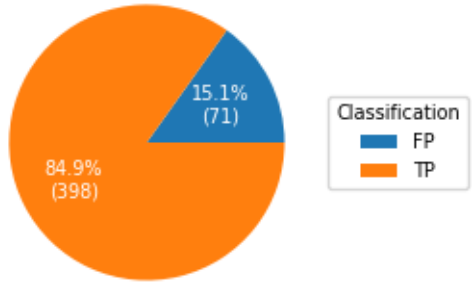
Better Performance





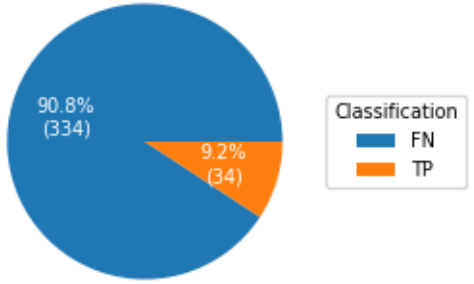


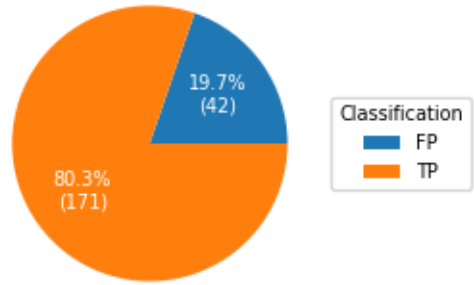
TP to FN Fraction

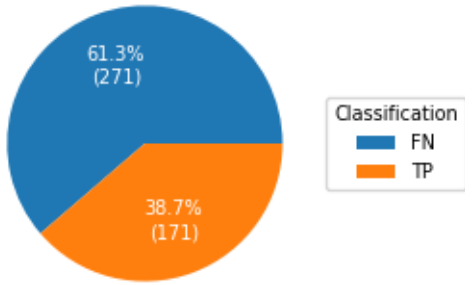


TP to FP Fraction

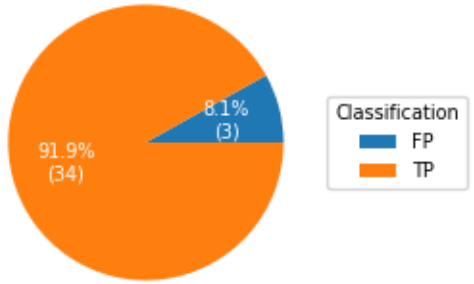
Worse Performance







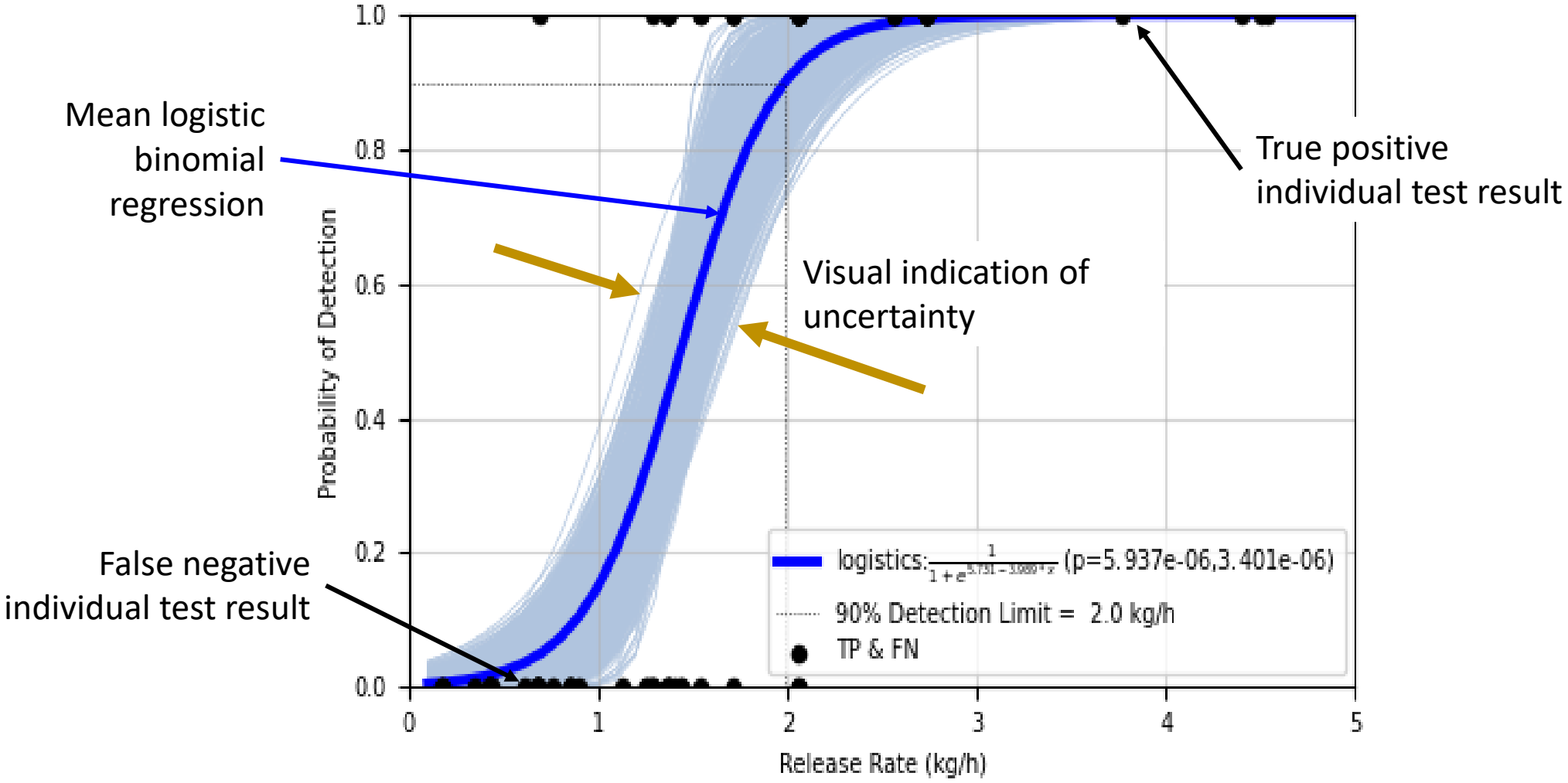
TP to FN Fraction



TP to FP Fraction

Results from 4 different solutions testing at METEC for ADED project

Metrics - Probability of Detection Curves



Quantification

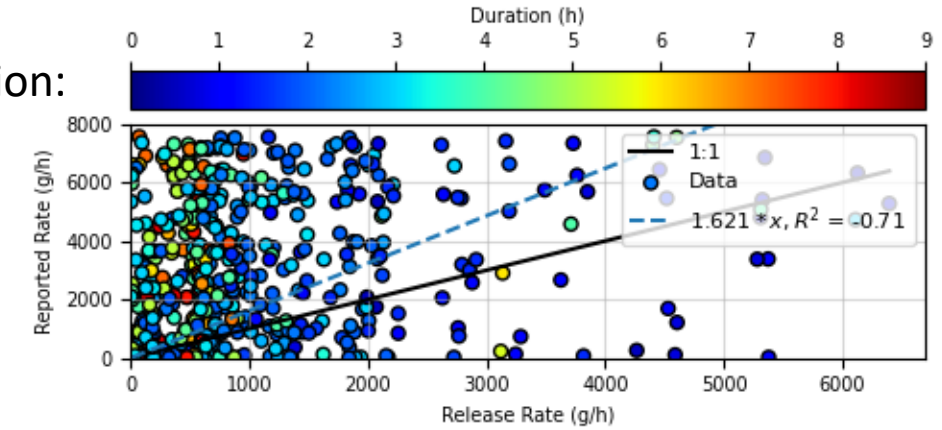
- Controlled releases at METEC
  - METEC is generally simpler than well pads currently being built in the field
- Test conditions are simpler than facility operations in the field:
  - Solutions detect “all emitters” – no need to distinguish between leaks and vents
  - No routine gas venting – pneumatic actuators or pumps, compressor engines, etc.
  - No hot or forced-flow sources

Note: Field conditions are more complex, quantification is likely harder

Secondary Classification:

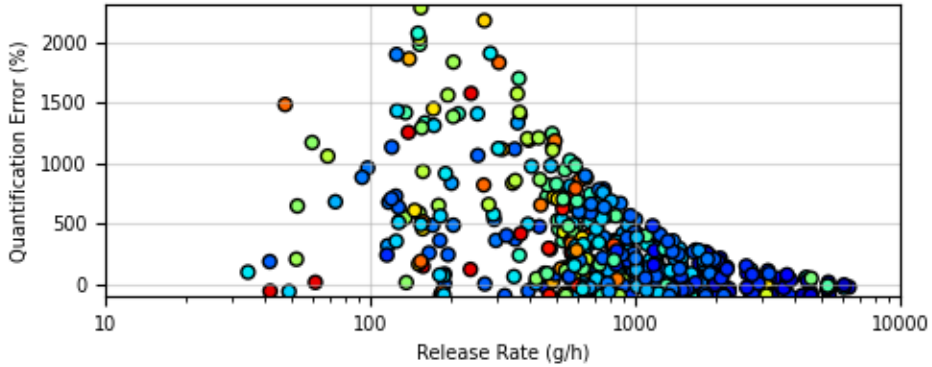
1:1 Plot

Performance over large number of releases

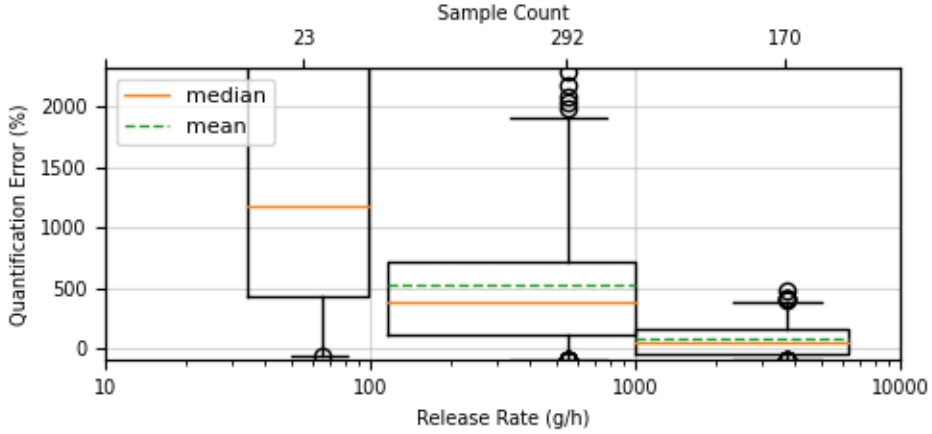


Relative Quantification Error

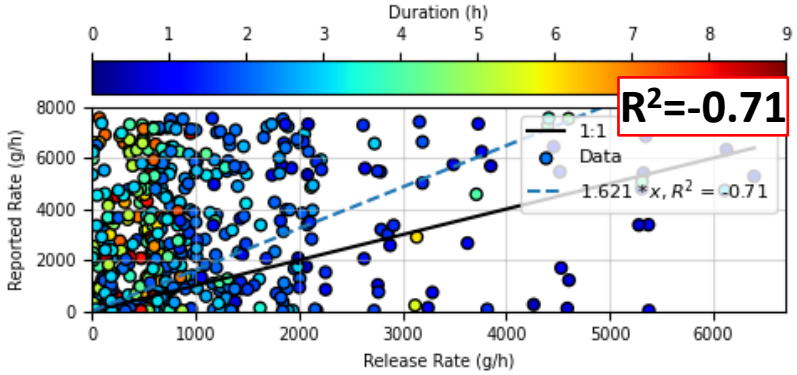
Error of individual releases



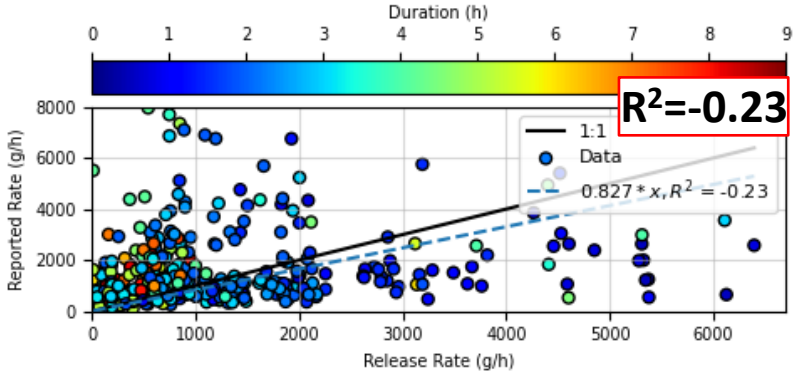
Binned Relative Quantification Error



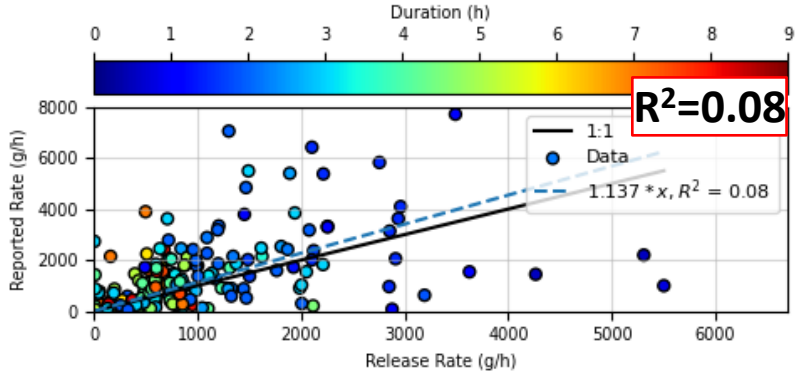
Accuracy of Individual Estimates



R^2=-0.71

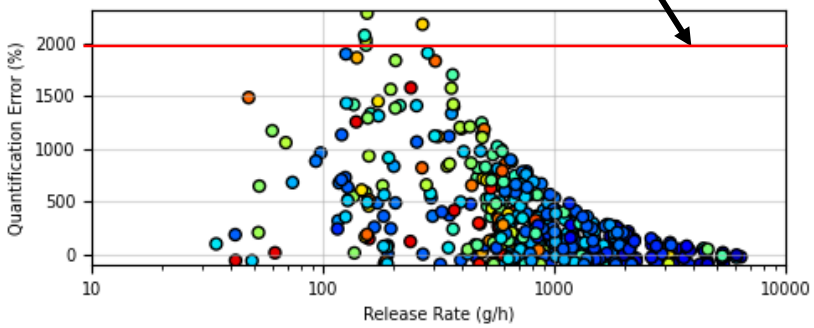


R^2=-0.23

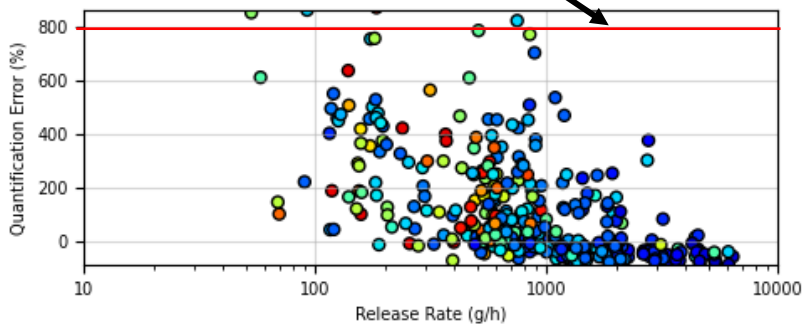


R^2=0.08

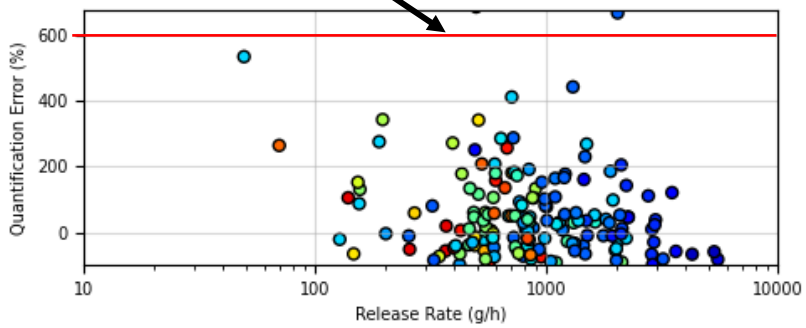
2000% Relative Error

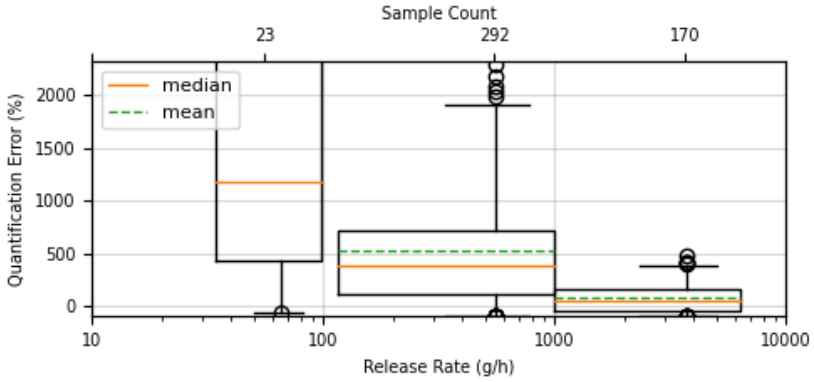


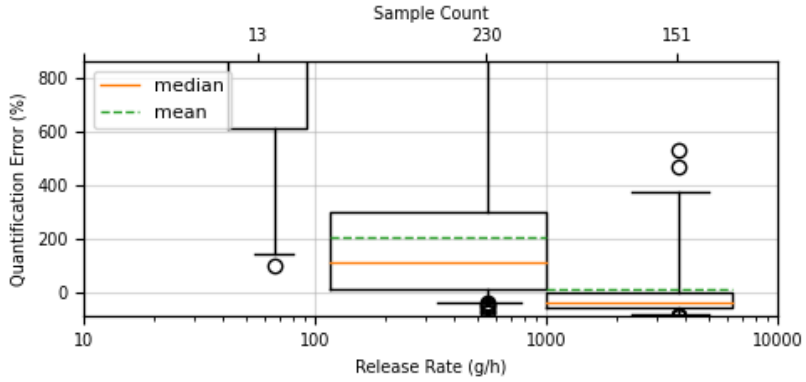
800% Relative Error

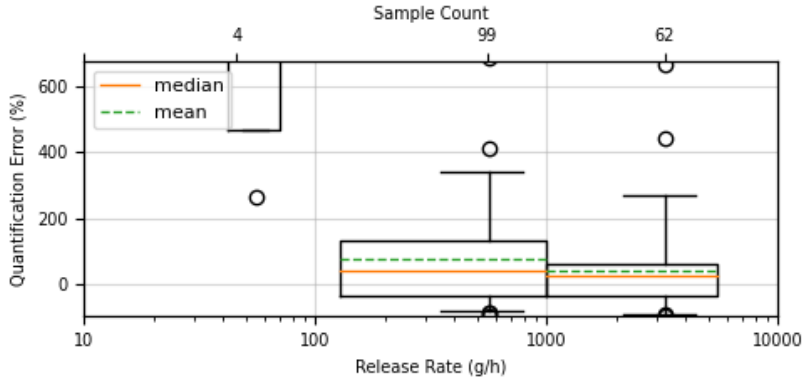


600% Relative Error

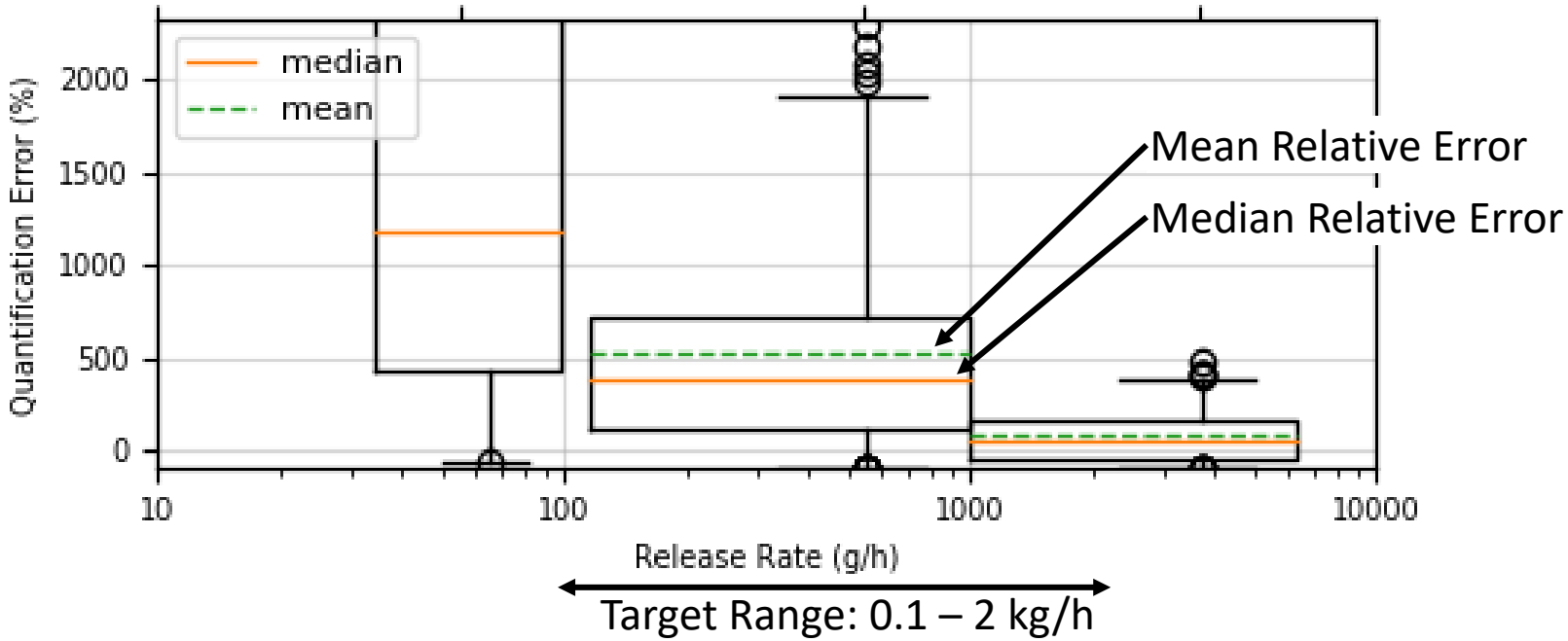


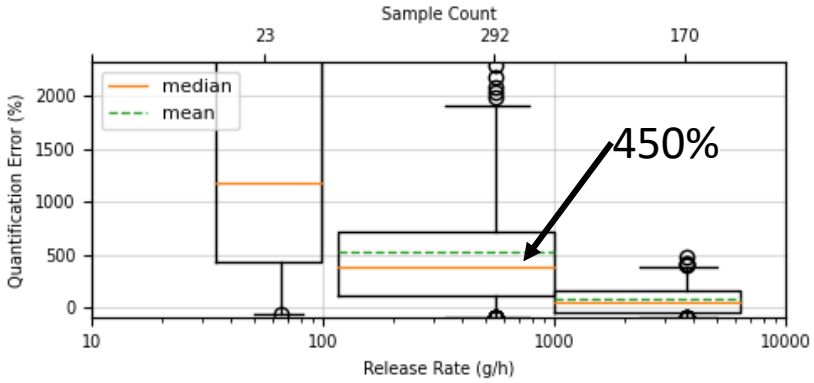


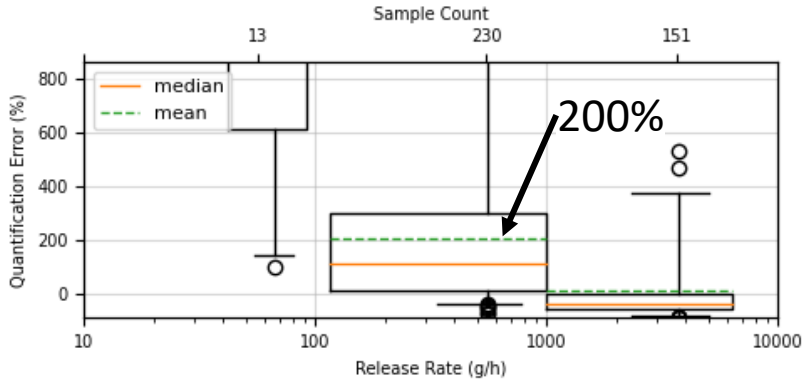


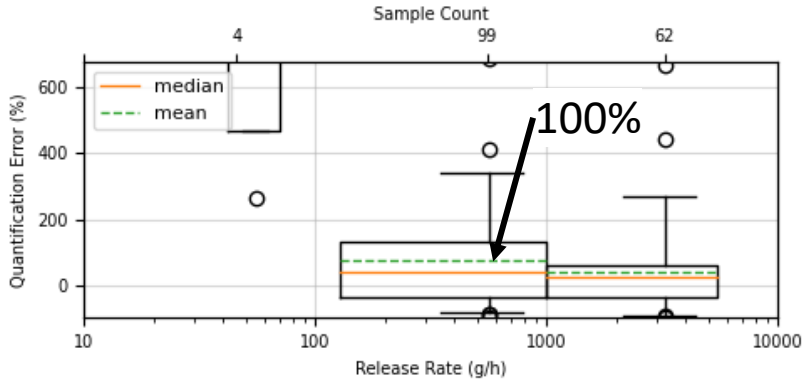


Accuracy for large(ish) sample counts:









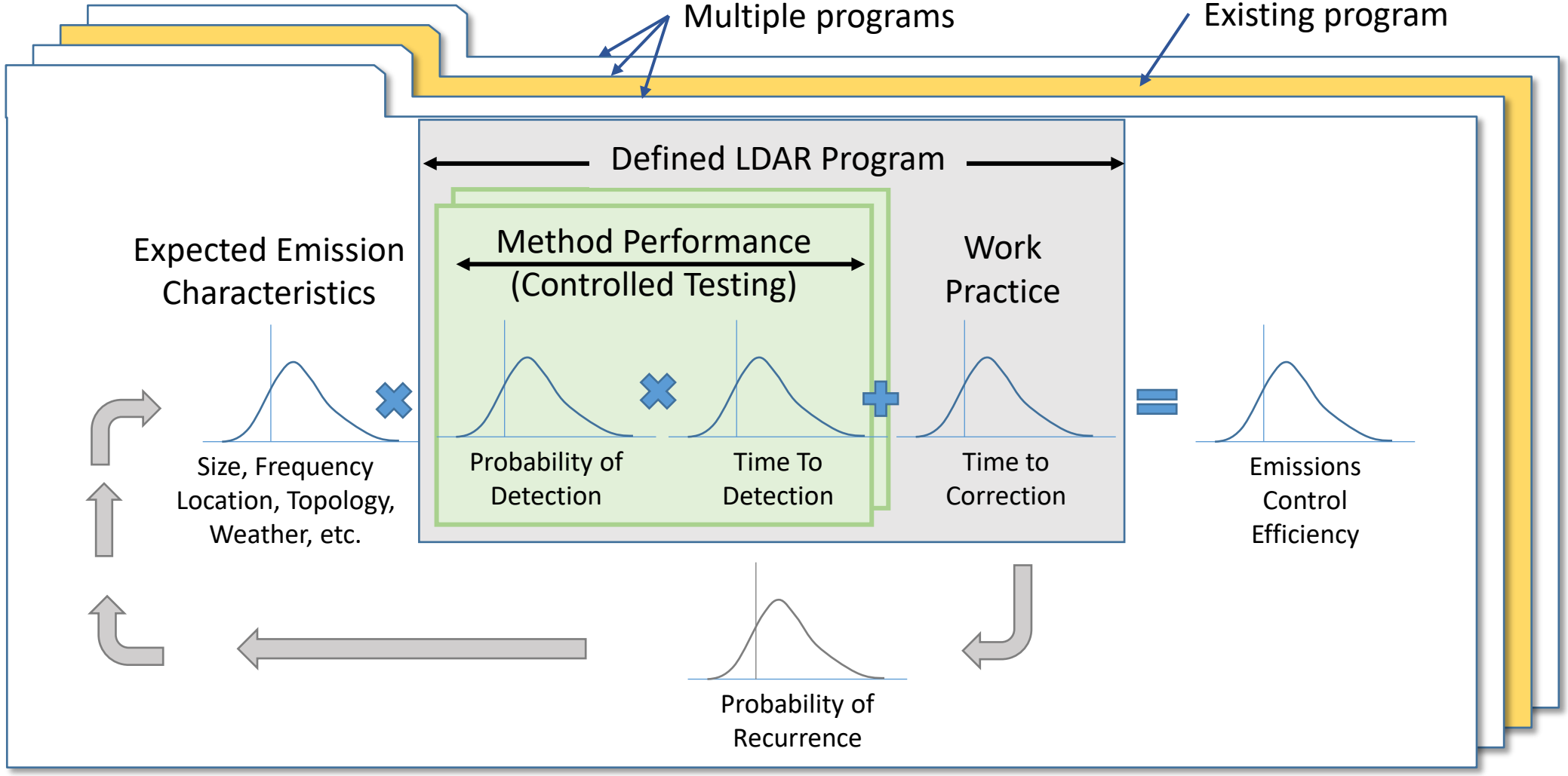
Using Test Results

Leak Detection and Repair (LDAR) *Programs*

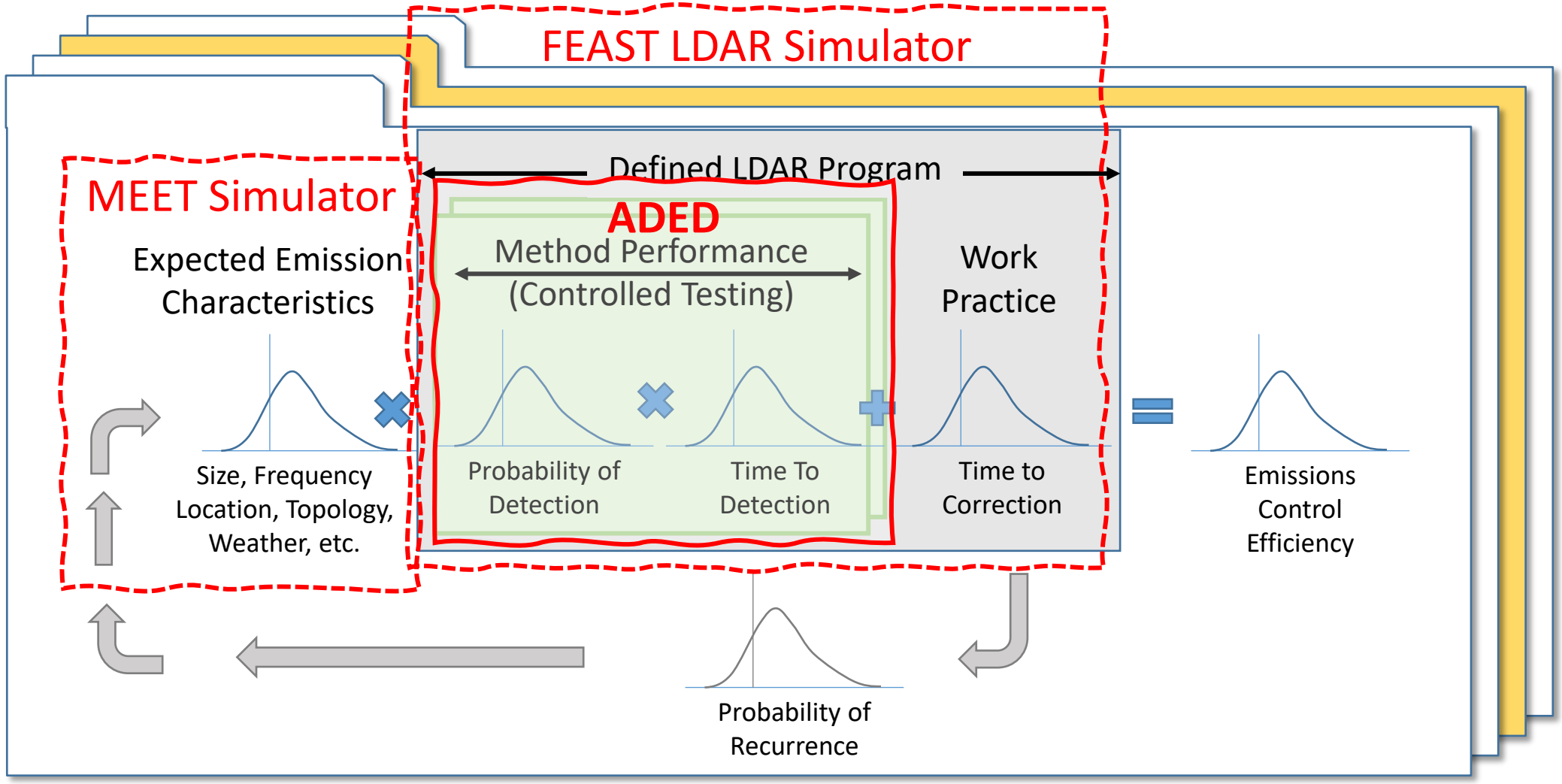
Detect & Diagnose **Repair** **Confirm**

Two solutions … one program

Stochastic Model-Based Program Analysis



ADED in Context of LDAR Program Assessment



Field Testing

What does the field trial include?

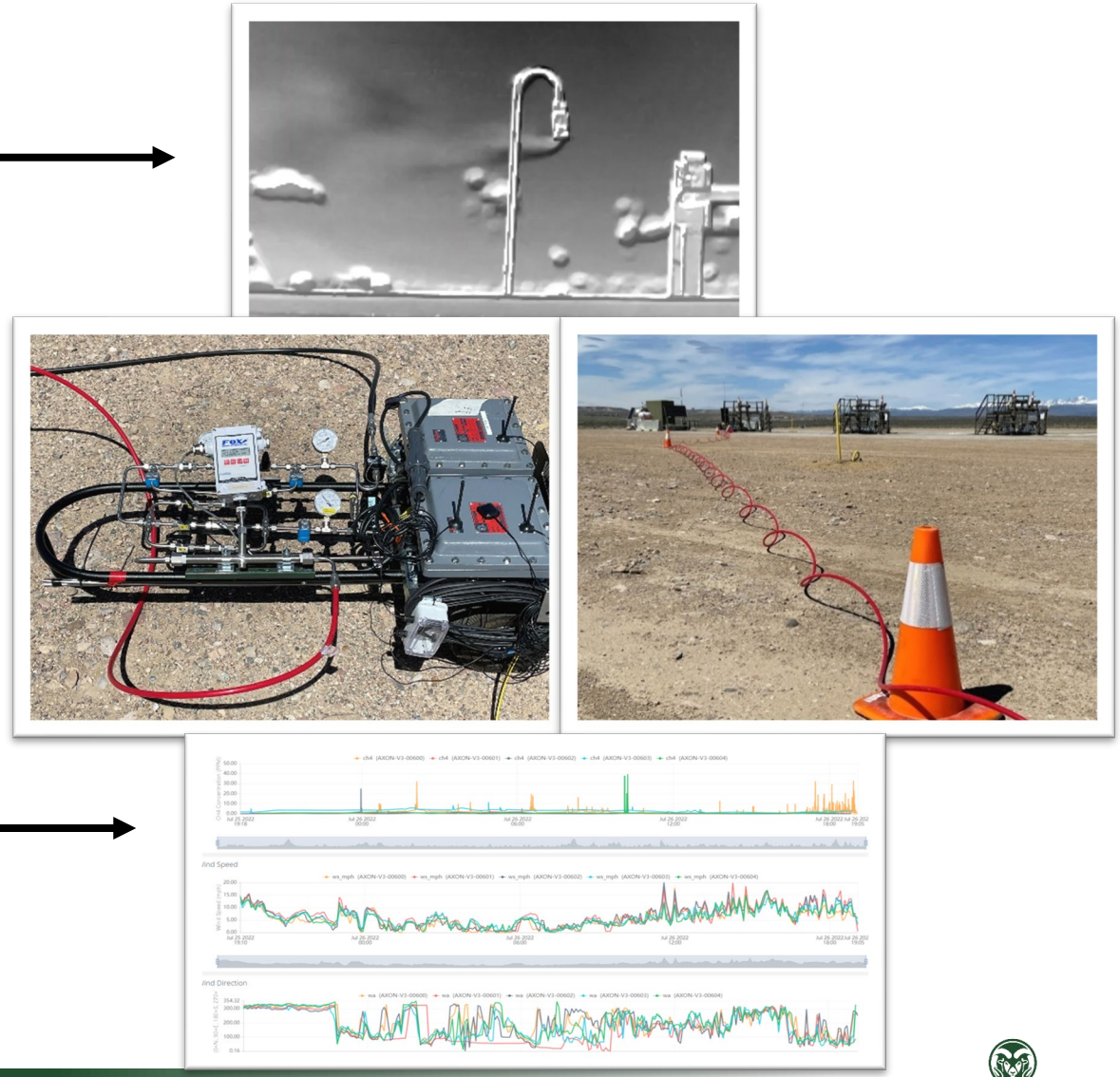
- To date:
  - 3 deployments completed
  - 7 weeks of evaluations
  - 10+ operational facilities
    - Partnered with multiple production and midstream operators
  - 10+ continuous monitoring solutions
    - Point sensor networks
    - Scanning/imaging
- 1 additional deployment planned

How is the field trial conducted?

1. Baseline facility
   - Detect and measure emission sources using OGI & Hiflow sampler.

2. “Challenge test”
   - Conduct controlled releases at locations throughout facility.

3. Collect data from solution dashboards.



What are we learning from the field trial?

- Probability of detection in field trials is generally lower than observed in controlled testing

- Potentially attributed to:
  - Lower sensor density in field deployments (i.e. fewer sensors/acre)
  - Increased variability in background due to routine emissions from pneumatic venting, exhaust, packing/seal vents, uncontrolled tank flash, etc.
  - Different analytics or different parameters used in controlled testing than deployed in field

Detection results from preliminary analysis of challenge tests conducted in field deployment #2

Solution	Detected	Maybe*	Not Detected
A	6 (18%)	-	27 (82%)
B	11 (33%)	4 (12%)	18 (55%)
C	-	11 (33%)	22 (67%)
D	-	-	15 (100%)
E	18 (55%)	9 (27%)	6 (18%)
F	2 (6%)	8 (24%)	23 (70%)
G	12 (37%)	16 (48%)	5 (15%)

*Maybe result indicates the study team could not discern if potential detection in data was attributed to our controlled release or other emission sources at the facility.

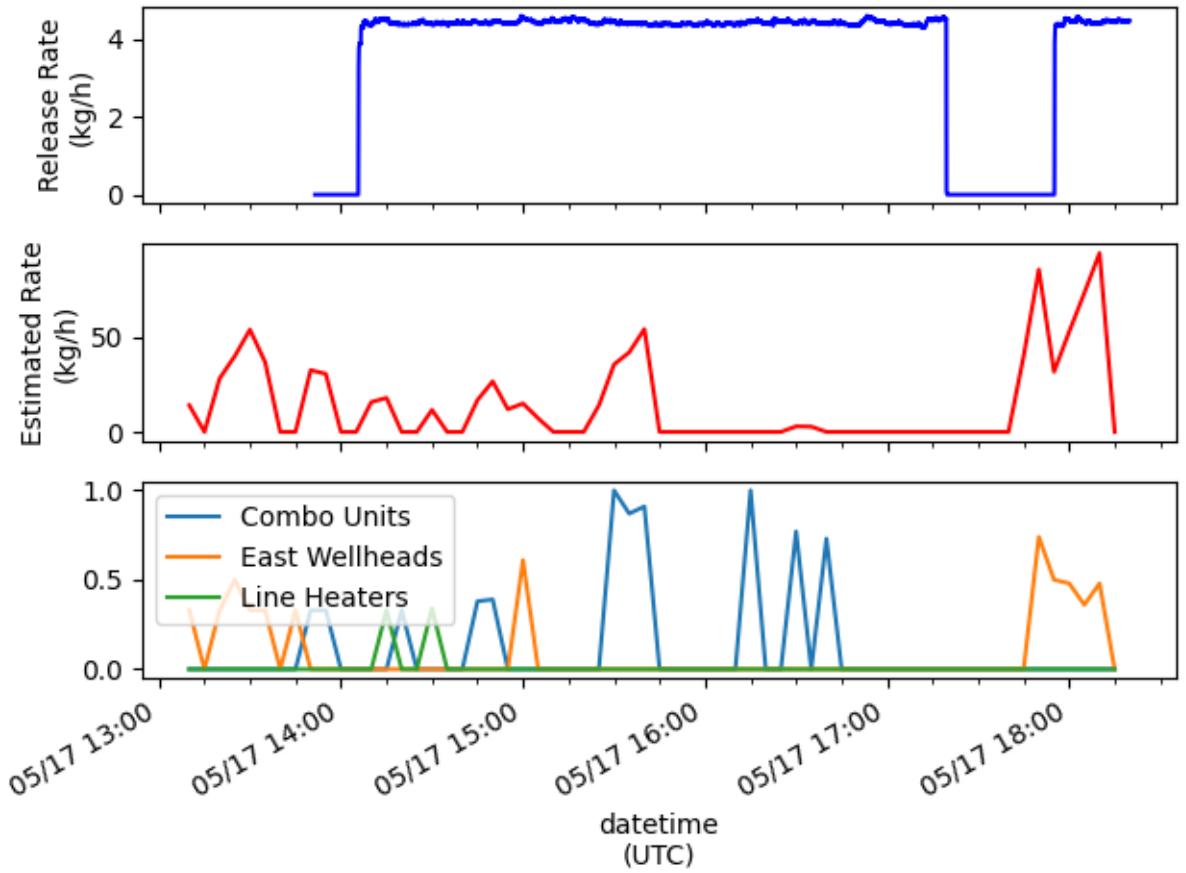
What are we learning from the field trial?

- Detection of continuous releases is often discontinuous in solution data

Stable controlled release flowrate for 3+ hour challenge test located at “Combo Units”

High variability in site emission rate estimate reported by solution prior to, during, and after challenge test.

Emissions correctly attributed to “Combo Units” by solution in discrete samples, however high variability in solution emission rate estimate and coarse attribution data make it difficult to determine if an operator would consider this a “detection” in practice.



Impact

Broader Project Impacts

- Protocols influencing external controlled testing
  - Appendix to survey protocol for application with remote sensing aircraft.
  - Stanford completed major field work utilizing this protocol for multiple aircraft.
  - CSU conducted testing of 1 aircraft solution under protocol in Midland TX. (Journal article accepted)
  - CSU consulted in separate SBIR award to advise on testing to CM protocol.

- Extensive interest internationally – discussions underway with EU/EC and industrial partner in Europe.

- Complimentary industry programs underway

Publications and personnel training

- Publications:
  - Controlled testing protocols and performance– In drafting
  - Field testing protocols and performance – Planned
  - Reconciling Performance from Controlled and Field Testing – Planned

- Personnel Training:
  - 2 Graduate students at CSU supporting controlled and field testing
  - 1 Graduate student at UT supporting field testing
  - 1 Graduate student at SMU supporting protocol development

Remaining Work

- Q1-Q2 2023
  - Complete final quarter of field deployment
  - Additional round of controlled testing at METEC
- Final tasks
  - Papers
  - Simulation of emissions

Thank You

Contact

Daniel Zimmerle, Director, Methane Emissions Program
Dan.Zimmerle@colostate.edu | 970 581 9945

@CSUenergy

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