Smart Methane Emission Detection System Development

DE-FE0029020

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U.S. Department of Energy

National Energy Technology Laboratory

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Presentation Outline

- Technical Status
- Accomplishments
- Lessons Learned
- Synergy Opportunities
- Key Findings
- Next Steps

TECHNICAL STATUS

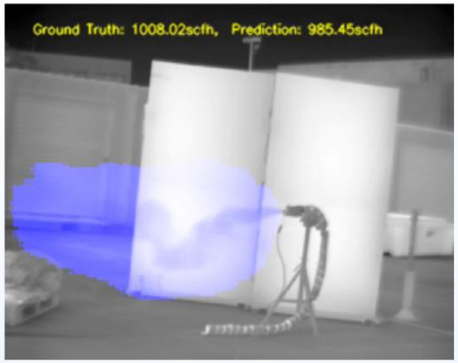
Technology Roadmap

Quantification of Methane — **2020**

Detection and Quantification from one unified platform

Phase 4

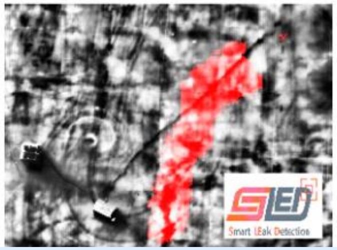
Methane Leak detected and Quantification



Aerial Deployment — **2019**

System Adapted to Aerial Vehicle operations

TRL 7



Methane Leak detected from aerial platform

System Demonstration — **2018**

System Demonstrated in Real world environment

TRL 7

Methane Leak detected in realistic environment

System Testing — **2017**

System Validated in relevant environment

TRL 6

Machine Learning Detected Methane Leak with Red Detection Mask

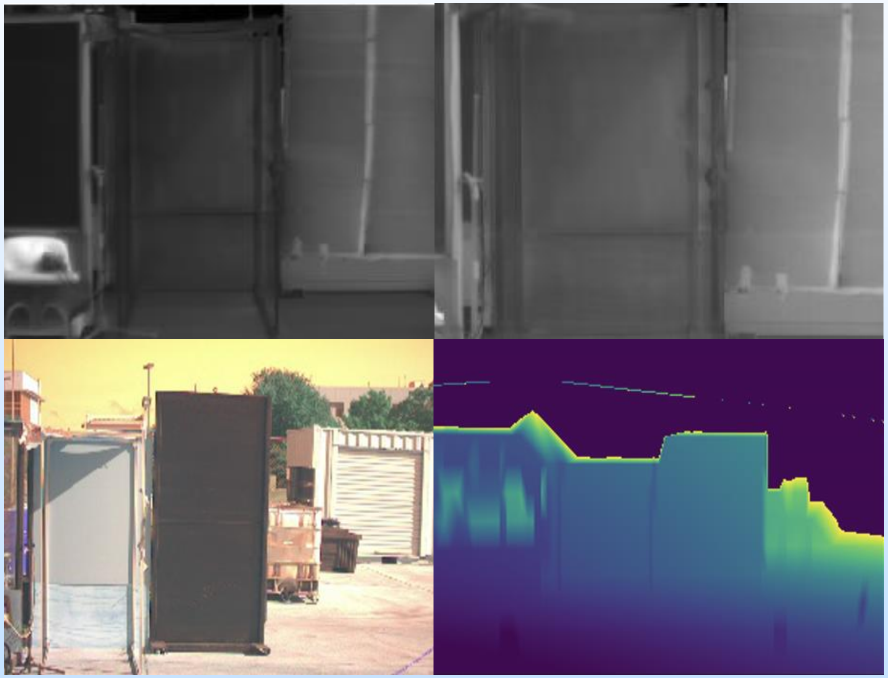
Technology Development — **2016**

TRL 3

Methane Leak imaged with MwIR OGI

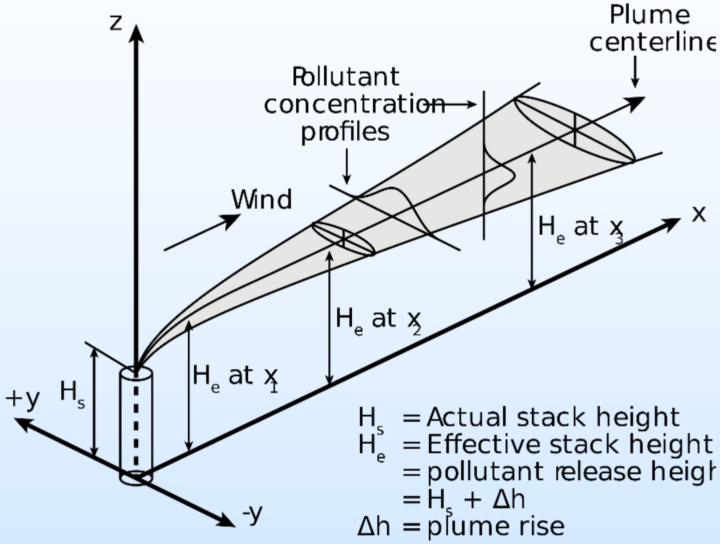
Sensors Investigated

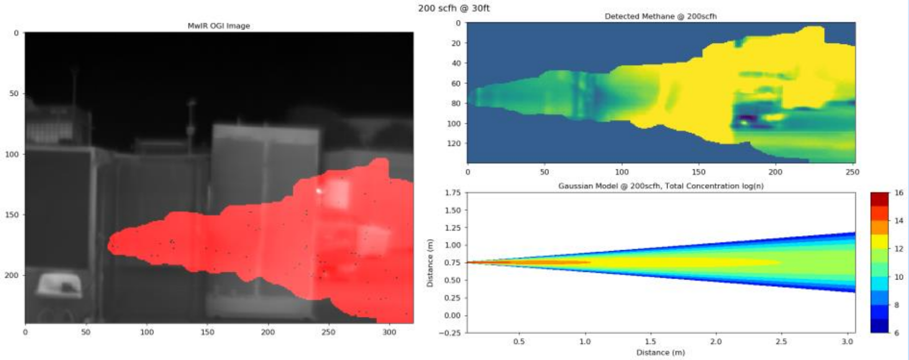
- Sensors:
  - Midwave Optical Gas Imager (Top Left)
  - Longwave Infrared Thermal (Top Right)
  - Visible (Bottom Left)
  - LiDAR (Bottom Right)
  - Weather Station (Not Shown)



Plume Modelling

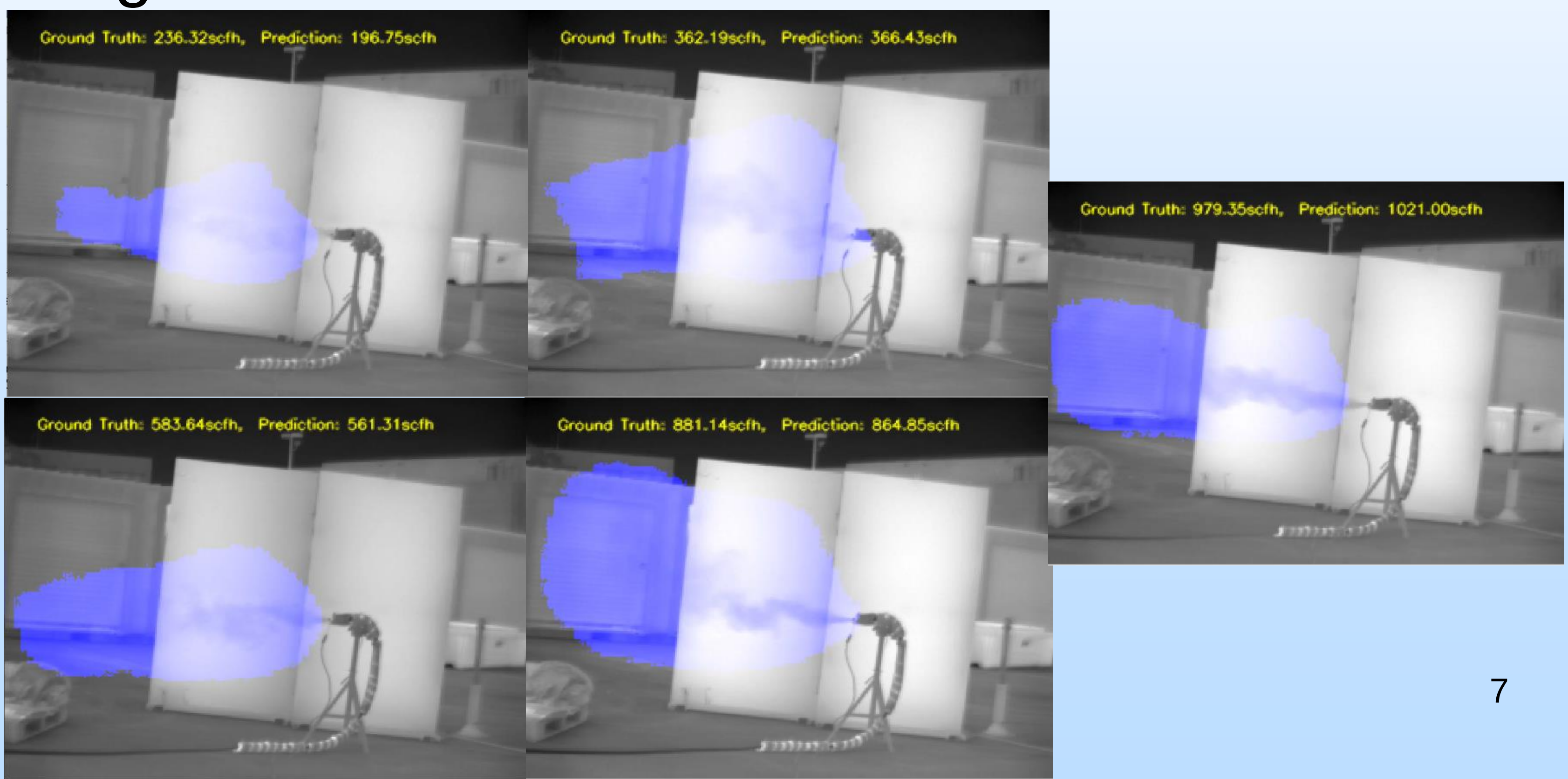
- Gaussian Dispersion Modelling
  - Dispersion models are used to estimate the downwind ambient concentration of methane emitted from sources.
  - Good Baseline Model for semi-stable plume conditions
  - For discontinuous or unstable conditions may need to use more complex modelling



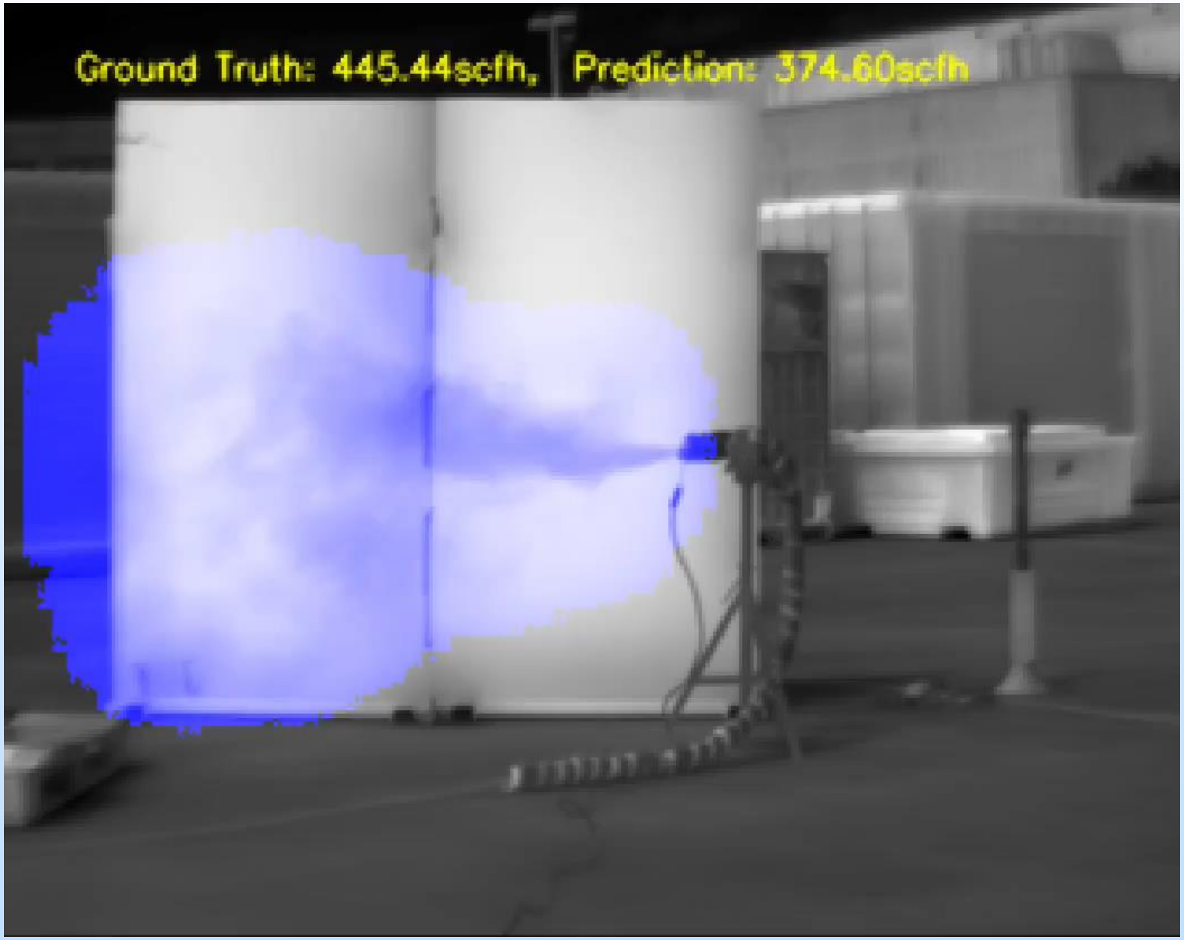


Quantification Algorithm Development

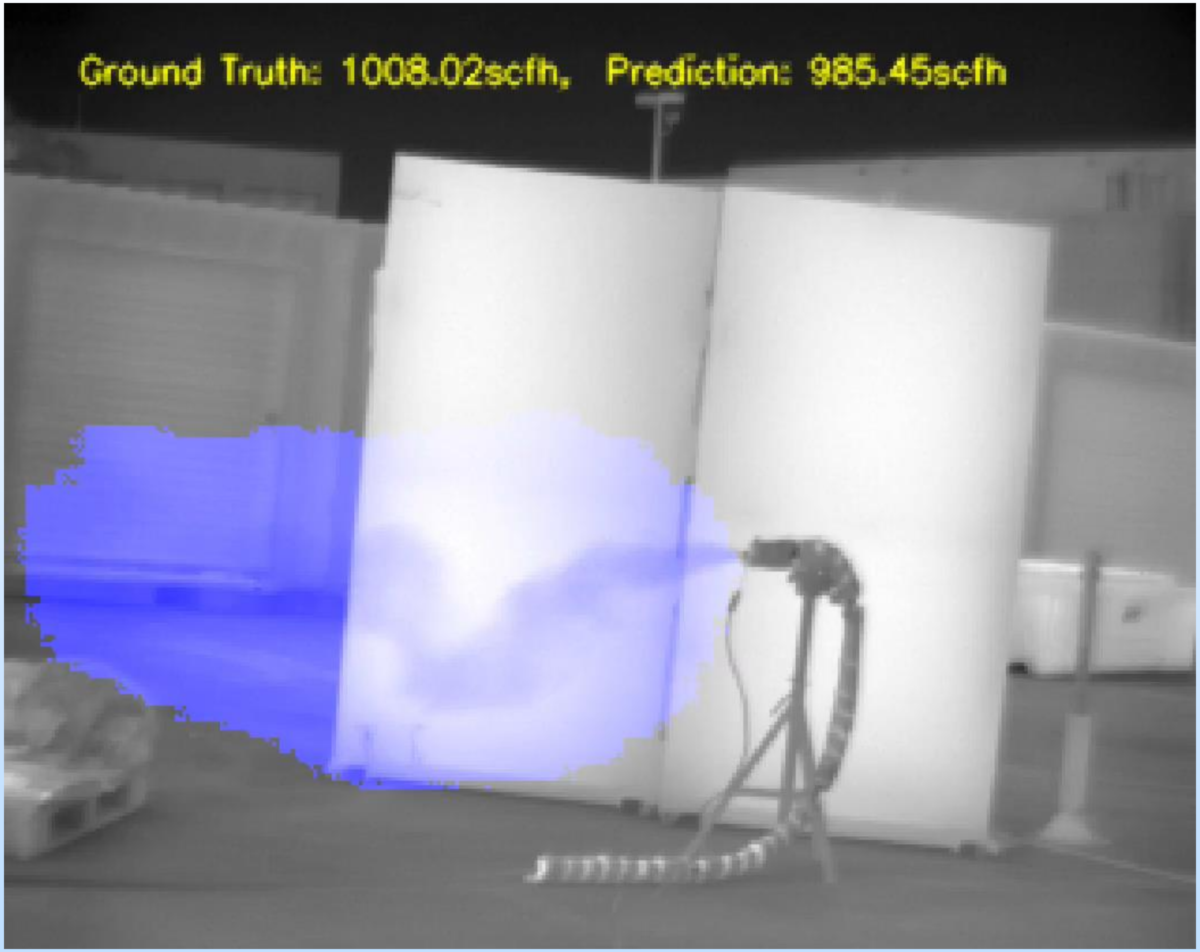
- Deep leaning convolutional regression models to quantify amount of detected methane in the image



Quantification Algorithm Qualative Analysis



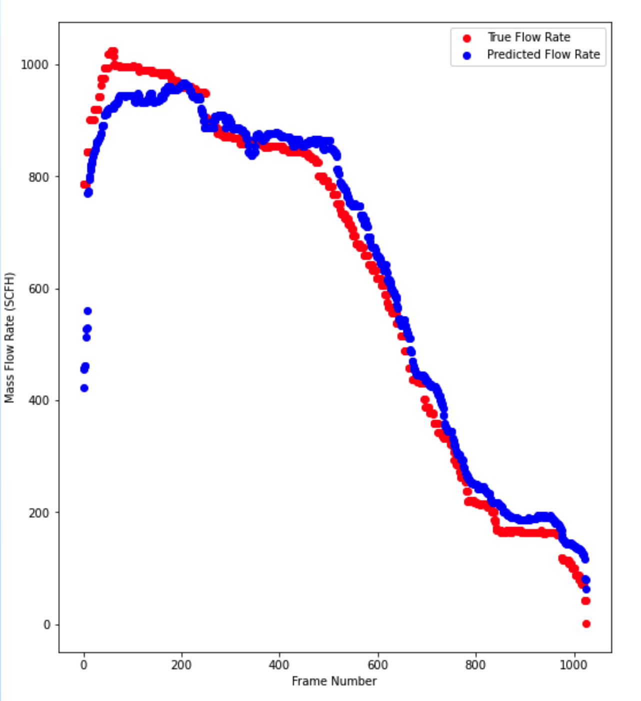
Quantification Algorithm Qualative Analysis

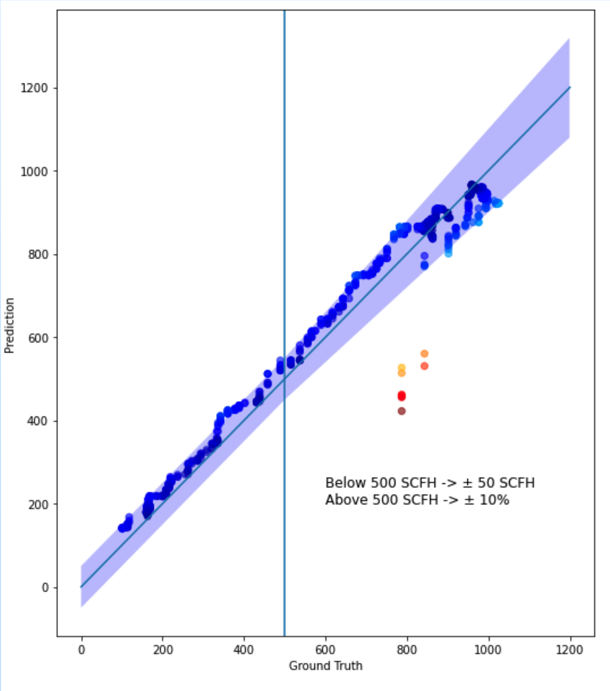


Accomplishments to Date

– Quantification Metrics On Valid Detection and ΔT

- Average Percentage Prediction Error: 12.72%
- Accuracy ±50scfh: 99.32%





Accomplishments to Date

– Algorithm Benchmarking on target deployment platforms

- Detection algorithm capable of running in real-time on most commercially available cameras

		FP32	FP16	INT8	Mixed	FP32	FP16	INT8	Mixed
Device	INPUT SIZE	512x640				240x320			
	Nvidia TX2	1.99 FPS	3.49 FPS	1.99 FPS	3.43 FPS	6.70 FPS	11.70 FPS	6.69 FPS	11.70 FPS
	Nvidia Xavier AGX	5.59 FPS	17.17 FPS	18.28 FPS	19.57 FPS	17.52 FPS	48.66 FPS	48.89 FPS	48.74 FPS

Lessons Learned

- Research gaps/challenges.
  - Wind Continues to be an issue in data collection / evaluation
  - Time constraints on collecting data with different backdrops
- Unanticipated research difficulties.
  - COVID-19 interrupted planned field trials

Synergy Opportunities

– Collaboration between this project and FE0031873 – Advancing Development of Emissions Detection (ADED) could be beneficial in developing commercial adoption of the technology as well as establishing validation and testing protocols

PROJECT SUMMARY

Key Findings

- Incorporation of LwIR and Atmospheric Conditions with the OGI imagery can provide enough information for Quantification
- Quantification still requires adequate ΔT between observed plume and backdrop

Next Steps

- Lighting conditions play a very important factor in correctly estimating methane absorption
  - Work is being done to better incorporate visible Luminance and UV data collected by weather system
- Temperature difference also plays a big role in detection and quantification of methane
  - Work is being done to accurately measure the temperature delta in the scene, and use this information in determining whether a quantification result can be trusted
- Improving quantification to within 10% of measured flowrates
- Quantifying usefulness of different sensor packages and combinations
- Collecting data without backdrop

Appendix

– These slides will not be discussed during the presentation, but are mandatory.

Benefit to the Program

- Natural Gas Infrastructure (Quantification and Mitigation)
  - Advancing pipeline inspection and repair technologies.
  - Advancing external leak detection and rate quantification technologies and methodologies.

Project Benefits Statement

- An autonomous, real-time methane leak detection system facilitates the early detection of emissions before they become a larger problem. Compressor station operators will be able to identify failing equipment in aging infrastructure and replace faulty components expediently, resulting in methane emissions being reduced significantly through early detection of non-compliant equipment. By adding the capability to estimate leak flow rates in conjunction with visual inspections, operators will be able to identify and stratify which components to replace first. This project is expected to produce the following outcomes and/or impacts:
  - Develop a system to reliably, accurately, and autonomously identify methane leaks at critical midstream sections of the natural gas distribution network in real-time for the purpose of mitigating methane emissions
  - Add a high degree of automation to the process of methane leak detection to minimize sources of human error, minimize response time to a leak event, and maximize midstream visibility
  - Assist in the quantification process by providing a means of collecting temporal and spatial image data of a leak event
  - Reduce operational costs of emissions detection technologies by significantly minimizing the need for operator involvement
  - Provide a solution that is scalable, cost-effective, and non-intrusive
  - Reduce methane emissions through early real-time, autonomous detection of methane leaks

Project Overview

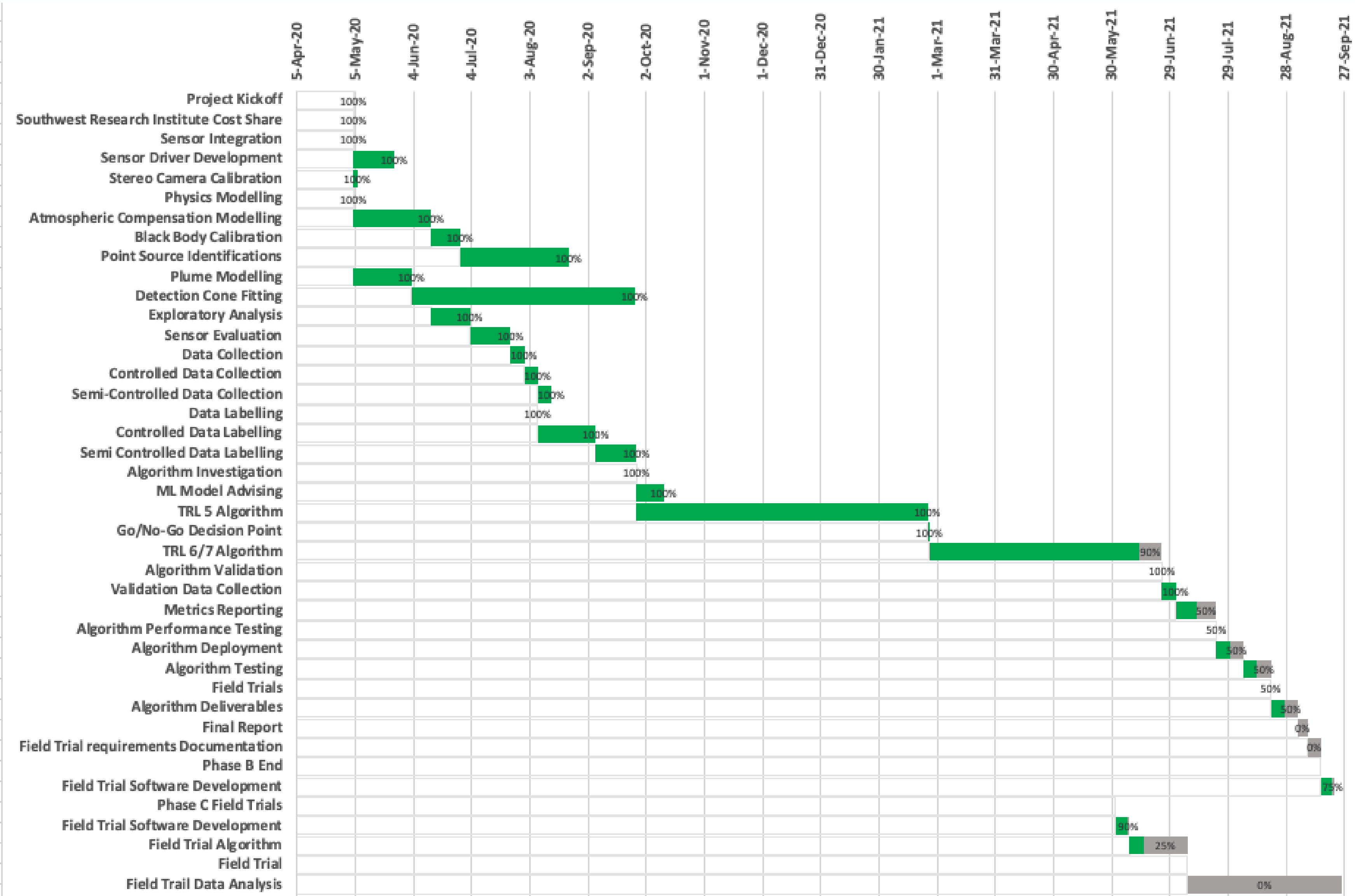
Goals and Objectives

- The major objective of this DOE research project is to develop an autonomous, real-time methane leak detection technology, the SLED/M, which applies machine learning techniques to passive optical sensing modalities to mitigate emissions through early detection.
- The goal during Phase 1 and 2 was to develop the prototype methane detection system with integrated optical sensors and the embedded processing unit. And integrate and field-test the prototype system, and then demonstrate the capabilities to DOE.
  - These phases aimed to advance leak detection technologies and increase speed and accuracy of inspections. The metrics targeted were fewer than 5% false positive rate, with a detection accuracy of 70% or greater
- Phase 3 focused on adapting the system developed under previous phases for use on a mobile aerial drone platform.
  - This phases aimed to advance aerial inspection techniques, and accuracy of inspections. The metrics targeted were fewer than 5% false positive rate, with a detection accuracy of 70% or greater
- Phase 4 is focusing on quantifying detected methane and building a commercialization pathway.
  - The goal of this phase is to advance methane quantification technologies, by quantifying methane to within ±50 scfh or 10% error, leading to more trust in QOGI technologies

Organization Chart

- Southwest Research Institute
  - Heath Spidle – Research Engineer
  - Jonathan Esquivel – Computer Scientist
  - Jake Janssen – Engineer
  - Joshua Ramirez - Student Analyst
  - Andrew Schaub, Ph.D – Research Engineer
  - Ryan McBee– Research Engineer
  - Swanand Bhagwat, Ph.D – Research Engineer
  - Sam Blaisdell – Assistant Program Manager
- Sierra Olympic Technologies
  - MwIR Optical Gas Imager (Cost Share Partner)
- Heath Consultants
  - MwIR Optical Gas Imager (Cost Share Partner)

Gantt Chart


5-Apr-20
5-May-20
4-Jun-20
4-Jul-20
3-Aug-20
2-Sep-20
2-Oct-20
1-Nov-20
1-Dec-20
31-Dec-20
30-Jan-21
1-Mar-21
31-Mar-21
30-Apr-21
30-May-21
29-Jun-21
29-Jul-21
28-Aug-21
27-Sep-21
Project Kickoff
Southwest Research Institute Cost Share
Sensor Integration
Sensor Driver Development
Stereo Camera Calibration
Physics Modelling
Atmospheric Compensation Modelling
Black Body Calibration
Point Source Identifications
Plume Modelling
Detection Cone Fitting
Exploratory Analysis
Sensor Evaluation
Data Collection
Controlled Data Collection
Semi-Controlled Data Collection
Data Labelling
Controlled Data Labelling
Semi Controlled Data Labelling
Algorithm Investigation
ML Model Advising
TRL 5 Algorithm
Go/No-Go Decision Point
TRL 6/7 Algorithm
Algorithm Validation
Validation Data Collection
Metrics Reporting
Algorithm Performance Testing
Algorithm Deployment
Algorithm Testing
Field Trials
Algorithm Deliverables
Final Report
Field Trial requirements Documentation
Phase B End
Field Trial Software Development
Phase C Field Trials
Field Trial Software Development
Field Trial Algorithm
Field Trial
Field Trail Data Analysis

Bibliography

– List peer reviewed publications generated from the project per the format of the examples below.

- Journal, one author:
  – Gaus, I., 2010, Role and impact of CO_2-rock interactions during CO_2 storage in sedimentary rocks: International Journal of Greenhouse Gas Control, v. 4, p. 73-89, available at: XXXXXXX.com.
- Journal, multiple authors:
  – MacQuarrie, K., and Mayer, K.U., 2005, Reactive transport modeling in fractured rock: A state-of-the-science review. Earth Science Reviews, v. 72, p. 189-227, available at: XXXXXXX.com.
- Publication:
  – Bethke, C.M., 1996, Geochemical reaction modeling, concepts and applications: New York, Oxford University Press, 397 p.