Smart Methane Emission Detection System Development

DE-FE0029020

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U.S. Department of Energy

National Energy Technology Laboratory

Oil & Natural Gas

2020 Integrated Review Webinar

Program Overview

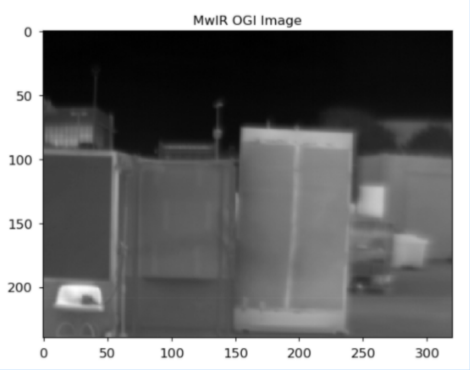
- Smart Methane Emission Detection System Development, DE-FE0029020
  - October 2016 – October 2021
  - Total Funding
    - Government Share: $1,811,107.00
    - Cost Share: $453,057.00
  - Funding for Current Phase: 03/2020-09/2021
    - Government Share: $888,604
    - Cost Share:
      - SwRI: $191,151
      - Sierra Olympics: $15,000
      - Heath Consultants: $16,000
    - Field Trial Partners
      - Ovintiv

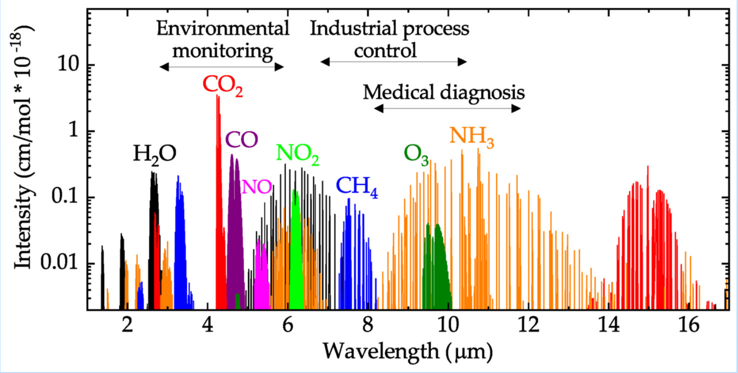
Project Overview
Goals and Objectives

- 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.
- Phase 3 focused on adapting the system developed under previous phases for use on a mobile aerial drone platform.
- Phase 4 is focusing on quantifying detected methane and building a commercialization pathway.

Technology Background

- Midwave Infrared (MwIR) Optical Gas Imaging (OGI)
  - Methane Gas absorbs energy at 3.3um wavelength
  - Methane Gas also absorbs energy at 7.7 (the very edge of the LwIR thermal band) 7.5-14um
    - More difficult to see in this band as the absorption rate is much lower
- The MwIR Image below is a still frame taken from an OGI camera of a methane leak from 30ft @ 400scfh
  - Finding the Methane in an image is very difficult without the motion of the methane in relation to the background
  - Methane only decreases the intensity slightly of the regions in the image directly behind it, there is still a lot of variation in the scene with a relatively simple backdrop

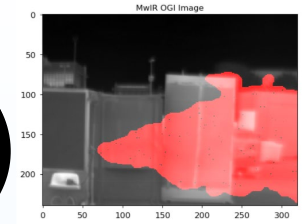


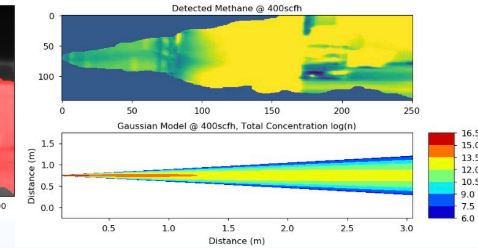


Technology Development

MwIR

CFD





PHASE 4

Quantification of Methane

2020

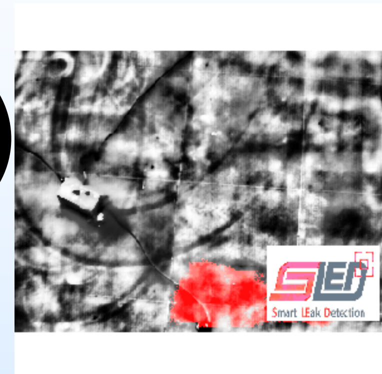
Detection and Quantification from one unified platform

TRL 7

Aerial Deployment

2019

System Adapted to Aerial Vehicle operations



Methane Leak detected from aerial platform

TRL 7

System Demonstration

2018

System Demonstrated in Real world environment

Methane Leak detected in realistic environment

TRL 6

System Testing

2017

System Validated in relevant environment

Machine Learning Detected Methane Leak with Red Detection Mask

TRL 3

Technology Development

2016

Methane Leak imaged with MwIR OGI

Advantages / Challenges

- Advantages
  - Locates Fugitive Emissions Quickly, in Complex environments and while moving
  - Detection mask enhances operators ability to see emissions in camera screen
  - Helps in Quickly Identifying Source of Leak
- Challenges
  - Optical Gas Imagers are very expensive
  - Absorption in the MwIR spectrum is complex and relies on many external and environmental factors

Technical Approach

- Technical Approach
  - To accomplish the task of quantification
  - Combine low cost sensors to augment OGI information (LwIR, Visible, LiDAR, Weather) not necessarily all of these sensors will be used in the final configuration but were added to the data collection rig
  - Using previously developed methane detection algorithm
    - Determine the distance and size of the detected emission
      - Experiment with LiDAR or Stereo Vision Disparity
    - Train a deep learning guided CFD plume model and estimate absorption along the path
      - Experiment with incorporating scene understanding using visible, LwIR to estimate background emissivity and absorption
      - Normalize MwIR information with humidity, wind and solar index

Project Scope

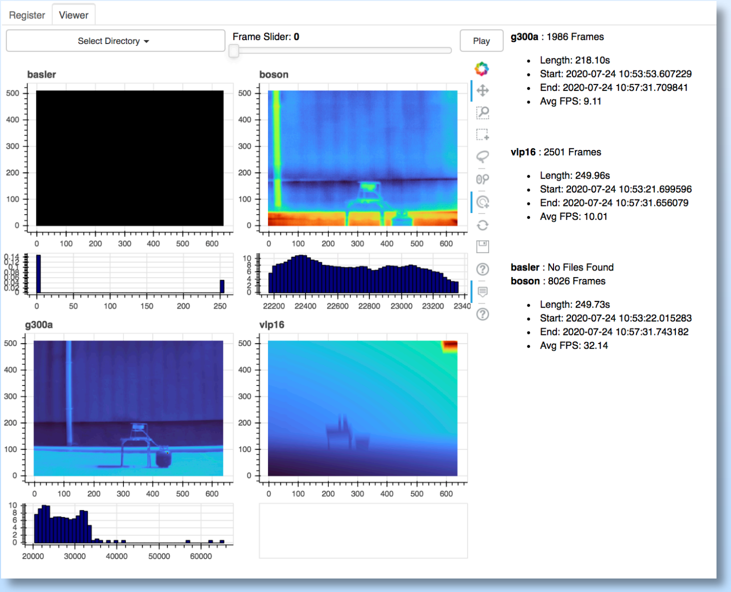
- Project Schedule
  - Data Collection Setup (Mar 2020 – Sep 2020)
  - Data Collection and Curation (Oct 2020– Nov 2020)
  - Algorithm Development (Nov 2020 – April 2021)
  - Go/No-Go (April 2021)
    - Ability to Quantify to within an order of magnitude methane leak in controlled environment
  - Algorithm Enhancement (April 2021 – July 2021)
  - Final Demonstration (Aug 2021)
    - Ability to quantify methane leaks within 2x the magnitude in controlled environments
  - Final Report (Sep 2021)
- Project Risks and Mitigation
  - Covid 19 has impacted Field Trial plans
    - Operator is recording and sending us data of their periodic inspections to test the algorithm on

Sensor Integration

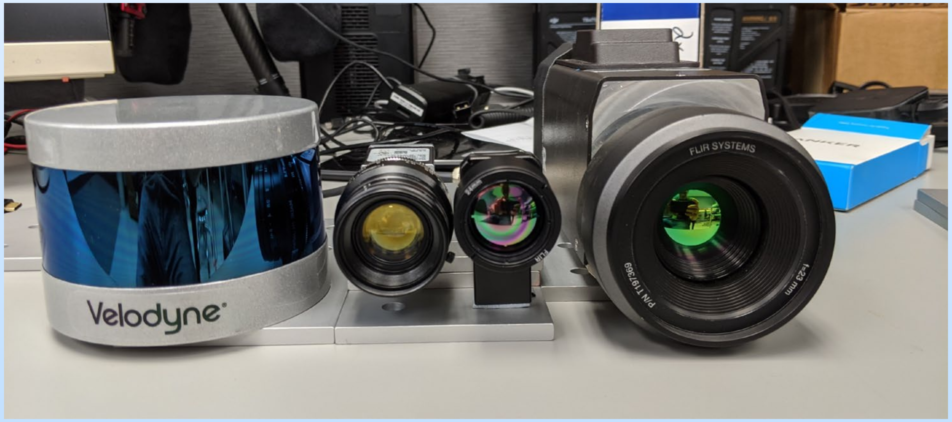
- The tasks needed to develop and improve upon quantification and detection
  - Need to estimate path absorption
    - Atmospheric compensation and normalization between MwIR and LwIR
    - Humidity, Pressure, Solar Radiance and Temperature for CFD and image modality normalization
  - Need to estimate size of detected plume
  - Scene understanding
    - Point source identification
    - Object reflectivity and absorption estimation
      - Visible

Sensor Integration

- Five primary sensors were chosen for initial data collection
  - MwIR OGI, LwIR, LiDAR, Visible Camera and a weather station



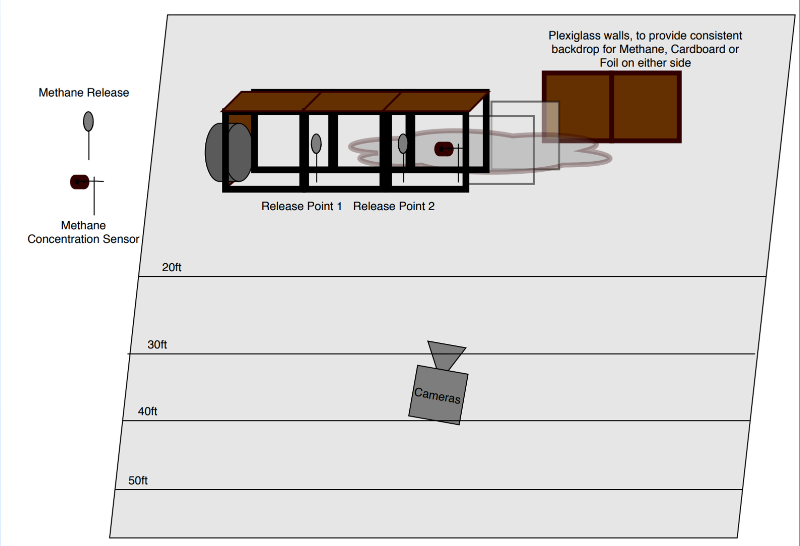
Data Collection Interface



Left to Right: Velodyne VLP-16 LiDAR, Basler Ace Visible camera, FLIR Boson LwIR and FLIR g300a MwIR OGI

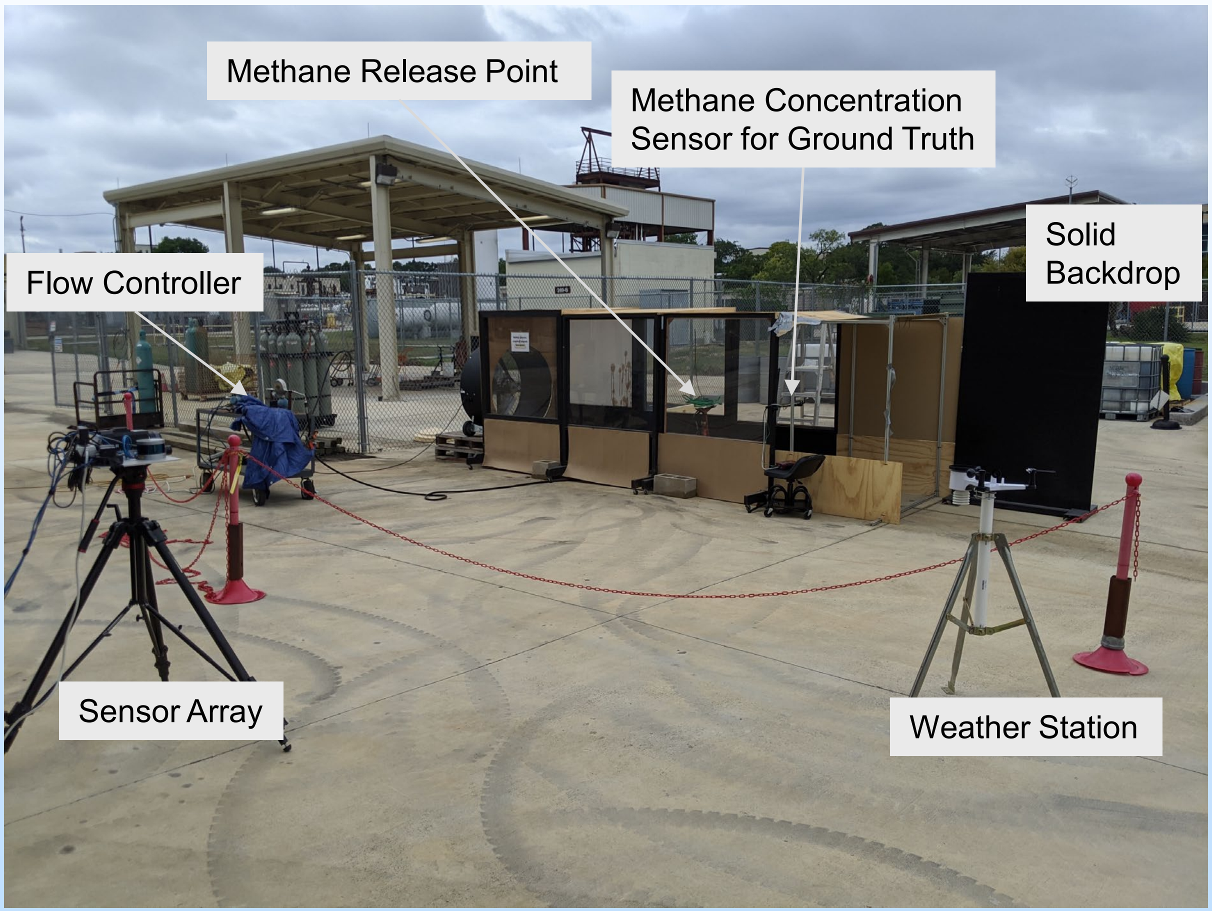
Controlled Data Collection

- Proper data collection is paramount to the success of any ML model
- Two types of data collection planned
  - Controlled
  - Semi-Controlled
- Controlled Data Collection
  - Attempt to control as many parameters as possible
  - Wind Tunnel
  - Flow Controller
  - Methane Concentration Sensor
  - Solid known Backgrounds
- Semi-Controlled Data Collection
  - Cluttered Background and Foreground
  - Methane release point in the open



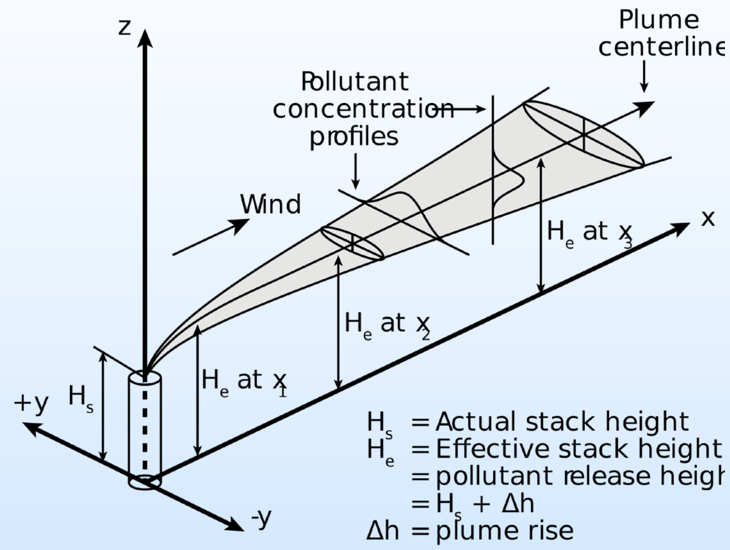
Controlled Data Collection Setup Diagram

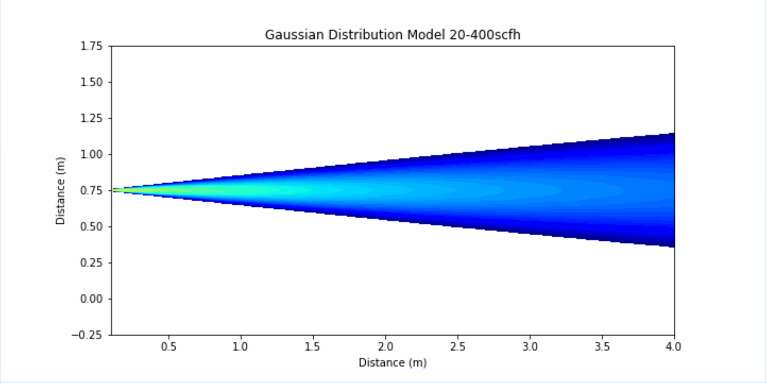
Controlled Data Collection Setup



Plume Modelling

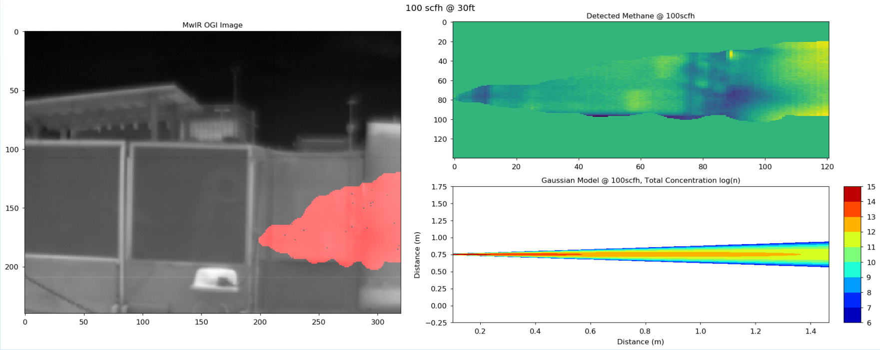
- Gaussian Dispersion Modelling
  - Dispersion models are used to estimate the downwind ambient concentration of methane emitted from sources.
  - Good Baseline Model for semi-stable plume conditions
  - For discontinuous or unstable conditions may need to use more complex modelling

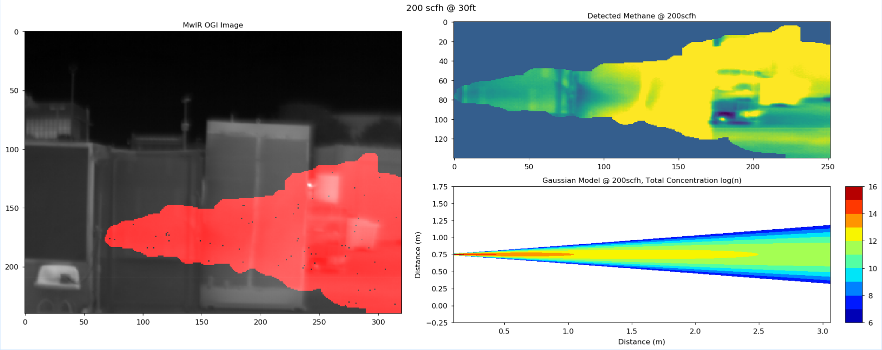


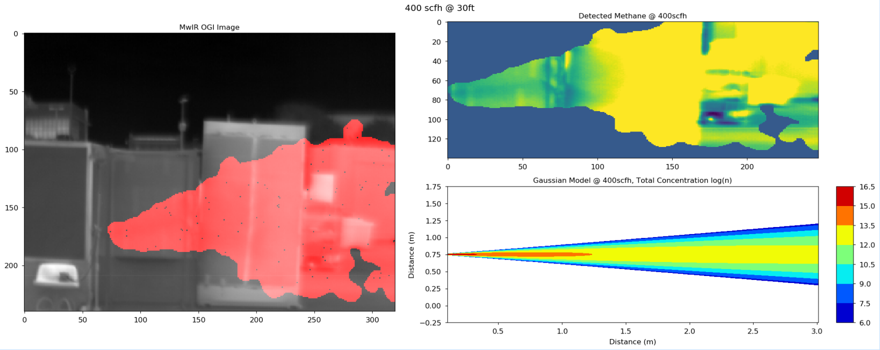


CFD and Optical Comparison

- Optical absorption as seen in the MwIR OGI camera vs Gaussian Plume modelling at the same Flow rate
- OGI imagery absorption patterns match the same concentration areas in the plume model

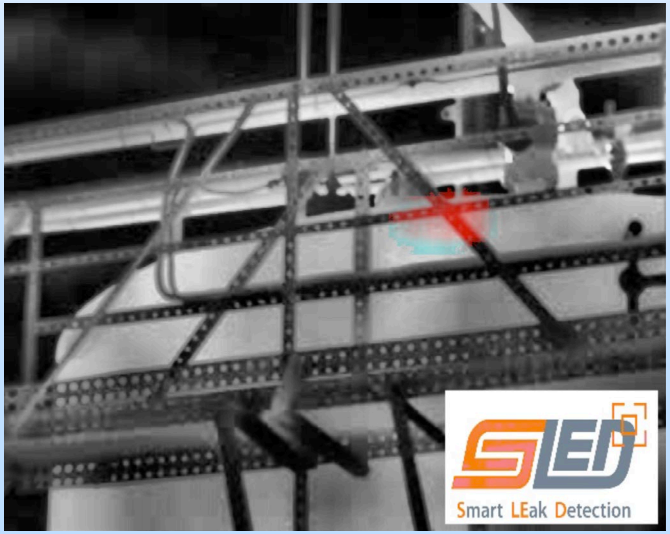






Field Testing

- As part of the Field Trials SLED has been evaluated on videos of real inspections provided by industry partners
- Plans to use SLED/M in actual inspection in the future



Commercialization Plan

- SwRI has begun work on SLED/M Commercialization plan
  - Competitor Analysis
  - Business Model
  - SWOT Analysis
  - IP Strategy
  - Revenue Analysis

Summary

- Project is progressing on schedule and initial data has been collected and is starting to be analyzed
- Starting on Machine Learning investigation and incorporation of the CFD modelling into the model

Appendix

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

Organization Chart

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

Gantt Chart

Project Kickoff Meeting	0 days	M 5/4/20	M 5/4/20
Southwest Research Institute Cost Share	**116.5 days**	**M 5/4/20**	**T 10/13/20**
Sensor Integration	**17 days**	**M 5/4/20**	**T 5/26/20**
Physics Modeling	**82 days**	**W 5/27/20**	**T 9/17/20**
Exploratory Data Collection	2.5 days	F 9/18/20	T 9/22/20
Sensor Evaluation	3 wks	T 9/22/20	T 10/13/20
Data Collection	**10 days**	**M 10/12/20**	**F 10/23/20**
Data Labelling	**35 days**	**M 10/19/20**	**F 12/4/20**
Algorithm Investigation	**165 days**	**M 11/16/20**	**F 7/2/21**
Algorithm Validation	**20 days**	**M 7/5/21**	**F 7/30/21**
Algorithm Performance Testing	**20 days**	**M 8/2/21**	**F 8/27/21**
Field Trials	**37 days**	**M 6/1/20**	**T 7/21/20**
Final Report	**5 days**	**W 5/27/20**	**T 6/2/20**
Phase B End	**5 days**	**W 6/3/20**	**T 6/9/20**
Phase C Field Trial	**80 days**	**M 6/1/20**	**F 9/18/20**