Public Quarterly Report

Date of Report: 2nd Quarterly Report – March 30, 2023
Contract Number: 693JK32210006POTA
Prepared for: The U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration (DOT-PHMSA)
Project Title: Accelerating Pipeline Leak Detection Quantification Solutions Through Transparent and Rigorous Scientific Validation
Prepared by: Colorado State University /Southern Methodist University
Contact Information: Stuart Riddick, stuart.riddick@colostate.edu/ Kathleen M. Smits / ksmits@smu.edu/ 719-200-7648; Wendy Hartzell/ Wendy.Hartzell@colostate.edu/ 970-218-2842; Richie Kolodziej/ richiek@smu.edu/ 224-688-5161
For quarterly period ending: Match 30, 2023

1: Items Completed During this Quarterly Period:

Item #	*Task #*	*Activity/Deliverable*	*Title*	*Federal Cost*	*Cost Share*
3	*2*	***Survey existing and emerging LDAQ operational practices. Summary of current RPs from TAP members and other contributors.***	Report on leak detection method applicability in adverse conditions.	$78,915	
4	*3*	***Testing protocols for controlled and field testing. Reviewed by TAP and revised.***	Testing protocols selected, reviewed and presented	$39,458	
5	*xx*	***2nd Quarterly Status Report***	2nd Quarterly Status Report	$2,000	

2: Items Not Completed During this Quarterly Period:

Activity 6, Task 2.3 – Guidance document on leak detection methods applicability in adverse conditions – Deliverable 2; is still in progress and under review by TAP members. The second payable milestone will be invoiced at the time of the 3rd quarterly reporting.

3: Project Technical Status

Progress and information were collected this quarter to complete Task 2.0: Investigate and document current and emerging LDAQ efforts. The following section outlines meetings with industry partners, the development of the industry questionnaire, results from industry discussions, initial draft guidance of applicability of LDAQ methods in adverse conditions and testing protocols for controlled and field testing.

Activity 4, Task 2.1, Survey Existing and Emerging LDAQ Protocols

During this task, the team investigated various methods used across the NG industry, including mobile platforms like walking, driving, and aerial. Many of these methods have varied in their use and are still being piloted by all supply chain sections. However, our results collected during our review indicate that specific consideration to adverse conditions for below-ground leakage has been considered in a limited capacity.

An industry questionnaire was created to document existing and emerging LDAQ methods across the Natural Gas (NG) supply chain. The questionnaire was developed by analyzing a wide range of peer-reviewed literature, PHMSA-sponsored research, and team experiences from prior research. The questionnaire was developed with two primary goals; (1) comparing and evaluating existing methods and (2) developing new technologies and methods to detect, locate and quantify methane emissions. As a result, many of the questions were developed over time and under constant review by the team following the ongoing discussions with industry partners. Shown in table (1) are the questions the team collected during discussions with the TAP.

Table 1: Survey questionnaire developed based on peer-review literature and PHMSA-sponsored documents for technical advisory board (TAP) member/solution prover discussions

Category	Questions
Outline of Basic Procedure	1. Can you describe how you conduct surveys? (details of walking, driving, UAV, fixed wing survey) 2. Working on distribution, gathering, or transmission lines? 3. How do you define detection? For example, in Weller et al. (2018) (Environ. Sci. Technol. 2018, 52, 11922−11930), a leak indication corresponds to a location where elevated CH4 concentrations (exceeding 110% of background levels) are detected during two or more mobile traverses for mobile surveys.
Leak Grading Standards/Leak Rate Standards	4. What are the detection criteria in order to define a leak or emission? a. Are there different grading systems for above-ground infrastructure compared to below-ground? i. Grading of leaks? ii. Time for repair or resurvey? iii. Leak rate/concentration? 5. Once you find a leak, do you quantify emissions? (if no, skip the rest of the questions) b. For each leak quantification method:

Category	Questions
	c. What method do you use? d. Can you describe the method? e. What is your confidence level in its accuracy?
Technology	6. What is the specific sensor you are utilizing for general walking surveys? 7. Do you utilize any other form of screening/different technologies? (Uav, Drone, plane method) f. What other equipment do you use in combination with normal surveys? iv. Example: GPS systems 8. Does the pipeline have any internal systems? (Volume-based monitoring system) g. Such as acoustic sensors on pipelines? h. If so, try to outline the procedures of these methods. 9. How do you account for background methane concentration? i. Agricultural areas with methane production from cattle where the background can tend to be higher (Weld County example) j. Natural seeps? Landfills etc? k. Do you change the limit of the detector that you are using based on knowledge of the local level background concentration? 10. Background for the discussion: When a new piece of equipment is introduced by an operator, follow up with these questions to get an understanding of what the operator knows and what the company sets as its internal standards. l. Lower detection limit - What the equipment is set to above the background in order to consider a detection. m. Precision - how close the series of measurements are to one another. n. Accuracy - How close the measurement is to the correct value or how close it can come to the actual/reference/known value. Largest allowable error under specific conditions. o. Range - upper and lower limits that the instruments can measure. The higher the range, the lower the precision. p. Resolution - the smallest amount of signal that can detect by the instrument reliably when the instrument is set to its maximum range. Or the smallest increment that can be detected. Can be hundredths, thousandths, or millionths. q. Sensitivity 11. Why did your company choose this technology or method over other options on the market?
Procedure for Technology	12. Survey detail questions - Note that these questions should be asked for each piece of equipment group being utilized in the survey r. What is the optimal speed for the detection of a Leak? s. What is the particular amount of time that is spent at each location? t. How many passes do you perform over the same pipeline section? u. What height above ground do you position the sensor? Or for a vehicle/UAV, what height above ground is the sensor mounted? v. What is the distance from the pipeline centerline do you perform leak detection? Is there a maximum distance? w. From your experience, how close do you need to be next to ROWs in order to have good gas detection? (not the altitude but rather the distance from the ROW). 2. Pinpoint the leak – after you've found a leak, x. After you've found a leak, what is the distance you check from a leak location for expansion? y. How well does the equipment capture the actual leak rate?

Category	Questions
	z. Is the equipment being utilized meant for the localization of a leak for a specific location or general location? How does the survey adapt to varied conditions? 13. How do your account for adverse conditions in your leak detection practices? aa. Changes to rain bb. Change to snow cc. Change to high wind conditions dd. Changes in relative humidity ee. Changes in atmospheric pressure ff. Rugged Terrain gg. Soil Type hh. Soil Moisture ii. Gas Composition jj. Surface complexities
Limitations	14. When on-site, try to identify limitations in the procedure/related issues. 15. Does experience with an instrument play a significant role in the possibility of finding a leak? 16. What situations are the most challenging? 17. What could be improved in your own solution? 18. Where do you notice gaps in procedure/sensitive aspects of the procedure?
Big Picture	19. Is your company considering new technologies/methods? Which ones and why? 20. Is this standardized across all operators in terms of procedures in your company? 21. Do you know about standardized procedures across other companies? 22. What is the top priority of your company from this testing? 23. What could your company benefit from understanding better as a result of this testing?

The questions were broken up into six major categories basic procedures, leak grading standards, technology, the procedure for technology, limitations, and the big picture. All questions asked are outlined in each section.

Upon completion of the initial survey and questionnaire formation, ten discussions with industry partners were conducted for our review. The discussion included field observations, where team members met with field operators, observed survey methods, and asked questions. Other meetings were set up on online platforms due to time constraints. Most field observations were sourced from utility companies around the western United States. This team had trouble getting in contact with upstream TAP partners, including gathering and transmission companies. Shown in table (2) are the locations, and sections surveyed during our review.

Table 2: TAP member and solution provider meeting dates, locations, and survey sections

Supply chain section#	Location	Discussion Type
Distribution	Denver, CO	Field Observation

Supply chain section#	Location	Discussion Type
Distribution	Denver, CO	Field Observation
Distribution	Pueblo, CO	Field Observation
Distribution	San Francisco, CA	Field Observation
Distribution	NA	Online Discussion
Distribution	NA	Online Discussion
Gathering	NA	Online Discussion
Distribution	NA	Online Discussion
Technology Provider	Fort Collins, CO	Field Observation
Service Provider	Fort Collins, CO	Field Observation
NA – Not Available		

These discussions were utilized to identify further the industry practices for an extensive range of survey methods and understand the applicability of these methods in adverse conditions. A qualitative analysis was then conducted on the data gathered this analysis acts as the initial step for preparing a guidance document on LDAQ in adverse conditions.

Results from the qualitative analysis of TAP discussions were incorporated during this task. The finalized document of the *Guidance Document on Leak Detection Methods Applicability in Adverse Conditions* (deliverable 2) is currently under internal review. This report will only include information collected from the TAP, that will be explored in more detail in the Guidance *Document on Leak Detection Methods Applicability in Adverse Conditions*.

Table 3: Definitions and Variables for qualitative analysis results

Data Variables	Definitions
Platform Number	The platform number lister during an industry discussion.
Section	Refers to section of the supply chain: distribution, transmission or gathering
Service Provider	Contractor used by the company for survey
Use	The section of pipeline the platform and technology are applied to
Platform	How the equipment is deployed: aerial mobile, driving, or handheld
Technology	Technology equipped on the platform being used
Height	Vertical distance above the ground the technology is kept during the survey
Distance	Horizontal distance from right of way or pipeline which survey is performed
Time	Amount of time spent for a single completed survey
Speed	Miles per hour, speed of travel of survey
Passes	A transect along the pipeline
Expansion	Area under the ground in which surveyor will check for movement of gas
Wind Speed	Wind speed limit in which operators will be called off
Wind Direction	The given direction or ideal direction of wind, usually downwind
Temperature	The temperature at which instrument is operated at
Rain	Weather event which results in higher moisture content in soil
Snow	Weather event where development of snow layer at the surface occurs
Soil Moisture	The amount of moisture present between pores of soil
Soil Type	Clay, Sand, or Gravel. Any soil considered by a protocol performed
Terrain	Consideration of remote location, and hard to reach pipeline
Detection Limit/Threshold	The minimum concentration required to set off an alarm on a given instrument
Background	The ambient concentration in the background environment not due to a leak event
Quantification	The ability of a given survey to calculate emission rate of a leak
Results Subscripts	
Not Specified – NS	Question was asked; however, answer was not given to the question
Not Identified - NI	Question was not asked
Operator Judgment - OJ	Based on operators experience certain aspects of survey are determined by the operator

Table (3) references definitions of variables collected during the discussions with the TAP. Table (4) was a part of the initial set of information collected from field observations in Denver, CO., over three days; the team was able to join walking survey operators who performed a walking survey on the service and main pipelines standard in urban areas. Primarily, these operators used handheld equipment to detect belowground leaks from the surface above the pipeline and check meter sets located along the structures.

During this field observation section, the team could understand operators' daily firsthand experiences on leaks. The team understood that companies generally leave operators open to interpret leaks as they present themselves without much guidance for adverse conditions. While the team collected grading standards and internal documents, the team did not find many similarities between information gathered from field operators, and the information provided in the internal documents. One if the examples is operators' definitions of leaks in terms of concentration, which differed substantially from concentration defined by internal documents.

Overall, the operators gave insight into two adverse conditions, including wind speeds and aboveground complexities, that can impact gas migration and plume development. However, only a few other details regarding adverse conditions or changes to operator protocols were noted.

Table 4: Information gathered during first active involvement and filed observation in the walking survey on distribution pipelines at Denver, CO

Meetings with Xcel: Survey variables defined by operators and Industry		
Platform Number	Platform 1	Platform 2
Section	Distribution	Distribution
Service Provider	NA	NA
Use	Service and Main Pipeline	Service and Main Pipeline
Platform	Handheld	Handheld
Technology	CGI Gold Gas Monitor	DP-IR, LMM-M, R-2
Height	Direct Contact	Direct Contact
Distance	Directly Above Main and Service line	Directly Above Main and Service line
Time	1:40-2:00 minutes	2:00 minutes
Speed	2-5 MPH	DNS -2-5 MPH
Passes	2 over service, 1 over Main	2 passes service, 1 pass main
Expansion	Bar hole	Bar hole
Wind Speed	30 MPH	25 MPH
Wind Direction	NS	NS
Temperature	NS	NS
Rain	NS	Reduce contact with ground less than 1 second
Snow	NS	NS
Soil Moisture	NI	NI
Soil Type	NS	NS
Terrain	NS	NS
Detection Limit/Threshold	OJ	OJ
Background	NS	NS
Quantification	Can Not Estimate	Can Not Estimate
CGI – Combustible Gas Detector **DP-IR – Detectopak Infrared** **NS – Not Specified** **NI – Not Investigated** **OJ – Operator Judgment**		

Table (5) references the second set of field observations, where the team was able to join and collect information from a local utility in California. During the five-day campaign, the team conversed with many research and development (R&D) engineers responsible for LDAQ advancement. While the ability to meet with practicing field operators was limited, the engineers gave insight into their efforts to adapt protocols to adverse conditions and gave insight into platforms that have quantification capabilities. Generally, operators follow similar procedures reviewed in the first set of field observations. For example, surveyors use handheld equipment and other emerging platforms to look for elevated surface concentrations along the main and service pipelines.

During the field observations, the R&D engineers provided an administrative perspective compared to our observations in Denver, CO. Similar to the initial field observations, operators are generally left to their own judgment when assessing a leakage situation in adverse conditions. However, after analysis of internal documents received from the engineers, the team noted a more comprehensive range of considerations for adverse conditions compared to the visit to Denver, CO.

The team identified three primary conditions: surface complexities, weather events like rain, and meteorological conditions such as wind. However, conditions such as soil characteristics are mentioned with little detail and specifics for how protocol changes are limited. Additional consideration for utilizing platforms in challenging-to-reach locations such as pipelines that are underwater are being developed. Overall, deeper consideration is given to adverse conditions and assisted in building our review.

Table 5: Information gathered during the second active involvement, field observation, and discussions with industry engineers primarily investigate emerging and current LDAQ in California

Meetings with California Utility: Survey Details Collected					
Platform Number	Platform 1	Platform 2	Platform 3	Platform 4	Platform 5
Section	Distribution	Distribution	Distribution	Distribution	Distribution
Service Provider	NA	NA	NA	NA	Bridger
Use	Service and Main Pipeline	Large Emitting Sources	Transmission Pipeline	Difficult to reach Distribution Pipeline	Cast Iron Pipeline
Platform	Handheld	Driving	Satellites	Drone	Helicopter/aerial
Technology	DP-IR, RMLD	Picarro Car - CRDS	NS	RKI open path Spectrometer	LIDAR
Height	Direct Contact	5 inches	NS	NS	NS
Distance	Directly Above	Directly above Main	NS	NS	NS
Time	DNS	DNS	NS	NS	NS
Speed	DNS, 2 - 5 MPH	25 MPH	NS	NS	NS

Meetings with California Utility: Survey Details Collected					
Passes	2 service, 1 main	6 passes, 3 drives total	NS	NS	NS
Expansion	Bar hole	Bar hole	Bar hole	Bar hole	Bar hole
Wind Speed	14 MPH	14 MPH	NS	NS	NS
Wind Direction	NS	NS	NS	NS	NS
Temperature	NI	NI	NI	NI	NI
Rain	1 day after	1 day after	NS	NS	NS
Snow	NS	NS	NS	NS	NS
Soil Moisture	NI	NI	NI	NI	NI
Soil Type	NS	NS	NS	NS	NS
Terrain	NS	NS	NS	NS	NS
Detection Limit/Threshold	OJ	7 SCFH	OJ	OJ	OJ
Background	NS	NS	NS	5 PPM	NS
Quantification	Can not Estimate	Estimate	Estimate	Estimate	Estimate

RM-LD – Remote Methane Leak Detector
DP-IR – Detectopak Infrared
CRDS – Cavity Ring Down Spectroscopy
LIDAR – Light Detection and Ranging
NS – Not Specified
NI – Not Investigated
OJ – Operator Judgment

Table (6) references the collection of the third set of discussions with the TAP. Information was collected from two online meetings with R&D engineers and field operators from a utility company in California. Note that this data differs from the previous sets collected; the team did not have the opportunity to meet in a field setting to observe survey methods directly. Nevertheless, information was provided to the group about the adjustments to protocol to account for adverse conditions. Similarly, to the first and second data collection sets, the organization primarily uses walking surveys to detect below-ground leakage by measuring surface concentrations along the main and service pipeline.

Overall, understanding that specific platforms require wind to operate was a discovery during this discussion. Similarly, engineers brought up details relevant to the ability to use other survey methods besides walking in distribution networks, given the relative complexities of the survey. This entity has moved to a primary walking survey based LDAQ system. With limited information available to the team, we note that surface complexities like past discussions present an adverse condition that is hard to overcome and complicates below-ground leaks. Different from past discussions is the consideration of wind having little impact on leak detection. Deeper consideration of other adverse conditions was not referenced during this set of discussions.

Table 6: Information gathered during the third set of discussions with industry engineers involved in R&D for leak detection.

Meeting with California Utility 2: Survey Details Collected				
Platform Number	Platform 1	Platform 2	Platform 3	Platform 4
Section	Distribution	Distribution	Distribution	Distribution
Service Provider	NA	NA	NA	Bridger
Use	Above and below ground	Above and below ground	Above and below ground	Used for super emitter
Platform	Driving	Driving	Handheld	Helicopter
Technology	AMLD - TDLAS	DP-IR Plus - axillary pump	DP-IR	LIDAR
Height	10 inches	5 inches	Direct Contact	NS
Distance	Above main Pipeline	Above main Pipeline	Above main and service pipeline	NS
Time	NS	NS	NS	NS
Speed	25 MPH	NS	2-5 MPH	NS
Passes	2	NS	2 service, 1 main	NS
Expansion	Bar hole	Bar hole	Bar hole	Bar hole
Wind Speed	Consider wind, NS	Considers wind	Does not consider	Does not consider
Wind Direction	NS	NS	NS	NS
Temperature	NI	NI	NI	NI
Rain	Does not consider	Does not consider	Does not consider	DNS
Snow	Does not consider	Does not consider	Does not consider	DNS
Soil Moisture	NI	NI	NI	NI
Soil Type	NS	NS	NS	NS
Terrain	NS	NS	NS	NS
Detection Limit/Threshold	OJ	OJ	OJ	OJ
Background	Depends 5-10 PPM	Depends 5-10 PPM	Depends 5-10 PPM	Depends 5-10 PPM
Quantification	Can Not Estimate	Can Not Estimate	Can Not Estimate	Estimates
DP-IR – Detectopak Infrared **DP-IR Plus – Detectopak Infrared Plus** **AMLD – Advanced Mobile Leak Detection** **TDLAS - Tunable Diode Laser Absorption Spectroscopy** **LIDAR – Light Detection and Ranging** **NS – Not Specified** **NI – Not Investigated** **OJ – Operator Judgment**				

Table (7) describes the information collected from an upstream supervisor of ESG and regulation from the TAP. The midstream information added a new perspective to our collection of discussions. Only one discussion was initiated with this source, where survey methods were discussed currently being piloted for use in their organization. Many of these methods are still in the early stages of development and are generally contracted out to a solution provider. Many current methods are not fundamentally different from those used along the distribution pipeline. Finding that most of the time, these systems are looking for leaks on above-ground infrastructure including wellheads, piping between pads, or compressor stations. Limited information was explicitly given to consideration for below-ground pipeline leakage.

Overall, the upstream section of the supply chain, based on our results, is in the progress of adopting new and emerging LDAQ methods, with many different solution providers contributing to fill the gap. Generally, this has led to limited considerations of adverse conditions by upstream companies. For example, one primary condition noted during the process was the rough terrain and locations of many sites, making walking and driving survey types challenging to utilize without posing a risk. Lastly, it was noted that transparency and being able to tell the exact details of the survey are difficult to identify due to solution providers needing to be more transparent. Therefore, the methods need to be available for the upstream companies to ensure accurate reporting and analysis of information.

Table 7: Information collected from the fourth set of discussions with midstream industry partners. These discussions were conducted with a supervisor of ESG and regulation.

Meeting with Gathering Company: Survey Details Collected						
Platform Number	Platform 1	Platform 2	Platform 3	Platform 4	Platform 5	Platform 6
Section	Gathering	Gathering	Gathering	Gathering	Gathering	Gathering
Service Provider	NA	NA	Scientific Aviation	Bridger - LIDAR	ARC Aerial	DNS - did not specify
Use	Pad Level	Pad level	Transmission Lines and all assets	Pad Level	Pad level	Pad Level
Platform	Handheld	CM	Drone	Helicopter/aerial	Drone	Satellite
Technology	OGI Camera	DNS	Laser Spectrometer	LIDAR	Laser	GHGsat
Height	NS	NS	NS	NS	NS	NS
Distance	NS	NS	Right Of Way	NS	NS	NS
Time	NS	NS	NS	NS	NS	NS
Speed	NS	NS	NS	NS	NS	NS
Passes	NS	NS	NS	NS	NS	9 Passes
Expansion	NS	NS	NS	NS	NS	NS
Wind Speed	NS	NS	Downwind	NS	NS	NS
Wind Direction	NS	NS	NS	NS	NS	NS
Temperature	NS	NS	NS	NS	NS	NS
Rain	NS	NS	NS	NS	NS	NS
Snow	NS	NS	NS	NS	NS	NS
Soil Moisture	NI	NI	NI	NI	NI	NI

Meeting with Gathering Company: Survey Details Collected						
Soil Type	NS	NS	NS	NS	NS	NS
Terrain	NS	NS	NS	NS	NS	NS
Detection Limit/Threshold	OJ	OJ	OJ	OJ	OJ	OJ
Background	NS	NS	NS	NS	NS	NS
Quantification	Can Not Estimate	Estimate	Estimate	Estimates	Estimates	Estimates
OGI – Optical Gas Imaging **LIDAR – Light Detection and Ranging** **GHGsat – Global Emissions Monitoring** **NS – Not Specified** **NI – Not Investigated** **OJ – Operator Judgment**						

Table (8) describes the information collected from five days of field observations that were investigated during experiments at the Methane Emission Technology Evaluation Center (METEC) in Fort Collins, CO. The information was collected from two solution providers in discussions with operators responsible for performing experiments. During the field visit, the team observed real-time UAV and driving surveys, which aided as the first observation this team has seen in the field for these surveys.

Overall, performance under varied wind speeds and wind direction posed challenges for the platforms tested during experiments at METEC. For the drone-based system noticing the low altitude, the drone was required to fly, and in some cases, the wind did not allow the system to operate. For the driving survey, the constant wind direction made detection difficult, increasing the time required for the driver to localize the leak. Nevertheless, these experiments demonstrated the applicability of these survey methods to be used in snow conditions that pose potential challenges for plume development.

Table 8: Information collected from field observations at METEC in Fort Collins, CO. Information was collected from solution providers that were involved in field testing for other projects.

Solution Testing: Survey Details Collected		
Platform Number	Platform 1	Platform 2
Section	NI	NI
Use	Above and below ground	Above and below ground
Platform	Driving	UAV
Technology	AM-LD+, TDLAS	Laser Spectrometer
Height	10 inches	10 to 15 different altitudes, starts 3-4 feet off the ground, 5 foot differences when high wind speeds, 15 feet when low wind speeds
Distance	Downwind	30 - 150 ft downwind
Time	1 hour - 30 min	1 hour - 45 min

Solution Testing: Survey Details Collected		
Speed	10 MPH	3-4 MPH
Passes	Multiple	Multiple
Expansion	NI	NI
Wind Speed	NI	4-20 MPH
Wind Direction	NI	NI
Temperature	NI	NI
Rain	NS	NS
Snow	NS	NS
Soil Moisture	NI	NI
Soil Type	NS	NS
Terrain	NS	NS
Detection Limit/Threshold	NS	NS
Background	NI	NI
Quantification	NI	Estimates
AM-LD+ - Advanced Mobile Leak Detection + **TDLAS - Tunable Diode Laser Absorption Spectroscopy** **UAV – Unmanned Aerial Vehicle** **NS – Not Specified** **NI – Not Investigated** **OJ – Operator Judgment**		

Activity 5, Task 2.2, Draft Guidance Document on Leak Detection Methods in Adverse Conditions Activity 6

Under TAP review.

5. Project Schedule

Activity 4, Task 2.1 - Survey existing and emerging LDAQ Protocols - Completed
Activity 5, Task 2.2 – Draft guidance document on leak detection method applicability in adverse conditions - Completed
Activity 7, Task 3.1 – Draft testing protocols for controlled and field testing for TAP review/comments – Completed
Activity 6, Task 2.3 – Guidance document on leak detection methods applicability in adverse conditions – In progress, will be updated upon during next quarter.
Activity 7, Task 3.1 – Draft testing protocols for controlled and field testing for TAP review/comments
Under TAP review.