ALBERTA METHANE FIELD CHALLENGE PROJECT REPORT

June 2019 Field Testing Campaign
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1. PROJECT OBJECTIVES

Bridger Photonics, Inc. (Bridger) had three primary objectives for deploying their Gas Mapping LiDAR™ (GML) methane leak detection and quantification technology at the Alberta Methane Field Challenge (AMFC) in June of 2019. Bridger's primary goal was to help AMFC fulfill its mission to "assess the real-world performance of new methane sensing technologies in comparison with conventional optical gas imaging-based leak detection surveys." This report contains a high-level overview of the GML technology and describes its deployment and performance at the AMFC. Bridger's second objective aimed to demonstrate their desire and ability to partner with an established Canadian flight service provider to enable rapid and cost-effective scaling of GML operations in Canada. For this project, Bridger contracted with Canadian flight service provider Airborne Energy Services (AES) for aircraft integration and deployment of the GML sensor. Bridger's final goal for this project was to demonstrate the value of GML leak monitoring technology to both Canadian operators and regulators as an enabling tool for cost-effective LDAR and emission auditing programs. Bridger and AES quickly, sensitively, and precisely identified, at the equipment level, natural gas production facilities that require (and, importantly, that do *not* require) follow-up from complementary ground-based technologies. GML therefore provides an "answer key" to operators and regulators, telling them precisely where to find the leaks and how to prioritize repair.

2. TECHNOLOGY DESCRIPTION

Gas Mapping LiDAR™ (see Figure 1), is changing the way methane emissions are discovered and managed. This disruptive technology uses proprietary laser-based remote sensor hardware and analytics to reduce the cost of identifying methane leaks, while improving safety and efficiency. Bridger offers GML as a leak monitoring data service that provides data product deliverables to make finding and prioritizing gas leaks simple. The GML sensor can be mounted on several types of light aircraft, including fixed-wing, helicopters, and drones (prototype) to provide a cost-effective solution for detecting, localizing and quantifying methane emission through the entire natural gas value chain. GML data products are configurable to meet customer needs and may include gas concentration maps with leak rates, 3D topographical imagery, aerial photography, and sensor coverage swaths. All data is geo-registered and viewable in simple, standard formats. These data products are enabled by proprietary hardware and analytics.

For the AMFC, Bridger and AES integrated the GML sensor on a Cessna 172 fixed-wing aircraft. The team has the flexibility to adjust flight altitude to meet mission requirements and flies at a nominal flight speed of 100 knots, which can also be varied. AES brings 34 years of experience, an outstanding safety record, and highly skilled pilots, to ensure efficient and reliable GML sensor deployment. Together, Bridger's advanced GML technology and AES's superior flight services provide the customer with the following benefits:

Safety: Along with the outstanding flight safety record of our team, we provide industry-leading detection sensitivity combined with auditable, geo-registered coverage swaths to minimize missed leaks (false negatives), which are safety risks.

Efficiency: Our team provides an "answer key" indicating which surveyed sites have leaks, we accurately quantify the leak rates, and we locate the leak sources to the equipment level, all to save operators and regulators time and money.

Cost Savings: Our solution is more cost-effective than visiting all sites with foot patrols and hand-held detection instruments.

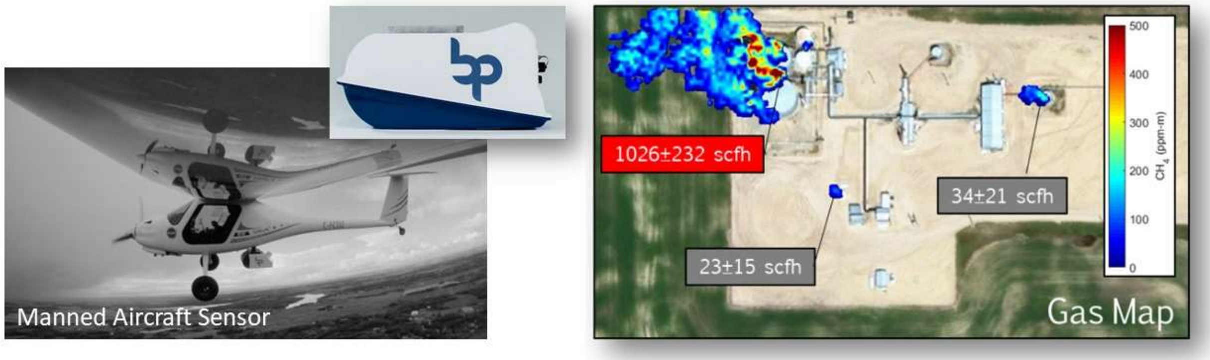

Figure 1. Left: GML Sensor hardware (manned aircraft version). Right: Satellite imagery with gas map overlay showing leak locations and leak rates.[1]

3. AMFC PARTICIPATION SUMMARY

For the AMFC Bridger and AES operated out of AES's facility at Villeneuve airport, located 20 km west-northwest of Edmonton, AB, and approximately 145 km north-northeast of the AMFC test sites. The Cessna 172 nominal flight speed of 100 knots (with the GML sensor installed) resulted in a 45-minute ferry time each way between Villeneuve and the test sites. Table 1 shows a summary of the GML site surveys performed by Bridger and AES during the AMFC. The GML was deployed on five separate days and performed a total of 65 site surveys. Bridger used the first day of deployment (6/16/2019) to train AES's pilot to fly the pre-programmed flight lines over the AMFC facilities to maximize efficiency and data quality of the GML scans. As a result, only four facilities were scanned over the course of 1 hour and 48 minutes on the first day. On subsequent deployment days, once the pilot was trained to fly the flight lines, an average of ten facilities were surveyed per hour of flight time. On days 2 thru 5 GML site surveys were performed for all AMFC sites scheduled for survey on that day. A total of 15 leaks were detected during 11 of the 65 site surveys performed during AMFC testing. Most sites were scanned twice to determine if a detected leak corresponded to an intermittent or persistent emission source. Of the 15 detected leaks 6 were detected on multiple passes indicating continuous emission. Further details regarding the leaks detected by GML during the AMFC will be left to reports generated by the AMFC scientific team.

Table 1. Summary of GML site surveys during the Alberta Methane Field Challenge.

Date	Sites surveyed	Start time	End time
6/14/2019	4 sites surveyed (15,16,22,32)	8:40 am	10:28 am
6/16/2019	17 sites surveyed (15,16,18,21,27,32,34,35,39,40,41,44,46,47,48,49,50)	9:28 am	10:59 am
6/17/2019	14 sites surveyed (17,18,21,22,24,27,30,31,34,41,44,46,48,50)	9:21 am	10:42 am
6/18/2019	14 sites surveyed (17,19,21,24,25,30,31,33,34,35,37,41,48,50)	10:01 am	11:17 am
6/20/2019	16 sites surveyed	1:21 pm	2:40 pm

[1] **Funding and site access for the left and right images provided by the Alberta Upstream Petroleum Research Fund. Measurements acquired by Bridger Photonics in collaboration with Lidar Services International and Z-Air.**

	(13,16,17,19,21,23,25,26,28,29,33,36,37,38,43,45)		

4. DATA PRODUCT EXAMPLE

The GML software and patented processing algorithms enable real-time visualization of methane plume imagery and scan coverage area overlaid on a map interface. The software visualization tools allow the sensor operator and pilot to view the scan area in real-time to ensure asset coverage. Built-in report generation functionality allows the sensor operator to generate reports from the real-time data that contains basic information about the aircraft flight path and detected plumes of elevated methane concentration that exceed a user-configurable concentration threshold.

After the flight is completed, the GML data may be transferred to Bridger via one of several established and secure data transfer channels for post-processing. A more detailed data analysis is performed in post-processing to identify equipment-level emission locations, quantify emission rates and generate the data product deliverables. Example GML data products acquired during the AMFC are shown in Figure 2 and Figure 3. Figure 2 shows a GML aerial photograph (Right) compared with a Google Earth satellite image (Left). The aerial photography data product may be particularly useful in cases where the satellite images are outdated – cases where the existing facility is different than, or doesn't even appear in, the satellite images.

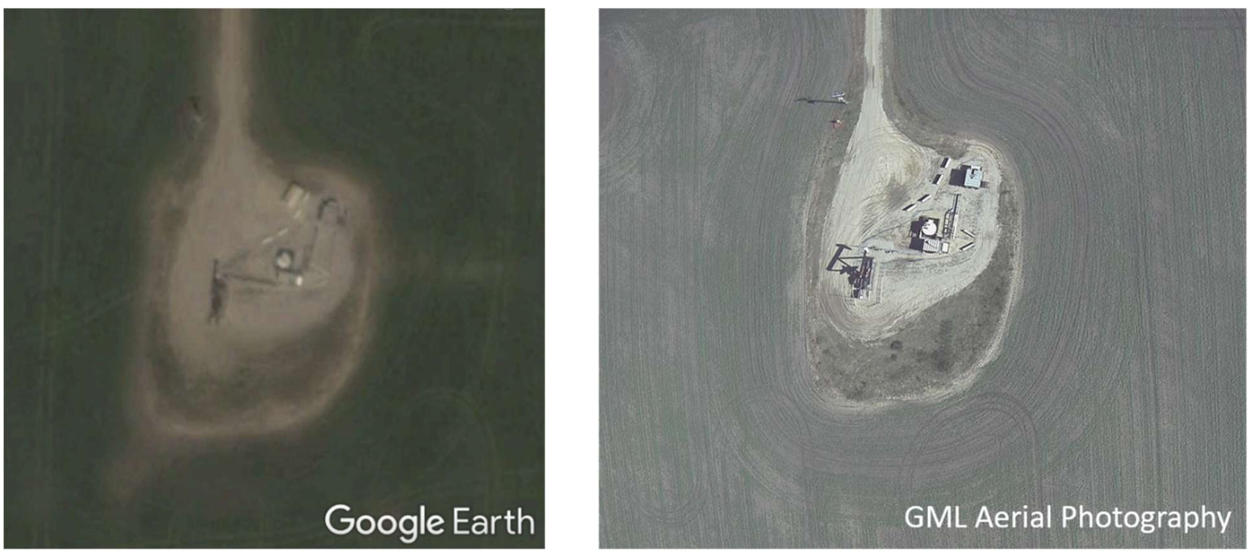

Figure 2. (Left) Google Earth satellite image of a well pad scanned using GML. (Right) GML aerial photograph of the same well pad.

Figure 3 shows examples of the plume image and scan coverage data products. In Figure 3 (Left), a methane concentration image, from the facility shown in Figure 2, is displayed in Google Earth. Data objects containing detailed information about the detected methane plumes are shown in Figure 3 (Center). The red and black dot icons indicate emission locations. Clicking on an emitter icon in Google Earth will open an annotation box listing emission attributes and details. Similarly, clicking on the blue shaded region surrounding the plume images will open a box summarizing all information associated with the enclosed plumes, including emission rate. The date, time and GPS location for detections shown in Figure 3 (Center) have been omitted to maintain facility anonymity. GML's ability to detect, localize, and quantify leaks enables deployment of field personnel directly to the leak source without wasting time and resources on sites or equipment that aren’t leaking. Finally, Figure 3 (Right) shows the GML scan coverage data product, which is used by the flight provider to verify asset coverage during the flight and may be used by the operator or regulator to confirm scan completion thereafter.

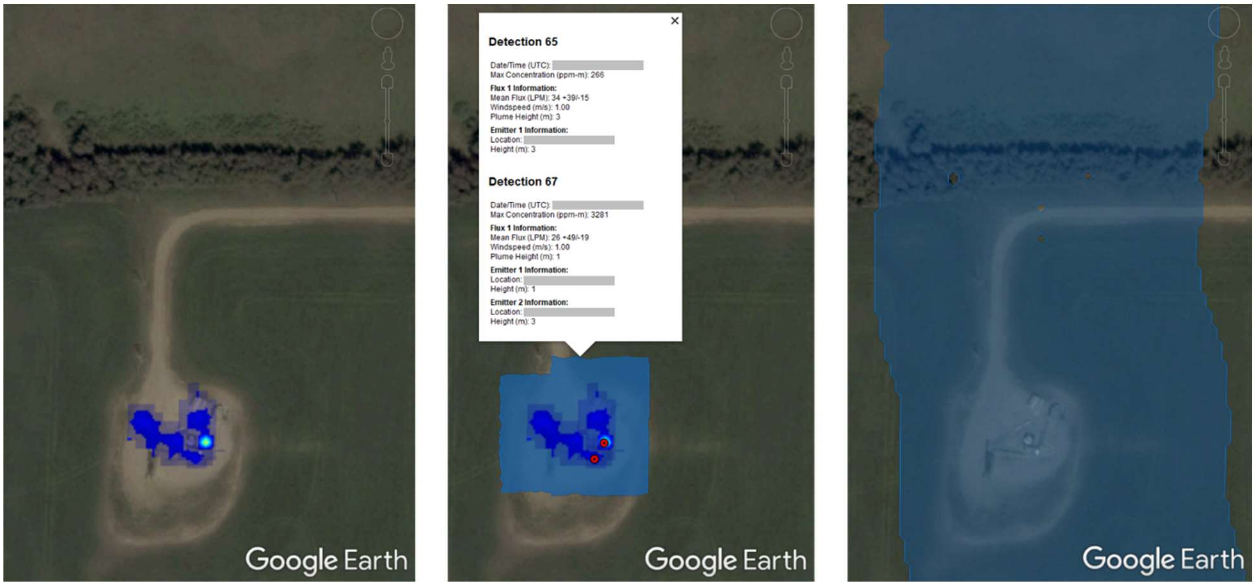

Figure 3. (Left) GML methane concentration plume image visualized in Google Earth. (Center) GML methane plume image with emitter locations and detection attributes visualized in Google Earth (time and location omitted for site anonymity). (Right) GML scan coverage data product visualized in Google Earth.

5. PERFORMANCE AND COST IMPLICATIONS

The GML sensor performed in accordance with expected performance specifications during the AMFC. For example, in calm winds, leaks with emission rates in the low tens of liters per minute were routinely detected (see Figure 3 Center). The main factors limiting site survey completion were the weather (GML is limited by heavy rain) and the site density. Bridger and AES encountered typical Alberta weather conditions during the AMFC testing, ranging from clear sunny days to afternoon thunderstorms to full days of monsoon-style rain. The GML was deployed in most weather conditions - sun, wind, light to moderate rain and clouds conforming to VFR flight clearances. The GML was not deployed in heavy rain, thunderstorms or cloud cover requiring IFR flight. Of the seven days Bridger was in Alberta for the AMFC, the weather on six days was suitable for GML deployment.

Participation in the AMFC did not change Bridger’s estimated cost for GML deployment, but rather validated previous cost estimates. The per-site cost to perform GML surveys depends on several factors, resulting in varying cost by region. Aircraft ferry time, site size, site density, repeat scans, and number of sites are the largest factors determining cost. GML averaged 10 site surveys per hour during AMFC testing, which confirmed that GML deployment costs, for jobs similar to the AMFC, will be well below that of site surveys performed by ground crews with hand-held detectors, such as IR cameras. For denser site regions, Bridger has previously demonstrated over 100 sites scanned per hour, leading to even lower per-site survey costs.