INSIGHT M
METHANE MANAGED

Formal Alternative Test Method

Insight M LeakSurveyor™

10 kg/hr Deployment

SUBMITTED TO

The United States Environmental Protection Agency
Air Emission Measurement Center (EMC)

SUBMITTED BY

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Table of Contents

1 Scope and Application **4**
2 Summary of Method **5**
3 Definitions of Method **6**
4 Interferences **7**
4.1 Planning for and Mitigating Interferences 7
4.2 LeakSurveyor Environmental Operating Envelope 8
4.3 Topography, Terrain, or Ground Cover 9
4.4 Aircraft Turbulence 9
4.5 Non-Environmental Interferences 9
4.6 Measurement Instrument Interferences 9
5 Safety **11**
5.1 Culture 11
5.2 Training 11
5.3 Aircraft Crew and Operations Safety 11
6 Equipment and Supplies **12**
7 Reagents and Standards **13**
8 Sample Collection, Preservation, and Storage **13**
9 Quality Control **13**
9.1 Integrated Quality Controls 13
9.2 Software System Controls 14
10 Calibration and Standardization **15**
10.1 Calibration and Maintenance 15
10.2 Hardware Standardization 16
11 Data Collection, Storage, and Reporting Procedure **16**
11.1 Flight Planning and Routing 16
11.2 Pre-flight Checklist and Day of Flight 17
11.3 Data Management, Processing, and Storage 17
11.4 Emissions Reporting to Oil & Gas Clients 18
12 Data Analysis and Calculations **19**
13 Method Performance **19**
13.1 Method for Determining Performance 19
13.2 Third-Party, Single-Blind Assessment via Controlled Release 20
13.3 Internal Assessment via Controlled Release 22
13.4 Operator Validation of Performance from Field Deployments 23
13.5 Assessment of Operating Envelope Conditions across Major Oil and Gas Basins in the United States 24

14 Pollution Prevention **27**
15 Waste Management **27**
16 References **27**

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1 Scope and Application

1.1 *Introduction*. This document outlines the Insight M protocol for deploying the LeakSurveyor methane spectrometer ("LeakSurveyor") for field surveys of oil and gas sites. LeakSurveyor is an airborne remote sensing instrument capable of surveying any and all onshore oil and gas infrastructure. LeakSurveyor collects reflected sunlight and measures the total concentration of methane along the complete path of the light entering the instrument. It is capable of identifying emissions to the facility level, as well as quantifying the amount of methane being emitted within a characterized range of error. Both detection and quantification have been validated via third-party, single-blinded testing (peer-reviewed and published), numerous internal controlled release tests, and field performance in over 20 oil and gas basins.

1.2 *Scope*. This protocol outlines an alternative test method using advanced methane detection technology for periodic screening for fugitive emissions and emissions from covers and closed vent systems in lieu of the procedures set forth in 40 CFR §60.5397b and §60.5416b(a)(1)(ii) and (iii), (2)(ii) through (iv), and (3)(iii) and (iv).

1.3 *Instrument*. The methodologies in this protocol are specifically designed to be applied with LeakSurveyor's advanced methane detection technology. Insight M is the sole producer and operator of the LeakSurveyor system. This document outlines the protocols employed by trained Insight M personnel and its contractors when conducting a field survey for methane emissions.

1.4 *Analytes.*

Analyte	CAS No.
Methane (CH_4)	74-82-8

1.5 *Applicability.* The methodologies described in this protocol are appropriate for detecting methane emissions from onshore oil and gas infrastructure. The methodologies are broadly applicable to any and all onshore oil and gas (upstream and midstream) point sources in the United States.

1.5.1 *Proprietary application*. The LeakSurveyor technology, analytical pipelines, and accompanying methodologies described in this protocol are the intellectual property of Insight M;

if you wish to deploy these methodologies, please contact info@InsightM.com for potential contracting.

1.6 *Spatial Resolution*. Deploying LeakSurveyor according to this protocol characterizes emissions at a facility-level spatial resolution, meaning the method has the ability to identify emissions within the boundary of any relevant facility, including (but not limited to) a well site, centralized production facility, or compressor station.

1.7 *Sensitivity*. The deployment of LeakSurveyor described in this protocol will achieve a 90% probability of detection of an emission source that is emitting methane at a rate of 10 kg/hr.

1.8 *Data Quality Objectives*. Adherence to the requirements of this protocol will guarantee sufficient quality of reported data obtained from aerial methane surveys using LeakSurveyor, and provide a means to bring alternative technology to mandated OGI and/or AVO monitoring of fugitive emissions components, covers, and closed vent systems without sacrificing detection and measurement rigor.

2 Summary of Method

2.1 *Principle*. This protocol describes the application of LeakSurveyor and methodology to detect methane emissions of 10 kg/hr or greater with a 90% probability of detection. LeakSurveyor is further described in full in the attached *Insight M LeakSurveyor Description of Technolog*y document.

2.2 *Pre-deployment activities.* Before deployment, flight planning identifies the facilities to be surveyed and assesses weather forecasts to estimate likely collection conditions. The goal of this effort is to facilitate survey of all target sites under meteorological conditions that ensure the target sensitivity.

2.3 *Deployment.* The instrument is mounted on the wing strut of a fixed-wing aircraft, such as a Cessna. Standard pre-flight checks ensure that the aircraft and instrument are operational and that safety protocols are followed. Once all pre-flight checks pass, the aircraft takes off and proceeds to the collection area, which has been determined during pre-deployment flight planning. Pilots who have completed training on the LeakSurveyor technology and operations fly the aircraft and sensor over the target infrastructure. As the plane passes above target infrastructure, the LeakSurveyor system collects nadir-view spectroscopic measurements that will later be analyzed for absorption of infrared light characteristic of methane absorption (please see the *Insight M LeakSurveyor Description of Technology* document for further discussion of the scientific basis for this approach). Additionally, an optical camera located within the LeakSurveyor instrument body collects RGB imagery of the site to help determine conditions on the ground as well as more accurately locate the likely source (within the facility) of detected methane. The complete facility is surveyed, with multiple overlapping (side-lap) passes collected if necessary to obtain complete spectroscopic and optical data coverage for the entire facility and surrounding area. During aerial data collection, LeakSurveyor operation and real-time meteorological conditions are monitored to ensure data quality objectives at the target sensitivity are achieved. Once the target sites have been surveyed, the plane returns to base. Once on the ground, the LeakSurveyor system is inspected for any issues that may have occurred during the day's collection.

2.4 *Post-deployment.* After completing post-flight safety and instrument inspections, the LeakSurveyor is connected to the Internet, and data upload begins. Please see the *Insight M LeakSurveyor Description of Technology* document for more information.

3 Definitions of Method

3.1 *Controlled Release* - A field test in which methane is released at well-characterized release rates and Insight M sensors are flown overhead, in order to assess instrument performance.

3.2 *Facility* - An oil and gas site, such as a well site, centralized production facility, or compressor station.

3.3 *False-positive rate* - The ratio between the number of negative events wrongly categorized as positive and the total number of positive events.

3.4 *Flight Path* - The planned pathways for flights designed to ensure complete LeakSurveyor coverage of target sites. Flight paths are made up of one or more flight lines over target sites, connected by turns.

3.5 *LeakSurveyor* - Patented Insight M sensor, composed of multiple subsystems designed to facilitate the collection and analysis of actionable and precise methane emissions data. LeakSurveyor is a light-aircraft-mounted methane gas imaging system that collects data to produce georeferenced methane emissions detections at onshore oil and gas sites.

3.6 *Pass* - Actual flight conducted along a planned flight line over one or more target sites. Single or multiple passes along a planned flight line may be used to collect methane data from target sites.

3.7 *Probability of detection* - the fraction of true release rates expected to be detected as a function of their release rate.

3.8 *Quantification* - The measured rate of loss for a detected emission source, in flux units (e.g., kg/hr, etc.).

3.9 *Quantification accuracy* - relative percent difference between true release rate and measured release rate. True release rates can be known only under controlled testing conditions.

3.10 *Sensitivity* - Emission source detection rate noted in flux units (e.g. kg/hr).

3.11 *Survey* - Aerial deployment of the LeakSurveyor to collect methane emissions data from one or more specified target sites.

3.11.1 A "survey day" or "survey flight" refers to a single day or flight, respectively, of methane data collection under this protocol.

3.11.2 A "contracted survey" refers to data collection and analysis under this protocol for a scope of target sites and survey timing agreed upon between Insight M and an individual client. A contracted survey is complete when Insight M has collected data, met data quality objectives for 100% of target sites under the contract, and reported survey outcomes; contracted surveys may be completed in one or more survey days within the period specified in the contract.

3.12 *Target sensitivity* - The sensitivity at which a survey will be conducted, defined by the probability of detection at a specific rate.

3.13 *Target site* - A facility designated to be surveyed under this protocol.

3.14 Units -

3.14.1 *kg/hr* - kilograms of methane (unless otherwise specified) per hour

3.14.2 *kgh/mps* - kilograms of methane (unless otherwise specified) per hour per meter per second of wind

4 Interferences

4.1 *Planning for and Mitigating Interferences.*

Insight M deploys its LeakSurveyor technology under this protocol according to a standardized operating envelope that has been defined based on well-characterized, known interferences. Our understanding of known interferences is based on controlled release testing in various locations and conditions, as well as our experience deploying this protocol in field conditions across the United States. Accordingly, deployment of Insight M's LeakSurveyor technology under this protocol involves (a) adhering to a strict operating envelope (see Section 4.2), (b) planning in advance to work around known or expected interferences to stay within our operating envelope, (c) monitoring conditions and adapting survey plans as needed to avoid interferences, (d) training analysts to identify and filter out instances of interferences that affect a discrete area, and (e) training analysts to identify instances of interferences that affect the overall quality of a dataset and subsequently targeting those areas for re-survey. Table 1, below, outlines the various operational constraints and the risk they pose to the safe and effective operation of the LeakSurveyor system.

4.2 *LeakSurveyor Environmental Operating Envelope.*

Some meteorological conditions interfere with the successful application of the LeakSurveyor technology according to this protocol by posing an aviation safety risk and/or reducing data quality beyond acceptable bounds. We mitigate these interferences when indicated by current conditions or weather forecasts by scheduling or rescheduling survey flights to a later date or time when conditions have improved.

4.2.1 *Sunlight and Cloud Cover.* The Insight M LeakSurveyor requires adequate sunlight to collect measurements. Adequate sunlight is available when the sun angle is at least 25 degrees above the horizon. Therefore, LeakSurveyor will only be deployed when the sun is at or above this threshold. Clear or mostly clear days with moderate cloud cover allow for optimal data collection. The density and type of clouds have different impacts on data collection. Our analysts and engineers review data quality indicators for each pass, identifying noise where possible and filtering out data that do not meet data quality objectives. When collected data do not meet data quality objectives, affected areas are marked for re-flight to collect data when conditions have improved.

4.2.2 *Wind Speeds*. We generally do not fly when wind speeds exceed 25 mph for aviation safety reasons. Additionally, wind speed affects the sensitivity of the sensor, where the source rates detected at 90% probability will increase with increasing wind speed. See Section 13 for further discussion of ensuring target sensitivity across wind speed variability.

4.2.3 *Temperature and Dew Point*. Extreme temperatures can affect the integrity of the LeakSurveyor hardware, the quality of data collection, and aviation safety. The LeakSurveyor instrument is operable within a ground temperature range of -5°C to 40°C. To ensure we meet data quality objectives, we operate within a narrower ground temperature range of 4°C to 40°C. Within this range, the LeakSurveyor's heating and cooling components maintain appropriate temperatures for quality data collection at altitude. We will not operate above 40°C due to aircraft safety at high temperatures.

Additionally, Insight M does not operate when temperatures fall below the dew point to eliminate the risks of condensation on sensitive equipment and airframe icing. To prevent potential condensation issues, the minimum ground temperature should be at least 1.5°C higher than the dew point to maintain a sufficient dew point spread at altitude. When planning survey flights, we generally apply a more conservative dew spread constraint of at least 4.5°C. However, we are able to collect data that meet data quality objectives at lower dew spread values when flying at lower altitudes above ground levels (AGL).

4.2.4 *Precipitation.* We do not operate in active precipitation due to the risk of water damage to the instrument. We also avoid takeoffs and landings on wet runways to ensure no water splashes onto the instrument.

4.2.5 *Visibility*. Flight conditions must be VFR (Visual Flight Rules) for the base airport and airports near the area of the survey. The visibility must be at least 5 nautical miles for flight safety and data quality. We will not perform surveys if the Air Quality Indicator (AQI) exceeds 150 at the base airport or within the planned survey area.

4.3 *Topography, Terrain, or Ground Cover.*

In some cases, variable reflectivity caused by topography, dense vegetation, standing water, or uneven snow cover can introduce noise within discrete areas of collected imagery. When we are aware of these interferences during the planning phase, we analyze solar incidence angles relative to terrain to determine the optimal orientation and timing for data collection and will adjust flight paths and timing to mitigate the interference from variable reflectivity during data collection. Any noise in the data resulting from these interferences is filtered out during data quality review by Insight M engineers and analysts, who undergo specific training to learn how to assess these cases. If necessary to meet data quality and completeness objectives, we will re-fly affected survey areas and adjust flight paths to mitigate interference from variable reflectivity.

4.4 *Aircraft Turbulence.*

Turbulence is difficult to plan for. In cases where the aircraft encounters extreme turbulence, there may be data quality impacts isolated to the period of turbulence. Since turbulence is apparent at the time of collection, the decision to re-fly an area can be made while the sensor is still in flight. As with variable reflectivity, any data quality issues resulting from turbulence are filtered out during data quality review by trained Insight M engineers and analysts. If necessary to meet data quality and completeness objectives, we will re-fly affected survey paths and adjust flight paths to mitigate interference from turbulence.

4.5 *Non-Environmental Interferences.*

Non-environmental interferences include aircraft availability, pilot requirements, local air traffic, and restricted airspace. These interferences are limited by diligent program planning and scheduling. However, in any scenario, survey crews have the authority to deem flights unsafe on any given day.

4.6 *Measurement Instrument Interferences.*

Insight M personnel are trained in the proper installation of the LeakSurveyor instrumentation. Additional interferences are mitigated by built-in self test software on the LeakSurveyor instrumentation, pre-flight checklists, and ongoing pilot monitoring of a live readout of instrument health and status during the flight. If the pilot encounters an issue with LeakSurveyor, an Insight M engineer is immediately tasked with diagnosing and resolving the in-flight issue. If the LeakSurveyor system fails and cannot be remotely troubleshooted during a flight, the pilot will land at the nearest airport for further assessment. If the LeakSurveyor system is still not operable after additional troubleshooting, Insight M will install a backup instrument system. The pilot will then conduct the remaining flight paths and resurvey any impacted paths, as necessary.

Risk Description	Mitigation Plan	Risk Likelihood
Significant cloud cover	Wait for conditions to improve, reschedule the flight.	Medium
High winds > 25 mph	Wait for conditions to improve, reschedule the flight. (Note that this wind speed is a safety threshold. See Section 13 for wind speed limits to ensure target sensitivity.)	Medium
Temperature < 4°C or > 40°C	Wait for conditions to improve, reschedule flight.	Low/Medium
Precipitation > 1 mm/hour	Wait for conditions to improve, reschedule the flight.	Low/Medium
Severe topography changes	Adjust survey flight path to account for sun angle and shadows; Address in analysis.	Low
Aircraft turbulence	Wait for conditions to improve, reschedule and re-fly survey path(s) affected by turbulence.	Low/Medium
Variable snow cover	Adjust survey flight path to account for uneven reflectivity and/or wait for conditions to improve and re-fly affected survey path(s); Address in analysis.	Low
LeakSurveyor system failure	Return to base and install a backup system.	Low

Airspace restrictions	Ensure appropriate flight approvals and licenses are acquired.	Low

Table 1: Risk description and mitigation plan table.

5 Safety

5.1 *Culture.*

Operational safety is the highest priority for all Insight M employees and contractors. Ensuring the safety of our employees, our flight vendors, and the general public is our top priority. We provide comprehensive training and implement strict protocols to mitigate risks and promote a secure work environment. By prioritizing safety, we strive to safeguard the well-being of every member of our team and communities.

5.2 *Training.*

All LeakSurveyor pilots undergo thorough training to prioritize safety and master equipment handling. Moreover, they are required to attain Operator Qualifications in addition to their training on Insight M's LeakSurveyor technology and protocol. Insight M has developed custom training to satisfy Veriforce CCT 728 "Aerial Leakage Survey" Operator Qualification. In addition, all Insight M analysts complete this same training to improve their ability to recognize potential emissions and assess data quality.

5.2.1 *Updating Training and Protocols*. Regular protocol updates are essential for staying ahead of evolving challenges and ensuring optimal performance and safety. We continuously review and refine our protocols to incorporate the latest industry standards, technological advancements, and feedback from our team members. By staying proactive and adaptive, we uphold our commitment to excellence and safety in all aspects of our operations.

5.3 *Aircraft Crew and Operations Safety.*

5.3.1 Aircraft operations requirements meet FAA standards outlined in the Code of Federal Regulations Title 14.

5.3.2 Vendors undergo a quarterly safety survey to ensure the individual pilots feel safe and are able to raise concerns.

5.3.3 Pilots must complete and submit preflight and post-flight checklists to ensure the aircraft and instruments are operational and that all safety protocols are followed. Safety-related measures taken during mandatory pre-flight checklists include completing a mechanical inspection of all Insight M instrumentation and confirming proper mounting of LeakSurveyor.

5.3.4 A Flight Route Summary is created to furnish pilots with anticipated flight duration and alert them to any potential hazards along the route.

6 Equipment and Supplies

6.1 *LeakSurveyor.* LeakSurveyor consists of multiple subsystems that enable the collection of actionable and accurate data. The full system was patented on November 12, 2015, under International Patent Number WO 2015/172056 A1 and US Patent number US 10,267,729.

6.1.1 The imaging subsystem contains the infrared spectrometer and an optical (RGB) camera. The optical camera collects imagery that is used to provide a synchronous snapshot of the scene around the emission. The full instrument is discussed at length in the *Insight M LeakSurveyor Description of Technology* document.

6.1.2 The compute subsystem contains a flight computer, a GPS/INS system, and a WiFi router. The flight computer runs all of the embedded flight software, which controls both cameras and the GPS/INS unit. The GPS/INS system records a log of all positions and orientations of the LeakSurveyor system during its collection period. The computer also runs a suite of proprietary software which allows the pilot to operate and monitor the system remotely via the WiFi router.

6.1.3 The power subsystem contains an FAA-approved battery and network-connected power distribution electronics, which enable our flight software to control the power states of all the devices.

6.1.4 These subsystems are housed in an aviation-grade composite fairing.

6.2 *LeakSurveyor Auxiliary Equipment*. LeakSurveyor is paired with several pieces of auxiliary equipment to facilitate and monitor the safe operation of the instrument.

6.2.1 Two tablets are used to facilitate data collection and flight plan navigation. The first tablet operates proprietary software that monitors the LeakSurveyor system, providing feedback on data quality and alerting the pilot to any equipment anomalies. The second tablet aids the pilot in navigating to designated collection areas and guides them through the planned flight routes.

6.2.2 Each aircraft is equipped with supplementary equipment such as spare cables, power supplies, and additional tablets, all critical for troubleshooting and maximizing data collection.

6.2.3 At the end of each flight day, the collected data is uploaded using a dedicated computer ensuring that all information is securely backed up and available for processing and analysis.

6.3 *Aircraft*. This protocol is for an aircraft-based survey method.

6.4 *Mounting Hardware.* For the mounting of the Leak Surveyor onto aircraft, an approved FAA Supplemental Type Certificated mounting system is utilized.

7 Reagents and Standards

[Reserved]

8 Sample Collection, Preservation, and Storage

[Reserved]

9 Quality Control

9.1 *Integrated Quality Controls.*

As part of this protocol, Insight M applies standard quality controls at every step, including during flight planning, before and during data collection, and during data processing and analysis.

9.1.1 *Flight Planning Quality Controls.* Insight M flight planning targets deployment of LeakSurveyor according to a strict, well-characterized operational envelope (see Section 4.2) as well as safe aviation practices.

9.1.2 *Data Collection Quality Controls.* On the day of flight, the instrument performs a built-in self-test to ensure that all components are working correctly. In addition, all operating conditions are continuously re-evaluated to ensure flight crew safety and successful data collection. If conditions in the field do not meet those specified in the operating envelope (see Section 4.2), the flight will be rescheduled. As part of this, wind conditions are assessed, and flight plans may be modified to a new altitude AGL, to ensure 10 kg/hr sensitivity is achieved.

Prior to takeoff, flight personnel must complete a pre-flight checklist, which includes properly booting up the LeakSurveyor instrument, confirming successful completion of the built-in self-test, confirming sensor operation, assessing current conditions for aviation safety, and ensuring hardware is properly set up and secured to mount.

During flight, pilots are in constant communication with flight coordinators on the ground who are monitoring live weather conditions and redirecting aircraft as necessary to maximize good data collection. Pilots also have a live readout of instrument health and status during the flight via an auxiliary tablet (see section 6.2.1). Part of this readout informs the pilot as to whether the instrument is operating in a nominal state, operating in a state that does not prevent collection but may impact data quality, or has experienced a failure that either is a critical data quality issue or prevents collection entirely. More information can be obtained by the pilot via the user interface if necessary.

Any time a pilot encounters an issue with LeakSurveyor that the system cannot automatically correct, an Insight M engineer is immediately tasked with diagnosing and resolving the in-flight issue. If an issue is successfully dealt with in flight, pilots will re-fly any passes that were collected in an error state. If the LeakSurveyor system fails and cannot be remotely resolved during a flight, the pilot will land at the nearest airport for further troubleshooting. If the LeakSurveyor system is still not operable after additional troubleshooting, Insight M will install a backup instrument system. The pilot will then conduct the remaining flight paths and resurvey any impacted paths, as necessary.

At the end of each flight, the instrument is inspected for damage or other issues that may have occurred during flight.

While we have numerous data quality checks on the processed data, these in-flight measures are an invaluable first line of defense to ensure good data quality.

9.1.3 *Data Processing & Data Analysis Quality Controls.* Automated and manual quality controls are applied at each step of data processing and data analysis, from copying and uploading data from the onboard instrument to final report generation of emissions results for clients. These controls help ensure that only quality data are processed, analyzed, and reported. Data quality indicators examined in these steps include but are not limited to: altitude AGL, presence of null or corrupt data, illumination levels, glare, ambient and sensor temperatures at collection, extreme yaw/pitch/roll variation, airspeed, difference between target and flown altitude, and automated flags relating to any data processing or instrumental anomalies. If data quality indicators indicate that data quality objectives are not met at any step, the data are excluded from further processing/analysis, and affected collection areas are marked for re-flight.

9.2 *Software System Controls.*

Insight M uses industry-standard software engineering best practices to ensure our data processing, data analysis, and report generation systems are accurate, reliable, and free of defects.

9.2.1 *Software Version Control*. All of our system code and configuration parameters are tracked in a version control system which lets us review, add, and remove changes in a well-defined and auditable manner.

9.2.2 *Code Reviews*. All software changes are peer-reviewed for functional correctness before being incorporated into our code base.

9.2.3 *Automated Tests*. In addition to code reviews, all software changes must pass an automated test suite which includes end-to-end, unit, and integration tests.

9.2.4 *Logging and Alerting*. Key application events and system-level metrics are captured by logging tools, and used to generate automated alerts which let us know in real-time if core functionality deviates from what is expected.

10 Calibration and Standardization

10.1 *Calibration and Maintenance.*

Every new sensor in Insight M's fleet goes through rigorous laboratory calibration and acceptance testing, as well as regular maintenance and calibration checks. Every LeakSurveyor must meet specific criteria to be deployed to the field.

10.1.1 *New sensor laboratory acceptance testing.* The following features are assessed in the lab for every new LeakSurveyor:

10.1.1.1 *Noise quantification.* Assessed by measuring the relationship between signal and noise over the dynamic range of the sensor. From this relationship, a sensor's fundamental noise floor, gain, and well depth can be determined.

10.1.1.2 *Methane detection sensitivity.* Assessed by determining the minimum path concentration of methane an instrument can see, with signal above a standardized signal to noise ratio.

10.1.1.3 *Stray light*. Assessed by illuminating a single spot on the sensor and looking for signal in the dark region of the sensor plane.

10.1.1.4 *Spatial focus.* Assessed by focusing spatial optics on a point source that is very far away.

10.1.1.5 *Spectral focus.* Assessed with a spectral calibration lamp which produces very narrow spectral lines within the sensor's wavelength region.

10.1.2 *New sensor flight acceptance testing*. A laboratory-calibrated instrument must also pass an in-flight test to ensure all components of the sensor function within specification in a flight environment.

10.1.3 *Ongoing maintenance and calibration checks.* Ongoing and routine maintenance is conducted for each sensor. During maintenance, Insight M personnel ensure all fittings are tight and wiring connections are correct. The sensor is inspected for any damage and is repaired and cleaned when necessary. Spectrometer output is thoroughly assessed in the lab and results compared to data collected during new sensor acceptance testing, as described above, to ensure consistent and robust signal quality. Sensors are re-calibrated if necessary to ensure consistent data quality.

10.1.4 *Field data quality assessment.* In certain instances, if collected field data is determined to be unusual or degraded, or if damage is reported in the field, the instrument may be returned to the lab early for inspection, repair, and/or updated calibration if necessary. See sections 9.1.2 and 9.1.3 for additional discussion of data quality assessment.

10.2 *Hardware Standardization.*

All production hardware components follow the following standard lifecycle:

- The item is purchased.
- The item is received.
- Our digital inventory is updated along with the associated purchasing paperwork.
- The item is placed in our physical inventory.
- The item is physically installed in a LeakSurveyor system and the digital inventory system is updated.
- The item is physically uninstalled from a LeakSurveyor system and the digital inventory system is updated.

By following this standard process, Insight M maintains traceability between each hardware item and the LeakSurveyor assembly in which it is installed. The installation and uninstallation steps commonly occur during periods of routine maintenance (described in Section 10.1.3). In this way, upgrades to our hardware systems are rolled out to the entire fleet and assemblies are kept constantly up to date in terms of hardware and software versions. Every new hardware installation is accompanied by supporting documentation that enables our technician team to carry out the operation across every LeakSurveyor in the same manner.

11 Data Collection, Storage, and Reporting Procedure

11.1 *Flight Planning and Routing.*

11.1.1 *Flight Planning*. All surveys begin with flight planning for the target sites to be surveyed by LeakSurveyor. Flight planning begins with the generation of safe and efficient flight lines. These lines, when flown at a designated altitude in straight, level flight, are designed to achieve comprehensive coverage at target sensitivity of designated operator facilities while maintaining operational safety, complying with aviation regulations, and maximizing flight efficiency. To achieve these goals, Insight M operations engineers take into account various factors, including terrain, airspace restrictions, ground features, and seasonal weather trends.

Additionally, flight plans are designed to be flexible, allowing for adjustments in flight orientation and altitude above ground level to accommodate changing conditions and adhere to specific regulatory requirements and data quality objectives.

11.1.2 *Flight Routing*. After flight plans are generated, Insight M flight coordinators begin planning daily flight routes. Flight routing takes into account forecasted weather conditions and various aviation considerations for all collection areas. By evaluating areas and days with favorable weather conditions, Insight M flight coordinators determine the most efficient and effective paths for aircraft to collect accurate, high-quality data that meet the data quality objectives of this protocol on any given day. This iterative process continues up to and throughout the day of deployment, with ongoing analysis of weather conditions and continuous flight tracking. This dynamic approach enables flight coordinators to promptly communicate real-time reroutings to pilots, facilitating flexible operations and enhancing the quality and efficiency of data collection.

11.2 *Pre-flight Checklist and Day of Flight.*

After determining that current field conditions are within the instrument's operating envelope, flight operations personnel mount the instrument to the wing strut of the aircraft (if it is not already mounted). Flight personnel complete required safety, operational, and aviation checklists before a flight can be cleared for takeoff and data collection.

The aircraft flies to the designated survey area (flight box) and target altitude AGL. The aircraft will completely cover all designated operator assets (target sites) in each flight box. Multiple flight boxes, representing multiple clusters of contracted assets, may be surveyed by an aircraft over the course of one flight day.

Upon landing, flight personnel complete post-flight checklists to ensure that all required safety inspections are complete.

11.3 *Data Management, Processing, and Storage.*

All collected data are stored onboard the LeakSurveyor instrument for the duration of the survey flight. When an aerial survey flight is complete, collected data are transferred from the LeakSurveyor to a dedicated standalone computer located in or near the hangar. During this copy, an initial quality assurance and data verification step confirms data validity before uploading all relevant data to our secure cloud-based processing platform. Data are simultaneously copied to a local backup drive with a consistent, independent cloud backup process. Insight M retains two full backups of the raw data for a minimum of 5 years. All data on the local standalone computer and LeakSurveyor are erased only after both the local and cloud backup copies of the raw data are validated as complete and accurate copies of all valid data from the LeakSurveyor instrument.

On completion of the upload, our processing pipeline validates and refines the spectrometer measurements and runs a series of processing steps including (a) georectification of all collected data based on recorded GPS and IMU data and (b) the processing of spectroscopic measurements into methane plume imagery. This pipeline additionally produces time-of-survey orthorectified georegistered optical aerial imagery aligned with the processed methane imagery to build a complete dataset representative of the time of any identified leaks. Both raw and processed imagery are retained in our cloud storage for at least 5 years.

11.4 *Emissions Reporting to Oil & Gas Clients.*

11.4.1 *Emissions data provided to the end-user.* Insight M provides operators with data for all validated methane emission detections. For each validated emission detection, the data provided include, but are not limited to:

- Detection Time: The date and time of detection
- Emission ID: A unique identifier for the emission that allows for comparison with past and future reports
- Associated Asset: The name and/or ID of the facility where the emission was observed
- Location: The estimated emission location, based on the shape and extent of observed methane (reported as a latitude/longitude coordinate)
- Emission Rate: The best estimate of emission rate from the source
- Geolocated methane plume images superimposed on a geolocated optical image to guide close-range follow-up surveys
- If applicable, notes regarding the emission, such as suspected intermittency, notification of liquids leaks, notification of emissions in the proximity of human-occupied structures, observed maintenance events, etc.
- Date that emission result is made available to the operator.

11.4.2 *Other survey data*. For each contracted survey, Insight M provides additional coverage data to the client, including for surveys that yielded no confirmed emissions. The survey data provided include, but are not limited to:

- Confirmation that the alternative test method described in this protocol was the test method deployed by Insight M for the complete survey.
- Confirmation of the facility-level spatial resolution of the survey and the validated sensitivity of the deployment.
- Survey coverage results for each target site, provided as a cumulative list of coverage datetimes. Coverage results are provided for all target sites in a contracted survey, whether or not any emission was detected at the site.

11.4.3 *Data delivery.* Data is delivered in the digital format(s) and at the cadence(s) agreed upon with each individual customer. Final analyzed and validated detection data, including the attribute data listed in 11.4.1, above, are available within 1-5 calendar days of the date of the survey and delivered to the customer no later than 5 calendar days after the survey. Survey data described in 11.4.2, above, are provided at the end of a contracted survey or at another cadence agreed upon with the individual customer. Reported emissions and coverage data are saved in our cloud database for at least 5 years.

12 Data Analysis and Calculations

12.1 *Summary*. Transforming raw data into geolocated methane plumes is done via the Insight M proprietary pipeline, which includes both automated and supervised analyses. The general procedure is summarized in the following processing steps:

- Raw methane data is automatically saved into a spatially-aware data structure and transformed into an estimate of methane enhancement.
- Methane enhancements are assessed by analysts and flagged if determined to be valid plumes.
- The source rate is automatically quantified for all valid plume detections.
- Valid methane detections are associated to their source. Multiple observations of a single source (resulting from multiple overflights) are grouped together into a single emission detection.

13 Method Performance

13.1 *Method for Determining Performance.*

Insight M relies on controlled release testing to validate system performance and ensure that expected methane detection thresholds are maintained in the field across expected environmental variability. We routinely participate in externally- and internally-conducted controlled release tests with the aim of generating datasets to assess detection sensitivity and noise across a variety of environmental conditions and deployment configurations. Controlled releases are conducted with one or multiple of our LeakSurveyor systems, which have identical hardware and onboard software and have been calibrated in the lab before deployment.

13.1.1 *Controlled release methodology*. The generalized approach for conducting a controlled release has been described in detail in Sherwin et al. (2021) and is briefly described here. The controlled release procedure requires methane to be released at known rates while the sensor surveys the release area. Typical survey patterns are alternating direction passes along a single flight line. Methane flow rates are measured with 'in-line' flow meters which record the flow rate as well as the temperature of the gas as it is released with high precision. The site is also instrumented with an anemometer (wind gauge) which records local wind data with high granularity. Recorded flow rate data (including null passes where no methane is released) is compared against both detections and leak rates calculated from LeakSurveyor measurements processed through the Insight M analytical pipeline. Through this analysis, methane leak rate quantification accuracy, sensitivity, and false-positive rates can be calculated for a given sensor.

During a controlled release, LeakSurveyor is mounted aboard fixed-wing aircraft and deployed as it would be in the field. Prior to the start of the controlled release, a release plan is created that is designed to test the instruments' sensitivity, quantification accuracy, and false positive rate. Prior to the start of a pass, a specific release rate is chosen based on the recommended release rate from the release plan and current wind conditions. One minute prior to the plane's overhead pass, the flow rate is held constant in order to obtain a steady state flow downwind of the release point. Once the plane is overhead, the release rate, wind data, and any relevant notes are recorded by the ground crew. This process is repeated multiple times throughout the test to gather a range of representative data.

13.2 *Third-Party, Single-Blind Assessment via Controlled Release.*

In the fall of 2022, Stanford University conducted a single-blind controlled methane release study of Insight M's LeakSurveyor technology. Testing took place over 5 days, from October 24th through October 28th (El Abbadi et al., 2024).

13.2.1 *Single-blind experimental design.* The Insight M test was part of a larger controlled release campaign assessing multiple airborne technologies, conducted by Stanford University researchers in October and November, 2022 in Casa Grande, Arizona. Researchers followed a peer-reviewed testing protocol (Sherwin et al., 2021; Rutherford et al., 2022). In summary, the ground team (consisting only of Stanford researchers) conducted a series of methane releases at a variety of controlled rates while aircraft and satellites passed over and collected measurements. Strict blinding protocols were maintained– prior to and during testing operators were provided with no information about activities on the ground, including ground conditions, the rate of release, and whether or not methane was being released. Detections resulting from data collected by the Insight M LeakSurveyor were assessed by Stanford researchers for sensitivity, false positive rate, and quantification accuracy.

13.2.2 *Data reporting*. Insight M elected to participate in a multi-stage unblinding of data to better evaluate technology performance. Stage 1 represents the closest approximation of true field conditions, where no ground wind measurements or release rate data was provided. We report these results in the next section.

13.2.3 *Summary of Insight M performance*. Over the 5 days of testing, a total of 191 valid controlled releases of varying emission rates were conducted. The tested rates ranged from 0.64

to 1,110 kg/hr, with 107 releases below 15 kg/hr. An additional 18 were null releases, where no methane was released to quantify the technology false positive rate. The full results of this test are published in El Abbadi et al. (2024). In summary:

- **Sensitivity**: The study reports that the largest missed detection was 10.47 kg/hr (representing the only missed detection above 10 kg/hr). The smallest detected plume was 3.40 kg/hr. A logistic regression fit to the data collected by the study demonstrates a 90% probability of detection of 8.9 kg/hr under testing conditions (see Figure 1 below).
- **False positive rate**: LeakSurveyor demonstrated a false detection rate of 0%.
- **Quantification**: Quantification accuracy was assessed with an r^2=0.87, with 38% of quantified rates falling within +/- 25% of the true flow rate, and 73% falling within +/- 50%. This is similar to performance demonstrated in the previous blinded testing of Insight M technology (Sherwin et al., 2021) which observed quantification error of approximately 40% (1 sigma).

The final published manuscript can be found in the Supporting Documentation submitted with this application.

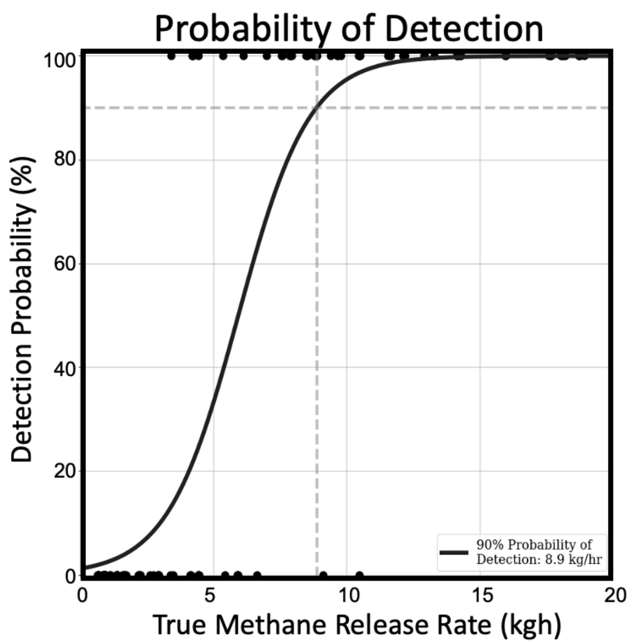

Figure 1: Probability of detection of the Insight M LeakSurveyor, calculated as the logistic regression fit to the data collected during single-blind testing by El Abbadi et al. (2024).

13.3 *Internal Assessment via Controlled Release.*

Controlled release datasets have been produced by Insight M scientists and engineers using the methodology described in Section 13.1.1 (as well as in the *Insight M LeakSurveyor Description of Technology* document). Controlled releases are designed to quantify performance across different axes of variability, including environmental conditions and deployment configurations.

As a remote sensing instrument, the two variables with the most significant impact on LeakSurveyor sensitivity are sensor height above ground and wind speed (Sherwin et al., 2021; Conrad et al., 2023). Additionally, different environments may impact sensitivity differently. The most important of these are related to overall moisture and reflectivity of the ground, where environments with green vegetation or moist conditions are less reflective than bright, dry environments. In the following sections, we describe characterized LeakSurveyor performance across these key variables.

13.3.1 *Description of the controlled release dataset.* The current controlled release dataset consists of 540 total flyovers collected at altitudes ranging from 1262 to 6063 ft altitude AGL, testing release rates ranging from 0 kg/hr (representing null releases) to 1201 kg/hr. Wind speeds during testing range from 0.01 to 15.3 mph, while testing conditions have been constrained to periods where solar elevation is >25 degrees and ground temperature is within 4 to 40°C. Controlled releases in this dataset have been conducted within two "endmember" environments encompassing a range of environmental conditions: a dry, desert environment (Arizona) with low, senesced vegetation and generally representative of dry basins; and a wet (irrigated) agricultural area (California) with moist soils and thick vegetation, generally representative of well-watered basins. Each of the 540 collected passes was processed through the commercially-deployed Insight M analytical pipeline (05/2024), and analyzed for detections using standard analysis procedures. Resulting detections are recorded, along with the quantified rate. This section evaluates the resulting dataset to characterize sensor sensitivity across different conditions.

Note that any future improvements made to Insight M data processing software that could change sensitivity will be assessed against this static dataset, and the modeling approach presented in 13.3.2, below, will be used to update the Insight M instrument fleet's sensitivity profile.

13.3.2 *Sensitivity as a function of sensor height and wind speed.* Insight M uses an empirical model of LeakSurveyor sensitivity as a function of sensor altitude AGL and local wind speed, following the methodology described by Conrad et al. (2023) and fit to the controlled release dataset described in Section 13.3.1, to characterize sensor sensitivity. This function underlies our operational capability to ensure target sensitivity at 90% probability of detection when collecting in a range of wind speeds.

13.3.3 *Sensitivity comparison between desert and green vegetation environments.* To understand the possible impact of scene variability on sensitivity, we compared the results of two days of controlled releases from the controlled release dataset described in section 13.3.1. One day of testing was conducted in Arizona (dry desert) and the other in California (wet vegetated). A comparison of the two datasets is provided in Table 2, below:

Location	California	Arizona
Date of collection	Sept 30, 2022	October 24, 2022
Scene conditions	Wet, agricultural, green vegetation	Dry, desert, senesced vegetation
Collection altitude AGL (avg)	1417’	1334’
Number of passes	39	40
Wind speed range during testing	5-12 mph	5-15 mph

Table 2: Comparison of two days of LeakSurveyor controlled release collection conditions.

Assessment of the results of these two datasets reveals a wind-independent 90% probability of detection of 2.93 kgh/mps in the California test, and 2.85 kgh/mps in the Arizona test. Statistical testing reveals no difference between the results of the two tests, indicating that LeakSurveyor sensitivity remains consistent across significant scene variability when deployed within its standard operating envelope (defined in Section 4.2).

13.4 *Operator Validation of Performance from Field Deployments.*

Insight M has deployed LeakSurveyor to all major onshore basins in the United States and has received operator feedback that validates reported detections in 19 basins, provided in Table 3 below. While this feedback does not represent a formal controlled release, it does demonstrate successful operation across a larger geographic scale than would be possible to test, supporting the conclusions in section 13.3. Surveys of these areas are conducted within the same operating envelope, including solar angle > 25 degrees, ground temperature within 4 to 40°C, and adherence to wind limits, ensuring that the performance characterized in our controlled testing is also applicable to these field collections.

Anadarko	Piceance
Appalachian	Powder River

Ardmore	San Joaquin
Arkoma	San Juan
Denver	TX-LA-MS Salt
Fort Worth	Uinta
Greater Green River	Ventura
Illinois	Western Gulf
Marietta	Williston
Permian	

Table 3: United States onshore oil and gas basins in which Insight M has deployed the LeakSurveyor technology and received client feedback validating reported detections.

Insight M also has operator-validated detections from international deployments, including in the Neuquén Basin in Argentina and multiple basins in Colombia.

13.5 *Assessment of Operating Envelope Conditions across Major Oil and Gas Basins in the United States.*

Insight M has reviewed meteorological data and confirmed that all environmental operating envelope limitations (as outlined in Section 4.2) are met in all major oil and gas basins in the United States. We reviewed hourly cloud cover, dew spread, precipitation, solar elevation, temperature, and wind speed data from Meteoblue for every United States county with at least 50 active producing oil and gas wells in Enverus Prism. For each county, we reviewed hourly data for every day from 2018-2023 using the centroid of the county based on 2023 TIGER/Line® data.

For each hour and county in the dataset, we annotated whether each operating envelope requirement was met individually and whether all operating envelope requirements were met simultaneously. Note that we selected a conservative ground-level dew point spread value for this analysis—this operational constraint varies by the altitude of the aircraft so there are cases where safe and effective collection at a smaller ground-level dew point spread is possible. We aggregated the six years of data to analyze local operating envelope variables for each county. We then reviewed individual county and basin-aggregated data to confirm that all six core meteorological operating envelope requirements are met, individually and collectively, across all major US oil and gas basins. The results of this analysis are summarized in Table 4 and Figure 2, below.

Basin	Operating Envelope Condition						Validation of Overlapping Conditions
	Cloud Cover <= 25%	Dew Spread >= 4.5°C	Precipitation <= 1mm	Solar Elevation >= 25deg	Ground Temperature >= 4°C and <= 40°C	Wind Speed within limit for 90% POD at 10 kg/hr	
Anadarko	✓	✓	✓	✓	✓	✓	✓
Appalachian	✓	✓	✓	✓	✓	✓	✓
Arkoma	✓	✓	✓	✓	✓	✓	✓
Bighorn	✓	✓	✓	✓	✓	✓	✓
Black Warrior	✓	✓	✓	✓	✓	✓	✓
Cherokee Platform	✓	✓	✓	✓	✓	✓	✓
Denver	✓	✓	✓	✓	✓	✓	✓
Forest City	✓	✓	✓	✓	✓	✓	✓
Fort Worth	✓	✓	✓	✓	✓	✓	✓
Greater Green River	✓	✓	✓	✓	✓	✓	✓
Illinois	✓	✓	✓	✓	✓	✓	✓
Los Angeles	✓	✓	✓	✓	✓	✓	✓
Marfa	✓	✓	✓	✓	✓	✓	✓
Michigan	✓	✓	✓	✓	✓	✓	✓
Montana Thrust Belt	✓	✓	✓	✓	✓	✓	✓
North Park	✓	✓	✓	✓	✓	✓	✓
Palo Duro	✓	✓	✓	✓	✓	✓	✓
Paradox	✓	✓	✓	✓	✓	✓	✓

Permian	✓	✓	✓	✓	✓	✓	✓
Powder River	✓	✓	✓	✓	✓	✓	✓
Raton	✓	✓	✓	✓	✓	✓	✓
San Joaquin	✓	✓	✓	✓	✓	✓	✓
San Juan	✓	✓	✓	✓	✓	✓	✓
Santa Maria	✓	✓	✓	✓	✓	✓	✓
TX-LA-MS Salt	✓	✓	✓	✓	✓	✓	✓
Uinta-Piceance	✓	✓	✓	✓	✓	✓	✓
Valley and Ridge	✓	✓	✓	✓	✓	✓	✓
Ventura	✓	✓	✓	✓	✓	✓	✓
Western Gulf	✓	✓	✓	✓	✓	✓	✓
Williston	✓	✓	✓	✓	✓	✓	✓

Table 4: LeakSurveyor Operating Envelope Requirements in U.S. Oil and Gas Basins. For each United States onshore oil and gas basin, this table depicts whether each operating envelope requirement under this protocol is met, as indicated by a checkmark (✓). The final column "Validation of Overlapping Conditions" indicates whether all operating requirements, taken together, are met simultaneously.

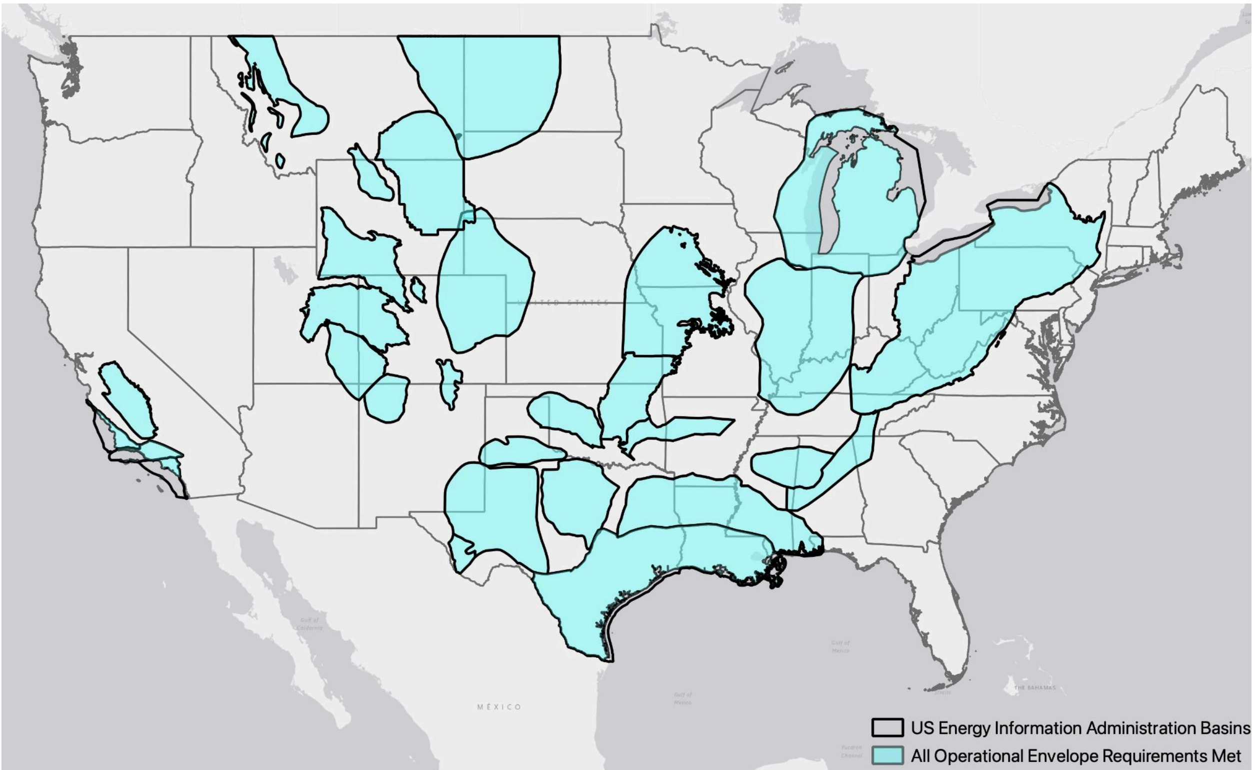

Figure 2. Map of United States Onshore Oil and Gas Basins and Validation of Operating Envelope Requirements under This Protocol. Sources: U.S. Energy Information Administration (basin geographies); Meteoblue (meteorological data tested for validating operating envelope conditions).

14 Pollution Prevention

Pollution is generated by aircraft during flight. Flight plans are drawn to ensure the most efficient paths of collection possible in order to reduce excess flight hours.

15 Waste Management

[Reserved]

16 References

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