Satellites deliver high value with rapid detection of the "Medium" sized leaks

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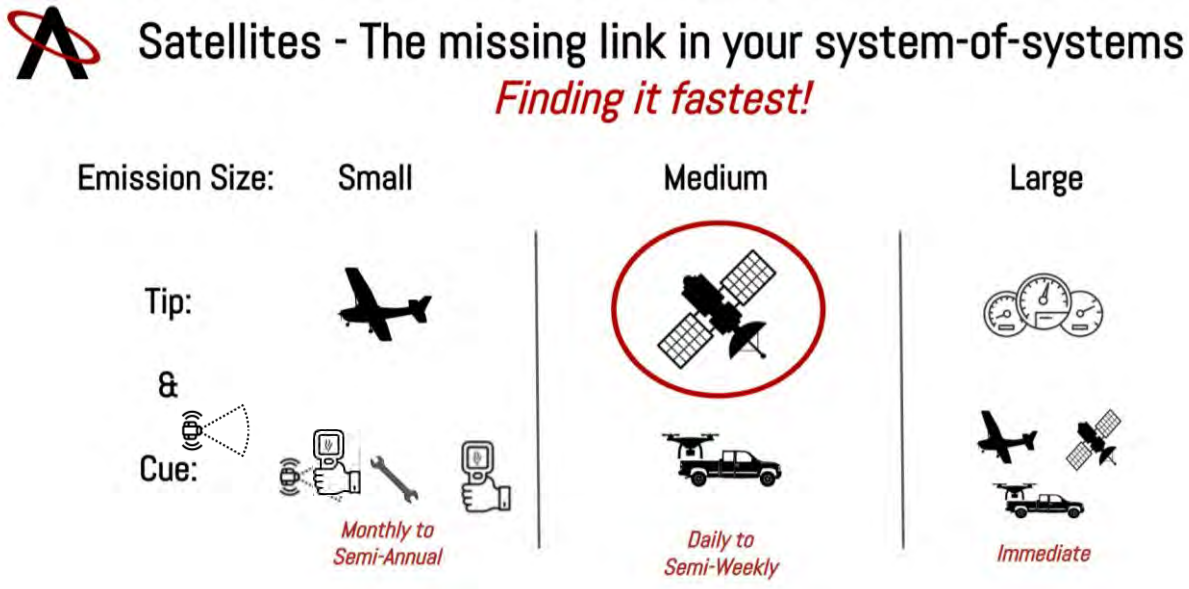
Executive summary: Satellites as an *"and"* rather than an *"or"*

Framing a system-of-system framework for natural gas leaks may benefit from the general characterization of emission events as small, medium, or large based on their overall size and economic impact. Satellites that provide full coverage and frequent monitoring are best used to cover "medium" leaks. The following definitions are used throughout this paper in explanation of this approach.



- "Small" leaks, as defined here, are uneconomic to repair; costs are not recovered within the quarter.
- "Medium" leaks are economical to repair and cover the cost of monitoring. They are not catastrophic to operations if left until the next survey, but they elevate risk exposure and are a costly waste of product that should be preserved.
- "Large" leaks are catastrophic in scope, exceed the Supervisory Control and Data Acquisition (SCADA) alarm threshold, and demand an all-hands-on-deck response, to include satellites. The loss from downed operations is significant and must be resolved quickly.

Medium leaks are best detected by frequent, full-coverage satellites, integrated into monitoring and detection procedures. Satellites are the missing link between infrequent aerial scans and centralized SCADA monitoring.

Introduction

"Keep the product in the pipe!" is Rule No. 1 for oil and gas producers. The volume and value of natural gas produced in the United States has doubled since 2010[1]. The economic importance of preserving each molecule has grown dramatically. The popular phrase for technology integration in pipeline monitoring and leak detection is "implement a systems-of-systems approach," but what does that even mean? We answer that question in this paper, through a discussion on categorizing leaks for effectively incorporating satellite monitoring into a pipeline monitoring system-of-systems, filling a critical gap in any natural gas production or transmission network.

Traditionally, SCADA systems continually monitor pipeline assets for critical dimensions, including pressure and flow to ensure continuity across an area. These tools detect and alert major safety and process disruptions. Trigger events are generally significant enough to shut-in the affected system so operations can locate and repair the damaged asset. These are high-dollar events, which commonly include significant safety and environmental exposures. Resolving them demands an all-hands-on-deck approach.

At the other end of the spectrum are the Small leaks, including fugitive emissions. In dense urban areas there is a safety risk which diminishes in rural areas where populations are sparse. From an operations perspective, these Small emissions on their own do not pose material threats to the operation itself. Importantly, the cost to repair will generally exceed the value of molecules saved over the duration. Small leaks are typically found sporadically by ground crews with sensors, and increasingly using aircraft-mounted sensors.

There is a gap between the Large emissions that shut down a system and the Small leaks that lack priority and can go unnoticed. Full-coverage satellites are a powerful tool to address the sizable gap between major releases and fugitives. Frequent, full-coverage satellites find emissions large enough to impact net revenue, quickly enough to preserve value, cheaply enough to offer measurable direct return on investment, and easily enough to fit within current operational practices and data management systems.

Processes should be put in place for integrating fast, frequent, and full-coverage satellite monitoring to find economically significant emissions (Medium and Large). Operators can optimize their current detection procedures by adding full-coverage satellites to existing SCADA, ground-based, and aerial platforms as part of a portfolio approach to leak detection. The result is a genuine system-of-systems that works within operational budgets while meeting the fundamental requirement to keep product in the pipe.

[1] https://www.bicmagazine.com/industry/powergen/in-2024-the-united-states-produced-more-energy-than-ever-before/

How large is *Large*? How small is *Small*? And where is the value?.....

For leak detection, the largest releases are simply too big to tolerate the delay of a semi-weekly or even a daily satellite pass. Fortunately, pipeline SCADA systems are able to detect these leaks. These are classified as the Large releases. While satellites are still able to provide valuable support in diagnosing what may have occurred, when, and importantly, where, they are not the first line of defense.

As defined here, Small releases fall short of providing an economic return if repaired. Small leaks are often below the detection threshold for routine satellite monitoring. The good news is that, while worthy of administrative management, Small leaks generally do not demand immediate response.

Medium leaks: Frequency and coverage are king

Until the arrival of satellite monitoring, common leak detection paradigms only differentiated between Large leaks and the Small ones. Traditionally, SCADA systems identify Large leaks almost immediately while smaller leaks are found through periodic, visual inspections of the right-of-way ("ROW"), including both aerial and ground-based patrols. Effective use of satellites up-ends the 2-tier leak categorization paradigm. These on-orbit platforms, circling hundreds of km above the earth, offer an ability to frequently, and cost effectively, monitor large and complex natural gas asset networks for emission sources well below today's SCADA alarm thresholds. Space-based remote sensing in this way introduces a third emission size category into the paradigm: the Medium-sized leaks: those smaller than SCADA, yet large enough that the value of lost product exceeds the cost of detection and repair. Space-based remote sensing can quickly, frequently and reliably detect leaks in the field exceeding 250 MCF/D (~200 kg/hr), and even smaller emissions given the right conditions.

Small leaks still require a higher fidelity monitoring scheme, using small aircraft or using ground-borne sensors, albeit with much higher costs and a lower sense of urgency. The ongoing importance for identification and repair of these smaller releases is discussed further in the next section.

If SCADA finds Large leaks almost immediately, and infrequent aerial surveys identify Small ones, the door is open for the logistical benefits of frequent, full-coverage satellites for the high value Medium leaks. These satellites can scan all of a producer's assets in a matter of days rather than weeks or months. On-orbit platforms deliver meaningful value by filling the gap between centralized measurements and infrequent surveys.

Show me the money

The economics are straightforward. On average, any leak found within a quarterly revisit will be 40-45 days old (or approximately half of the 90-day revisit period). By contrast, a leak found on a weekly revisit cycle is only emitting, on average, for 2-3 days before the operator will be alerted. Assuming $3/MBTU gas, a 250 MCF/day (~200 kg/hr) release detected by satellite will contain over $30,000 in lost product alone. This does not include mitigation of environmental and safety risk, process efficiency benefits, or mitigation of regulatory penalties.

Following a pipeline repair and system restart, operations personnel commonly experience a pressure surge that causes yet another breach in a different location. In these cases, it could be nearly 3 months until another aerial patrol could find such cascading emissions. Satellites can confirm system integrity within a week of repair. Until SCADA can effectively pinpoint such releases along every mile of pipe, there is no other solution that offers an economic return that can compete with satellite monitoring services.

In recent years, the Environmental Protection Agency had proposed significant penalties for uncontrolled gas emissions, under a "Waste Emissions Charge" (WEC) program. In 2025, this scheme is off the table. The value in efficient satellite monitoring nevertheless remains!

Large leaks: find them fast and fix them fast, using everything you've got

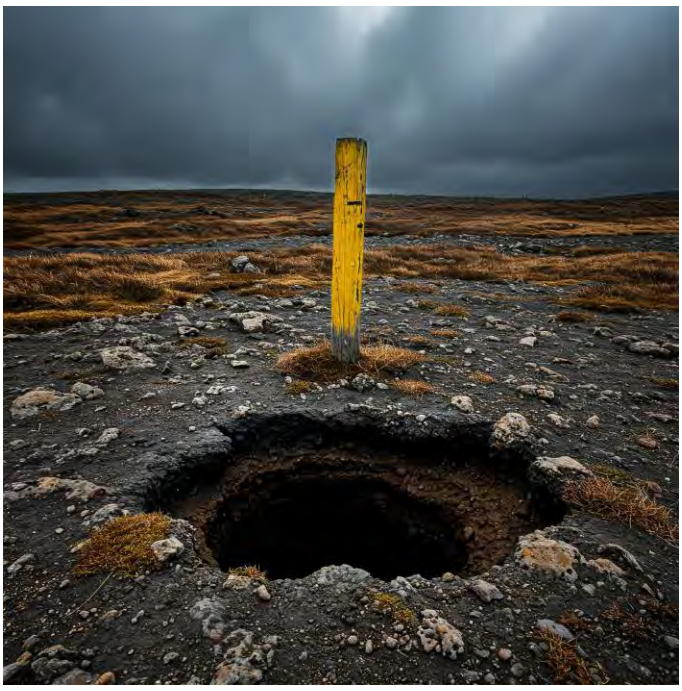


Figure 1: Imagery from an unspecified Large leak site.

Since the earliest days of sensor technology, pipeline operators have looked to SCADA systems for real-time measurement and monitoring of system health, notably relying on their rapid alerts when any dimension exceeds healthy parameters. Among the most basic SCADA alerts are unplanned pressure drop or flow imbalance. The limiting factor to these tools is the detection threshold: a release large enough to cause a measurable pressure drop or detectable difference in flow rate between the entrance and exit of a pipeline system will be Large enough to have created an environmental or safety problem. This type of event is generally Large enough to require the affected system to be shut in long enough to implement the necessary repair. These are high dollar events demanding an all-hands-on-deck approach.

A growing catalogue of experience reveals a truth, perhaps counter-intuitive: methane detection alone is ineffective in locating Large leaks. The reason that methane detection alone is insufficient is that, while one might expect to find the leak by finding the gas, often within minutes of a blowout event, there is no longer a gas plume to detect: the Operations Center has already shut down the entire subsystem. With no product flowing through the pipe, there will be no emission from the hole, and no plume for a detector to find. Therefore, if a sensor is tuned for *methane only*, it cannot locate a dry hole. Satellite monitoring can find Large blowouts, with or without the gas flowing.

What is the value in hours and days to halt a gas production operation? Reducing the outage by even a day can easily pay for a year of satellite monitoring. Finding Large leaks faster is yet another sizable benefit offered by a robust, operations-focused satellite monitoring program.

Small leaks: indicators of system-wide issues *and* potentially larger leaks

At the other end of the spectrum are fugitive emissions and Small leaks, namely the ones where the repair costs exceed the market value of the lost product over the quarter. Often, systems have multiple Small leaks in proximity and can be an indicator of a larger operational or maintenance situation that requires attention. Operators might consider the location and placement of these leaks when asking broader questions: How many Small leaks per mile in one balance area? How does one balance area compare to another? What might be occurring in one area that is different from any other? These questions (among others) can inform various groups within the company on investment and repair priorities. Pipeline Integrity personnel would like to compare performance of company systems. Maintenance would like to forecast effort (and therefore, budget). Management prioritizes the elimination of economic surprises (from anyone and everyone). The list goes on. These are critical issues for maintaining continuous operations.

Small leaks are harder to find and can take the same time to fix as a Large leak. These are typically isolated by ground crews carrying sensors, and more recently they can be detected by aircraft-mounted sensors. Because they are Small, detection costs can be high relative to lost product value, so the time between campaigns to locate these leaks is typically measured in months rather than days.

While these leaks are measurable, they generally do not threaten operations. Yet, Small leaks can, and do, become precursors to the Large ones; notably when they start as pinhole corrosion events and are left untended. There is clear merit in detecting Small leaks, cataloguing them, and addressing them methodically. By the time a Small leak has grown Large enough for a satellite to see, it needs to have already been addressed.

It can be nearly impossible to maintain a zero-leak environment across expansive, complex gas production and distribution systems; it is entirely reasonable to aim for a “no-surprises” environment.

Satellites are an "*and*" rather than an "*or*"

An important point to reiterate is not that satellites replace other sources of monitoring; to the contrary. Operators should be using them all. This is the system-of-systems approach. In-line SCADA, on-premises fence line and fixed sensors, on-demand drone, periodic aerial, and frequent satellite observations all provide insight into the complex asset mix and highly dynamic operating environment, each with their own frequencies, detection thresholds, strengths, and weaknesses. Operators should use them all in the right mix that is most economically viable. More sensors that offer different insights provide the operator a more complete picture of assets and that gives them more flexibility, visibility, and opportunity to address leaks, and threats, more proactively.

Why today? What's changed? Well, everyone was watching the wrong satellites

Between governments and venture capitalists, hundreds of millions of dollars have been spent to launch satellites capable of detecting greenhouse gasses. Many of these with a goal of raising money and publicity. Academics and technologists spent years crowing about capabilities, often more theoretical than actual, to detect and report leak rates to meaningless decimal places. The satellites that focused on smaller and smaller detections sacrificed coverage area to do it. This narrow view made the satellites useless to operators, but sensational for well-financed satellite providers. These resulted in bright images without any operational application. The lack of coverage meant that the particular type of satellite was only suited for the 'name and shame game' rather than as an asset to empower energy operators.

Now for the first time, satellite systems with wider coverage, more frequent revisits and faster reporting are finally focused on the issues that matter to the operator, empowering improved safety, improved integrity and improved economic environmental performance.

(Note: An economic study is available upon request, at *solutions@orbitaladvisors.space*.)