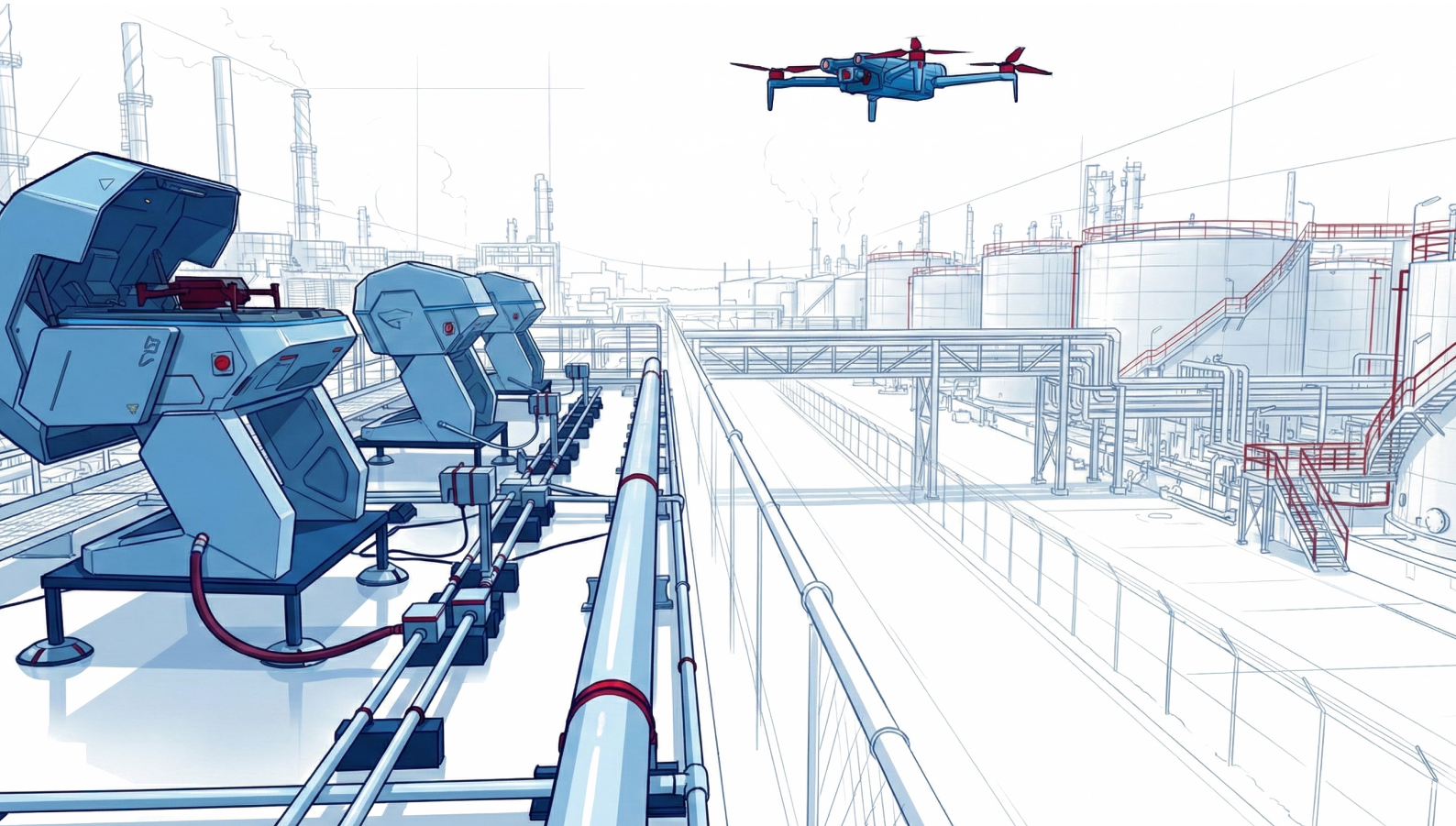
Chevron

The Robotics Journey

drone in a box

February 2026

human energy ®



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Robotics for working at heights and in confined spaces is moving from pilots to everyday practice. The driver is clear: keep people out of harm's way while improving the quality, speed, and traceability of inspection and maintenance. Documented deployments show meaningful reductions in exposure and turnaround impact, with data that is denser and more repeatable than manual spot checks. At the same time, standards and procedures are evolving so that robotic outputs can support risk based inspection and fitness for service decisions. The opportunity is real, but adoption is not automatic. Success requires disciplined change management, site readiness, and a focus on the human side of the transition.

This article offers a practical path forward. We outline where robots and drones add the most value today, from visual inspection and nondestructive testing to targeted cleaning and coating. We highlight lessons learned from Chevron's Robotics program and our partners, reflecting field results across a range of assets and environments. Our intent is to help owners, service providers, developers, and standards bodies move from isolated trials to scaled, repeatable deployment. The goal is consistent: reduce exposure, raise reliability, and make better decisions with better data. With collaboration and disciplined execution, robotics becomes another tool for operational excellence, supporting safe, reliable, and ever cleaner energy.

Part 2
drone in a box

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THE READINESS PROBLEM: WHY DRONES-IN-A-BOX MATTER FOR ENERGY OPS

Human availability is now the primary constraint on how quickly and how often drones can be used in energy operations. When aerial inspections depend on pilots, travel, and on-call crews, response is delayed, inspection frequency is limited, and coverage cannot scale across large asset networks. Moving from human-flown drones to autonomous drone-in-a-box (DiB) systems removes that constraint.

DiB changes the operating model. Instead of being tools that are mobilized when people are available, drones become infrastructure that is already in place. Positioned at critical assets and integrated into digital workflows, these systems are ready to launch in seconds. Inspection, monitoring, and response are driven by risk and operational need, not scheduling, travel time, or workforce availability.

This shift enables consistent use at scale. Autonomous, regulatory-compliant, and digitally connected DiB systems move operations beyond manual, episodic flights to continuous readiness. Inspections can be repeated reliably, field events can be assessed immediately, and monitoring can extend across entire asset networks without increasing headcount, travel, or personnel exposure.

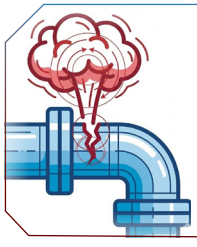
At the same time, operators need predictabl regulatory pathways, especially for beyond visual line of sight (BVLOS) and remote operations centers. A digital backbone for fleet, airspace, and data management must link each launch to automated approvals, system health checks, and analytics pipelines that push findings straight into asset, integrity, and safety workflows. Finally, continuous technology hardening, targeted training, and early engagement with regulators and communities are what turn DiB from successful trials into standard infrastructure embedded in how energy assets are monitored and run.

In the sections that follow, we break down what it takes to move from pilot projects to a DiB network that supports routine inspection, rapid incident response, and emissions monitoring across multiple sites. We look at individual, concrete use cases and how they perform in practice, then show how stacking these missions on the same DiB infrastructure creates a proven path to ROI. Along the way, we connect the technical, regulatory, and digital building blocks back to safety, operational reliability, and lower-carbon performance for energy operators.

If rapid response is manual, reliability stops where people can't be

INDUSTRY CHALLENGES

Increasing inspection backlog and aging assets



Global Asset Condition: global oil and gas assets (offshore platforms, refineries) are **older than 40–50 years**. Backlog has been growing for maintenance and inspection activities, accelerated by COVID cuts and postponements.
US oil and gas: PHMSA states that half of U.S. pipelines are at least 50 years old, average age of US refineries is 74 years (from original comissioning), offshore platform are 40+ years old. Backlogs exceeding 34,000 man-hours, about 90% of upstream investment is required to offset declines in existing fields.

Operational resistance to digital change



Global Context: inspection & maintenance data is still analog, paper/PDF/spreadsheet-based inspection reports and manual data entry. **<1% of field data is in usable form** for decision-makers or analytics systems. RBI and predictive maintenance are conceptually mature but practically constrained by poor data quality.
Effiency requirement: collect, tag and store data in digital format with enough metadata for full **uitilization of AI tools** in the future.

Aging workforce and shrinking talent pool

Persona: **56 years old**, works 46 hours per week, has 26 years of experience in the oil & gas sector, 14 years with current employer, earns up to $81,808 per year, **retires in** less than **10 years**
Key Activities: >50% waiting for work orders, searching data, routine rounds and responding to alarms (with >90% false alarms)



Regulation to slash oilfield methane

Global Methane Pledge: oil and gas operations responsible for around 80 million tonnes of methane every year. >150 countries committed to cut anthropogenic methane at least 30% below 2020 levels by 2030. OGMP 2.0 (UNEP / CCAC) defines five reporting levels, requiring operations to **measure much more frequently**.
US regulation: US methane framework aims to cut methane by roughly 80% between 2024–2038 (~1.5 billion tonnes CO_2-eq). O&G emits over 10 million tonnes of methane a year (about a quarter of US anthropogenic methane)



REGULATION: WHAT IT TAKES TO DEPLOY DRONES BVLOS

Serious, but increasingly solvable

To deploy drones and transition to autonomous flights, operators need a clear view of the rules. Drone deployments fall under aviation frameworks built on one distinction. Visual line of sight (VLOS) means the pilot can see the drone with unaided eyes at all times. Beyond visual line of sight (BVLOS) covers everything beyond that. Even above fenced facilities, the airspace remains national airspace.



In the United States, the FAA regulates all civil aviation including small unmanned aircraft. Part 107 is the baseline for commercial UAS operations and assumes VLOS by default; BVLOS currently requires individual waivers. As of late 2025, the FAA published a Notice of Proposed Rulemaking for a new Part 108 rule, "Normalizing Unmanned Aircraft Systems Beyond Visual Line of Sight Operations," which would enable low altitude BVLOS at scale without individual waivers. Chevron and other oil & gas majors contributed to the new rule to ensure the industry can apply and deploy safely and effienciently.

In Europe and regions following the EASA model, most industrial BVLOS and DiB use cases sit in the "Specific" category. Operators must obtain operational authorization based on a structured risk assessment (such as SORA), an Operations Manual and proof of insurance. Unlike the FAA's waiver approach, EASA's framework is already mature with existing precedents for fully autonomous DIB systems.

Across jurisdictions, regulators ask for the same four building blocks:

1. A structured **operational risk assessment** that classifies the site and airspace, then defines safeguards such as geofencing, altitude limits and fail safe behaviors.

2. **Production site specific procedures** covering launch and landing areas, no fly zones around flares and helipads, weather minima, communications and emergency landing plans.

3. Clearly **defined roles and accountability**, including a remote pilot in command, named observers or site contacts, and a responsible person who owns overall compliance.

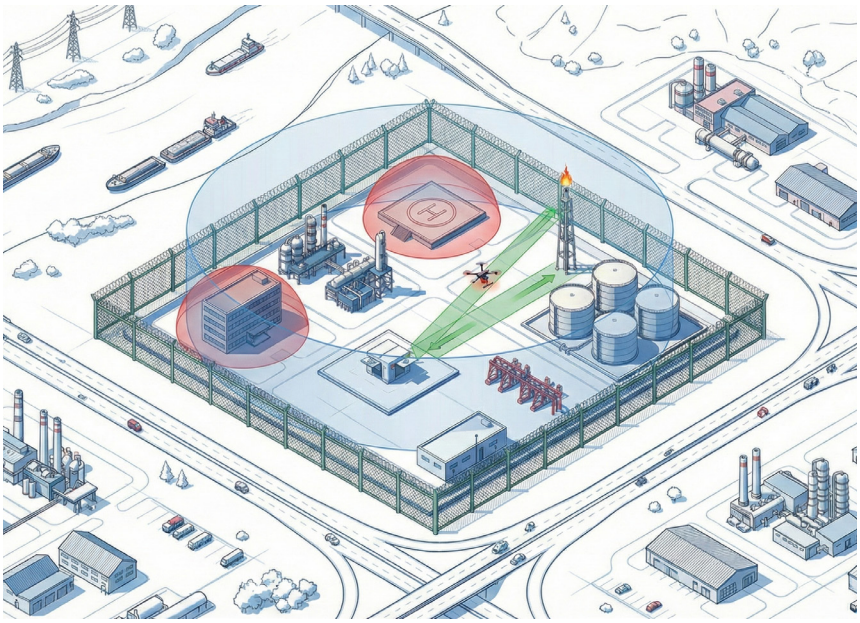
4. **Technology enablers** such as Remote ID, maintenance logs and, for higher risk profiles, detect and avoid capabilities and robust cybersecurity.

DIB systems do not create new regulatory barriers, but they raise the bar on supervision. Regulators want evidence that automated sorties can be paused or terminated during site emergencies, that flight schedules deconflict with helicopter traffic and flare operations, and that the system connects to UTM (uncrewed traffic management) services where airspace is shared. These are engineering and procedural problems, not regulatory dead ends.

For most production sites, **regulation is serious but solvable**. The frameworks are known, precedents exist, and BVLOS rules are moving from exception to routine. EASA is already producing operational authorizations while the FAA transitions to a scalable structure. Both are converging.

Regardless of jurisdiction, the operating organization carries the ultimate risk. Under the proposed Part 108, the FAA shifts accountability from the individual remote pilot to the company. EASA has always placed this burden on the operator.

The harder part is internal: aligning HSE, operations, aviation and IT/OT cybersecurity around a single, documented system that satisfies both the regulator and your own risk committee.

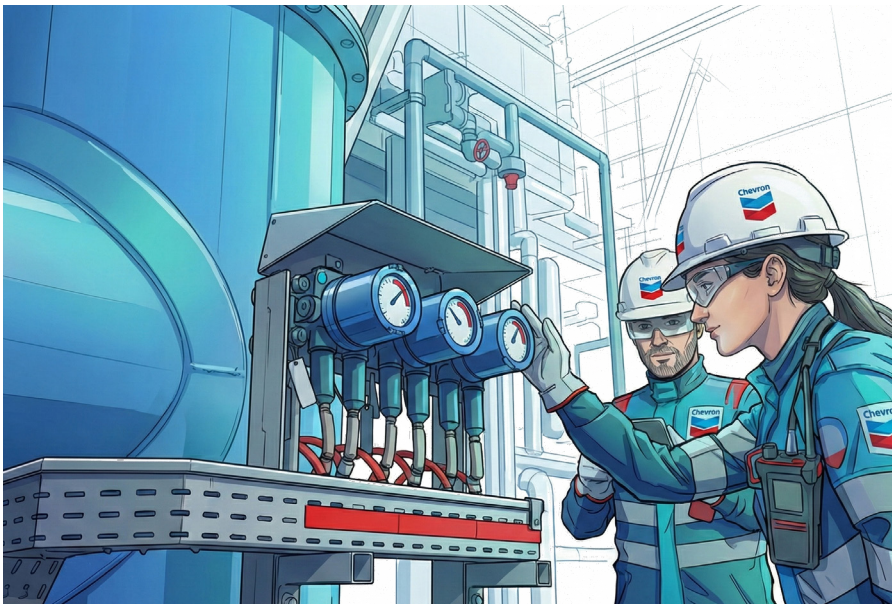


CURRENT-STATE BASELINE

The traditional way of doing it

Most day-to-day monitoring on oil and gas sites depends on people in the field. Operators walk or drive fixed routes to listen for abnormal sounds, feel for vibration, read gauges and check handheld gas detectors. For equipment at height or hard to reach, teams mobilize scaffolding, man-lifts, rope access or ladders. These access methods are major cost drivers and rival the inspection scope itself.

Methane monitoring follows a similar pattern. Leak Detection and Repair (LDAR) programs rely on handheld analyzers and optical gas imaging (OGI) cameras to meet regulatory requirements. In practice, technicians walk lines and climb structures with OGI equipment, sometimes supported by piloted drone services. Security and emergency response are also built on traditional models. Sites depend on guards, fences, fixed cameras and patrols on foot or by vehicle, with thermal or fence-line systems in higher-risk areas. When storms, suspected leaks, flare anomalies, fires, or third-party intrusions occur, many operators charter helicopters or ad hoc drone flights to get eyes on the asset. Even where piloted drones are used, workflows that involve mobilizing a pilot, flying, downloading imagery and writing reports can stretch over several days before data becomes actionable.



Most operators have already optimized within the existing paradigm: better patrol routes, digital work orders, rugged tablets, more cameras, and risk-based inspection to prioritize high-risk assets. But the structure remains the same: people are still the primary data collectors in hazardous environments, and most programs still rely on periodic, snapshot-style surveys for leaks, corrosion, and security issues. Industry guidance acknowledges that aging assets, growing inspection backlogs, and constrained budgets are making it harder to sustain compliance and uptime with purely time-based, manual regimes, while only a fraction of available data is used to drive decisions.

FINANCIAL DEPLOYMENT MODELS

CAPEX vs OPEX

For production sites, deploying DiB systems can shift capital expenditure and internal headcount to a more predictable operating expense model with faster access to specialized expertise. At the same time, it increases dependence on the vendor's product roadmap, service quality, and long-term stability. By clearly contrasting today's "traditional" approach, manual rounds, scaffold-intensive inspections, snapshot leak detection and repair (LDAR), guard patrols and underused asset data, decision-makers can see drone-in-a-box as a way to change how inspection and monitoring are carried out across the site.

On production sites, three deployment patterns are common:

1. **Site-owned, site-operated.** asset owner buys the docks and drones (CAPEX), certifies its own pilots/remote operators, and runs everything in-house.
2. **Site-owned, vendor-operated.** site carries the hardware on its books (CAPEX), the vendor (or an integrator) operates the system and supplies it as a managed service (OPEX).
3. **Vendor-owned, service model** ("Drone-as-a-Service" / RaaS). The vendor retains ownership of the hardware and charges a recurring fee per site, flight hour, or data product (OPEX).

A mature Drone-as-a-Service or Robotics-as-a-Service (RaaS) offer bundles:

- Dock(s), drones, and payloads (RGB, thermal, optical gas imaging (OGI), and in some cases LiDAR)
- Flight management software, mission planning, and integration with site operational technology (OT) and information technology (IT)
- Daily operations support, including remote pilots, flight monitoring, and data quality checks
- Data processing and analytics, such as corrosion or defect detection, methane plume analysis, and anomaly alerts
- Maintenance, spares, and hardware and software upgrades.
- Regulatory support, including operating approvals, beyond-visual-line-of-sight (BVLOS) waivers, and safety case documentation.

DIB SOLUTION OVERVIEW

An industry-grade DiB program is an operational technology (OT) and information technology (IT) capability that runs automated flights under defined safety rules, such as no-fly boundaries, weather limits, and automatic return or landing if communication is lost.
The collected data must be linked to time, location, and equipment identifiers and then routed into maintenance work management systems, security monitoring systems, and digital twin workflows. Findings must become traceable actions and long-term trends, not isolated videos. It is important to confirm strong cybersecurity: network separation from control systems, multi-factor login, role-based permissions, encryption for stored and transmitted data, and complete audit logs. Plan the required site changes, including reliable power, resilient connectivity, safe dock placement, and protection against lightning and electrical interference.
Finally, establish training and governance so personnel can handle exceptions, maintain the system, and operate it under plant safety and permit-to-work requirements. Success requires aligning technology, processes, and responsibilities end-to-end, with clear ownership and measurable performance targets across the full workflow from mission planning to work order closure. This is inherently cross-functional, involving operations, maintenance, inspection, security, information technology, and cybersecurity, and it typically requires structured upskilling so staff can supervise autonomy, validate evidence quality, and run the associated digital workflows.



HARDWARE

AIRCRAFT

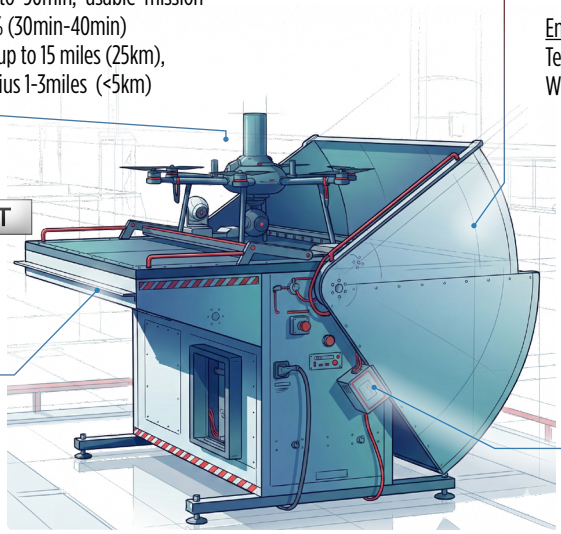
battery powered drone, ready to take off in less then 30 seconds

Technical capabilities (typical):
Fligh time up to 50min, usable mission time 60% - 80% (30min-40min)
Flight distance up to 15 miles (25km),
operational radius 1-3miles (<5km)

DOCKING STATION "THE BOX"

Weatherproof enclosure / landing target /alignment aids

Environmental envelope (typical):
Temp. operating range-13°F (-25°C) to 113°F (+45°C) .
Wind up to 12 m/s (operation); 8 m/s for takeoff/landing.



BATTERY MANAGEMENT

recharging batteries in 30 to 60 minutes specialized vendors integrate a battery swapping mechanism to increase air-time.

COMPUTE & COMMUNICATION

Box and drone are linked at all times through private LTE / 5G connection and redundant backhaul. Communication to control room via site secure connection (LAN).

Edge computer take over Pre-flight checks, geofencing, automated launch/recovery, data upload, collision avoidance and other AI routines

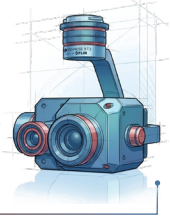
PAYLOADS

DiB payloads determine what the system can measure and automate. In practice, it is more reliable to deploy dedicated DiB units, each configured around one primary payload and one mission type, rather than swapping payloads. Swapping introduces manual intervention, downtime, higher risk of configuration errors, and inconsistent data baselines. Equally important is backend consistency: all payloads and attachments should write into the same data platform with common metadata, asset identifiers, timestamps, and audit trails.

ZOOM & THERMAL CAMERAS

Routine visual rounds and inspections

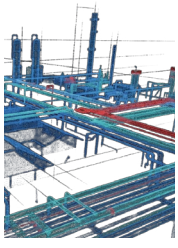
- gauges/valves
- corrosion spotting
- flare monitoring
- assett anomalies
- insulation hot spots
- electrical issues



3D SCAN

Photogrammetry / LiDAR generate 3D pointclouds and digital twin models

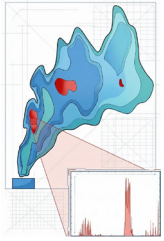
- volumetrics
- as-built verification
- documentation for turnarounds and MOC packages



GAS MONITORING

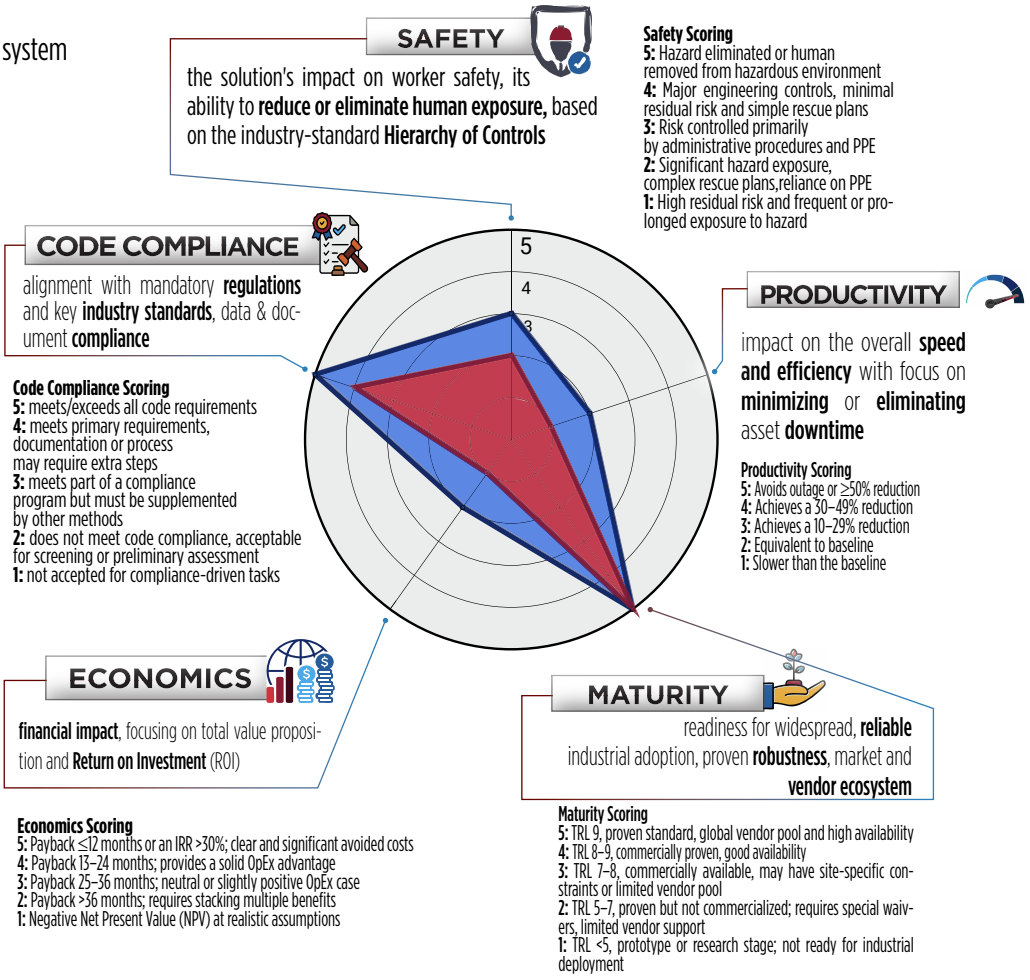
Optical gas monitoring (OGI) and methane quantification

- LDAR screening
- leak confirmation
- compliance evidence
- Quant + grading
- follow-up screening



SOLUTION FIT
a holistic rating system

In order to understand the full potential of DiB solutions we need to assess it from various angles. Therefore we are introducing a five axis evaluation matrix. We rate **Safety**, **Productivity**, **Maturity, Economics,** and **Code Compliance**. Depending on work type, planned/unplanned events, budget restrictions, and data insights this will contribute to assessing the right method to use.
We have defined a guideline on how to score each metric from 1 to 5 and for every solution we discuss we provide our own, qualitative and objective rating in a spider graph.
This rating system is based on experience and market feedback from asset owners and service companies, as well as technology providers.



EXAMPLE: FLARE MONITORING
visible-emissions observations

Traditional flare monitoring relies on fixed flare instrumentation (e.g., pilot flame presence monitoring) **plus human visual checks**. Operators or trained observers periodically watch the flare for visible emissions and document results (commonly via EPA Method 22–type observations in regulated settings).
This approach is generally compliant but labor- and attention-intensive, and it often becomes reactive during upsets, requiring additional observation time and documentation (or the use of fixed, time-stamped video surveillance as an alternative in some regulatory frameworks).

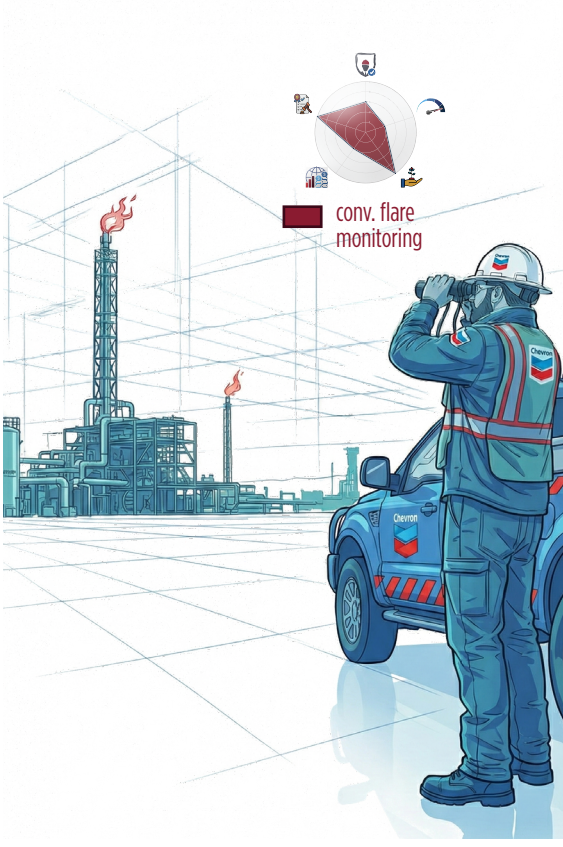
Safety - 3 requires people to be physically present and attentive in/near operating and high-traffic areas (even if observation is from a "safe spot")

Productivity - 2 daily Method 22 observations are 5 minutes, if smoking is detected the monitoring burden escalates to 2-hour observation. Plus several hours of driving to observation points.

Maturity - 5 Manual observations + fixed instrumentation are fully mature. Standards and procedures in place.

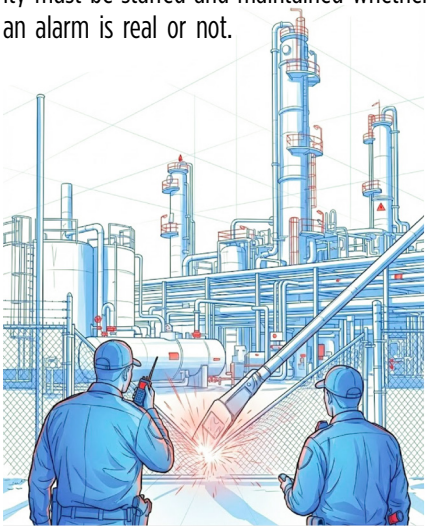
Economics - 2 characterized by labor and mobility cost for observation itself but also for documenting and record keeping.

Code Compliance - 5 aligns directly with regulatory constructs (Method 22 observations; pilot flame monitoring; defined limits) providing a compliant work process.



SAFETY & EMERGENCY RESPONSE

Large Oil & Gas facilities commonly maintain 24/7 security coverage and patrol capacity. The conventional model for intrusion/alarm verification, fire/spill confirmation, and post-storm damage assessment is built on two layers: standing readiness (people, vehicles, equipment, procedures) plus dispatch/verification effort to get "eyes on" and report back. The standing-readiness layer is often invisible in incident-by-incident accounting, but it dominates at large sites because the capacity must be staffed and maintained whether an alarm is real or not.

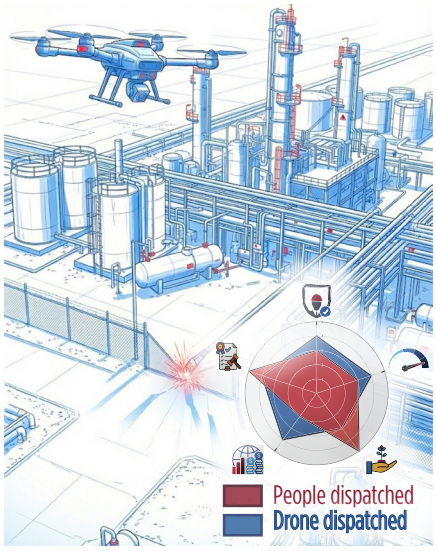


The second layer is driven by volume and by the reality that many alarms are nuisance activations. Independent public-safety analyses commonly find 94% to 98% of burglar/security and fire alarm activations are false, which helps explain why "verify first" is such a powerful lever.

Public-sector costing reinforces that even short verification responses are not trivial when fully burdened (e.g., one jurisdiction reports $137 for a 16-minute two-officer alarm response).

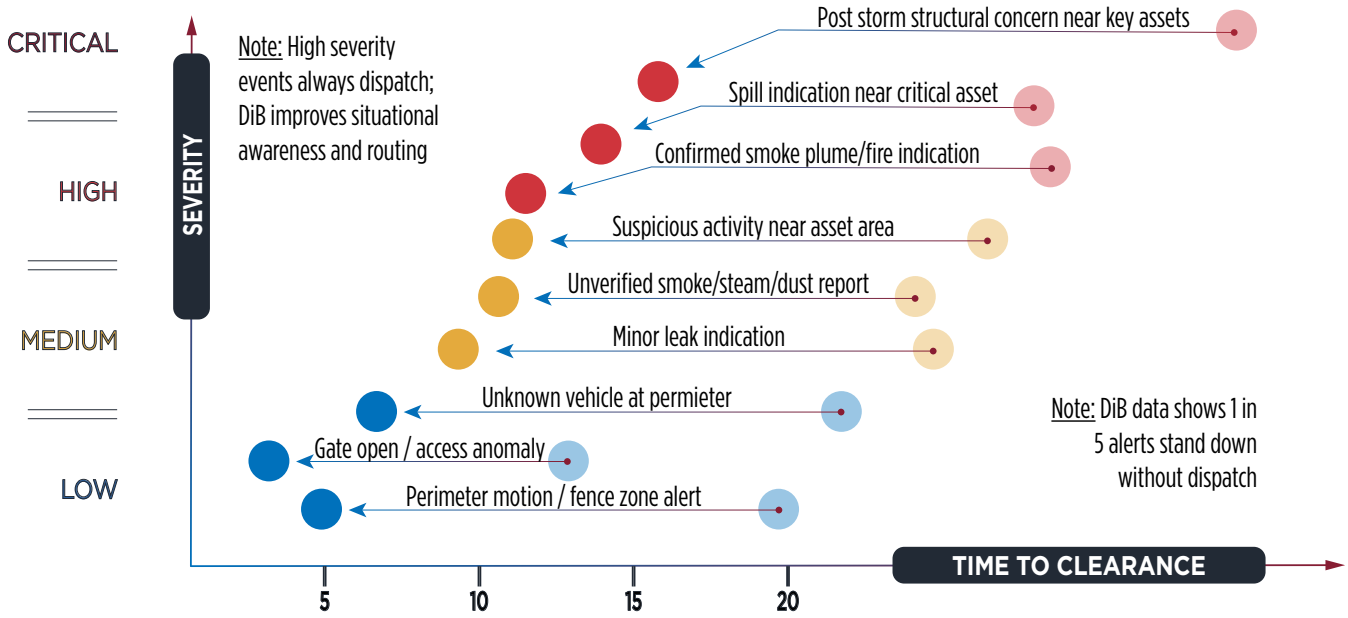
A DiB capability directly targets the first minutes of uncertainty by providing event-driven aerial verification. When an alert triggers, a docked drone can launch along pre-approved geofenced routes to stream live optical/thermal video to the incident command, supporting faster true vs false classification. Stand-off fire/spill confirmation, and rapid post-storm perimeter and road-passability checks are done before personnel are sent into uncertain conditions. Independent "drone as first responder" programs document an average drone response time of ~172 seconds, arriving several minutes earlier than ground units, and clearing ~20% of calls without dispatching ground resources.

This is positioning DiB as a decision accelerator, not a replacement for people on scene. Faster confirmation also reduces risk during evolving situations. Federal Highway Administration (FHWA) data shows that every additional minute an incident remains active increases secondary-event probability by 2.8%; compressing response time by 15 minutes lowers that risk by 42%. In industrial operations, where hazards compound with delay, early aerial verification closes the gap that matters most.



TRADITIONAL RESPONSE VS DIB RESPONSE

when minutes matter



WORK AT HEIGHTS AND HIGH-RISK INSPECTION

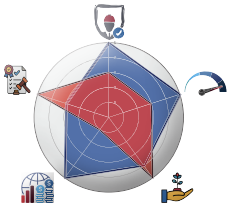
high value use case for structural integrity assessment at heights

Work at heights inspection is a high-leverage Drone-in-a-Box application because **access** is what **drives exposure, schedule risk, and cost**. Oil & Gas sites routinely need to assess flare stacks, tank roofs, piperacks, or elevated structures where conventional methods depend on rope access, scaffolds, cranes, permits, and standby rescue. DIB changes the unit economics by making access repeatable (scheduled flight routes for trending across large operating sites) and rapid (on-demand flights), so teams can gather condition evidence before mobilizing specialized crews.
Safety is the primary ROI driver: reducing time at height directly reduces exposure to one of the industry's most persistent severe hazards. In 2023 alone, the U.S. construction and maintenance sectors recorded 421 fatal falls, underscoring the moral and financial imperative of "hazard elimination." Cost savings follow naturally from avoiding scaffolding, crane runs, and minimizing operational disruption.

DIB replaces the repeatable, elevated, visual portion of inspection demand (routine condition checks, post-storm/post-upset verification, flare tip visual health, tank roof/seal condition, piperack leak/thermal anomalies), while not replacing the legally/engineering-required hands-on elements (UT thickness, internal tank entry, mechanical repairs). The ROI improves sharply when you convert "mobilize a crew + permit + access" into scheduled or on-demand flights that (a) reduce exposure hours at height and (b) narrow the scope and duration of the remaining hands-on work.

The operational impact is best understood by analyzing three critical asset classes where DiB replaces "blind" access with data-driven targeting: Flare stacks, Storage tanks (esp. floating roofs) and Piperacks.

STORAGE TANKS (AST)

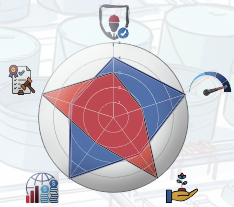


U.S. installed fleet: **130k**
Floating roof ASTs: **11k**
Cost per Event: $0.8k (month)
$95k (5y)
Potential Savings with DiB: **50% - 80%** (visual)

Rope access / Scaffold
DiB

Frequency at Scale
API 653 governs the "Inspection, Repair, Alteration, and Reconstruction" of tanks. For floating roof tanks it mandates **monthly** visual **inspection** for leaks, shell distortions, signs of settlement, and the condition of the foundation. In addition **every 5 years** seal gaps, roof drainage and fabric integrity need to be checked.

PIPERACKS

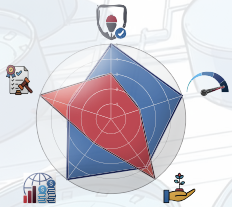


U.S. installed fleet:
800km - 1,300km (500-800miles)
Scope per year/site:
700m - 1.7km (2.3k ft - 5.6k ft)
Cost per year/site: $50k - $127k
Potential Savings with DiB: **30% - 50%** (visual)

scaffold / cherry picker
DiB

Reduction Scaffolding and elevated platforms
Refineries operate many kilometers of piperacks, each carrying 30-50 meters of piping per rack meter. API 570 mandates external inspections every 5-10 years (Class 1 piping). DiB systems have the potential to **cut costs to $15/meter** ($175/meter is the estimated baseline). In addition they enable high frequency monitoring and deliver superior data for RBI optimization.

FLARE STACKS



U.S. installed fleet: **4,229**
Events per year/site: **2-4**
Cost per Event: $50k - $75k
Potential Savings with DiB: **70% - 90%** (visual)

rope access
DiB

Shutdown Avoidance
Conventional flare tip inspections often require dangerous climbs or production shutdowns. DiB enables **"in-service" inspection** using high-zoom thermal optics to monitor pilot lights, refractory cracks, and tip deformation while the asset remains live. This eliminates mobilization cost of a manual climb and, more importantly, **prevents the revenue loss associated with unplanned outages.**

PIPELINES

The worldwide trunk and transmission pipeline network encompasses approximately 2.28 million kilometers (1.42m miles) of infrastructure. This massive network represents one of the most critical energy transportation systems globally, requiring systematic inspection and maintenance programs to prevent failures that could result in environmental catastrophes, economic losses, and loss of life.

North America dominates global pipeline infrastructure with 973,040 kilometers (605k miles), representing 43% of the worldwide network.

The Pipeline and Hazardous Materials Safety Administration (PHMSA) mandates that operators inspect surface conditions on or adjacent to each pipeline right-of-way at intervals not exceeding three weeks, requiring at least 26 inspections annually. For the U.S. network alone, this translates to over 21 million kilometers of annual inspection requirements, creating enormous logistical and financial burdens under traditional methods.

Key regulatory requirements include:

- **High Consequence Area (HCA) pipeline segments**: near dense populations, navigable waterways, or sensitive habitats. Must receive integrity assessments at least every five years; about 44% of hazardous liquid pipelines are in HCAs.
- **Right-of-way (ROW) surface monitoring:** required at least 26 times per year (no more than three weeks apart) to spot leaks, encroachments, excavation, erosion, damaged markers, and other abnormal conditions.
- **Offshore pipelines:** face tighter rules, weekly leak surveillance plus annual ROV or in-line inspections.

Pipeline integrity management (per ASME B31.8S) targets three threat groups:

1. **Time-dependent threats:** external corrosion, internal corrosion (including MIC), and stress corrosion cracking (often near welds); corrosion is the main focus of most inspection programs.
2. **Time-independent threats:** manufacturing defects, construction/fabrication flaws, and equipment malfunctions such as valve or seal failures.
3. **Stable threats:** third-party damage from excavation or impacts (about 25% of incidents), natural forces (landslides, seismic events, flooding, erosion), and operational stresses beyond design limits.

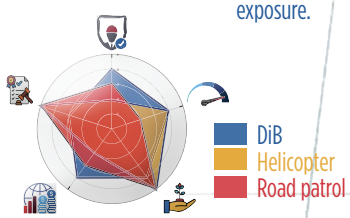
Because each threat demands different tools and intervals, operators manage a complex matrix of inspection methods and frequencies.

Current inspection relies mainly on in-line inspection (ILI) "smart pigs" that use electromagnetic and ultrasonic testing to locate corrosion-related metal loss; geometry pigs identify dents and deformation. Hydrostatic testing pressure proves strength but is disruptive, costly, and doesn't pinpoint defect type/location, so it's used sparingly.

External visual inspection underpins routine pipeline monitoring and ROW compliance. Traditionally, manned helicopter or fixed-wing patrols scan for leak indicators, unauthorized excavation, encroachments, erosion/land movement, and equipment damage or vandalism. Limitations include high cost, low-altitude safety risk, minimal documentation, weather restrictions, and inability to detect gas leaks, thermal anomalies, or subsurface issues.

Practical takeaway

Road + helicopter remains strong for compliance over long corridors; DIB is strongest where you need frequent, documented, repeatable surveillance (HCAs, crossings, encroachment hotspots, geohazard areas) and want to reduce routine exposure.



TECH INSIGHT

MULTI-ROTOR VS VTOL

Multi-rotor drones hover and maneuver precisely, making them ideal for close inspection, confined spaces, and detailed imaging. The tradeoffs for that control are shorter range and endurance. VTOL fixed-wing drones combine vertical takeoff/landing with efficient forward flight, enabling longer corridor coverage and faster surveys, but with less hover time and typically larger operating footprints. Both technologies are available as DiB kits, but from different vendors. This adds complexity for seamless coverage of production sites and pipelines.



multi rotor drone
Flight time: 20-45 minutes
Speed: up to 50km/h (34 mph)
Coverage per flight: up to 7km^2 (2.7 sqmiles)

VTOL fixed wing drone
Flight time: 60-180 minutes
Speed: 108km/h (67 mph)
Coverage per flight: up to 50km^2 (19 sqmiles)



ESG, EMISSIONS & ENVIRONMENT

Audit-Ready Methane Management Across the Value Chain

Methane (CH_4) is the primary component of natural gas and a material topic in Environment, Social & Governance (ESG) for upstream and midstream operators. It is shorter-lived than CO_2, but much more potent on a 100-year basis. This makes methane reduction one of the fastest levers to reduce near-term warming, and it is increasingly tied to investor expectations, community trust, and regulatory compliance (license-to-operate).

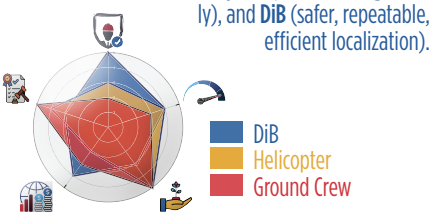
Policy is tightening in major markets: the U.S. Environmental Protection Agency (EPA) final rule expands methane controls, including defined survey cadences, repair timelines, and a "super-emitter" framework that can leverage advanced detection. In Europe, the Methane Regulation requires regular measurement, rapid leak elimination, and restrictions on venting and flaring.

DiB systems add value by turning methane monitoring from occasional campaigns into high-frequency, repeatable, and event-triggered operations. Instead of relying mainly on periodic leak detection and repair (LDAR) surveys, a permanently installed DiB can execute scheduled site sweeps (daily/weekly) and rapid dispatch after alarms or process anomalies, improving the probability of detecting intermittent high-impact emission events.

Field validation work sponsored by the U.S. Pipeline and Hazardous Materials Safety Administration (PHMSA) and Gas Technology Institute (GTI) indicates drone methane sensing can detect leaks across 0–45 standard cubic feet per hour under realistic conditions, and that performance improves materially when missions use multiple passes and box-pattern surveys.

However, meteorology (e.g., inversions and fog), site obstacles, sensor payload weight, and the complexity of quantification mean DiB is most defensible as a detection and localization layer, complemented by fixed sensors and periodic quantification protocols.

Comparison of methane LDAR methods: **ground crews** (mature, compliant but higher exposure), **helicopters** (fast screening, costly), and **DiB** (safer, repeatable, efficient localization).



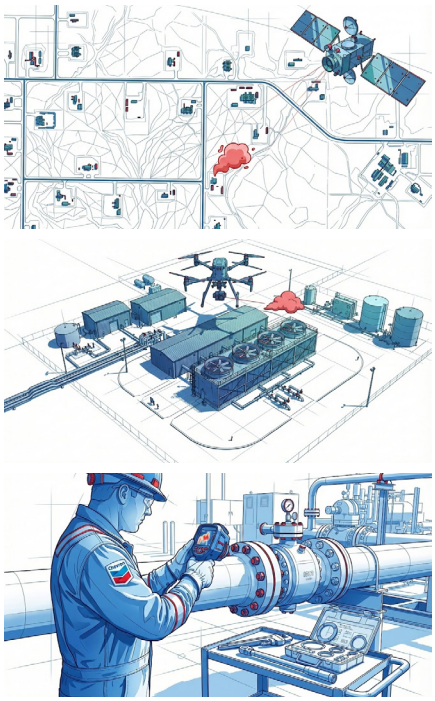
	what DiB enables	How it shows up in ESG reporting & assurance
E Environment	Faster detection and repair; higher monitoring frequency; better coverage of difficult-to-reach components	Improved methane intensity trajectory; documented LDAR cycles; "time-to-detect/time-to-repair" metrics
S Safety & Community	Fewer hazardous exposure events; reduced manual work in high-risk zones	Reduced HSE exposure hours; fewer emergency responses; stronger community trust signals
G Governance	Automated logs, geotagged evidence, repeatable procedures, data retention	Stronger audit trail; supports MRV maturity and third-party assurance readiness

METHANE MANAGEMENT AT SCALE

From Detection to Verified Repair

An effective methane program is a layered "detect–localize–repair–verify" system that combines complementary technologies. Satellites provide daily, basin-scale screening, but at kilometer-scale spatial resolution, so they primarily flag larger events, "super-emitter", that must be investigated on the ground. Crewed aircraft then act as flexible, higher-sensitivity regional screening to narrow the search area and prioritize response. Continuous Monitoring Systems (CMS), fixed sensors at sites, provide near-real-time alerts but typically require follow-up to localize and confirm. Leak Detection and Repair (LDAR) programs using optical gas imaging (OGI) and/or U.S. Environmental Protection Agency (EPA) Method 21 remain the compliance-grade, component-level baseline.

A DIB system is the operational "glue", it can be dispatched immediately after a satellite/aircraft/CMS indication to localize emissions at asset level, generate auditable evidence, and then re-fly to verify repairs. This combined approach makes the most sense because it reduces time-to-detect and time-to-repair while improving inventory credibility where measured emissions often exceed reported inventories.



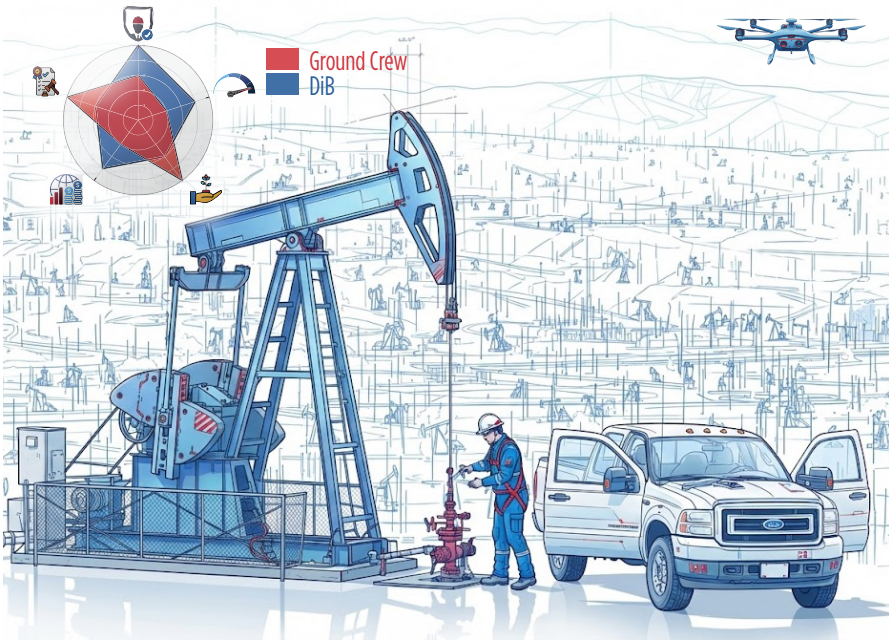
UPSTREAM OPERATIONS

The operational shift from "Windshield Time" to "Exception Management"

The core inefficiency in upstream operations is the "Route": driving to every well pad to verify it is running correctly. Field crews spend significant time leak surveys, spill-prevention checks, security walkdowns, and routine rounds. In practice, a field operator may cover 15–30 well sites per shift. 80-90% of these visits result in no action because the well is operating normally.

On one side regulatory requirements reinforce the need for routine site surveillance. Federal Spill Prevention, Control, and Countermeasures (SPCC) expectations drive periodic visual inspections of tanks, piping, drainage systems, and process vessels. Many jurisdictions add more frequent requirements, including daily audio/visual/olfactory (AVO) checks, documentation retention, and defined inspection schedules for wellheads and associated equipment. For a representative 30-well operation with a battery, separators, and storage, the cumulative inspection touchpoints across daily, weekly, monthly, and annual requirements can be significant.

On the other side, compliance is only part of the workload; the remainder comes from operational optimization, troubleshooting, and maintenance coordination.



While upstream operators have invested heavily in automation (SCADA/RTUs for pressures and rates, artificial lift controllers for performance, and automated tank gauging/LACT for measurement), these systems largely lack visual context. Sensors are effective where installed, but they cannot see staining, corrosion, vegetation encroachment, standing water, degraded containment, unauthorized access, or early-stage mechanical issues that present visually or thermally before they become alarms. This visual surveillance gap is what drives continued routine site visits even in highly instrumented fields.

DiB systems are positioned to close that gap by delivering automated, repeatable visual and thermal monitoring on a scheduled basis. The proposed use case is distinct from emergency response, work-at-heights inspection, pipeline patrol, and emissions programs. Here, the focus is routine basin and well-site surveillance: consistent imagery from predefined angles, AI-assisted change detection, and time-stamped records that strengthen auditability.

DiB does not eliminate the need for field staff, it shifts site visits from check runs to intervention runs, reserving people for hands-on work such as sampling, adjustments, repairs, and non-telemetered readings.

DIGITAL INSPECTION DATA AS MULTIPLIER

Long term Value, Accuracy, Speed, and Predictive Maintenance Outcomes

DiB creates the most value when inspection outputs become structured, traceable data. Paper and unstructured PDFs don't scale, they are hard to validate, reuse, and link to assets. A digital-thread approach ties each inspection to asset IDs, time/location, procedure, and evidence, improving audit defensibility.

DiB standardizes high-frequency, repeatable, georeferenced inspection events that integrate into our enterprise systems: edge capture to data lake, mapped to asset hierarchy and taxonomy, then routed into the systems teams already use. This helps feeding the maintenance system (CMMS), the asset reliability system (APM/RBI), or the site mapping system (GIS). With frequent tagged evidence, Risk Based inspection can shift toward "living RBI," where new condition signals trigger targeted reassessments, reduce inspector variability, and better link operating envelopes to integrity decisions.

Furthermore, AI becomes practical when metadata, labels, and outcomes are governed: detect > localize > repair > verify.

While the long-term value of digital inspection data is not fully measurable today, the rise of AI-powered operations and integrity systems makes high-quality digital data a key differentiator in an increasingly competitive landscape.

The strategic choice is not only which drone platform to deploy, but how to govern, store, and integrate inspection data so it remains trusted, searchable, and ready for analytics.

MODELING THE BUSINESS CASE

A Case study for a mid-sized U.S. refinery

Return on investment for DiB is defined by facility footprint, asset density, inspection frequency, and how well drone imagery connects to existing work-order systems. Larger sites with dispersed assets and high patrol cadence generate the strongest returns. Main challenges that delay decisions and action are difficulty quantifying avoided costs that never appear on an invoice, and uncertainty about integration effort with existing maintenance workflows.

A practical deployment requires at least two docking stations. in order to deliver the redundancy and service overlap that make automated inspection operationally reliable. Total investment includes hardware, software, training, and integration (power hookup, mounting, network security, standard operating procedures).

For a mid-sized refinery, initial setup typically ranges from $350,000 to $625,000, with integration work driving most of the variation. Annual operating costs run from $60,000 to $120,000 for software licenses, maintenance, and remote pilot support.

Operators can purchase outright, lease with predictable monthly payments, or contract the entire operation as a service to shift staffing and compliance responsibilities to a provider.

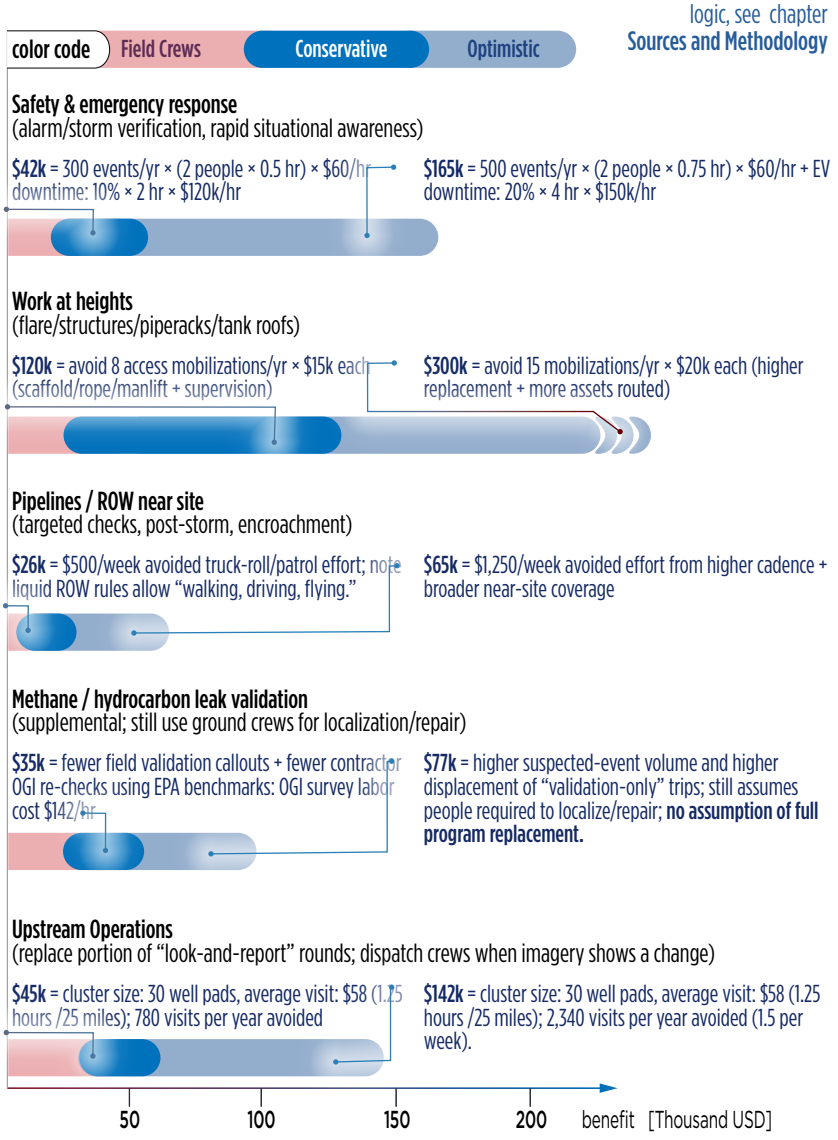
A refinery running two docking stations performs alarm verification, thermal inspection of elevated structures, pipeline response, and targeted methane screening at difficult-to-access locations.

Even under the most conservative assumptions, avoided scaffolding mobilizations and reduced dispatch labor yield approximately $250,000 in gross annual savings. After $120,000 in operating costs, the net benefit is roughly $130,000, placing **worst-case payback at three to four years.** Sites with higher asset density and inspection frequency can compress that window to under 18 months, depending on how consistently avoided costs are captured.

This conservative model excludes several high-value benefits. Avoided downtime being a major factor. A typical refinery carries an hourly value of $125,000. In addition, specialized scaffolding setups frequently exceed $20,000 per mobilization. Digital information that DiB systems collect and the value of this data to train AI systems are also not taken into account.

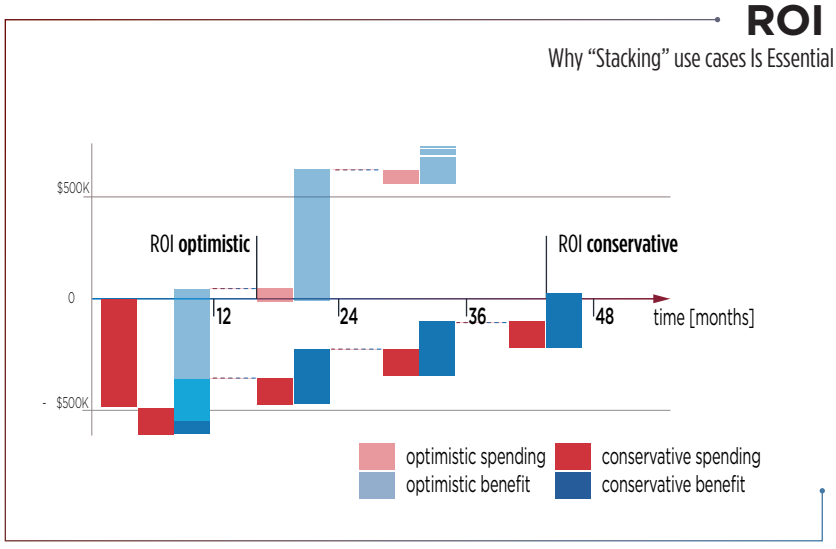
When all these factors receive appropriate weight, total annual value often doubles or triples the conservative baseline. This is illustrated in the **optimistic case with an ROI in 12-18 months**.

NOTE: all numbers are assumptions . For sources and calculation logic, see chapter **Sources and Methodology**



ROI

Why "Stacking" use cases Is Essential



EVOLUTION OF THE ECOSYSTEM

the way the industry works

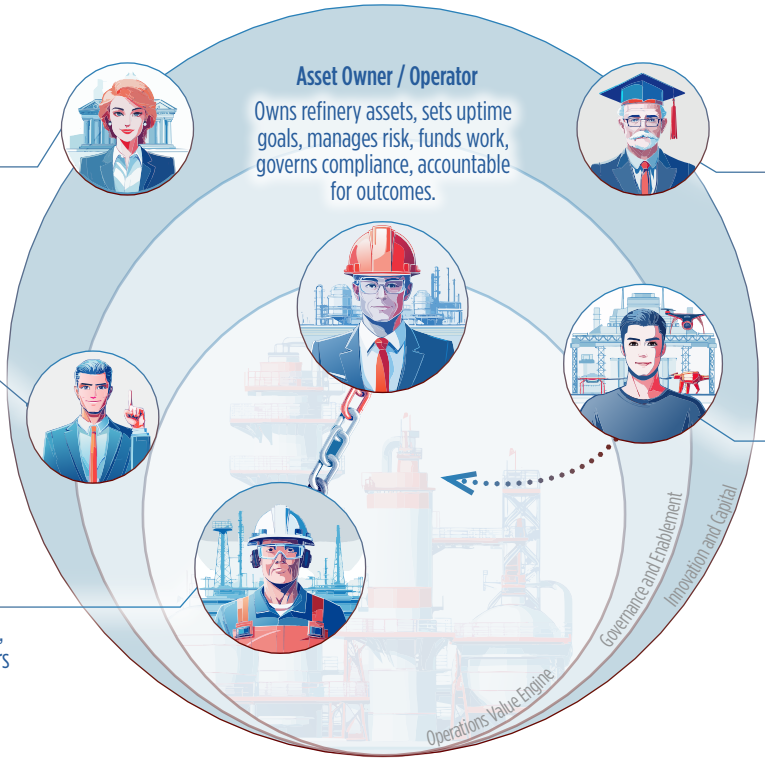
For decades, the industrial service model has been straightforward. Asset owners define what needs to be done. Service providers bring crews to do the work. Payment follows hours worked, day rates, and scope-defined tasks. This approach aligned with physical reality: inspection, maintenance, and turnaround work varies by site, requires experienced teams, and demands rapid, safe response.

A mature ecosystem formed around this core relationship. Regulators and standards bodies set accepted methods. Technology providers delivered tools that improved measurement and documentation.

The commercial logic stayed constant: more hours meant more revenue, and the best providers commanded premium rates for skilled labor.

A paradigm shift is happening to this model. Advanced systems now deliver the same inspection outcomes with fewer site visits, fewer technicians, and less time on task. Technology developers providing autonomous platforms, continuous monitoring, and data-driven workflows increase productivity per job. When a drone completes a flare stack inspection in hours instead of days the traditional billing model breaks down. Productivity gains reduce billable hours even as the value delivered to the plant increases.

Realizing the full potential of advanced inspection technology demands a step change across the industry. For service providers, the hub-and-spoke model, built on dispatched crews and hourly billing is itself a barrier. Adoption slows down when the operating model punishes efficiency. A fundamental change in mindset, commercial structure, and workflows is required.



Investors and shareholders

Provide capital for scaling, demand measurable outcomes, shape governance, set return horizons, enable commercialization globally.

Regulators / Standards bodies

Define acceptable methods, safety and environmental rules, evidence requirements, audits, enforcement, and operating permits criteria.

Service Providers / Contractors

Executes inspections and maintenance, provides crews and equipment, delivers safe work, relies on multi year service level agreements.

Academia & Startups

Create and validate new methods, publish findings, develop talent, benchmark performance, reduce uncertainty.

Tech providers / Integrators

Supply & Support systems and digital stack, integrate data flow, automate workflows, enable decisions faster.

THE ROLE OF THE SERVICE PROVIDER

Service providers sit in the inner core because they power refinery execution. Many hold asset-specific knowledge: crews understand equipment condition, access limits, and failure modes as well as, and sometimes better than, in-house teams.

That expertise remains essential, but its use is shifting. Automation and remote inspection cut routine mobilizations and focus field work on the highest-risk tasks. Meanwhile, demand is rising for remote analytics and assurance, anomaly validation, compliance evidence. Pricing should evolve toward outcomes: availability, integrity assurance, faster response.

THE ROLE OF THE TECH PROVIDER

Technology developers have traditionally operated in the second ring, supplying tools that support plant teams from the outside. DiB and autonomy-enabled systems move them inward. But high technology costs remain a significant barrier, particularly when pricing reflects anticipated value capture rather than product quality or customer fit. This approach slows adoption and disrupts the feedback loops needed for continuous improvement.

Tech providers must refocus: deliver robust, field-proven products that meet operator requirements, lower the entry threshold for oil and gas, and build structured channels to capture field experience and improve iteratively.

FROM ASPIRATION TO ADOPTION

drone-in-a-box as standard infrastructure

For the past decade, drones in the energy sector have operated primarily through innovation teams and isolated pilots. They functioned as specialized tools checked out from a warehouse, flown by a contractor, and returned to storage between campaigns.

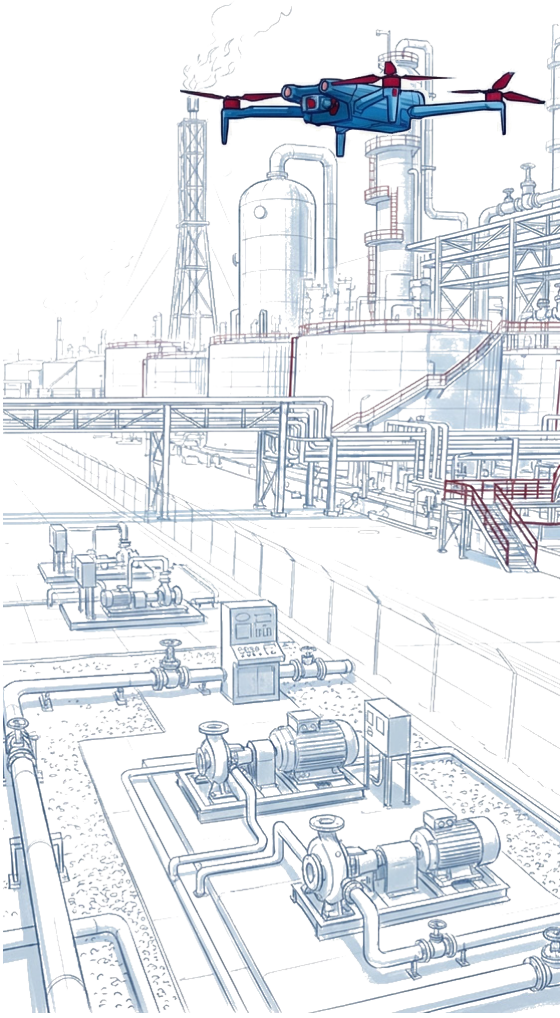
DiB systems represent a different operating model. When deployed correctly, they function as fixed infrastructure comparable to security cameras, gas detection sensors, or perimeter monitoring systems rather than portable equipment requiring mobilization for each use. This shift to infrastructure creates three operational changes.

First, successful DiB deployment becomes invisible to most users. Automated flights run on schedule, data uploads directly to asset management systems, and alerts feed into established dashboards. The objective is seamless data flow, but direct integration into the tools maintenance teams already use.

Second, infrastructure demands high availability. The conversation shifts from flight specifications to mean time between failure and system uptime targets. Operators apply the same preventive maintenance discipline to docking stations as they would to compressors or pumps. Reliability becomes the primary performance metric.

Third, value scales with network deployment. A coordinated network of ten, twenty, or fifty sites managed from a central operations center delivers measurable return on investment. This fleet approach distributes fixed costs across multiple locations, improving unit economics per inspection.

Underpinning this shift is a convergence of site-specific digital twins and simulation environments. Platforms such as NVIDIA Omniverse and Skydio's simulation tools allow operators to validate flight paths and sensor coverage against a physics-accurate site model before a flight occurs. The necessary ingredients, physics-based models, domain knowledge, real-world inspection data and autonomous drone systems are already in place. Their convergence is **creating the conditions for Physical AI in industrial inspection**. How digital twins and AI are accelerating that transition is examined in the future articles in this series.



CALL TO ACTION

collaboration is key

No single entity holds the full solution. The energy industry is complex, hazardous, and heavily regulated. No single vendor can resolve it from the outside, and no operator can solve the digital transformation puzzle in isolation. The solution is not technology alone. In the AI world, leading tools are replaced by better ones in months. What makes them succeed is rapid iteration with end customers in the feedback loop. DiB works the same way. It does not just challenge inspection workflows; it challenges how oil and gas organizations learn and adapt, demanding a **shift from fixed to growth mindset** across every function.

To the Asset Owners: Lead the commercial evolution. Technology cannot reduce costs if procurement still rewards inefficiency. Challenge vendors to bid on outcomes: uptime, verified inspections, leak-free operations. Do not treat DiB as just another widget. Reach the outcomes you seek by challenging current ways of working and committing to continuous improvement across every function that touches how work gets done.

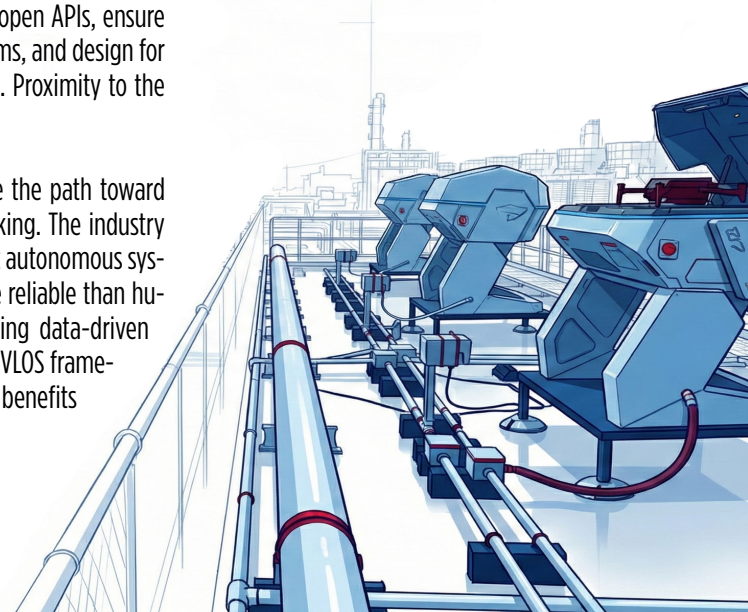
To the Service Providers: The era of selling hours is sunsetting. Autonomy is a multiplier for your expertise, not a threat to your workforce. Use DiB to handle dull, dirty, and dangerous routine work, freeing skilled crews for complex repairs and interpretation. The service provider of the future is an Integrity Partner, not a labor supplier.

To the Tech Partners: Usability now matters more than capability. Build open APIs, ensure data flows into legacy systems, and design for field conditions, not the lab. Proximity to the industry is key.

To the Regulators: Continue the path toward performance-based rulemaking. The industry is ready to demonstrate that autonomous systems can be safer and more reliable than human operators. By prioritizing data-driven waivers and standardizing BVLOS frameworks, you unlock safety benefits that save lives.

The Final Step

We have the hardware. We have the software. We have the regulatory pathway. The barrier to adoption is no longer technological, it is organizational. The winners of the next decade will stop waiting for the perfect time and instead build learning teams across operations, integrity, procurement, and maintenance to capture experience, close feedback loops, and realize value at scale.



ABOUT THE AUTHORS

The authors are a joint team from Chevron's Technology, Projects, and Execution team and industry experts. We welcome collaboration, reach out to compare lessons learned, explore pilot opportunities, and accelerate safe, reliable adoption together.



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ABBREVIATIONS AND ACRONYMS

DiB	Drone-in-a-Box	MOC	Management of Change
BVLOS	Beyond Visual Line of Sight	PPE	Personal Protective Equipment
PHMSA	Pipeline and Hazardous Materials Safety Administration	ROI	Return on Investment
UNEP	United Nations Environment Programme	NPV	Net Present Value
CCAC	Climate and Clean Air Coalition	TRL	Technology Readiness Level
VLOS	Visual Line of Sight	EPA	Environmental Protection Agency
UTM	Uncrewed Traffic Management	US DOT	United States Department of Transportation
FAA	Federal Aviation Administration	HCA	High Consequence Area
UAS	Unmanned Aerial Systems	ROW	Right-of-Way
EASA	European Union Aviation Safety Agency	ASME	American Society of Mechanical Engineers
SORA	Specific Operations Risk Assessment	MIC	Microbiologically Influenced Corrosion
HSE	Health, Safety, and Environment	ESG	Environment, Social & Governance
IT/OT	Information Technology / Operational Technology	EUMR	European Union Methane Regulation (2024/1787)
OGI	Optical Gas Imaging	GTI	Gas Technology Institute
LDAR	Leak Detection and Repair	GWP	Global Warming Potential
CAPEX	Capital Expenditure	CMS	Continuous Monitoring Systems
OPEX	Operating Expense	AVO	Audio/Visual/Olfactory
RaaS	Robotics-as-a-Service	SCADA	Supervisory Control and Data Acquisition
LTE	Long-Term Evolution (the standard for high-speed wireless communication for mobile devices and data terminals)	RTUs	Remote Terminal Units
QA	Quality Assurance	LACT	Lease Automatic Custody Transfer
LiDAR	Light Detection and Ranging	CMMS	Computerized Maintenance Management System
FTE	Full-Time Equivalent	GIS	Geographic Information System
EAM	Enterprise Asset Management		

SOURCES AND METHODOLOGY

Page	Claim & Source or reference
4	"Average age 56 years"; "50% retire within 10 years": https://www.orionjobs.com/resources/blog/the-aging-workforce-in-oil---gas--how-can-recruitment-adapt-/ "46 hours per week": https://www.energy.gov/sites/default/files/2025-08/National%20USEER_08282025.pdf "12-hour shifts, 28-day rotations": https://drillers.com/working-28-days-row-can/ "Oil & gas salary $81,808-$125,240": https://www.rigzone.com/news/new_report_shows_usa_oil_and_gas_wages_by_industry-10-mar-2025-179875-article/ "Offshore platforms 40+ years old": https://www.weforum.org/stories/2024/04/decommissioning-oil-and-gas-platforms/ "US refinery average age 74 years": https://www.reuters.com/world/us/lax-oversight-allows-us-refineries-pollute-waterways-report-2023-01-26/ "PHMSA US pipelines average 41 years": https://www.phmsa.dot.gov/sites/phmsa.dot.gov/files/docs/technical-resources/pipeline/gas-distribution-integrity-management/6604 "90% false alarms (fire/gas systems)": https://www.hochikieurope.com/blog/new-research-shows-90-of-false-alarms-are-down-to-faulty-apparatus "Maintenance backlog 4-6 weeks acceptable": https://www.getsockeye.com/blog/maintenance-backlog-management/ "80 million tonnes methane annually": https://www.edf.org/media/iea-unep-and-edf-announce-comprehensive-metrics-report-action-and-measure-progress-oil-and "Global Methane Pledge: 159 countries, 30% reduction by 2030": https://www.ogci.com/methane-library-item/global-methane-pledge/ "US 80% methane reduction 2024-2030": https://bidenwhitehouse.archives.gov/wp-content/uploads/2024/11/US-Methane-Action-Plan-2024-Update.pdf "OGMP 2.0 methane reporting framework": https://www.airmo.io/ogmp-2-0-gold-standard "Oil & gas data analytics challenges": https://www.katalystdm.com/news/oil-and-gas-data-analytics-when-subsurface-data-becomes-a-natural-resource/
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14	EIA Refinery Capacity Report PDF (2025 report): https://www.eia.gov/petroleum/refinerycapacity/refcap25.pdf EIA Daily Prices (includes USGC 3:2:1 crack spread): https://www.eia.gov/todayinenergy/prices.php 49 CFR §195.412 (ROW inspections; 26/year; walking/driving/flying): https://www.law.cornell.edu/cfr/text/49/195.412 49 CFR §192.705 (gas transmission patrolling intervals; walking/driving/flying): https://ecfr.io/Title-49/Section-192.705 40 CFR §60.18 (Alternative work practice; OGI for equipment leaks): https://www.law.cornell.edu/cfr/text/40/60.18 40 CFR §65.7 (Alternative work practice; OGI; broad applicability): https://www.law.cornell.edu/cfr/text/40/65.7 EPA OGI Stakeholder Workshop (refinery sector; links to docket): https://www.epa.gov/stationary-sources-air-pollution/optical-gas-imaging-stakeholder-workshop Federal Register (OGI cost points incl. $85k camera; $3,950/week rental; program cost examples): https://www.govinfo.gov/content/pkg/FR-2011-08-23/html/2011-19899.htm BLS Security Guards OOH (pay): https://www.bls.gov/ooh/protective-service/security-guards.htm BLS OEWS Commercial Pilots (wage estimates): https://www.bls.gov/oes/2023/may/oes532012.htm BLS ECEC (Dec 2024; wages vs benefits shares): https://www.bls.gov/news.release/archives/ecec_03142025.htm https://www.bls.gov/opub/ted/2024/compensation-costs-for-private-industry-workers-averaged-44-40-per-hour-in-september-2024.htm Public procurement price exemplars (Axon / Skydio / dock-based DFR): https://www.omniapartners.com/suppliers-files/A-D/Axon/Contract_Documents/3544-21-4615/3544-21-4615_AM9_Axon_2025_02_04.pdf https://www.irs.gov/newsroom/irs-sets-2026-business-standard-mileage-rate-at-725-cents-per-mile-up-25-cents?utm_source=chatgpt.com "300–500 events/year," "8–15 work-at-height mobilizations/year," "weekly patrol savings," "validation hours saved per event," "leak-suspect volumes," etc. **Logic required:** build from (1) incident logs, (2) work orders/CMMS, (3) contractor invoices, and (4) dispatch records; then compute unit economics (cost per event / per mobilization / per patrol) and apply a conservative substitution rate.


Chevron