Drone Programs that Scale: Reducing Complexity in BVLOS Missions with Integrated Autonomy

1. INTRODUCTION

Industry Driver: The Rapid Rise of BVLOS Flights

As the demand for long-range missions and comprehensive UAV system deployment intensifies, BVLOS operations are rapidly expanding across the commercial and defence sectors. Despite that accelerated adoption, scaling drone missions has traditionally been difficult to achieve.

Programs continue to face a distinct gap between successful flights and repeatable, large-scale operations. This is largely due to operational models that are too complex, resource-intensive, and difficult to standardize.

- Between 2020 and 2023, the number of FAA-approved BVLOS operations grew by 22x, from 1,229 to 26,870.
- The FAA approved 2.5x more Part 107 waivers in 2024 than in 2023 (~3x more than in 2022), with BVLOS missions making up roughly 25% of 2024 approvals.

As organizations look for ways to extend mission range, minimize resources, and expand use cases, BVLOS has become a focal point for both industry investment and regulatory attention.

Market Momentum: Policy, Adoption, Regulation

BVLOS flights have vastly expanded what drone programs are capable of. As a result, automation and platform integration have become all the more critical to success as program complexity scales. At the same time, progress has been enabled globally through waivers, approvals, and controlled testing environments. However, while U.S. operators navigate FAA channels, international frameworks like SORA 2.5 increasingly require assessment of ground risks related to population density and aircraft characteristics.

BVLOS missions are increasingly critical for commercial and defence applications that demand endurance:

- **Infrastructure** operators require repeatable inspection workflows, while public safety organizations want faster aerial access over longer distances.
- **Logistics** providers are focused on moving time-sensitive cargo more efficiently across every inch of operations from worker hours to path routing.
- **Defence** missions may be longer-range, high-risk, and take place in contested environments, where integrated autonomy can help reduce cognitive load and support ISR.

Increased mission complexity

At the same time, as BVLOS missions extend farther, the operational environment has become more difficult to manage.

Longer ranges lead to more variables: route complexity, weather exposure, battery limits, and communication reliability. That added complexity means mission success depends not only on the drone itself, but also on the approach to operations. Even when BVLOS pilot projects are successful, expanding them into recurring operations consistently across different missions, teams, and geographies presents multilayered, unique challenges.

Challenges compound further when drone missions use multiple aircraft or operate in dynamic environments. Coordinating several drones, performing in-air adjustments, and maintaining consistency across flights all increase the burden placed on operators and program systems (Dobrev et al. 2024). BVLOS scaling therefore comes down to handling complexity in a way that is repeatable and efficient.

Bridging the gaps between pilot projects, single flights, and scalable programs requires operational standardization to reduce risk and allow for repeatable missions at scale. This is where integrated autonomy becomes most important, helping convert BVLOS from a series of flights into a structured and scalable program.

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2. CHALLENGES

Core Challenge: Compounding Complexity

Scaling a drone program is typically constrained by a confluence of challenges. Planning, compliance, flight, and documentation traditionally existed separately across systems and workflows. That fragmentation leads to increased friction and repeated manual inputs that introduce error, increase workloads, and add administrative burden.

- A 2025 report by the U.S. Department of Transportation identified UTM infrastructure and technology in particular as major hurdles to scaling BVLOS operations.

1. Operational Fragmentation

In many programs, operators move between their planning tools, which introduces friction at each point. That can lead to multiple manual data transfers, duplicate data inputs, and extra cross-checking. As a result, operations are slowed and the risk of inconsistency rises.

Often, interoperability is limited, which causes complexity when scaling across aircraft types and software environments. This makes standardization much more difficult to achieve.

2. Operator Burden

Longer, complex missions place a significant burden on operators, which can ultimately limit consistency and mission success. Simultaneous management of routes, constraints, airspace boundaries, vehicle status, contingencies, becomes a risk.

Even in well-structured programs, the resulting cognitive load becomes more pressing. The result is a high-stakes decision environment with increased training demands and more serious consequences for human error.

3. Inconsistent Workflows

Even where procedures are defined, mission execution can vary due to operator experience, local conditions, software, and platform-specific requirements. That variability makes it more difficult to ensure that missions are planned and executed consistently, particularly as programs expand across regions or use cases.

Such inconsistent workflows reduce repeatability and make missions harder to audit. When procedures differ across operators or locations, benchmarking becomes more difficult and standardization cannot be achieved at scale.

4. Regulatory & Compliance Complexity

Operators often manage airspace rules, flight approvals, logs, and documentation across all flight phases. While that can be managed on a small scale, such requirements become harder to coordinate as operations expand. Issues related to documentation, audits, or records can all lead to delays and risk, particularly across regulatory jurisdictions.

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3. THE SOLUTION

Core Solution: Integrating Mission Planning & Flight Control

AI-supported planning helps optimize flights, missions, and programs, and those simplified workflows and generate measurable savings. By integrating mission planning with flight control systems, it is increasingly possible to standardize workflows and reduce the resources and time spent operating drone programs, making them more feasible.

This can be illustrated using the Shearwater-Embention integrative model:

1. **Seamless transfer of plans** from Smart Flight into Veronte Ops can improve continuity from pre-flight through execution.
2. **The flight control environment** handles execution and monitoring, which reduces friction across the entire mission cycle.

3. **AI and machine learning** support decision-making by accounting for weather, terrain, airspace, aircraft performance, and telemetry.
4. **Mission reliability** can be boosted by improving operator efficiency and lowering cognitive and administrative burdens.
5. **Scalable programs** are increasingly possible with greater consistency across missions, teams, and environments.

This way, we are able to build predictable programs with execution that's in line with mission goals. The aim is not to replace operators, but rather reduce operator burden by providing them with decision support, reduce manual interventions, and build consistency:

- Depending on mission variables, pilot workloads can be reduced by over **90%**
- It is possible to raise mission transit efficiency by over **25%**

By reducing workloads and increasing efficiencies, operators are able to oversee more missions and scale up their operations.

Intelligent Mission Planning

Shearwater's Smart Flight™ is engineered to optimize routes while assessing go/no-go readiness based on common constraints related to weather, terrain, airspace, and chosen aircraft. These platform capabilities are especially important for BVLOS missions that struggle with consistency and endurance.

- **Intelligent mission planning** strengthens the foundation for repeatable BVLOS operations
- **In-flight monitoring** can execute adjustments to planned routes in real-time as conditions change
- **Fewer variables** need to be managed prior to launch, including weather, terrain, airspace, and aircraft limitations
- Constraints can be addressed earlier and more systematically via go/no-go assessments, contingency planning, and route optimization

Most Go/No-Go tools check routes against basic thresholds, like whether forecasted wind is under the limit and whether distances are within range. Smart Flight™ goes further. Using high-resolution micro-weather and specific aircraft performance, it simulates the entire flight before launch, confirming whether the aircraft can climb over terrain and descend safely, stay within altitude limits and flight geography, and land with the required energy reserve. The software then re-checks against live conditions throughout the flight.

The result is a more confident go/no-go decision and predictable execution: fewer unnecessary groundings when a mission is safe to fly, and fewer aborts and airborne surprises when it launches.

Flight Control Integration

Embention's Veronte Ops and Veronte Autopilot were engineered to help operators build a certifiable ecosystem for UAV applications and regulated BVLOS operations. Optimized plans from Smart Flight™ can be integrated into the flight environment, with Veronte Ops as the interface for mission control, monitoring, and management.

- **The disconnect** between planned and flown missions is reduced
- **Smart Flight™ plans** can be imported directly into **Veronte Ops**, allowing for better execution while avoiding manual activities that can introduce delay or error
- **Tighter alignment** between route intent, autopilot behavior, and operational oversight, helping to reduce BVLOS complexity in real-world deployments

Data and telemetry feedback loops

Smart Flight™ supports both mission planning and real-time optimization, from telemetry and weather inputs to terrain mapping and aircraft performance.

- **Changing conditions** across the operating environment are autonomously adapted to, based on live weather, telemetry, and performance data
- **Feedback loops** extend beyond individual missions: operational data from each flight refines the platform's understanding of weather and performance over time, improving future planning.
- **Autonomous rerouting** is adaptive and efficient, reducing the need for manual intervention in dynamic environments

Compliance support and logging systems

As BVLOS operations scale, the need to document decisions, maintain auditability, and align with regulatory requirements increases. Integrated autonomy entails embedding compliance and mission records within the operational workflow rather than treating them as separate administrative tasks.

The Veronte ecosystem is purpose-built for regulated environments, with Veronte Ops serving as a central platform that integrates data sources and tools while maintaining safety and system integrity.

- **Supports mission execution**, traceability, and operational control
- **Closer integration** of planning, execution, and monitoring enables more consistent recordkeeping and reduces the burden of fragmented reporting
- Integration links optimized planning with the control layer, supporting **a more coherent approach** to mission oversight, execution tracking, and post-mission review
- **Reduces reporting friction** and better supports certification, approvals, and recurring deployments

Reduced Manual Intervention

Operator workloads can be reduced by improving overall efficiency, achieved via automated route planning and more exception-based operating models.

- **Automate route generation** and optimization for both fixed and dynamic missions
- **Update trajectories in-flight** using live data (weather, telemetry, aircraft performance)
- Shift operations toward **exception-based management**, surfacing decisions only when thresholds are exceeded
- Enables operators to focus on higher-value oversight and decision-making

Streamlined Compliance and Reporting

Integrating planning, monitoring, and mission records improves compliance and simplifies reporting:

- **Regulatory and operational constraints** (population density, airspace rules, altitude limits, mission boundaries) can be embedded into planning and optimization
- **Compliance** shifts to earlier in the mission lifecycle, allowing for more proactive, decision-aligned operations
- **Traceability** is improved through the Veronte ecosystem, supporting regulatory auditability
- Veronte Ops execution and **monitoring** gives access to onboard, fast, and user logs
- **Mission data** (e.g., CSV) can be exported for analysis, documentation, and reporting

To scale successfully, organizations must think carefully about how planning, control, compliance, and data workflows will fit into existing systems and teams. Ultimately, adopting integrated autonomy in BVLOS operations is not only a technology decision, it requires a systemic approach.

Solution Implementation Considerations

System Integration Strategy

Often, the key question for operators is not only which tools provide the most features, but also which approach reduces growing complexity — all without creating new burdens.

Some key considerations include:

- **Build vs. buy tradeoffs**: time to deployment, internal engineering capacity, and long-term support requirements.
- **Interoperability** with drone platforms, autopilots, ground control systems, and compliance tools.
- **API and data architecture requirements** to ensure mission plans, telemetry, and reporting data can move cleanly across systems.

Change Management

Moving from manual or fragmented processes to semi-autonomous operations can alter how missions are planned, supervised, and documented. This means that adoption must be actively managed.

Organizations can plan for:

- **Training operators** on new planning, monitoring, and exception-handling workflows.
- **Supporting the transition** from manual execution toward semi-autonomous decision-supported operations.
- **Aligning operations**, compliance, and IT teams so the system is adopted as part of one coordinated operating model.

Regulatory Alignment

As BVLOS frameworks continue to evolve, operators will require systems that incorporate airspace boundaries, mission logging, and the thorough documentation that is expected by regulators and internal oversight teams.

Implementation should account for:

- **Alignment** with current and emerging BVLOS rules, approvals, and operational frameworks.
- Support for **auditability** through structured mission records, logs, and traceable workflows.
- The ability to strengthen **certification and approval processes** by making operations more consistent and easier to document.

Data and Security Considerations

Data handling and security are central implementation issues, especially when organizations are operating in regulated, high-value, or defence-related environments.

Key considerations include:

- **Secure handling** of telemetry, mission plans, and operational records across the mission lifecycle.
- **Clear controls** around data storage, access, retention, and system integration points.
- **Defence-specific requirements** like secure communications, resilience against disruption, and operational continuity in degraded environments.

Logistics: Time-Sensitive Delivery at Scale

Time-sensitive logistics missions place immense pressure on route planning, endurance, and payload management. This ultimately impacts turnaround times. In the case of medical deliveries, those challenges are amplified as operators must move critical supplies reliably — often across long distances and variable conditions.

- **Weather awareness** is considered critical for delivery reliability, particularly for emergency delivery missions.
- When delivering in urban areas, **population density and ground-exposure data** becomes all the more important, informing route selection and risk management.

Integrated autonomy helps to connect planning and execution for greater efficiency. Shearwater's Smart Flight™ system allows for dynamic route planning and optimization based on weather, terrain, airspace, and battery performance, while Embention's Veronte environment helps carry those plans forward into mission execution. Together, the combined systems reduce manual coordination and make delivery operations more repeatable.

Sources: Embention, Long et al. 2026, Glick et al. 2022, Raivi et al, 2023, Shearwater Aerospace

Defence: Success in High-Stakes Environments

Defence BVLOS missions often take place in contested, high-stakes environments where operator workloads and mission complexity can reduce the odds of success. In ISR and similar missions, the ability to launch rapidly, adapt in real time, and support decision-making can be mission critical.

- In high-stakes environments, the loss of situational awareness due to **cognitive overload** can lead to fatalities and mission failure
- With AI and automation, **decision quality** can be improved, particularly in highly complex environments

Integrated autonomy reduces this in-theatre complexity by minimizing cognitive load and speeding up decisions. Specifically, Shearwater's Smart Flight™ supports mission planning and risk-aware optimization, while Embention's Veronte environment helps to translate those plans into controlled mission execution.

Sources: Embention, Hu et al., 2025, Shearwater Aerospace, Sherwood 2018, Wei et al, 2024, Zak et al., 2022

Infrastructure Inspection: Safer, Repeatable Operations

Infrastructure inspection missions are often recurring, compliance-heavy, and safety-centric, making consistency especially critical. Standardizing workflows can be particularly helpful in such cases.

Sectors like utilities often require repeatable coverage, thorough documentation, compliance and auditing, and processes that help reduce worker exposure to hazardous environments. Autonomy integrations also help standardize inspection workflows and automating repeat flight paths for recurring missions.

Shearwater's Smart Flight™ helps generate mission plans that account for operational constraints, while Embention's Veronte environment supports execution and monitoring in a controlled mission framework.

- Drone inspection missions can deliver impressive results, with one 2024 paper highlighting a potential **return on investment** of up to 10x during road inspections (Askarzadeh et al.).
- BVLOS missions also present unique **safety benefits,** allowing for remote operation of dangerous infrastructure monitoring tasks

Sources: Askarzadeh et al. 2024, FAA 2022, Poleo 2021, Wei et al 2024, USDT 2019

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5. CONCLUSION

Future Outlook: Scalable Drone Operations

Moving beyond incremental aircraft improvements, the progress of BVLOS programs is increasingly being shaped by operational innovation.

As a result, repetitive and data-intensive tasks like route optimization and real-time replanning are being made increasingly efficient. These capabilities will better support the industry's transition from manual activities to supervisory control, and operators will be better able to focus on high-consequence decisions.

At the same time, more complex mission architectures, like multi-drone coordination, are requiring tighter integration between planning, control, and system monitoring. This is increasingly addressed by AI-driven autonomy. Scalability will also depend on integration with broader airspace systems. As UTM and ATM frameworks also evolve, BVLOS operations will need to meet higher expectations. Integrated autonomy can be central to addressing these requirements, while AI will allow for better adaptive planning and in-flight performance.

Today, barriers to BVLOS scaling are no longer limited to technical feasibility. Operational complexity is becoming increasingly paramount: fragmented systems, manual coordination, inconsistent workflows, and compliance burdens. With advanced autonomy and interoperable systems, we are now able to help operators address these core BVLOS scaling challenges in a more consistent, integrated workflow.