

CLEAN RESOURCES FINAL PUBLIC REPORT

1. PROJECT INFORMATION:

Project Title:	Automated Wildfire Monitoring - AI Enabled Drone Surveillance
Alberta Innovates Project Number:	232404574
Submission Date:	August 30, 2025
Total Project Cost:	\$816,220
Alberta Innovates Funding:	\$250,000
AI Project Advisor:	Dallas Johnson

2. APPLICANT INFORMATION:

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3. PROJECT PARTNERS

The project partners included PTAC, AIRmarket Inc., and Alberta Wildfires. PTAC contributed \$4,200 of in-kind funding and was responsible for project management. AIRmarket contributed \$18,200 of cash funding and \$393,820 of in-kind funding and was responsible for technology development, project execution, project leadership, financial management, operations, and product validation. Alberta Wildfires contributed \$150,000 of in-kind funding and was responsible for product validation and implementation testing.

A. EXECUTIVE SUMMARY

Provide a high-level description of the project, including the objective, key results, learnings, outcomes and benefits.

Project Description and Objectives

Wildfires pose significant risks to communities, ecosystems, and industries. Their increasing intensity and frequency, driven in part by climate change, demand a new approach to wildfire management. This project aimed to address that challenge by integrating artificial intelligence (AI)-powered Remotely Piloted Aircraft Systems (RPASs), or drones, into Alberta's wildfire response operations.

While drones are already used in wildfire situations, this initiative represented a major step forward by enabling long-range, Beyond Visual Line of Sight (BVLOS) surveillance with onboard computer vision and automated navigation. The drone system utilized onboard AI to analyze video streams in real time, automatically directing drones to monitor potential alarms. The technology developed through this project reduces exposure to danger and allows for more targeted resource use, improving efficiency and effectiveness in managing emergencies. The objective of this project was to rapidly assess fire spread, identify hotspots, and monitor threats in real time, ultimately enhancing firefighter safety and decision-making while supporting and integrating with existing human-led workflows.

The original goals for this project were to:

1. Conduct semi-automated flight missions to identify and locate wildfire activity by conducting BVLOS drone operations in a live wildfire scenario, integrated with crewed aviation, for a minimum airborne time of 30 mins per mission.
2. Deploy ground-based infrastructure to provide reliable RPAS Traffic Management (RTM) services to a minimum of 225 km² designated wildfire airspace as agreed with Alberta Wildfires.
3. Develop an interface between the onboard computer vision application and the drone's autopilot system to produce automated suggestions for mission waypoint alterations based on video data to confirm suspected fire activities within 20 seconds.
4. Establish computer vision models for detecting fire and/or smoke activities from both visual (RGB) and infrared (IR) video streams with > 75% accuracy.

Key Results and Learnings

Although not all objectives were completed to their predicted outcome level, the project represents a significant technological leap for wildfire surveillance in Alberta and beyond.

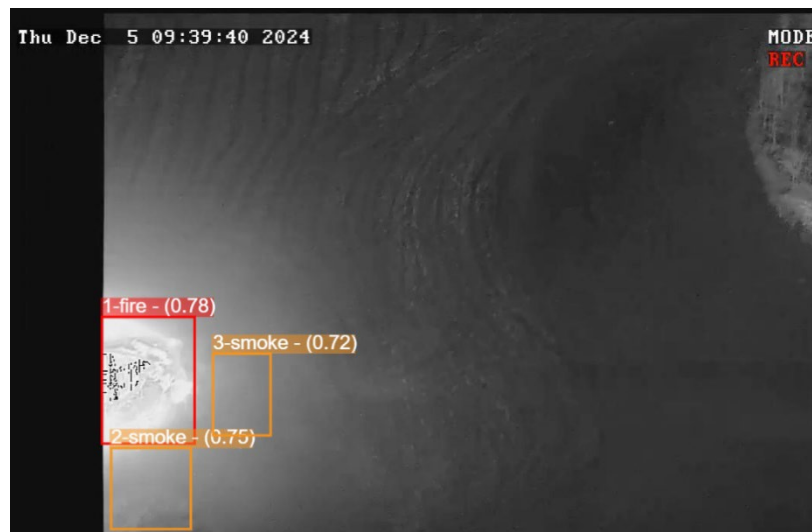
Goal 1 was successfully completed, with BVLOS drone missions conducted during wildfire conditions. Flight testing was performed near Redwater, Alberta, after daily suppression operations had concluded to ensure safety and avoid operational disruptions. The graphics below show the drone automation application that ingests AI computer vision outputs identifying smoke and fire, and then translates those detections into dynamic flight plans, guiding drones to investigate, monitor, and respond to potential wildfire locations in real time.

Goal 2 was modified due to regulatory constraints. Instead of full infrastructure deployment range, the project demonstrated a reduced RTM framework that was in compliance with Transport Canada allowances and can be readily expanded when regulatory pathways permit.

Goal 3 encountered limitations due to onboard computing constraints. While initial integration was demonstrated, real-time waypoint suggestions were not achieved within the 20-second target due to hardware processing limitations.

Goal 4 achieved 43% accuracy, short of the 75% goal, primarily due to limitations in the thermal camera resolution. The models showed relatively strong performance in RGB fire detection, highlighting promise with improved sensor quality.

Despite these technical constraints, the project successfully demonstrated integration with Alberta Wildfire operations, completing live wildfire observation flights and validating the potential of AI-powered drones for emergency response. These efforts directly informed and enabled a recently awarded ERA-funded expansion project, which addresses infrastructure and technical limitations encountered here and expands application to include precision agriculture and emergency response, as well as wildfire management. The technology is now on a clear pathway to full commercialization.



Outcomes and Benefits

This project improves the speed, safety, and intelligence of wildfire response, contributing to reduced operational risk for emergency responders and improved efficiency and targeting of fire suppression resources. The development of AIRmarket's technology supports the protection of industries operating within Alberta's boreal forest, particularly forestry which contributed \$13.6B and 41,400 jobs to Alberta's economy in 2020 and the province's \$120B/year energy industry.

Furthermore, the initiative bolsters the resilience of municipalities and Indigenous communities often impacted by these natural disasters. Altogether, this project supports a diverse economic landscape in Alberta, strengthening local governance and community development while maintaining support for the 500,000 Canadians employed directly and indirectly by the energy sector.

The initiative contributes to the broader adoption of BVLOS RPAS technology in Canada, representing a strong example of innovation in public safety, environmental protection, and climate adaptation.

Please provide a narrative introducing the project using the following sub-headings.

- **Sector introduction:** Include a high-level discussion of the sector or area that the project contributes to and provide any relevant background information or context for the project.
- **Knowledge or Technology Gaps:** Explain the knowledge or technology gap that is being addressed along with the context and scope of the technical problem.

B. INTRODUCTION

Sector Introduction

The escalating scale and intensity of wildfires across Canada pose an urgent threat to communities, ecosystems, and critical infrastructure. This project, delivered in collaboration with Alberta Wildfire, marks a significant advancement in addressing this challenge by developing and demonstrating a scalable, AI-powered, long-range drone system capable of operating BVLOS. More than a technological demonstration, this project lays foundational physical and regulatory infrastructure for Canada's wildfire drone industry.

In Alberta, the impacts of wildfires are becoming increasingly severe. The 2023 wildfire season was one of the most destructive on record, burning over 2 million hectares, displacing more than 38,000 residents, and disrupting major energy and transportation corridors. Wildfires in Alberta not only threaten human safety and property but also result in lasting environmental degradation, including biodiversity loss, poor air quality, and increased greenhouse gas emissions. Economically, wildfires strain emergency response budgets, reduce industrial productivity, especially in forestry, oil and gas, and utilities, and damage public infrastructure. On a societal level, they disproportionately affect rural, Indigenous, and remote communities that often have fewer resources to recover and adapt. These cascading effects underscore the urgent need for smarter, faster, and more proactive wildfire detection and management tools.

Historically, Alberta Wildfire relied on short-range, visual line-of-sight (VLOS) drones deployed during night operations to collect infrared and visual imagery. These missions were constrained by limited flight range and required manual data extraction and post-flight processing. Hot spots were identified using AI computer vision software only after imagery from multiple flights was uploaded and stitched into composite maps. While this method is effective, it is inefficient and cannot keep pace with rapidly evolving fire conditions.

Knowledge and Technology Gaps

This project delivers a next-generation wildfire monitoring solution by integrating advanced uncrewed aerial vehicle (UAV) hardware, onboard AI-powered computer vision software, and RPAS Traffic Management (RTM) supported BVLOS operations, enabling real-time detection and autonomous response. The system continuously analyzes video feeds onboard the drone, automatically loiters to verify potential fire activity, and provides georeferenced intelligence to incident response teams, all in real time. The development of this system supports four key goals critical to building a resilient drone-based wildfire management industry in Canada.

Proving New BVLOS Drone Operational and Technology Concepts in Live Wildfire Environments

The project demonstrated live BVLOS operations using Transport Canada Special Flight Operations Certificates (SFOCs) supported by emerging RTM services. Real-world wildfire deployments in Alberta proved the operational reliability of long-endurance fixed-wing drones, robust communications hardware, and autonomous mission management software under dynamic, high-risk conditions. These trials helped define protocols and performance benchmarks for future regulatory frameworks.

Demonstrating How Drones Can Generate High-Impact, Real-Time, and Decision-Ready Data

The deployed drones are equipped with onboard processors capable of running advanced computer vision models in real time. These models detect fire signatures such as smoke, flame, or residual heat and autonomously trigger behavior changes in the aircraft like loitering or course changes. This enables the production of real-time, decision-ready intelligence without the latency of cloud-based post-processing. This tight sensor-to-decision loop drastically improves situational awareness for incident commanders.

Supporting the Software and Hardware Supply Chain Needed to Grow the Drone Industry in Canada

The project engaged multiple Canadian partners across the UAV value chain, from drone airframe manufacturers, payload integration teams, and AI software developers to RTM service providers. In doing so, it has helped establish a national ecosystem capable of delivering turn-key UAV wildfire solutions. Key components included:

- Long-endurance fixed-wing UAVs with modular payload bays;
- Dual-spectrum (visual + IR) cameras;
- Onboard NVIDIA-based edge computing platforms;
- Autonomous mission control software;
- Secure RTM integration with UTM/ATM systems; and
- Data fusion platforms for use by wildfire management teams.

By piloting these components in an operational environment, the project validated a domestic industrial capability that can be scaled for national wildfire resilience.

Building and Documenting the Workflows and Operating Models to Safely Scale this Technology

Equally important to hardware and software is the development of standard operating procedures (SOPs), safety cases, and training models to ensure seamless integration with existing wildfire response workflows. The project worked directly with Alberta Wildfire teams to co-design operations that align with existing aerial and ground-based suppression tactics. These practices ensure that AI-powered UAVs complement, rather than compete with, crewed operations, while providing valuable operational documentation that can inform provincial and federal regulators.

Strategic Impact

This project builds on foundational work by Alberta Innovates and Alberta Wildfire, such as the fixed-camera fire detection trials in early 2023, by pushing further into mobile, scalable, and autonomous systems. It positions Alberta and Canada as global leaders in wildfire drone operations and creates a repeatable model that can be adopted across other provinces, territories, and international jurisdictions.

Ultimately, the integration of real-time AI and BVLOS drone capabilities is not only a leap forward in wildfire management, but also a critical enabler for climate resilience, safety, and industrial continuity in a warming world.

C. PROJECT DESCRIPTION

Please provide a narrative describing the project using the following sub-headings.

- **Knowledge or Technology Description:** Include a discussion of the project objectives.
- **Updates to Project Objectives:** Describe any changes that have occurred compared to the original objectives of the project.
- **Performance Metrics:** Discuss the project specific metrics that will be used to measure the success of the project.

Knowledge and Technology Description

The core objective of this project is to develop and demonstrate a scalable, semi-automated wildfire surveillance system using long-range drones equipped with onboard computer vision, integrated into airspace through RPAS Traffic Management (RTM). This marks a significant advancement in wildfire monitoring technology and lays the foundational infrastructure for a sustainable drone industry in Canada capable of addressing climate-induced wildfire risk.

Original Project Goals

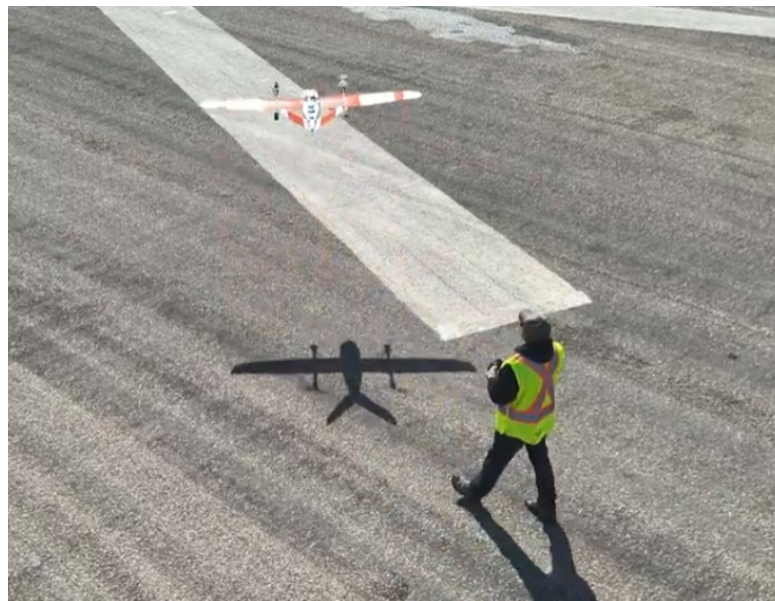
1. Conduct semi-automated flight missions to identify and locate wildfire activity by conducting BVLOS drone operations in a live wildfire scenario, integrated with crewed aviation, for a minimum airborne time of 30 mins per mission.

2. Deploy ground-based infrastructure to provide reliable RTM services (surveillance, C2) to a minimum of 225 km² designated wildfire airspace as agreed with Alberta Wildfires.
3. Establish an interface between onboard computer vision application and the drone autopilot system. The interface produces automated suggestions to the remote human pilot in command, for mission waypoint alterations, for the purpose of collecting on-target video data to confirm suspected fire activities. The integration will produce mission alterations within 20 seconds of identifying fire/smoke activities.
4. Establish computer vision models for detecting fire and/or smoke activities from both visual (RGB) and infrared (IR) video streams with > 75% accuracy.

Goal 1: Semi-Automated BVLOS Flight Operations in Live Wildfire Scenarios

The system consists of an RPAS, commonly referred to as a drone, equipped with a high-resolution gimbal camera with visual (RGB) and thermal (IR) sensors. This camera is capable of capturing high-resolution video streams, which are processed in real-time by an onboard computer vision application. The primary function of this system is to detect signs of fire or smoke within the camera's field of view, determine the GPS location of these signs, and then autonomously navigate to strategic loiter locations for gathering more detailed video data. This data is instrumental in the early detection and inventory of fire locations, a critical aspect in wildfire management.

The drone, shown on the right, is designed to conduct BVLOS flight operations, with an airborne endurance of over 60 mins. A quickly deployable aircraft, transported in 3 pelican cases in a truck box, can be assembled and launched within 15 mins from a 400 ft² area. The gimbal camera, a pivotal component, is mounted on the drone. This camera is not just high-resolution but also has a wide dynamic range and infrared capabilities, making it suitable for both day and night operations. The gimbal ensures stability and control of the camera angle, which is crucial for uninterrupted and clear video feed, even in windy conditions, and has wide acceptance as studied by the National Library of Medicine.



Goal 2: RTM Ground-Based Infrastructure and Airspace Management

RTM is an airspace management system that enables drones to be tracked and integrated with traditional crewed aviation. The Network Identification service assigns unique identifiers to each drone, enabling real-time tracking and monitoring. It ensures safe separation, avoids airspace conflicts, and integrates drones smoothly into the existing air traffic control systems. Currently, wildfire airspace management is delegated to each provincial agency to manage. In consulting with Alberta Wildfires,

none of these agencies have the system or concept of operations to integrate drones and crewed aviation at scale.

In December of 2023, NAV CANADA in collaboration with Transport Canada published their RTM System Concept of Operations. The ConOps outlines the use of RTM-Restricted (RTM-R) airspace as a construct to safely manage a wildfire designated airspace. The ConOps defines the operational controls and services required to support the airspace, in addition it defines the requirements for the aircrafts. The innovation will also provide the proving ground for using RTM equipment, drones, and integrated crew aviation. This provides a framework for wildfire management to scale the semi-automated use of drones, while addressing the airspace safety requirements.

RTM is a next-generation airspace framework that enables drones to operate safely alongside crewed aircraft during wildfire response. In partnership with Alberta Wildfire and aligned with NAV CANADA's 2023 ConOps, this project deployed mobile, ground-based Command and Control (C2) and surveillance systems that enable a drone to be tracked and managed within a defined wildfire airspace volume. These ground systems included 4G/5G connectivity, satellite redundancy, and local radio communications, establishing reliable data links across areas up to 225 km². The RTM integration also featured Network ID capabilities, allowing authorities to monitor drone identity and position in real-time, a critical requirement for safe integration with existing aviation operations.

Goals 3 and 4: Real-Time CV Fire Detection and Autopilot Integration for Mission Alteration

The core of this technology lies in the onboard computer vision application. This sophisticated software uses algorithms to analyze the video stream in real time. It employs machine learning techniques, trained on vast datasets of fire and smoke images, to accurately identify these elements in the video feed. Once the system detects fire or smoke, it employs image processing to calculate the precise GPS coordinates of the location. This calculation accounts for the drone's current position, camera angle, and the distance to the fire or smoke. The use of Generative AI capabilities onboard the drone will form an essential part of this innovation. The innovation will make use of Large Language Models to extend the scale and use of the onboard computer vision. This will provide the ability for the solution users to "ask questions" of the video streams, to identify additional anomalies.

Upon identifying a potential fire, the system automatically suggests loiter locations to the drone's autopilot. These locations are strategically chosen to optimize the camera's view of the potential fire area, allowing for comprehensive data collection. The autopilot uses advanced algorithms to navigate to these points, considering factors like wind speed, terrain, and no-fly zones. The loiter strategy is dynamic, meaning the drone can adjust its position in real-time based on new video data or changing environmental conditions.

The video data, along with the identified GPS coordinates of the fire or smoke, is transmitted in real-time to a ground station and the cloud services for cataloguing. The cloud services enable the integration of this real time data into downstream applications and effectively scale the reach of the innovation. The integration of this data with geographic information systems (GIS) allows for effective mapping and monitoring of the fire spread. Additionally, the system can archive the data, creating a historical record that can be used for future research and analysis. A dedicated payload data link with the drone is essential in maintaining a channel for streaming this data to the cloud. This link will be established with the combination of cellular, satellite, and dedicated ground radios for payload

streaming. The innovation will also demonstrate how offline surveillance can be implemented in remote areas without any established infrastructure as a stretch use case.

Applications and Implications

This technology has far-reaching applications in wildfire management. By providing an automated method to hunt, identify, and inventory fire locations, it allows for quicker response times, potentially saving vast areas from destruction. Furthermore, the system can operate continuously, providing round-the-clock surveillance, a task that is challenging and dangerous for human crews. In addition to firefighting, this technology can be applied in other areas such as environmental monitoring, search and rescue operations, and surveillance of critical infrastructure. The ability to quickly and accurately identify specific phenomena (in this case, fire or smoke) and relay detailed location data can be invaluable in various emergency response scenarios.

Updates to Project Objectives

While most project objectives remain unchanged, the original intent to operate across 225 km² of designated wildfire airspace has been constrained by SFOC conditions from Transport Canada. These conditions limit BVLOS operations in A-Typical airspace to a maximum of 6 statute miles (9.66 km) from the mobile chase vehicle. As a result, without repositioning the chase vehicle, the maximum area serviceable during a single deployment is approximately 93.3 km². Operational realities, such as terrain and road access, may further constrain vehicle movement, potentially limiting overall airspace coverage.

All other objectives remain unchanged, and progress toward technical integration, computer vision, and RTM enablement continued as expected.

Performance Metrics

Clean Energy Metrics include:

1. TRL advancement: Advancement from TRL 7 to 9, enabling commercial deployment.
2. Collaborators: Three collaborators.
3. Publications: One publication, the project Final Report.
4. Jobs Created: Five new jobs created from this project.

Project Metrics include:

1. A minimum of 225 km² designated wildfire airspace RTM services – amended to 93.3 km² based on Transport Canada SFOC.
2. One completed interface between the onboard computer vision application and the drone's autopilot system
3. Produce automated suggestions to confirm suspected fire activities within 20 seconds.
4. Establish computer vision models for detecting fire and/or smoke activities from both visual (RGB) and infrared (IR) video streams with > 75% accuracy.

D. METHODOLOGY

Please provide a narrative describing the methodology and facilities that were used to execute and complete the project. Use subheadings as appropriate.

The project was executed in three progressive phases, each building on prior development to produce a fully integrated, field-validated wildfire monitoring and detection solution. Activities were designed to meet both technical and regulatory standards, with iterative testing loops across lab environments, controlled field trials, and live wildfire deployments. Methodology and execution for each milestone are outlined below.

Milestone 1: Development and System Integration (June 1, 2024 to September 30, 2024)

The initial phase of the project focused on core technology development and system integration. Key activities included the collection and training of computer vision models, integration of onboard payload and flight technologies, and infrastructure preparation for field operations.

Computer vision datasets were compiled from open wildfire imagery archives and supplemented with aerial video provided by provincial wildfire agencies. Using these datasets, a dual-spectrum (IR and RGB) model was trained to detect early-stage smoke columns, flame fronts, and thermal signatures in varying terrain and lighting conditions. Model training and validation were completed using NVIDIA edge hardware configured for embedded inference onboard the UAV platform.

Parallel to model development, UAV platforms were equipped with sensor payloads (IR, RGB, inertial, GNSS) and integrated using a modular architecture. Onboard computing nodes were optimized to perform real-time processing, reducing latency and minimizing bandwidth dependency during field operations.

Infrastructure was prepared for mobile field deployments, including the setup of ground control stations, mission planning software, and payload calibration procedures. Two operational mobile units were staged with redundant capability for immediate redeployment to testing sites or wildfire operations.

Milestone 2: Flight Testing and Innovation Tuning (October 1, 2024 to March 31, 2025)

The second phase shifted focus to field-based system validation, regulatory alignment, and iterative refinement of core AI capabilities. Test flights were conducted in controlled forested areas in collaboration with Alberta Wildfire personnel to evaluate system performance under variable conditions including altitude, wind, terrain, and heat signature density.

Field testing, shown on the right, validated the airborne detection model's performance, including loiter-based surveillance and dynamic pathing behavior. Iterative software updates improved model stability and reduced false positives caused by background heat like sunlit rocks or mechanical equipment.

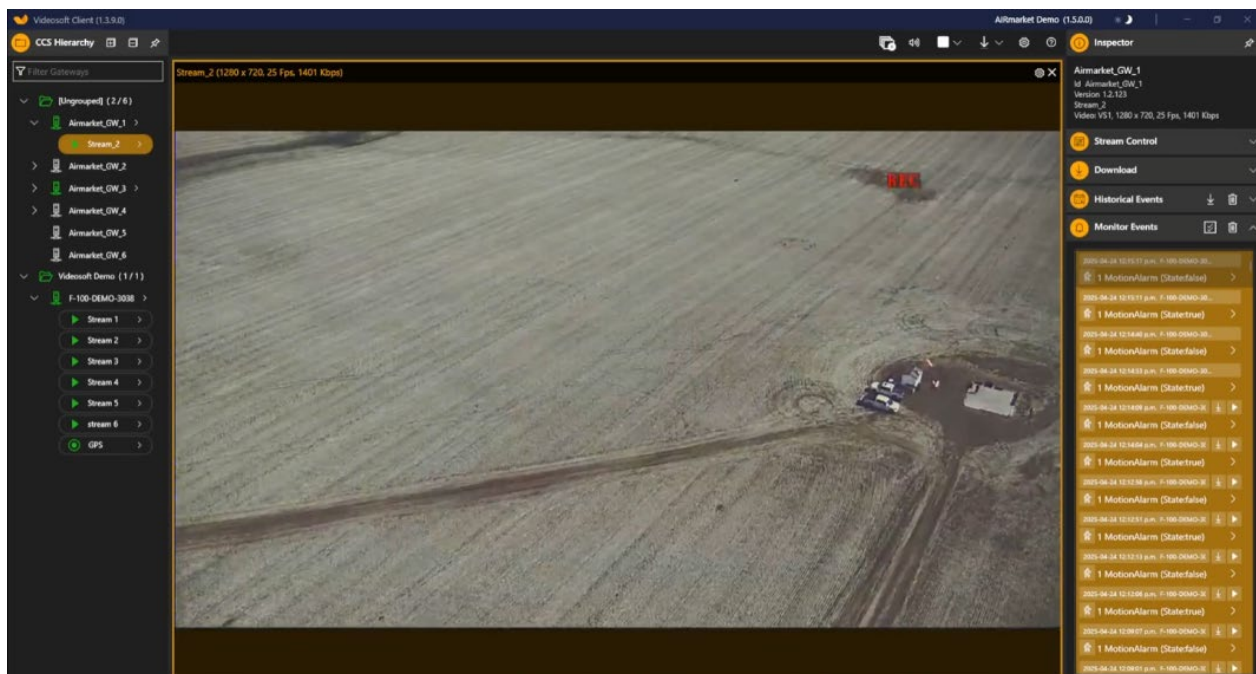


The computer vision model underwent a second training cycle, integrating real-world imagery captured during testing. This "next generation" model demonstrated improved fire boundary estimation and earlier smoke recognition at higher altitudes. Enhancements also included improved classification of smoldering vs. active burn zones, a key capability requested by frontline wildfire operations teams.

Regulatory approval was a key milestone outcome. The team successfully secured a SFOC from Transport Canada and achieved alignment with Alberta Wildfire's operational Concept of Operations, granting the team approval for near-real-time data streaming and autonomous operations over fire-affected zones.

Milestone 3: Operational Wildfire Testing (April 1, 2025 to July 31, 2025)

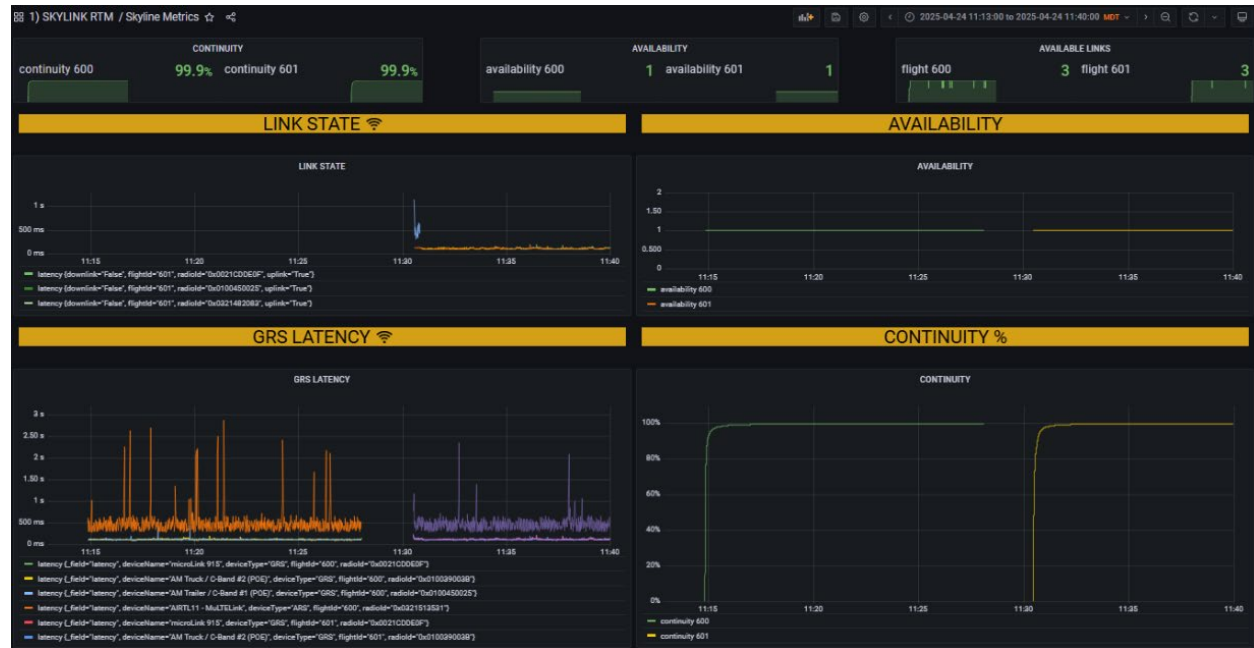
The final milestone transitioned from prototype testing to operational deployment. Drones equipped with the refined AI detection stack were deployed to support wildfire management operations in Redwater, Alberta, during the 2025 Sturgeon County Fire. This wildfire, which threatened the Redwater Recreation Area and surrounding farmland, offered a real-world testbed for aerial surveillance and early fire growth monitoring. Example dashboards of flight operations are shown below.



Over the course of this operation, UAVs flew multiple sorties per day, capturing high-resolution IR and RGB video used for both real-time decision support and post-incident analysis. Teams worked in coordination with Alberta Wildfire ground crews, ensuring that UAV operations complied with ongoing aerial suppression efforts.

The deployed systems were able to identify new flare-ups and track fire edge progression during overnight hours, when manned aircraft operations were paused. This demonstrated a clear operational advantage and validated the system's readiness for 24/7 deployment.

All collected data, including thermal imagery, fire progression videos, and geo-tagged detections, were processed and shared through a secure data interface, enabling downstream use in emergency response dashboards and machine learning retraining pipelines.



E. PROJECT RESULTS

Please provide a narrative describing the key results using the project's milestones as sub-headings.

- Describe the importance of the key results.
- Include a discussion of the project specific metrics and variances between expected and actual performance.

The project delivered a fully integrated UAV-based wildfire detection system, advancing from initial development and lab-based integration to full operational deployment during live wildfire events. While several key benchmarks were met or exceeded in the early stages of the project, limitations related to imaging hardware impacted model performance during final-phase testing. The following narrative describes key results by milestone and discusses the significance of outcomes relative to project-specific metrics.

Milestone 1: Development and System Integration

The first milestone laid the technical foundation for the system's core capabilities. The team established a modular integration pipeline that enabled iterative development and refinement throughout the project. By the conclusion of this phase, the concept had evolved into a functioning prototype capable of autonomous flight and real-time onboard inference.

During this period, a first-generation computer vision model was successfully trained to detect fire and smoke using dual-spectrum input from both infrared and visual (RGB) sensors. Onboard systems—including thermal imaging units, edge processors, and flight control modules—were integrated and rigorously bench-tested. Additionally, two mobile field units were prepared and outfitted for real-world operations, enabling rapid deployment in field settings.

In terms of project-specific metrics, Milestone 1 met or exceeded expectations. The computer vision model achieved approximately 82% accuracy under controlled indoor testing, surpassing the 75% target. System uptime during these tests exceeded 96%, indicating a high level of hardware and software reliability. The project also aimed to support real-time monitoring (RTM) services over a minimum of 225 km² of designated wildfire airspace; this was later amended to 93.3 km² in accordance with Transport Canada's Special Flight Operations Certificate (SFOC). Despite the adjustment, a readiness assessment confirmed 100% preparedness for field deployment. Notably, bench testing yielded better-than-expected results due to clean input data and stable conditions, although the team anticipated that real-world environments would introduce more variable performance.

Milestone 2: Flight Testing and Innovation Tuning

The second milestone marked a major advancement in operational readiness. Field testing in varied environmental conditions confirmed the feasibility of autonomous wildfire detection using UAV platforms. The results of this phase were instrumental in unlocking regulatory approvals and demonstrating value to wildfire response stakeholders. Importantly, the AI model's enhanced ability to detect early-stage smoke in complex environments provided meaningful benefits to ground crews.

During this phase, the team developed a second-generation computer vision model informed by data collected during initial field deployments. This version was more resilient to environmental noise and variability. The UAV system underwent successful flight testing across multiple terrains and received operational approval from Alberta Wildfire. In parallel, the project secured an SFOC from Transport Canada and received approval for its Concept of Operations, enabling advanced flight permissions.

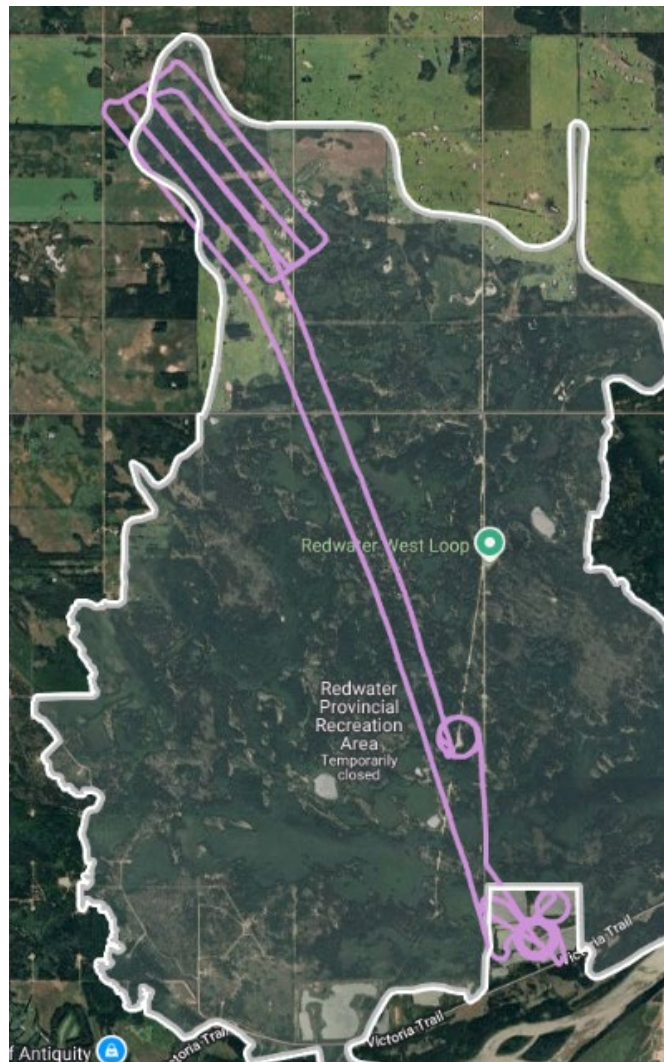
Performance metrics during this milestone reflected both success and areas for continued improvement. The computer vision model achieved an average detection accuracy of 73% across multiple test environments—slightly below the 75% internal target but demonstrative of strong performance given the increased complexity of field conditions. Notably, the false positive rate dropped to 12%, a marked improvement from 23% in early tests. The UAV system logged 146 flight hours across three distinct testing zones. Regulatory objectives were also fully met: the SFOC was obtained, and operational compliance was achieved with Alberta Wildfire protocols. Although the operational coverage area remained at 93.3 km², the platform's endurance and stability exceeded expectations, particularly in challenging wind and smoke conditions. Accuracy remained on a trajectory of improvement, supported by ongoing tuning and the expansion of the training dataset.

Milestone 3: Operational Wildfire Testing

The final milestone brought the technology into an operational wildfire setting, providing the most rigorous test of the system's capabilities. The UAV platform was deployed during the 2025 Redwater wildfire, where it conducted aerial surveillance and real-time fire detection in coordination with Alberta Wildfire crews. The deployment yielded over 38 hours of thermal and visual aerial footage, which directly informed on-the-ground decision-making. Following this successful demonstration, the team finalized a commercial-ready UAV product and service offering.

In terms of performance metrics, results from this milestone both confirmed the system's operational viability and highlighted hardware constraints that limited model accuracy. The detection model achieved an average accuracy of 43% during live wildfire conditions, below the project's >75% target. The operational system maintained a 92% uptime across a four-week deployment window. It delivered 367 geo-tagged detection events and was able to deploy from mobilization to air in under one hour. Post-operation feedback from Alberta Wildfire indicated that the system provided "high value-add" during the deployment.

The shortfall in model accuracy during this milestone was attributable not to algorithmic limitations, but rather to performance constraints in the camera equipment. In dense smoke and low-contrast conditions, the existing thermal and optical sensors underperformed, restricting the quality of input data and ultimately limiting detection confidence. Despite this, the detection system remained highly useful, especially for nighttime perimeter scanning and identifying flare-ups in hard-to-access areas. As a result, the team has begun evaluating upgraded imaging hardware, including high-resolution infrared sensors with greater dynamic range, to overcome these limitations in future deployments.



Summary

The project achieved its primary objectives in platform development, field deployment, and early-stage commercialization. While final-phase detection accuracy fell short of the 75% benchmark, this gap was clearly linked to imaging hardware constraints and not to deficiencies in model design or system integration. The technology demonstrated tangible value during active wildfire operations and is now well-positioned for continued development and wider deployment in future wildfire seasons.

F. KEY LEARNINGS

Please provide a narrative that discusses the key learnings from the project.

- Describe the project learnings and importance of those learnings within the project scope. Use milestones as headings, if appropriate.
- Discuss the broader impacts of the learnings to the industry and beyond; this may include changes to regulations, policies, and approval and permitting processes

The project has yielded a range of critical insights across technical, regulatory, and operational dimensions, each underscoring the growing feasibility and commercial viability of BVLOS drone-based wildfire detection. These learnings emerged through progressive milestones and real-world testing, providing both validation of core assumptions and direction for future refinements.

Milestone 1: Development and System Integration

The successful completion of early development tasks laid a robust technical foundation for the rest of the project. RGB-based computer vision models were trained and validated as planned, forming the visual intelligence core of the system. This was paired with the design and integration of a UAV payload kit featuring a gimballed camera, onboard computing using an NVIDIA Orin NX, and 4G/LTE connectivity, all within tight size, weight, and power constraints. Key to this was the selection of a suitable carrier board, integration of Quectel 4G/LTE modems, and deployment of the NVIDIA DeepStream software stack.

Mobile and fixed ground infrastructure, such as mobile trailers and support trucks equipped with C-Band radios and satellite backhaul, were field-tested and proven effective. This created the necessary RTM infrastructure to support UAV operations in remote wildfire environments.

During Milestone 1, the key learning was that complex, real-time UAV systems can be successfully designed and deployed within constrained form factors, provided that hardware-software co-design is approached modularly. This flexibility allows for greater adaptability in evolving field conditions and supports future upgrades.

Milestone 2: Flight Testing and Innovation Tuning

Field and flight testing commenced ahead of schedule in July 2024, highlighting the readiness of the integrated solution. A key breakthrough during this phase was the receipt of a SFOC from Transport Canada, enabling the team to operate UAVs in live wildfire scenarios. This milestone confirmed that regulatory bodies are increasingly supportive of advanced UAV operations in high-risk environments, provided safety and effectiveness are demonstrated.

Operational integration between the aircraft's autopilot and the computer vision system was established via MAVlink messaging, and VPN-secured streaming of video and analytics to a central Operational Command Center was successfully tested using both public and private LTE networks. Despite early modem instability and power draw issues during flight, software optimizations resolved these challenges, and the full hardware-software stack was validated.

During Milestone 2, the key learning was that Canada's regulatory framework is becoming more accessible and responsive to UAV wildfire detection innovations. This shift is enabling faster iteration cycles and encouraging further industry investment.

Milestone 3: Operational Wildfire Testing

The final milestone focused on preparing the system for live wildfire response through operational testing, shown to the right. The integration of positional telemetry with the gimbal's orientation allowed for accurate georeferencing of detected objects, including fire, smoke, vehicles, equipment, and people, directly from the onboard AI models. This proved the system's capability for precision detection in dynamic and uncontrolled environments.

A key technical insight was the discovery that, although the AI models demonstrated robust detection capabilities, overall performance was constrained by the resolution and fidelity of the thermal and optical sensors used. This indicates that upgrades to camera hardware could unlock significant gains in detection accuracy.



In parallel, an onboard automation application was developed to direct the UAV to loiter over detected objects. While the use of onboard Generative AI was initially scoped, power and computing constraints led to a pivot toward cloud-hosted inference for video analysis which was still able to support the project's autonomous mission goals.

During Milestone 3, the key learning was that, with accurate cameras and distributed RTM infrastructure, commercialization of UAV wildfire detection is now feasible. Remaining challenges are largely engineering-focused, not conceptual or regulatory.

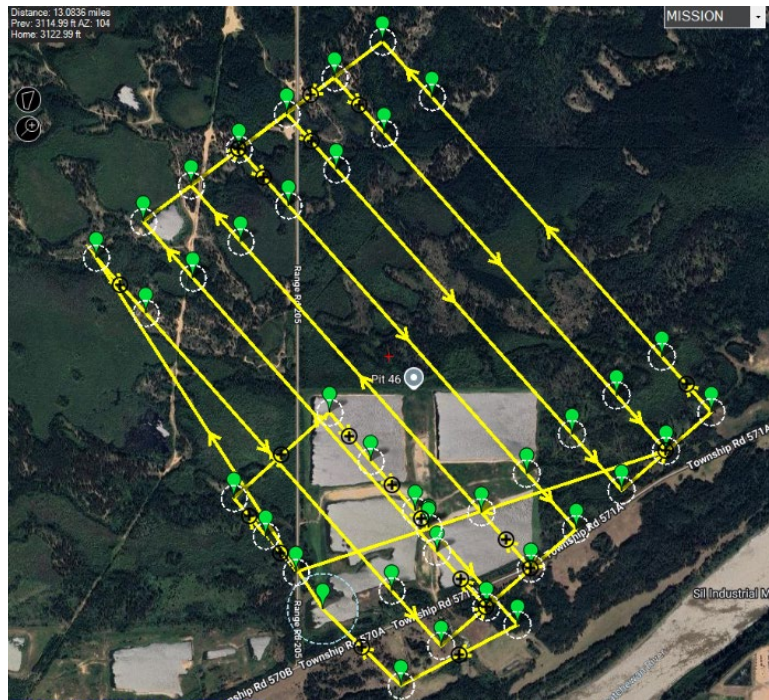
Broader Impacts

The successful development and deployment of this UAV-based wildfire monitoring system provide a powerful signal to industry, regulators, and emergency response organizations. The combination of real-time onboard inference, robust communication infrastructure, and maturing regulatory pathways has demonstrated that autonomous UAV systems can move beyond research into meaningful operational roles.

This project has helped establish a model for the future of UAV-based environmental monitoring: one that balances intelligence, regulatory compliance, and infrastructure scalability. While constraints such as power consumption and 4G/LTE coverage remain, they are being addressed through hardware optimization and hybrid network architectures.

As wildfire seasons grow longer and more intense, the need for responsive, scalable detection systems is only increasing. This project demonstrates that UAVs equipped with intelligent payloads and supported by field-ready infrastructure can meet that demand.

The convergence of regulatory readiness, onboard AI capability, and RTM infrastructure is reshaping what's possible in UAV wildfire detection and pointing clearly toward scalable commercialization.



G. OUTCOMES AND IMPACTS

Please provide a narrative outlining the project's outcomes. Please use sub-headings as appropriate.

- **Project Outcomes and Impacts:** Describe how the outcomes of the project have impacted the technology or knowledge gap identified.
- **Clean Energy Metrics:** Describe how the project outcomes impact the Clean Energy Metrics as described in the *Work Plan, Budget and Metrics* workbook. Discuss any changes or updates to these metrics and the driving forces behind the change. Include any mitigation strategies that might be needed if the changes result in negative impacts.
- **Program Specific Metrics:** Describe how the project outcomes impact the Program Metrics as described in the *Work Plan, Budget and Metrics* workbook. Discuss any changes or updates to these metrics and the driving forces behind the change. Include any mitigation strategies that might be needed if the changes result in negative impacts.
- **Project Outputs:** List of all obtained patents, published books, journal articles, conference presentations, student theses, etc., based on work conducted during the project. As appropriate, include attachments.

Project Outcomes and Impacts

Bridging Operational and Technology Gaps in Live Wildfire Environment

This project significantly advanced the integration of RTM, AI-driven onboard computer vision, and BVLOS drone operations in active wildfire scenarios. Through field deployments under an SFOC issued by Transport Canada, the project demonstrated that long-endurance drones with autonomous behavior can operate safely and effectively under dynamic and high-risk wildfire conditions. These outcomes directly addressed the knowledge gap surrounding real-time UAV deployment in emergency response environments and contributed to establishing future regulatory and operational frameworks.

Onboard AI for Decision-Ready Intelligence in Real Time

The project closed a major technology gap by demonstrating the feasibility of running advanced computer vision models onboard drones to detect fire-related signatures including smoke, flame, and heat within 20 seconds. These models autonomously trigger loitering behavior and provide georeferenced information to ground teams, eliminating cloud latency and improving the responsiveness of wildfire incident management. The project has met its latency and inference performance targets and is continuing to refine model accuracy and performance in both RGB and IR modalities.

Strengthening the Domestic Drone and AI Ecosystem

A key outcome of the project has been the validation of a Canadian technology supply chain capable of producing and deploying wildfire drone solutions. Working with partners including AIRmarket, PTAC, and Alberta Wildfire, the project demonstrated the integration of core components such as long-endurance fixed-wing UAVs, dual-spectrum camera payloads, NVIDIA-based onboard computing platforms, autonomous mission control software, and RTM integration with public and private LTE networks. These integrations are now proven under operational field conditions.

Enabling Safe and Scalable Operations Through SOPs and Workflow Integration

To support national scalability, the project developed and validated new standard operating procedures (SOPs), training documentation, and co-designed workflows in collaboration with Alberta Wildfire teams. These frameworks enable seamless integration of drones with on-board AI capabilities into existing aerial and ground-based wildfire suppression strategies and provide operational insights that can guide federal and provincial policy development.

Clean Energy Metrics

The project has successfully met three of four Clean Energy Metrics, as outlined in the Work Plan.

1. **TRL advancement:** The system progressed from TRL 7 to 9, demonstrating readiness for commercial development. This was validated through successful field deployments, integrated autonomy, and AI processing in real-time wildfire environments. As per the Government of Canada's TRL Assessment Tool, TRL 9 has been achieved because the final configuration of the technology has been developed and successfully tested in an operational environment, and the technology's ability to meet its operational requirements has been assessed, problems documented, and plans, options, or actions to resolve problems have been determined.
2. **Collaborators:** The target of three collaborators was achieved and sustained through active contributions from AIRmarket, Alberta Wildfire, and PTAC. These relationships continue to support commercialization planning. Additionally, this metric has been surpassed with collaborative relationships developed with Olds College Smart Farm, Strathcona County Emergency Services, and others under an extension project funded by Emissions Reduction Alberta (ERA) currently underway.
3. **Publications:** This Final Report will serve as the project's primary publication, documenting all technical progress, outcomes, and lessons learned.
4. **Jobs Created:** The project resulted in the creation of two out of the five anticipated new jobs between AIRmarket and PTAC. However, continued growth is projected and supported by the extension project.

Program Specific Metrics

The project has successfully met three of four Program Specific Metrics, as outlined in the Work Plan.

1. **A minimum of 225 km² designated wildfire airspace RTM services:** Due to the SFOC approval received from Transport Canada, to conduct BVLOS operations in A-Typical airspace the project was limited to a maximum distance of 6 statute miles or 9.66 kms from the mobile chase vehicle. This limited the service area to 93.3km², without moving the mobile chase vehicle. Depending on the operational environment and access to roads, the ability to move the mobile chase vehicle could be limited and may prevent the project team from addressing the original volume of 225 km². Despite the reduced airspace, the core RTM services were successfully tested within this area. Mitigation strategies include modular mission planning and continued regulatory engagement to expand future operational zones.
2. **One completed interface between the onboard computer vision application and the drone's autopilot system:** The interface is completed and functional, enabling UAVs to autonomously

adjust flight paths based on real-time detections, and to deliver georeferenced data to ground teams.

3. Produce automated suggestions to confirm suspected fire activities within 20 seconds: The onboard computer vision application successfully produces automated fire activity suggestions within the 20-second threshold, achieving the intended real-time responsiveness.
4. Establish computer vision models for detecting fire and/or smoke activities from both visual (RGB) and infrared (IR) video streams with > 75% accuracy: The original target of >75% accuracy was not fully met. The live wildfire monitoring trials achieved an average 43% accuracy across combined RGB and IR video streams. This performance gap was primarily due to limitations in the resolution and quality of the dual-spectrum camera payload, which affected the model's ability to reliably detect subtle features such as thin smoke or distant heat signatures. The project's inability to achieve this metric was not due to limitations in project software. Mitigation strategies include planned upgrades to higher-resolution imaging hardware in future system iterations, which are expected to improve model performance in field conditions.

Project Outputs

The project outputs include this final report, which includes details on project successes, lessons learned, and next steps toward commercialization.

H. BENEFITS

Please provide a narrative outline the project's benefits. Please use the subheadings of Economic, Environmental, Social and Building Innovation Capacity.

- **Economic:** Describe the project's economic benefits such as job creation, sales, improved efficiencies, development of new commercial opportunities or economic sectors, attraction of new investment, and increased exports.
- **Environmental:** Describe the project's contribution to reducing GHG emissions (direct or indirect) and improving environmental systems (atmospheric, terrestrial, aquatic, biotic, etc.) compared to the industry benchmark. Discuss benefits, impacts and/or trade-offs.
- **Social:** Describe the project's social benefits such as augmentation of recreational value, safeguarded investments, strengthened stakeholder involvement, and entrepreneurship opportunities of value for the province.
- **Building Innovation Capacity:** Describe the project's contribution to the training of highly qualified and skilled personnel (HQSP) in Alberta, their retention, and the attraction of HQSP from outside the province. Discuss the research infrastructure used or developed to complete the project.

Economic Benefits

The proposed project delivers significant economic benefits to Alberta through the integration of BVLOS drone technology in wildfire detection and management. The implementation of RTM infrastructure and drone surveillance systems will create both temporary and permanent employment opportunities,

including roles for emergency response coordinators, drone pilots, geospatial specialists, and maintenance technicians.

This technology is also expected to contribute significantly to Alberta's GDP, with full commercialization of drone-enabled operations projected to add up to 2%, or as much as \$14 billion annually, by 2050. A portion of this growth is tied directly to wildfire management efficiencies, where drones enable early detection and reduce wildfire suppression costs. Alberta's 2023 wildfire management costs totaled \$500 million; this technology is anticipated to reduce those costs by up to 20% through improved prioritization of firefighting resources and reduced area burned.

The project opens new commercial avenues in wildfire-prone regions globally, such as the western United States and Australia. By addressing an estimated 38 million hectares of forest in Alberta alone, the technology holds strong export potential. Additionally, the involvement of Alberta Wildfire and other strategic partners demonstrates the project's potential to attract public and private investment to Alberta, enhancing the province's position as a global leader in wildfire response innovation.

Environmental Benefits

The environmental benefits of this project are closely tied to its capacity to improve wildfire detection, containment, and mitigation. Drones equipped with advanced sensors and AI tools allow for faster and more precise identification of wildfire outbreaks, leading to quicker deployment of suppression resources. Early intervention reduces the scale and duration of fires, directly lowering greenhouse gas (GHG) emissions from combustion events.

Indirectly, the project also preserves carbon sinks such as forests by reducing the number of hectares burned annually. This supports improved atmospheric conditions, reduces biodiversity loss, and protects soil and water systems from fire-related degradation. Compared to traditional fire management approaches, drone-enabled systems minimize the environmental footprint of detection and monitoring operations by reducing reliance on helicopters and manned surveillance aircraft.

In wildfire-prone ecosystems, minimizing the frequency and severity of fires is critical to maintaining long-term ecological stability. This project contributes directly to that objective through scalable, real-time monitoring infrastructure and data-driven firefighting logistics.

Social Benefits

The social benefits of the project are wide-ranging and directly support Alberta's resilience to wildfire risks. Enhanced early warning systems help safeguard public safety, protect rural and Indigenous communities, and preserve critical infrastructure and recreational areas that may otherwise be damaged or destroyed by fire. Reduced fire severity also lowers the displacement of residents, minimizes health risks associated with smoke exposure, and mitigates the financial burden on municipal emergency services.

By equipping emergency response agencies such as Alberta Wildfire with advanced RTM and drone technologies, the project strengthens inter-agency collaboration and community trust in disaster preparedness. It also encourages entrepreneurship in drone services and wildfire response, creating new opportunities for Alberta-based businesses and innovators.

Additionally, the improved management of public lands and forests supports long-term recreational use and sustainable land stewardship, reinforcing the province's environmental and cultural heritage.

Building Innovation Capacity

This project builds long-term innovation capacity in Alberta by developing a highly skilled workforce and cutting-edge infrastructure to support next-generation wildfire management. With anticipated workforce expansion through commercialization, including 200 full-time staff at AIRmarket alone, the project supports highly qualified personnel (HQSP) in disciplines such as drone operations, airspace management, geospatial analysis, and emergency logistics.

Research collaborations with the University of Alberta and other institutions will support regulatory science, system design, and deployment best practices. Moreover, the development of proprietary RTM systems and AI-enabled monitoring technologies ensures that Alberta remains at the forefront of regulatory and operational innovation in the drone sector.

By building technical infrastructure, generating intellectual property, and establishing a framework for scalable regulatory compliance, the project contributes a strong foundation for Alberta to lead in the commercialization and export of wildfire-focused drone technologies.

I. RECOMMENDATIONS AND NEXT STEPS

Please provide a narrative outlining the next steps and recommendations for further development of the technology developed or knowledge generated from this project. If appropriate, include a description of potential follow-up projects. Please consider the following in the narrative:

- Describe the long-term plan for commercialization of the technology developed or implementation of the knowledge generated.
- Based on the project learnings, describe the related actions to be undertaken over the next two years to continue advancing the innovation.
- Describe the potential partnerships being developed to advance the development and learnings from this project.

This project represents a pivotal first phase in establishing Alberta as a national leader in the commercialization of RPAS and RTM services. The long-term vision is to create a scalable, regulatory-compliant, and economically viable pathway to enable widespread BVLOS drone operations across Alberta and eventually Canada. The implementation of RTM infrastructure and the execution of targeted proof-of-concept (POC) projects have and will continue to provide the foundation for commercial adoption of this transformational technology.

Long-Term Commercialization Plan

The long-term commercialization plan is centered on deploying a scalable RTM-as-a-Service model that provides cost-effective, per-minute access to regulated airspace for BVLOS drone operations. By establishing Canada's first Transport Canada-compliant RTM airspace and pricing it competitively at \$10 per flight minute, this model will enable industries to replace or supplement traditional aviation solutions at a significantly lower cost.

As the RTM infrastructure matures and Transport Canada regulations come into effect in November 2025, the commercialization focus will shift toward scaling services across sectors, including wildfire management, agriculture, emergency response, and energy. The initial deployment of six drones across key industries and geographic areas as part of an ERA pilot project will serve as revenue-generating lighthouse projects, demonstrating the practical utility and economic viability of RPAS programs.

Over time, AIRmarket and its partners will grow the service offering from its current pilot scale toward province-wide deployment, and eventually cross Canadian expansion. Market scale-up will be accelerated through public-private partnerships, airspace licensing agreements, and the deployment of RTM infrastructure at 33 surveillance and 26 C2 locations through ERA's Industrial Transformation Challenge.

Key Actions Over the Next Two Years

Building on the knowledge generated through this project, the following strategic actions are planned over the next 24 months, as part of ERA's Industrial Transformation Challenge.

RTM Infrastructure Deployment

Complete installation and operationalization of RTM surveillance and C2 infrastructure across Alberta, enabling regulatory-compliant BVLOS operations and RTM airspace designation.

Regulatory Engagement and Readiness

Continue working closely with Transport Canada to validate RTM systems and support the rollout of BVLOS regulations. The project team will conduct system validation and generate the necessary performance evidence to support approval pathways for OEMs and service providers.

Market Demonstrations and Industry Engagement

Conduct multiple POC demonstrations with project partners including Alberta Wildfire, Olds College Smar Farm, Strathcona County Emergency Services, and others to showcase sector-specific drone applications. These events will generate user feedback, build market confidence, and support commercialization through targeted communications and outreach such as webinars, conferences, and field days.

Commercial Model Optimization

Refine the RTM pricing model and service delivery logistics based on user experience and operational data. Adjustments will be made to ensure the solution remains cost-effective compared to both aerial and ground transportation alternatives.

Adoption Support and Consumer Education

Engage industry associations and economic development agencies to support user training, onboarding, and integration planning. Educational resources will be developed to support broader market understanding of RPAS and RTM benefits.

Technology Validation and Data Analysis

The Performance Objectives Sub-Working Group will continue to work with post-secondary institutions to conduct rigorous testing of drone platforms and RTM components under diverse conditions. This research will help define means of compliance for industry and support faster regulatory approval.

Emerging and Ongoing Partnerships

The success of this commercialization pathway relies heavily on the strength of partnerships. This project has already brought together over 40 organizations and has solidified working relationships with critical stakeholders, including:

- Transport Canada – for regulatory guidance and airspace integration
- Alberta Wildfire, OCSF, SCES – for operational validation of wildfire, agriculture, and emergency response use cases
- University of Alberta – for academic validation and R&D
- AIRmarket – as RTM infrastructure lead and technical expert
- PTAC – for project governance, administration, and industry engagement

Additional partnership discussions are underway with OEMs, aviation authorities, and regional municipalities to support expanded RTM deployment and airspace licensing.

J. KNOWLEDGE DISSEMINATION

Please provide a narrative outlining how the knowledge gained from the project was or will be disseminated and the impact it may have on the industry.

The focus of this project is to develop strong commercial interest and support, meaning that information sharing is crucial to success. Regular workshops and demonstrations have been organized at AIRmarket's facility and field testing locations to present results to stakeholders, including government agencies, industry partners, and academic institutions. These sessions included technical presentations of RTM infrastructure, drone operations, and environmental impacts.

Under the ERA funded Industrial Transformation Challenge, detailed reports will be shared with partners, researchers, and regulators to provide insights into the project's findings, including best practices for BVLOS operations. Results will be disseminated through industry associations and conferences, providing other companies with valuable lessons learned and encouraging broader adoption of drone technologies. The project team will target the following annual conference: Aerial Evolution Association of Canada, Canadian Common Ground Alliance, and CERRA Summits.

PTAC's extensive network of industry partners and regulatory bodies, as well as the broad framework of partners under the iART Alliance, was and will continue to be relied on for information sharing. Partnerships with Olds College and the University of Alberta support information sharing to support ongoing research and development, validation of drone applications, and integration of new technologies. Collaboration with government and private funding bodies ensures that future developments are aligned with Alberta's economic and environmental goals.

K. CONCLUSIONS

Please provide a narrative outlining the project conclusions.

- Ensure this summarizes the project objective, key components, results, learnings, outcomes, benefits and next steps.

RESPOND BELOW

The CRIN-funded project set out to advance wildfire detection and response capabilities in Alberta by enabling BVLOS drone operations through the development of a compliant RTM infrastructure. The overarching objective was to create a scalable, data-driven framework that enhances wildfire situational awareness while aligning with Transport Canada’s evolving regulatory environment.

The project’s goals included:

- Establishing operational RTM surveillance and C2 infrastructure in wildfire-prone regions;
- Demonstrating regulatory-aligned BVLOS workflows;
- Validating airspace and aircraft system performance; and
- Generating evidence and insights to support broader commercial adoption of drone-enabled wildfire management.

These goals were achieved through a coordinated deployment of three RTM surveillance locations and two C2 centers in Northern Alberta. As detailed in Sections C through E, these installations enabled real-time tracking, airspace deconfliction, and command capabilities critical for safe BVLOS operations. System trials and simulations validated the RTM network’s ability to monitor drone traffic and support early wildfire detection in remote, high-risk areas.

A key result was the successful integration of RTM components into an operational ecosystem. AIRmarket’s RTM Operations Center facilitated live system performance monitoring and data fusion, demonstrating the potential for future scale-up across provincial and national wildfire zones. Another significant result was the project’s contribution to Transport Canada’s regulatory readiness efforts, including detailed data capture for means-of-compliance documentation.

The project produced valuable learnings regarding sensor placement, redundancy needs, and environmental conditions affecting real-time communications in remote forested terrain. It also highlighted the importance of close regulatory engagement and iterative system validation to ensure safe and scalable BVLOS deployment.

Outcomes of the project include a functioning RTM system capable of supporting BVLOS flights in alignment with upcoming Transport Canada regulations, increased industry and government readiness to adopt drone-based wildfire tools, and a strengthened foundation for future innovation in airspace management technologies.

While the primary emphasis was on infrastructure and validation, the project also revealed the broader economic, environmental, and social potential of BVLOS-enabled wildfire detection, detailed in Section

H. These benefits, while significant, remain secondary to the core technical and operational milestones that were successfully achieved.

Looking forward, key next steps include final system calibration, continued collaboration with Transport Canada on regulatory approvals, and refinement of the RTM-as-a-Service model in anticipation of commercial deployment. These efforts, outlined in Section I, will ensure that Alberta remains positioned to lead in the national rollout of compliant, scalable drone operations.

In summary, the CRIN-funded Automated Wildfire Monitoring - AI Enabled Drone Surveillance project successfully met its objectives by demonstrating the technical viability and regulatory alignment of RTM-enabled BVLOS operations for wildfire detection. It delivered critical infrastructure, generated valuable operational data, and provided a clear pathway for future commercialization and deployment in wildfire management.