GRETCHEN WHITMER
GOVERNOR

STATE OF MICHIGAN
DEPARTMENT OF TRANSPORTATION
LANSING

BRADLEY C. WIEFERICH
DIRECTOR

October 24, 2023

Dear Reader:

On behalf of the Michigan Department of Transportation (MDOT) and the Michigan Aeronautics Commission, thank you for taking the time to review the *MDOT Uncrewed Aircraft Systems (UAS) Connected Corridor Feasibility Analysis Final Report*. We appreciate the collaborative approach exhibited by all that came together to assist in the completion of this report.

MDOT believes it remains vitally important that all consumers of this report keep in mind that the landscape around advanced UAS operations is one that continues to evolve as regulatory frameworks mature, technology advances, and public benefit becomes realized. Therefore, while this report reflects the consultant team's understanding at the time of publication, it should not be viewed as the Department's strategy around supporting advanced UAS operations within the State, which will be developed in the coming months.

As the State continues to explore and invest in advanced technology infrastructure, MDOT remains committed to developing and preserving a safe, high-quality, statewide air transportation system that continues to serve and connect people, communities, and the economy through transportation.

Sincerely,

Mike Trout, Director
MDOT Office of Aeronautics
Michigan Aeronautics Commission

AERONAUTICS BUILDING • 2700 PORT LANSING ROAD • LANSING, MICHIGAN 48906
www.michigan.gov/aero • (517) 335-9283

MDOT UAS Connected Corridor Feasibility Analysis Final Report

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Prepared By:

Airspace Link, Inc.
Project Contact: Colby Free
Email: colby.free@airspacelink.com

Prepared For:

Michigan Department of Transportation
Office of Aeronautics

Solicitation Contact: Laura Dotson
Email: Dotsonl2@Michigan.Gov

Contract Administrator: Laura Dotson
Email: Dotsonl2@Michigan.Gov

Project Manager: Linn Smith
Email: SmithlS0@Michigan.Gov

Assistant Project Manager: Alicia Morrison
E-mail: MorrisonA5@Michigan.Gov

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Introduction

Michigan Department of Transportation Office of Aeronautics (MDOT AERO) collaborated with industry experts to conduct an Uncrewed Aerial System (UAS, or “drone”) Connected Corridor Feasibility Analysis in three geographic areas within Michigan, applying industry-specific insights while focusing on Michigan's unique characteristics. The study ultimately supports Michigan's vision of enabling key UAS stakeholders with a repeatable **blueprint** for shared-use digital and physical infrastructure that can be implemented across the state supporting UAS operations at scale.

The recommended infrastructure will provide drone operators the necessary resources needed for operational approval waivers to safely achieve commercialization and ensure the safe adoption of drones. This will generate benefits in line with Michigan's strategic transportation and mobility goals and directly serve the needs of local communities, all while integrating drones safely into the national airspace putting Michigan first in integrating UAS into the state’s robust transportation network.

Michigan and its industry partners have taken an aviation-systems approach to identifying requirements and analyzing current capabilities in order to reach the desired end state of scaled UAS adoption. This report clearly articulates where the state stands in its current capabilities, and how it can utilize emerging best practices from other states who have established similar goals. Ultimately, this report provides a data-driven and rigorously detailed capabilities outlined in the preface (*A State of Michigan Strategy for UAS* Adoption). Additionally, the report outlines the recommended progression through the planning & analysis phase of the Drone Integration Framework while highlighting the feasibility and impact a Drone Infrastructure Corridor would have in the State of Michigan.

Report Objectives

The Drone Corridor Feasibility Analysis is intended to support MDOT AERO in assessing the opportunities, technology, and safety requirements for establishing foundational digital and physical infrastructure to support a range of advanced commercial, civic drone, and future Advanced Air Mobility (AAM) use cases. This analysis will also focus on the community impact and the integration of drones and AAM into the multi-modal transportation network in Michigan. This feasibility analysis’ goals and objectives are to:

1. Identify the highest value areas of opportunity to implement a UAS-connected corridor.
2. Identify and measure the impact a UAS-connected corridor would have in communities in Michigan.
3. Analyze infrastructure and technology needs for the implementation of a UAS-connected corridor.
4. Determine the approach for developing a Federal Aviation Administration (FAA) safety case and for operational approvals and international approvals where required (i.e., cross-border operations).
5. Summarize the program implementation approach.
6. Present the overall design of the system, including the allocation of functional requirements.

7. Identify the main components, including their functions and proposed installed locations.
8. Identify the external interfaces of the system.
9. Present the system development, implementation, and validation approach.
10. Propose the task order breakdown of activities necessary to achieve an operational Drone Corridor.

This Document is the primary contract deliverable for the MDOT Drone Corridor Feasibility Analysis Contract No. 220000000277 and presents preliminary design and implementation information for the purpose of planning future program phases. The feasibility analysis meets the stated project objectives by performing preliminary assessments across key locations of interest in all geographic areas to drive towards the recommendation of specific location(s) of interest, where a more comprehensive technology assessment, capital infrastructure deployment strategy, and safety case plan will be conducted. The main objective of this project is to inform next step decisions to be made by MDOT for follow-on implementation of a Drone Corridor(s).

Approach

The Airspace Link Team's approach to this project focuses primarily on deploying the right infrastructure and services to enable safe Beyond Visual Line of Sight (BVLOS) UAS operations that will meet the requirements for FAA Operational Approvals. Obtaining BVLOS Operational Approvals from the FAA can only be achieved currently in partnership with an approved FAA test site or Partnership for Safety Program (PSP). For this reason, Airspace Link has formed a partnership with the FAA-approved Northern Plains UAS Test Site (NPUASTS) in North Dakota.

Airspace Link, Thales, and NPUASTS were key in designing and building a $28M BVLOS UAS Operational system for the State of North Dakota that is going through final FAA approvals after 18 months of hard work and continuous engagement with the FAA. The Airspace Link Team (hereafter referred to as "the Project Team", see Appendix C) was able to fold in all the lessons learned on the ND project to the Michigan feasibility study project. The Project Team is confident in its ability to obtain BVLOS UAS approvals for initial BVLOS UAS operations in the State of Michigan, since these operations will be conducted against a similar system to the one presented in the ND project.

To optimize costs and maximize return on digital and physical infrastructure investments, the Project Team also evaluated how multiple locations of interest may be served by a centralized UAS Network Operations Center (NOC) configured with secure communications, situational awareness, and monitoring systems. This report provides specific details regarding the benefits of such a NOC.

Preliminary Assessment for Location Determination

Technological, cost, and program management constraints dictated that the Project Team take a geographical areas-approach to establishing UAS adoption. Those constraints, such as the effective range of ground-based communications, navigations, and surveillance infrastructure, and the prohibitive costs of establishing immediate state-wide operating volumes led to the need for prioritization of services and a deep understanding of regional user needs. The MDOT AERO RFP established Areas 1 and 2 around SE Michigan and a cross-border location to be determined with Ontario, Canada, as the defined areas of interest for the establishment of UAS corridors.

The choice of Areas 1 and 2 presented the opportunity for clear and immediate applications of the corridor, such as automotive parts transportation and industry champions and beneficiaries who would be vested stakeholders. The Project Team identified active mobility, electrification, and workforce initiatives abound to leverage momentum and support. Areas 1 and 2 include a large serviceable population, though less densely located than other major metropolitan areas and in the case of UAS adoption, was a major advantage in commercialization, routing for minimized ground risk, and clear user needs for enhanced services. Areas 1 and 2 are also located in a major manufacturing hub, with an unparalleled history of mobility leadership and the workforce to match. Detroit Metropolitan area has, in the past decade, attracted technology start-ups through a combination of responsive policy and affordability. It is, in short, primed for this evolution in transport, services, and mobility.

MDOT AERO left Area 3 as undefined (broadly scoped as the entire landmass of Michigan in the RFP). This gave the Project Team a chance to learn from the initial analysis collected in Areas 1 and 2, and apply it through an analytic framework to ultimately build a data-driven capacity for location selection that would achieve the following:

1. Provide a serviceable market for a proven application of UAS technologies, tapping into existing industry uses and momentum.
2. Provide novel insights into the anticipated impact and return on investment of establishing shared-use UAS infrastructure.

As such, the MDOT UAS Use Case Scorecard was developed. The use cases in SE Michigan centered around manufacturing, public sector agencies, health care, retail and commercial enterprise delivery and logistics operations. In keeping with the second goal of identifying and analyzing novel impact, the Project Team looked for transportation regions within Michigan that would differ from SE Michigan in demographics and use cases, while still meeting the first goal of a serviceable market with understood potential applications of UAS technology. The Project Team collected and funneled use cases from across the state through a use case selection process. The selection process included applying a scoring method that uses qualifying criteria that align with the MDOT 2045 Mobility Plan, MDOT Aviation Systems Plan (MASP), strategic impact criteria and operational criteria. Details of each criterion set are provided in Table 1 and Table 2. Table 1 shows the location criteria as they were identified in the MASP. Table 2 shows an accumulation of several criteria sources, best tailored to reflect the requirements of the Feasibility Analysis. The Project Team documented the equitable, defensible, and data-driven process comparing the impact of use cases relative to alternative applications and then grouping them by region for final selection.

The Traverse City region was determined to most closely meet the goals mentioned above while scoring high marks in supporting the strategic transportation planning goals of the state, and most closely mimicking the successful approach and lessons learned from Areas 1 and 2. Unlike Areas 1 and 2, the use cases for Areas 3 centered on land and maritime public safety and services, package delivery to rural, remote, and seasonally isolated populations, and infrastructure and natural resources management. There were several existing industry applications and potential for applications, such as agriculture/viticulture, coastal search & rescue and maritime operations, environmental and forestry management, inspection, and surveying. The Project Team also identified relevant and interested stakeholders from academia to law enforcement and economic development organizations. Lastly, the Traverse City area has unique assets for enabling aviation technology adoption supported by tangible efforts to attract the high-tech industry business and workforce. These include:

- Traverse City is home to Northwestern Michigan College's (NMC) UAS program - the only Federal Aviation Authority (FAA) UAS Collegiate Training Program in Michigan. NMC's Engineering Technology UAS Degree includes training in electrical systems, hydraulics, robotics, technical and programming design, and GIS. NMC's Aviation Program is an FAA-approved flight training and ground operations school to train pilots and technicians.
- The United States Coast Guard (USGC) Air Station in Traverse City oversees search and rescue operations across the Northern Great Lakes, including all of Lake Michigan and a greater part of Lake Superior and Lake Huron.
- Traverse City is home to Michigan Technological University's Grand Traverse Area Research Center, providing access to advanced MTU Unmanned Aerial Vehicles research and development programs.
- Traverse City's Cherry Capital Airport is the third-largest airport in Michigan in passenger traffic
- Cherry Capital Airport Authority, in partnership with the USGC and the Grand Traverse County Sheriff's Office has hosted emergency disaster training exercises and is supportive of UAS activities and businesses.

Traverse Connect serves to facilitate the key partners, stakeholders, and community buy-in that is needed to streamline the initial research study in the Grand Traverse Region. Traverse Connect will bring new enterprises to the region that are at the forefront of drone commercialization and BVLOS skyway infrastructure, providing them with a test bed for innovations, facilitating key partnerships and introductions, navigating state infrastructure, and assisting with site selection for company offices and headquarters. In short, the Traverse City region has strong attributes representative to Area 3 in addition to fundamental strengths that make it ideal for initiating UAS activity and infrastructure investments.

Table 1: Use Case Evaluation and Identification Methodology, based on the MDOT Aviation Systems

	2045 Mobility	MDOT Aviation Systems Plan					
Objectives	Operations within **Strategic Multimodal Corridors (SMC)**	Serves Population Center	Serves Business Center	Serves Tourism Center	Provides Access to General Population	Serves Isolated (including seasonally) Areas	Enables All Weather Access
Definition	Does the use case exist within or service an SMC (defined as integrated, multimodal system serving the movement of people, services, and goods that are vital to the economy).	Does the use case serve the most densely populated areas of the state (defined by 250 ppl per sq. mile).	Does the use case serve or positively impact businesses in areas of the state with increased business activity (defined employment projections of at least 3,000 by year 2040).	Does the use case serve or exist in ra easonable distance to tourist locations within Michigan (defined by counties with $75 million or more in visitor spending).	Does the use case serve non-business, non-recreational use within Michigan (i.e., law enforcement, healthcare organizations, educational institutions, etc.).	Does the use case serve islands that have year-round residents (Beaver, Bois Blanc, Drummond, Harsens, and Mackinaw Islands).	Does the use case enhance or positively impact all-weather operations and access.

Table 2: Use Case Evaluation and Identification Methodology, Tailored to The Requirements of The Feasibility Analysis

	Proposal Preliminary Criteria					
Objectives	Economic, Community and Environmental Impacts	Existing Air Traffic Infrastructure	Airspace Characteristics and Risk	Ground Infrastructure	Ground Risks	Community Network Coverage and Quality
Definition	What are the economic effects of the implementation & adoption of UAS activity across selected locations. What are the positive environmental impacts.	Does the use case leverage existing communications, surveillance infrastructure or sensor networks.	Does the use case interfere with existing manned/unmanned flight paths, aeronautical imaginary surfaces related to airports, and/or applicable State of Michigan approach plans.	Are there MDOT-owned rights-of-way and existing/planned multi-modal facilities and state-owned airports that may serve as nodes for the use case.	What is the cumulative risk profiles for the use case based on authoritative GIS datasets maintained through direct connections with government agencies.	Is the use case able to leverage existing/planned infrastructure for connected autonomous vehicles (CAV).

Preliminary Analysis Results

Areas 1 and 2 Overview

Figure 1: Geographic Boundaries of Areas 1 and 2

The Project Team collected key demographic, geographic, and economic information about the general study areas to understand their unique attributes and characteristics. This information provided the necessary context to develop use cases that support the area's strengths, provide the most significant benefits, and are transferable to other locations in Michigan that share the same attributes.

Figure 1 shows the first two study areas included in this case study; Areas 1 and 2. The data in Figure 2 and Figure 3 highlights demographic, social, and economic details for the population data relevant to the study within these two study areas.

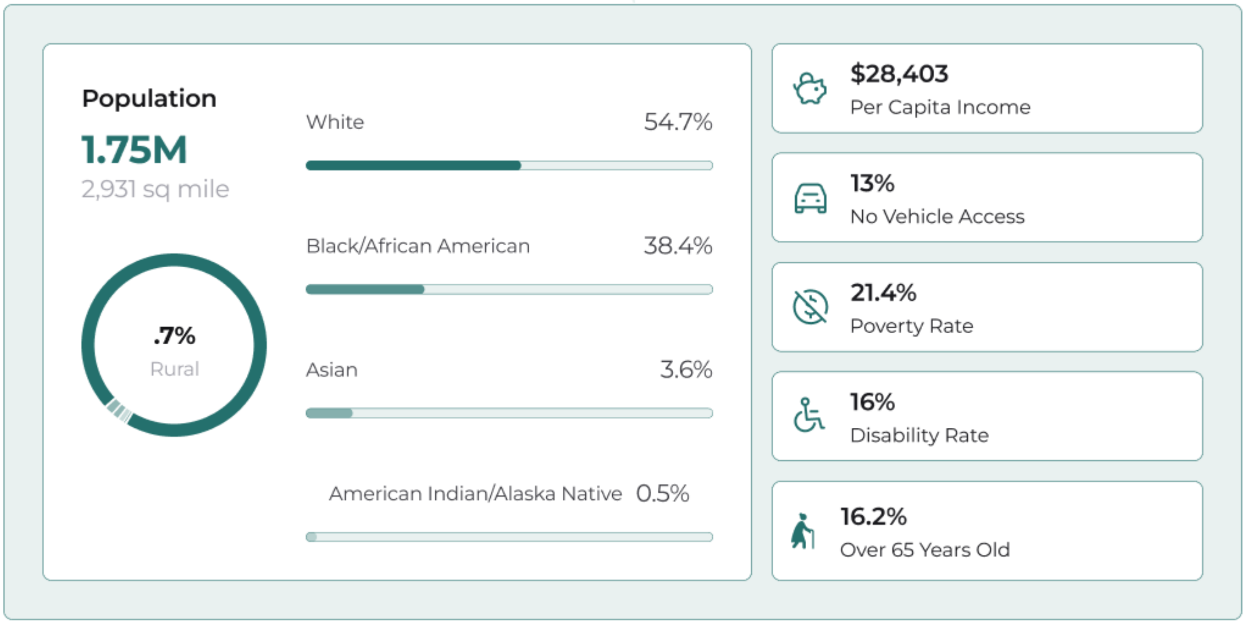


Figure 2: Demographic Overview of Areas 1 and 2

Figure 3: Job Classification in Areas 1 and 2

Stakeholders

Introduction

When scaled, drones will impact people's day to day lives in direct and indirect ways that crewed aviation does not, considering the low-altitude airspace they will occupy. For this reason and countless others, this project depended on early, often and sustained engagement with stakeholders of all manners. How we identified those stakeholders most relevant to the preliminary portion of the study is described below in great detail. The method of communications with those stakeholders varied, including:

1. Email Communications
2. Media and Social Media communications
3. Briefing progress to existing Government and Industry bodies (i.e., the UAS Task Force, and the Council for Future Mobility and Electrification)
4. Hosting multiple UAS Summits, Town Halls and other group conferences that were held hybrid in-person and virtual for accessibility

The Project Team's approach to this portion of the preliminary assessment includes the identification of initial key stakeholders, users, and use cases for the UAS Corridor. Compatible use cases were determined as those that provide immediate and long-term benefits to the communities near the locations of interest in Areas 1 and 2. The Project Team researched a broad spectrum of potential BVLOS drone operational use cases for all areas and narrowed down use case candidates qualified by a best-fit analysis leveraging the attributes and strengths of each area (i.e. economy, geography, demographics, transportation infrastructure, utilities, air and ground risk, etc.).

Methodology

As a part of the UAS Use Case Scorecard approach, the Project Team weighted stakeholders in accordance with Michigan's strategic transportation and mobility goals, as well as lessons learned from preliminary analysis of Areas 1 and 2. In addition, the Project Team considered and weighed stakeholder impact (see Table 3). Stakeholders from existing associations, private/public partnerships (P3), regional or state transportation, and mobility initiatives who would benefit from or be vested in the success of establishing a UAS corridor became factors in the decision-making process. Additionally, the Project Team assessed whether there were industry clusters and/or major national or international employers with headquarters located within the recommended area of operations who would directly benefit from the establishment of shared-use UAS infrastructure. Equally important where the drone-as-a-service operator stakeholders who would ultimately need to be incentivized to establish operations in the prescribed area; as such we conducted market analysis to understand the likelihood for commercialization of services, or at least the ease of transferability of testing capabilities in the area (could assets or IP be lifted/shifted into a similar region or application within the state).

Stakeholder Impact						
Objectives	Leverages **Existing P3 / Associations**	Leverages **Existing Transportation Initiatives**	Proximity to **Corporate HQs**	Proximity to **Industry Clusters**	Operators: Path to Commercialization	Operators: Transferability
Definition	Is the use case of benefit or interest to existing private, public partnerships or related associations.	Is the use case able to leverage funding, expertise, momentum or other capital of existing transportation initiatives.	Is the use case located in proximity to corporate HQs that are of particular significance to Michigan, or a relatively high quantity of corporate HQs.	Does the location of the use case have the potential to impact a known industry sector cluster, i.e., high-tech manufacturing.	Does the use case provide a clear path to commercialization for the operator.	Can the Operator easily transfer assets, experience or qualifications to new use cases/ locations.

Table 3: Stakeholder Impact Evaluation Methodology

Working with the stakeholders provided relevant insights, resources, and information throughout the project. These stakeholders are positioned to facilitate, through direct or collaborative roles as necessary, the process of implementing and leveraging the future drone infrastructure in Michigan.

The Project Team then used the list of qualified use cases to identify a stakeholder registry* creating a list of contacts and contact details (i.e., organization, title, role, area of interest, phone number, email, etc.) that would be used to further socialize and validate use cases that aligned with organization interests and geographic location within the corresponding study areas. The Project Team coordinated events with the MDOT PMO to engage the stakeholders in reviewing the project vision, objectives, approach, and use case.

Stakeholder Registry								
Name	Contact (email/ phone)	Type (Internal/ External)	Org.	Title	Role	Influence (H,M,L)	Area (1,2,3)	Comms Cadence

Table 4: Stakeholder Registry

The Project Team also connected with its drone partner ecosystem and compiled an operator registry to identify qualified drone service providers within the United States that are well-positioned to support the use cases identified in the use case selection process. Information gathered on the service providers includes but is not limited to company name, market focus, headquarters location, regulatory certifications, customer partnerships, location of current test sites and operation sites, and more. This information was used to further qualify all use cases through the identification and validation of service availability for each ensuring that if MDOT should invest in UAS infrastructure in support of the preliminary use cases existing operators would be immediately available and incentivized to leverage the infrastructure.

UAS Operator Registry (excerpt)							
Company	Industry Role	Operator/ Airline Partnerships	Commercial Partnerships	Regulatory Certifications	Public Ticker	HQ Location (City)	...

Table 5: UAS Operator Registry (excerpt)

Lastly, the Project Team sought to understand the true user needs of the community through a partnership with local engagement organizations, as the community would ultimately accept and adopt the capability or see it as an infringement or worse. This community acceptance criteria are factored in heavily in the Impact Analysis section, pages 45-51, and Appendix D.

Once the initial set of use cases was identified, the Project Team applied a use case selection process to narrow down the candidates even further, applying a scoring method that uses the same qualifying criteria from Areas 3, that of aligning with the MDOT 2045 Mobility Plan and MDOT Aviation Systems Plan, Strategic Impact Criteria and Operational Criteria. For more, see Table 1: Use Case Evaluation and Identification Methodology, based on the MDOT Aviation Systems.

	2045 Mobility	MDOT Aviation Systems Plan					
Objectives	Operations within **Strategic Multimodal Corridors (SMC)**	Serves Population Center	Serves Business Center	Serves Tourism Center	Provides Access to General Population	Serves Isolated (including seasonally) Areas	Enables All Weather Access
Definition	Does the use case exist within or service an SMC (defined as integrated, multimodal system serving the movement of people, services, and goods that are vital to the economy).	Does the use case serve the most densely populated areas of the state (defined by 250 ppl per sq. mile).	Does the use case serve or positively impact businesses in areas of the state with increased business activity (defined employment projections of at least 3,000 by year 2040).	Does the use case serve or exist in ra easonable distance to tourist locations within Michigan (defined by counties with $75 million or more in visitor spending).	Does the use case serve non-business, non-recreational use within Michigan (i.e., law enforcement, healthcare organizations, educational institutions, etc.).	Does the use case serve islands that have year-round residents (Beaver, Bois Blanc, Drummond, Harsens, and Mackinaw Islands).	Does the use case enhance or positively impact all-weather operations and access.

Table 6: Use Case Evaluation and Identification Methodology, based on the MDOT Aviation Systems

Findings

After a preliminary analysis of the opportunities in Areas 1 and 2, it became clear that the use cases would be associated with public sector agencies, healthcare, retail and commercial enterprise delivery, and logistics operations that are expected to drive high value in terms of economics, public health and safety, social benefits, improved operational efficiencies, and sustainability. Use case examples that aligned to MDOT and Michigan's strategic goals included package delivery across international borders, servicing historically disadvantaged communities, increasing supply chain resilience in major manufacturing hubs, as well as multimodal opportunities.

The Project Team then used the list of qualified use cases to identify stakeholders that would be leveraged to further socialize and validate the uses cases that aligned with their organizational interests and geographic location within the corresponding study areas. The Project Team coordinated events along with the MDOT PMO to engage the stakeholders reviewing the project vision, objectives, approach and use case details with the stakeholders. Examples of initially identified stakeholders include but are not limited to those shown in Figure 4.

Figure 4: Potential Stakeholders of a UAS Corridor in Michigan (Areas 1 and 2)

Use Cases

Overview

A critical and novel aspect of the blueprint is in the detailed, repeatable, and defensible process for determining a designated area or drone corridor location with the highest return on investment. To do so, the team identified use cases that would jump-start drone operations and provide immediate and long-term benefits to the communities within Areas 1 and 2. This was done by researching and recording a broad spectrum of potential BVLOS drone use case candidates, then down-selecting the candidates via a best-fit analysis leveraging the attributes and strengths of each geographic area.

MDOT Aviations System Plan Criteria
Serves Population Center
Serves Business Center
Serves Tourism Center
Serves Isolated (including seasonal) Areas
Enables All Weather Access
Provides Access to General Population
Strategic Impact Criteria
Leverages Existing P3 / Associations
Leverages Existing Transportation Initiatives
Proximity to Corporate HQs
Proximity to Industry Clusters
Operators: Path to Commercialization
Operators: Transferability
Economic, Community, and Environmental Impacts
Drone Operational Criteria
Existing Air Traffic Infrastructure
Airspace Characteristics & Risk
Land Use and Zoning
Ground Risk
Communications Infrastructure
Population Characteristics
Operator & Technology Maturity
Laws, Rules, and Regulations

Figure 5: Criteria Used to Determine Use Case Viability

The major potential benefits of all use cases were identified, providing the information necessary to align use cases with community interests and the prospective outcome of the use cases. The Project Team then down-selected the candidates further with a scoring method that uses qualifying criteria in alignment with the MDOT 2045 Mobility Plan, MDOT Aviation System Plan, Strategic Impact Criteria, and Drone Operational Criteria.

One novel insight that emerged was the outsized value of selecting a single, champion use case to initiate planning and momentum around. This is perhaps antithetical to the accepted logic behind investing in shared-use emerging infrastructure, the colloquial “build it and they will come” approach. While the investment in public-use infrastructure must be able to service a wide variety of known and to-be-discovered uses, the Project Team discovered it was critical to select and socialize an initial use case that met all the scoring criteria, had strong, vested stakeholders and a clear business/community need that would be addressed to produce performance metrics. Taking the alternative approach often led to unclear requirements, lack of interest or stakeholder investment, and could stall or delay the momentum critical to being an-early adopter.

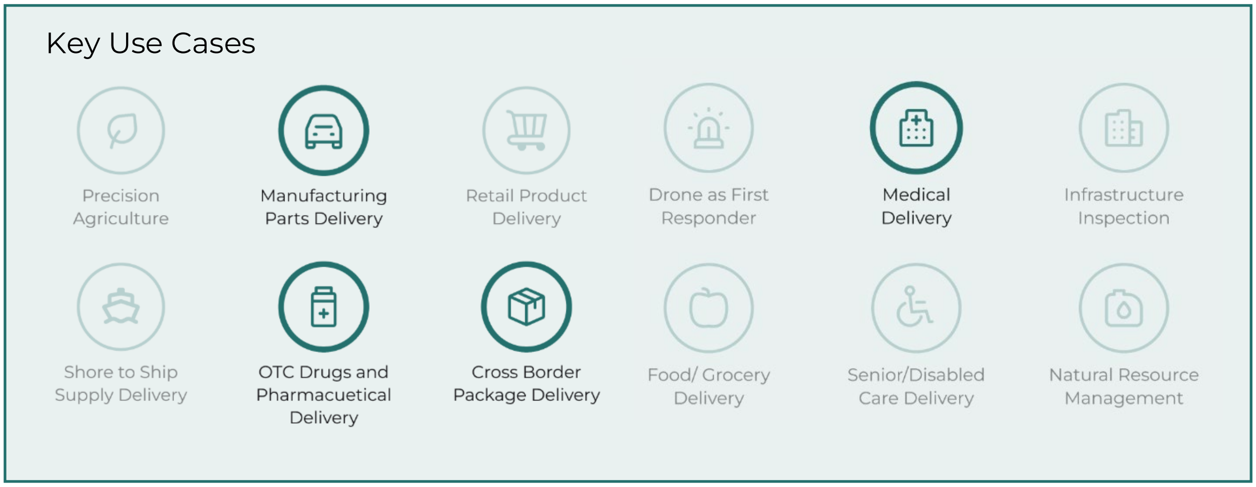


Figure 6: Identified Key UAS Use Cases

Figure 7: Identified Benefits of Key UAS Use Cases

Risk

Air Risk

Introduction

As the regulator of the US Airspace and manager of the National Airspace System, the FAA is accountable to the public and aviation stakeholders to ensure the USA has the safest, most efficient aerospace system in the world. This mission and mandate require the FAA to ensure that any new addition to the National Airspace System does not present an unacceptable risk to the public or other airspace users. The risk exposure for the latter is what airspace awareness is meant to address. Airspace awareness, which is comprised of all air traffic and the operational environment, is based upon the notion that non-cooperative surveillance is required to detect crewed aviation that may intrude on the planned UAS flight volumes. This enables airspace awareness for relevant stakeholders and supports an appropriate risk/threat mitigation timeline. In the mid/long-term, it is expected that on-board Detect and Avoid (DAA) capabilities will contribute substantially to requirements for UAS to stay well clear of other airspace users and to enable mitigation actions in cases of potential or expected conflicts.

Long term, DAA will provide the main tactical mitigation to the risk of reduced separation events with crewed aircraft or any other obstacle. However, in the shorter term, ground-based surveillance will continue to play a critical role in this safety function. Even once-reliable DAA capabilities are available, we must assume that it will only contribute to tactical safety management as small UAS will not have the power nor payload capability to carry DAA that will perform reliably beyond 1-2 miles. It's important to note that not all UAS will carry airborne surveillance or on-board DAA systems. Thus, ground-based surveillance will still serve as a critical input to the DAA function for small UAS that cannot carry airborne surveillance. This assessment described herein validates the significance of ground-based non-cooperative surveillance infrastructure to facilitate airspace awareness and associated services.

Methodology of Airspace Characterization

The approach to characterizing airspace and estimating its associated air risks for Areas 1 and 2 leveraged the Project Team's existing quantitative analysis and visualization capabilities. These capabilities provided a standardized and repeatable process to help identify areas of increased air risk for proposed operations in low-altitude airspace (<1,200' Above Ground Level (AGL)). Thales' Digital Aviation Integration Platform (DAIP) is the tool used to support the analysis and visualization capabilities. The output of the aforementioned platform provides historical traffic density and actual track counts of cooperative traffic at specific altitudes. Collecting, processing, and visualizing cooperative traffic provides only a partial view of the total airspace picture but is still highly relevant to evaluating air risks. To complement the cooperative traffic view, the deployment of primary sensors to detect non-cooperative targets when there are no Terminal Radar Approach Control Facilities (TRACON) or terminal radar data available can help provide a more complete air traffic picture and overall situational awareness to end-users.

To evaluate air risk, airspace metrics were used specifically to estimate the likelihood of a reduced separation event between uncrewed and crewed aircraft[1]. These violations or events are just one of the main factors in computing the UAS operation's air risk. Metrics were computed using the following sources:

- FAA System-Wide Information Management (SWIM) system track data from Air Route Traffic Control Centers (ARTCCs) and/or Terminal systems
  - Track data from ARTCCs are attained from the FAA's SWIM Flight Data Publication Service (SFDPS)
  - Track data from Terminal systems are attained from the FAA's SWIM Terminal Automation Information Service (TAIS)
- FAA Radar
- MDOT ground surveillance sensors

Airspace metrics include:

- Traffic density/count (by altitude and time of the day)
- Unmitigated background potential reduced separation events per hour(s) of flight (by altitude and time of the day)

When no historically significant set of Uncrewed Aircraft (UA) trajectories was available, a more generic method was used to characterize the unmitigated air risk associated with a specific airspace volume. The airspace volume under analysis was mapped using a mesh of H3 cells (hexagon) and using historical recorded crewed aviation traffic, to compute the number of reduced separation events assuming a UAV is stationary at the center of each cell and a "hockey-puck" volume. The result, in terms of number of events per unit of time, in the form of a graphical map can help plan the mission to avoid "hot spots" and therefore minimize the risk of a reduced separation event between an uncrewed and crew aircraft.

The figure below is a computed example around Areas 1 and 2 using only SWIM terminal radar data. The method requires availability of significant recording of crewed aviation in the airspace. The air risk model can be complemented by using MDOT ground surveillance infrastructure.

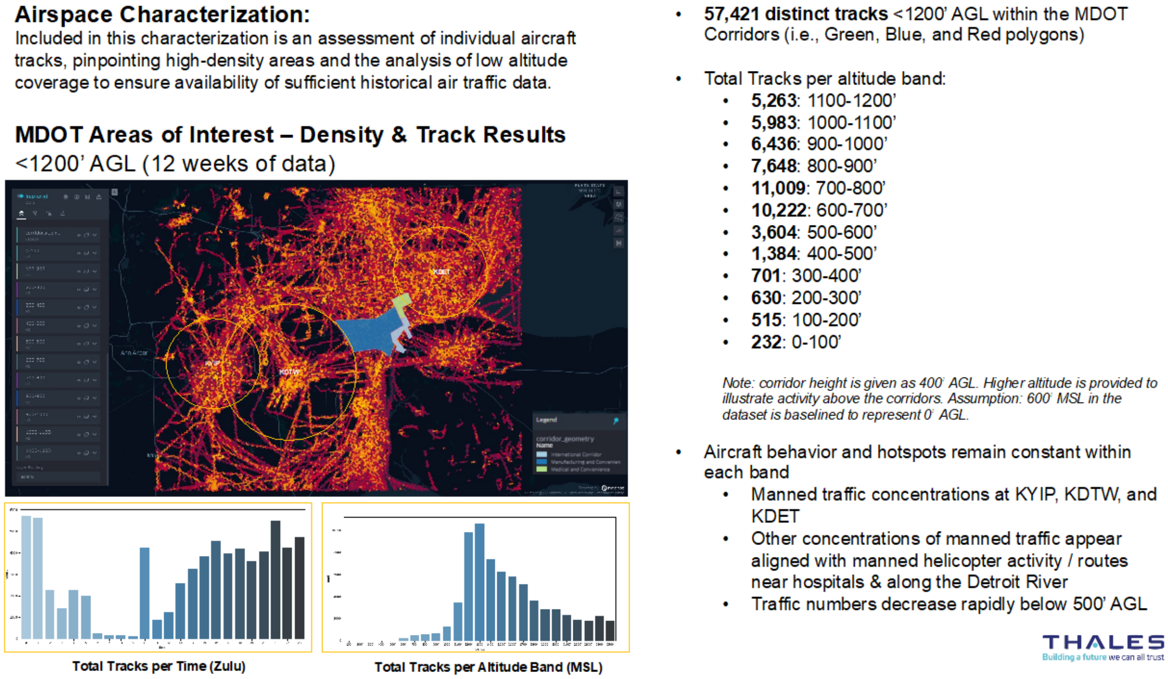


Figure 8: Airspace Characterization using Historical Track Data

The characterization of airspace is one component of the overall Operational Risk Assessment (ORA). The other components comprise of assessing ground risks and how well the area (i.e., service volume) can be covered by surveillance sensors and Command and Control (C2) capabilities. Figure 9 illustrates this holistic approach to assessing not just the operational risks, but also the infrastructure analysis necessary for this feasibility study.

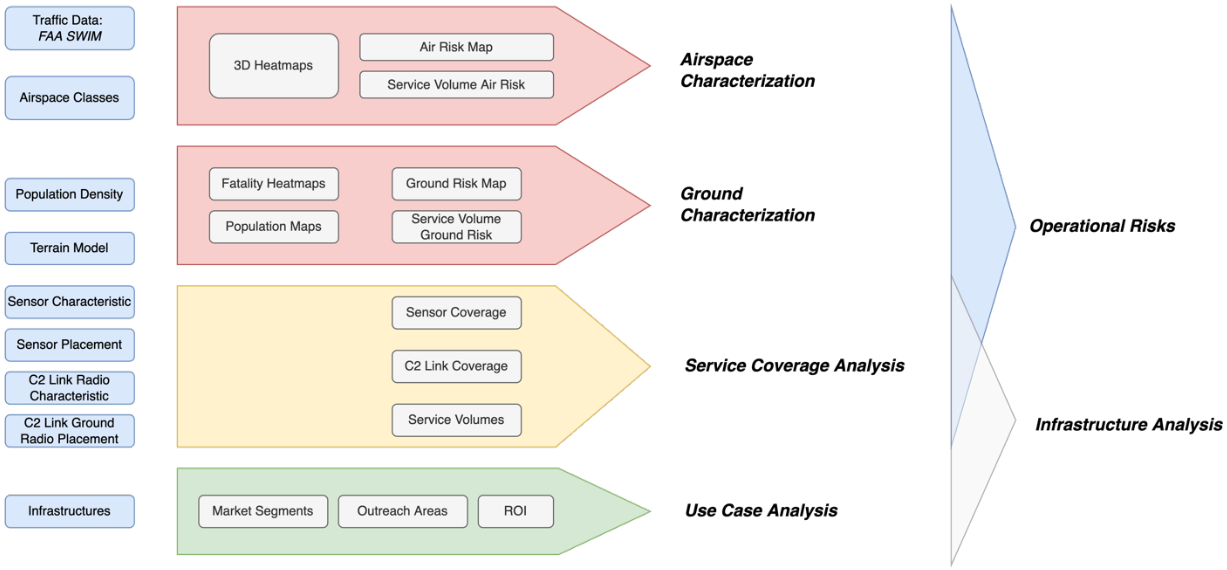


Figure 9: Airspace Characterization Process as Part of the Overall Operational Risks and Infrastructure Analysis Process

In general, this repeatable process can be applied not just to the defined corridor boundaries provided by MDOT, but to any region in the National Airspace (NAS). The corridor boundaries are defined here as the MDOT Service Volumes (MSV) within the overall MDOT Areas of interest (Areas 1,2, and 3). MDOT Service Volumes are generally described as the areas where both surveillance and command and control (C2) performance requirements are met. The MDOT Service Volumes are a subset, or the union, of where C2 coverage and surveillance volumes overlap. From the MDOT Service Volumes, surveillance sensor and communications network infrastructure are assessed for coverage and availability.

The following separate analyses were conducted to provide the airspace characterization and service coverage picture:

- **Airspace Characterization**: Use of surveillance data to allow for the estimation of air risk. For the purposes of this project, low altitude is defined here as navigable airspace less than 1,200 feet GL. Airspace characterization analyses used this height as the upper threshold to bound the surveillance data.
- **Radar Coverage Analysis**: Analyzes the line-of-sight capability of the surrounding radar sites to inform the completeness of the surveillance data.

Computing air traffic density becomes a method to which air risk can be estimated. With this relationship, the computed air traffic density represents the most conservative view of the airspace picture and ultimately presents the unmitigated air risks for a defined airspace volume since aircraft tracks, in this context, are seen as intruders within the service volume.

Preparing the Dataset

The air traffic density analysis examined historical cooperative traffic from 1,200 feet AGL to the surface in the service volume from the period of June 2021 – August 2021. The June through August months were chosen as they represent a period of **peak traffic** activity around the Detroit metropolitan area during the calendar year. This same period was then used for the airspace characterization analysis in Area 3. Processing peak traffic is important as it provides a dataset that best represents the densest crewed traffic activity for a specific region and time period. To justify the period corresponding to peak traffic activity, the following FAA databases were used:

- Aviation System Performance Metrics (ASPM)
- Terminal Area Forecast (TAF)

The ASPM online access system provides data on Instrument Flight Rules (IFR) and Visual Flight Rules (VFR) flights to and from the airports covered under ASPM (including the Core 30 and OEP 35 airports, which serve major metropolitan areas and serve as hubs for airline operations), and all flights by ASPM carriers, including flights by those carriers to international and domestic non-ASPM airports. From the FAA's ASPM database, the Metric Module was used to collect information on aircraft departure and arrival times and flight delays at selected airports compared to the schedule and flight plan times. For the purposes of this project, Detroit Metro Wayne County (KDTW), Coleman Young Municipal (KDET), and Willow Run (KYIP) airports were selected. Due to availability of the metrics per airport, the only metrics considered in this report are those of KDTW.

The FAA's TAF database is the official FAA forecast of aviation activity for U.S. airports. It contains active airports in the National Plan of Integrated Airport Systems (NPIAS) including FAA towered airports, federal contract towered airports, non-federal towered airports, and non-towered airports. Forecasts are prepared for major users of the NAS including air carrier, air taxi/commuter, general aviation (GA), and the military. For the purposes of this project, the Calendar Year 2021 TAF Report was used to collect counts of GA traffic since the ASPM system does not collect GA traffic counts.

From the ASPM database, peak flight operations and activity, along with GA counts for calendar year 2021, binned by hour (Local time), are depicted in the tables below. The red dashed outline around the total flight operations during months 6 (June) through 8 (August) highlight the peak activity.

Table 7: Number of Departures per Hour per Month at DTW Airport

Sum of Departures for Metric Computation

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	8	21	29	32	20	29	5	26	20	20	21	28
1	4	6	9	2	3	3	4	2	2	5	4	4
2	3	5	1	1	1	4	2	4	0	3	1	4
3	0	4	4	2	2	4	1	1	11	15	12	4
4	4	6	5	0	1	2	2	1	3	2	4	14
5	7	5	3	5	2	23	87	92	100	58	80	78
6	217	203	398	448	405	433	436	443	367	404	501	531
7	265	248	299	298	375	552	694	751	637	737	818	809
8	1198	1147	1328	1358	1561	1654	1676	1594	1640	1579	1579	1613
9	472	398	412	402	422	369	314	327	301	304	145	197
10	1323	1281	1560	1486	1546	1425	1500	1502	1322	1348	1285	1187
11	141	69	120	218	267	230	212	214	196	255	220	170
12	770	659	777	836	1046	1107	1105	1158	1249	1150	1107	1037
13	206	230	328	224	201	409	574	552	531	567	523	510
14	602	503	680	714	674	683	701	573	534	588	593	531
15	828	716	601	669	641	667	584	692	655	643	707	694
16	1029	864	1230	1278	1430	1284	1473	1402	1367	1318	1207	1190
17	212	214	263	229	242	371	366	376	407	534	466	411
18	136	112	209	210	214	436	465	464	497	593	653	579
19	598	410	496	647	586	272	212	173	156	148	156	225
20	818	734	995	720	734	864	981	881	823	835	710	676
21	852	790	986	1105	1258	1350	1066	1015	920	795	782	948
22	118	101	152	120	109	339	604	654	691	737	661	647
23	39	31	35	37	32	60	55	40	59	59	139	91
Grand Total	**9850**	**8757**	**10920**	**11041**	**11772**	**12570**	**13119**	**12937**	**12488**	**12697**	**12374**	**12178**

Table 8: Number of Arrivals per Hour per Month in DTW Airport

Sum of Arrivals for Metric Computation

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
40	13	94	126	197	191	225	215	152	166	186	201
9	7	6	6	18	11	20	16	5	1	15	20
6	8	5	2	5	2	3	2	15	19	12	7
1	3	5	2	2	2	2	2	2	5	7	21
14	10	32	32	27	46	45	33	46	32	18	16
148	116	193	192	169	252	227	226	157	177	194	204
91	76	77	81	150	228	321	284	297	312	277	235
801	898	1127	1074	1165	1069	1156	1201	1115	1072	1071	1099
588	412	342	332	304	427	404	307	245	212	200	225
592	442	719	726	734	929	890	874	877	868	819	679
206	184	175	239	379	322	307	317	294	356	260	227
607	476	685	780	839	826	993	1064	1161	1178	1120	1029
318	394	515	461	399	548	557	512	502	500	531	528
720	585	709	757	774	716	854	818	667	630	590	579
937	929	884	887	942	857	852	1086	966	953	942	834
823	684	971	990	1050	1071	1191	1024	1099	1110	1003	1131
199	209	293	243	263	389	419	474	479	514	512	500
557	409	472	586	553	675	682	623	624	682	701	680
720	659	816	720	833	562	470	306	314	390	440	446
1253	1090	1145	1072	1124	1238	1398	1419	1383	1433	1257	1241
678	628	902	942	895	1118	1030	1128	1005	948	873	1010
177	142	185	211	223	379	409	438	470	534	453	342
235	228	235	284	222	354	336	231	305	312	574	606
131	140	292	288	463	318	336	342	283	274	307	295
9851	**8742**	**10879**	**11033**	**11730**	**12530**	**13127**	**12942**	**12463**	**12678**	**12362**	**12155**

Table 9: Total Number of Departures and Arrivals per Month at DTW Airport

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total Departures	**9850**	**8757**	**10920**	**11041**	**11772**	**12570**	**13119**	**12937**	**12488**	**12697**	**12374**	**12178**
Total Arrivals	**9851**	**8742**	**10879**	**11033**	**11730**	**12530**	**13127**	**12942**	**12463**	**12678**	**12362**	**12155**
Grand Total	19701	17499	21799	22074	23502	25100	26246	25879	24951	25375	24736	24333

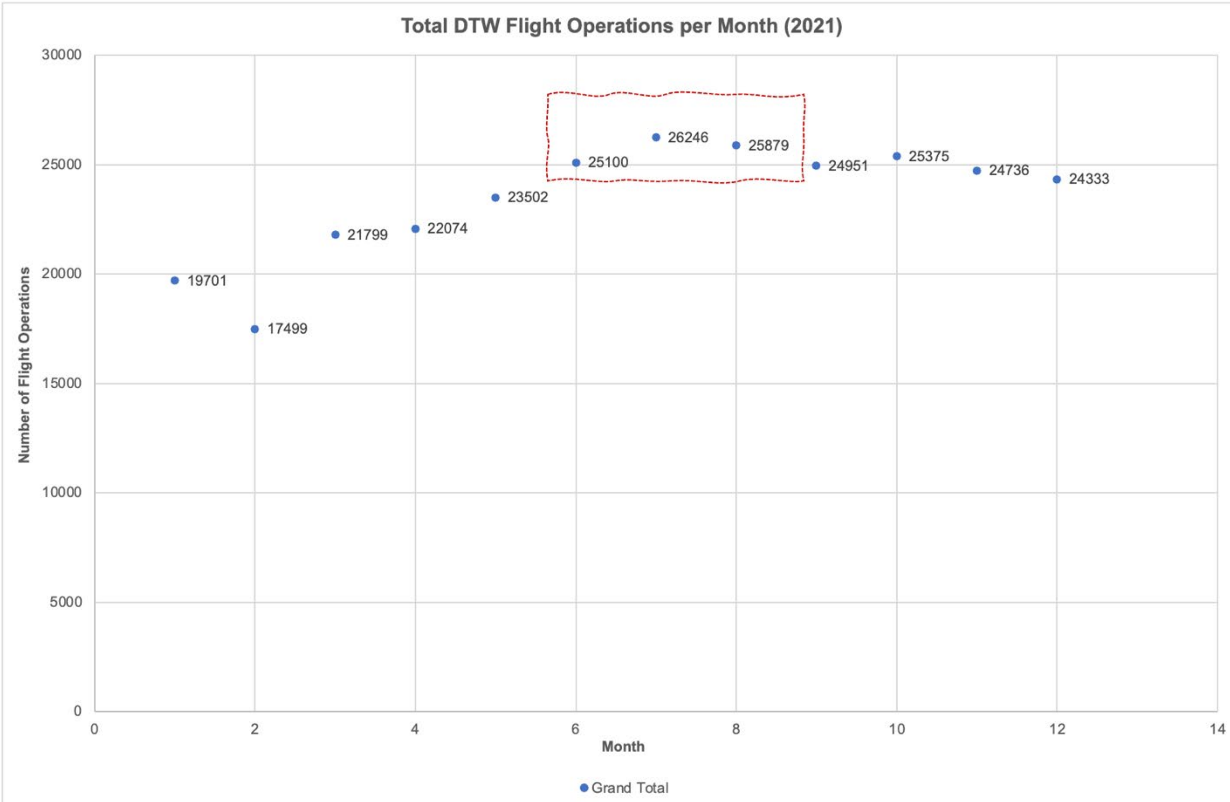


Figure 10: Peak Number of DTW Flight Operations in 2021

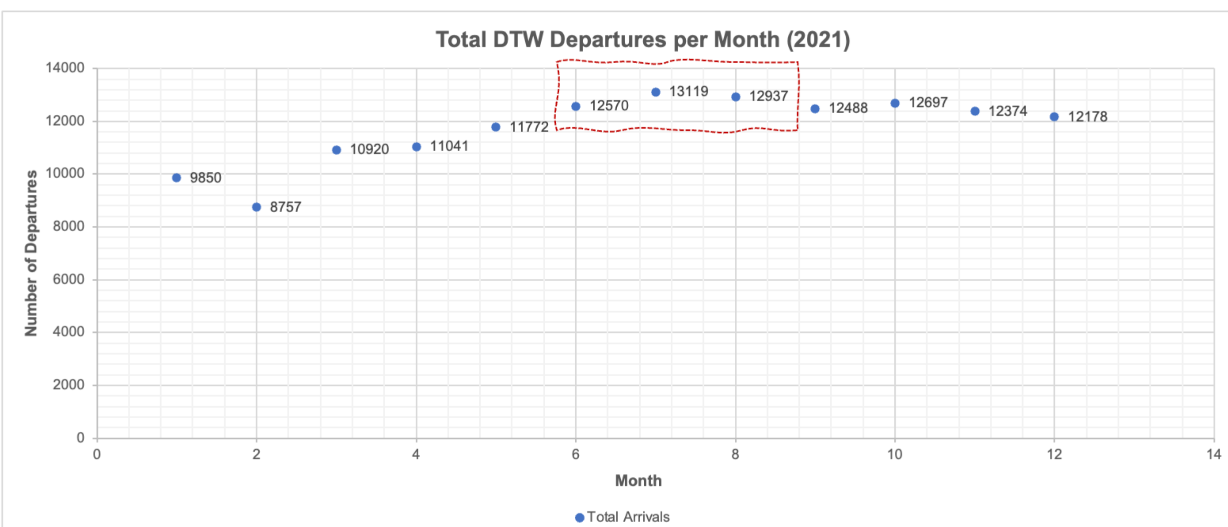


Figure 11: Peak Number of DTW Departures in 2021

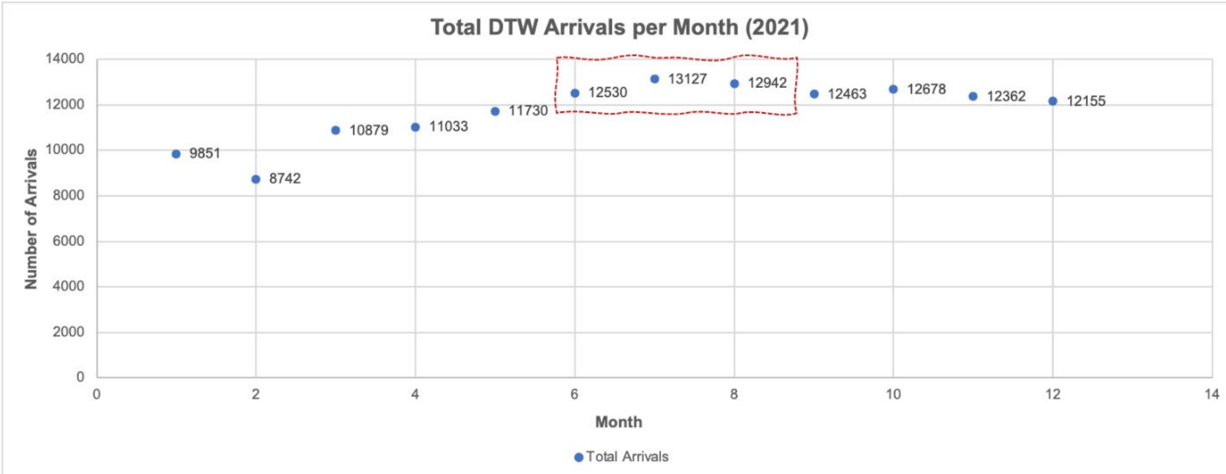


Figure 12: Peak Number of DTW Arrivals in 2021

APORT_NAME	Sum of LOC_GA	Sum of ATN_GA
Detroit City	21781	22961
Detroit Metro Wayne Co	0	4245
Detroit Willow Run	23542	21105
Grand Total	**45323**	**48311**

Table 10: Summary of General Aviation Traffic of Local Airports

Analysis Components - Data Quality

With the peak activity timeframe identified and justified, collection of all traffic data for the regions of interest was achieved using the DAIP. To ensure the quality of the analysis, the authoritative sources of air traffic data originated from the FAA; specifically, the FAA's System-Wide Information Management (SWIM) network. Thales has been onboarded with the FAA as an official industry SWIM services consumer and has met all security and performance requirements required by the SWIM program office to consume all available data topics via the NAS Enterprise Messaging Service (NEMS). As such, and for the purposes of this task, all cooperative crewed surveillance track and position data (i.e., track reports) in terminal airspace were sourced from the SWIM Terminal Data Distribution System's (STDDS) Terminal Automation Information Service (TAIS).

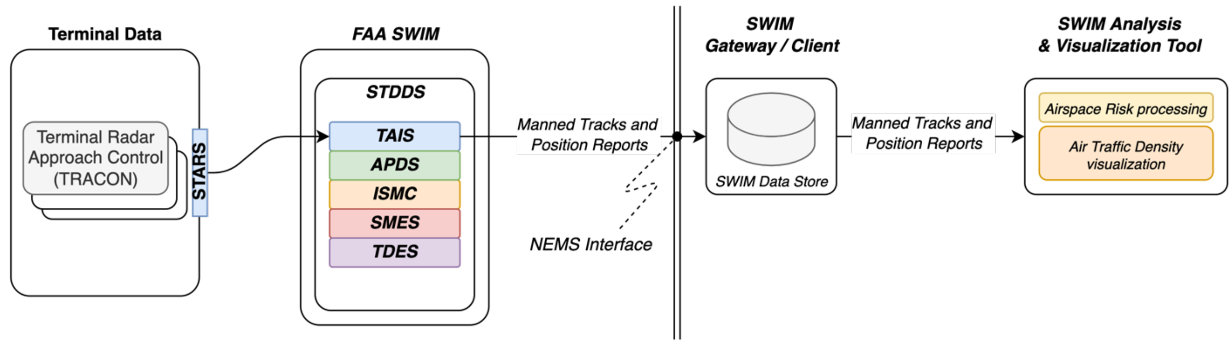


Figure 13: SWIM Data Information Flow[2]

Figure 13 shows that terminal data originating from TRACON facilities were made available to the SWIM service via the Standard Terminal Automation Replacement System (STARS) interface, from which the TAIS service publishes operational live flight plan data, track data, sign-in/sign-out (SISO) data, alert data, Instrumental Meteorological Conditions (IMC) data, traffic count data, and performance monitoring data to authorized SWIM service consumers via NEMS. From the NEMS interface, the Thales SWIM Gateway consumes and logs all available information. The use of the Digital Aviation Integration Platform allows an end-user (e.g., data analyst) to query the Air Traffic Management (ATM)-authoritative track report data to process target reports for a given geographical area, where visualization capabilities of the tool can output histograms of track counts, all binned by altitude band (in hundreds of feet), or hourly time slice. Air traffic densities and track information can also be overlaid onto a geographical map, or a Visual Flight Rules (VFR) aeronautical chart. For this study, it is important to note that the output of the traffic reports from the TAIS service, specifically the reported altitude, were provided in Mean Sea Level (MSL). Thus, the following assumption was made when preparing the airspace characterization analysis: due to the varying field elevation values in the vicinity of the KDTW and KDET, 600’ MSL was assumed to represent 0’ AGL for the dataset.

Operational Environment - MDOT Operational Areas and Characteristics

As an input to the Digital Aviation Integration Platform, the regions of interest had to be known so air traffic data could be pulled from the collected SWIM data to create the Jun-August 2021 dataset. Three MDOT areas of interest within the State of Michigan were proposed, as discussed in the beginning of the report. Two (2) of these areas are depicted in Figure 1. Each Area encompasses greater Detroit, MI. It is important to note that Areas 1 & 2 also include the geographies of Canadian cities (e.g., Windsor, Ontario). Area 3 is discussed later in this document.

Inside Areas 1 and 2 lie the defined MDOT BVLOS Corridors (i.e., MDOT Service Volumes) as seen in Figure 14. Each Corridor represents a specific use case.

- Blue Corridor: Pharmaceutical/Manufacturing/Automotive Package Delivery use case.
- Red Corridor: International/Cross-border use case
- Yellow Corridor: Medical/Organ Tissue Package Delivery use case.

[2] The STDDS system is comprised of additional information services, such as the Infrastructure System Monitor and Control (ISMC), Airport Data Service (APDS), Surface Movement Event Service (SMES), and the Tower Departure Event Service (TDES).

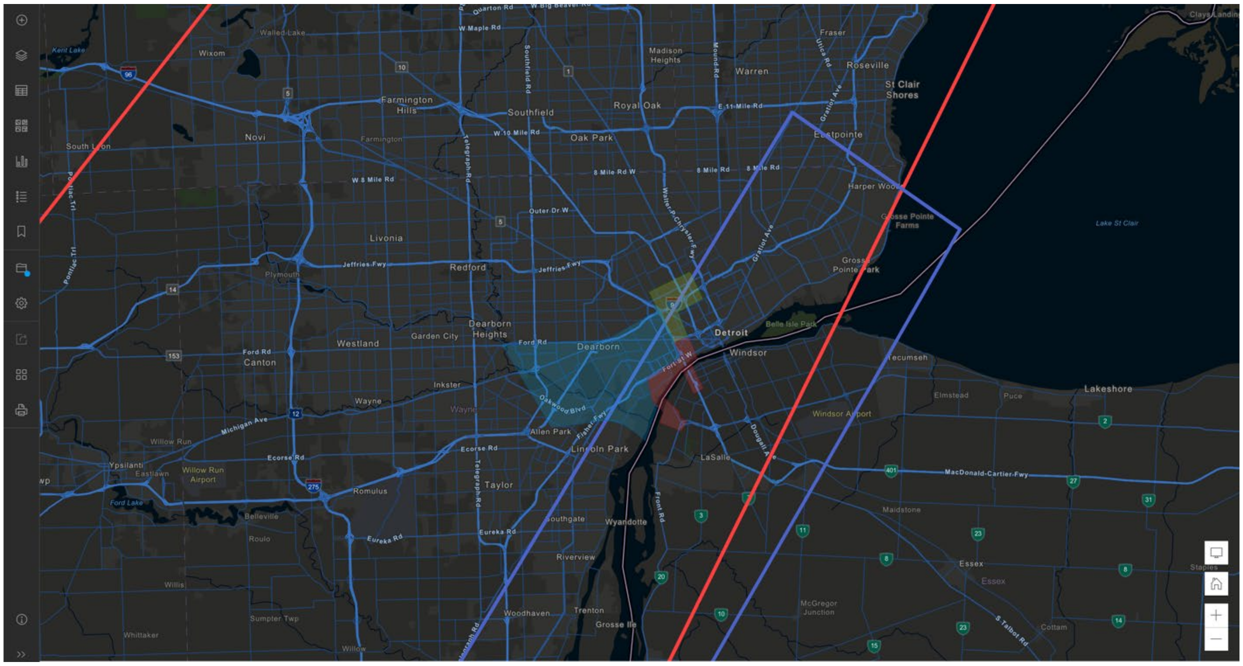


Figure 14: Zoomed in view of Areas 1 and 2 with MDOT Corridors

Based on these known BVLOS Corridor locations, the operational area surrounding the corridors were analyzed to understand potential impacts of the terrain, obstacles, airspace definitions, and ultimately the operational activity on the definitions of the corridors. Said differently, once MDOT had identified where it wished to conduct BVLOS operations, it was imperative to understand if and where low altitude crewed traffic is operating in the same airspace, and if and how nearby airports could affect the initial definitions of the corridor dimensions. Depending on the impact (e.g., proximity to airport surface; prohibited areas; other regulatory constraints; etc.), the corridors could potentially need to be redefined in terms of dimension and/or geography. Equally important was understanding how well these corridors and service volumes can be covered by the surveillance and C2 infrastructure. Thus, an assessment of the types of cooperative and non-cooperative surveillance sensors, as well as C2 equipment was made to determine if adequate coverage of the corridors can be achieved based on the emplacements of said sensors and equipment.

Operational Areas 1 & 2 Characteristics

Figure 15 illustrates the corridors in Areas 1 and 2 in relation to nearby airport facilities. On average, the distance from the center of the corridors to KDTW and KDET, respectively, is 10 statute miles (sm.).

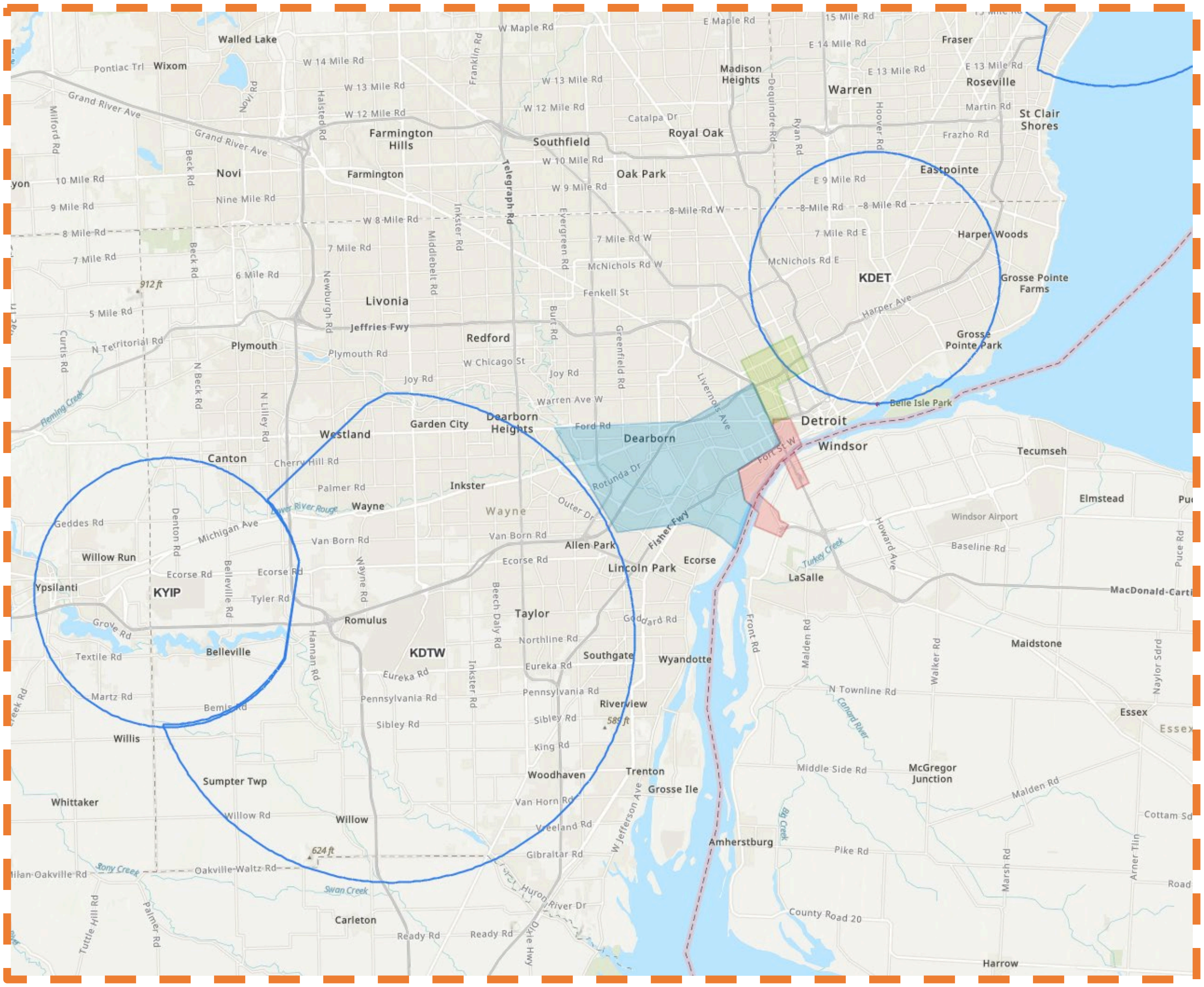


Figure 15: MDOT Operational Areas 1 and 2 with Corridor overlay (orange dotted outline represents the area to pull data from SWIM)

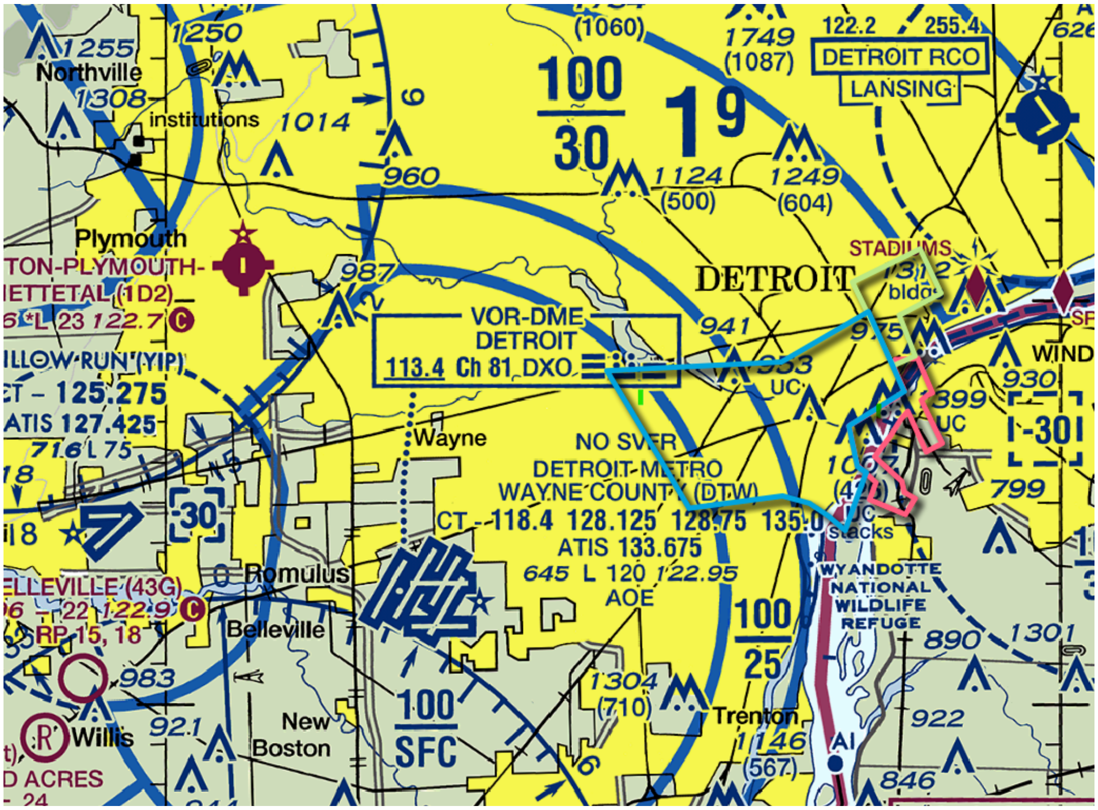


Figure 16: Detroit Terminal Area/VFR Sectional Chart with Corridor Overlay

The same corridors are overlaid onto a VFR Sectional Chart in Figure 16 to further illustrate the surrounding operational environment and aeronautical characteristics. Using geospatial data, aeronautical information, and information gathered from Air Traffic Control (ATC) Subject Matter Experts (SMEs), we can discern that the operational area surrounding Areas 1 and 2 is complex and this complexity is influenced by the varying types of operational activity and existing ground-based infrastructure. For instance, the operational area contains mixed use of air traffic comprising of Commercial Air Carriers, General Aviation, Private/Business Jet operations, Helicopter operations, as well as Governmental operations (e.g., Department of Natural Resources (DNR)) that could be present at low altitudes. There are also three large airports of varying airspace class designations within 20 statute miles of downtown Detroit serving these mixed-use airspace operators. These airports are the Detroit Metro Wayne County Airport (KDTW) – Class B Airspace; Willow Run Airport (KYIP) – Class D Airspace; and Coleman Young Municipal Airport (KDET) – Class D Airspace. Outside of the Class B and D airspaces, the surrounding Class G and E airspaces serve the majority of the GA community. As the corridors were defined with a ceiling/height of 400’ AGL, fortunately, these corridors underly the Class E Airspace, which begins at 700’ AGL, as well as underly the Class B shelves of KDTW. There are also seven operational helipads/heliports in and around the vicinity of the BVLOS Corridors. These helipads/heliports support a varying degree of operations, as listed in Table 11.

Table 11: Helipad/Heliport Identification and Use

Helipad ID	Helipad/Heliport Facility	Operational Use
MI96	Detroit Border Patrol Helipad	Government Use Helipad
MI74	WDIV-TV Channel 4	News Helicopter Helipad
5MI0	Detroit Medical Center Helipad	Medical Use Helipad
0MI9	Henry Ford Hospital Helipad	Medical Use Helipad
MI40	Fairlane Plaza	Private Use Heliport
MI07	Dearborn Helistop	Private Use Heliport
56MI	Beaumont Hospital Helipad	Medical Use Helipad

The operational area also overlies terrain characterized as an Urban Area, which is defined as territory encompassing at least 5,000 persons, the minimum qualifying threshold of the population density criteria for an urban area (Federal Register, 2022). The presence of obstacles (i.e., buildings, towers, stacks, utility poles, antennas, windmills, etc.) within and around the corridors, as seen as blue icons in Figure 17, also present challenges to navigable airspace because the height of these types of obstacles can reach up to 400’ AGL.

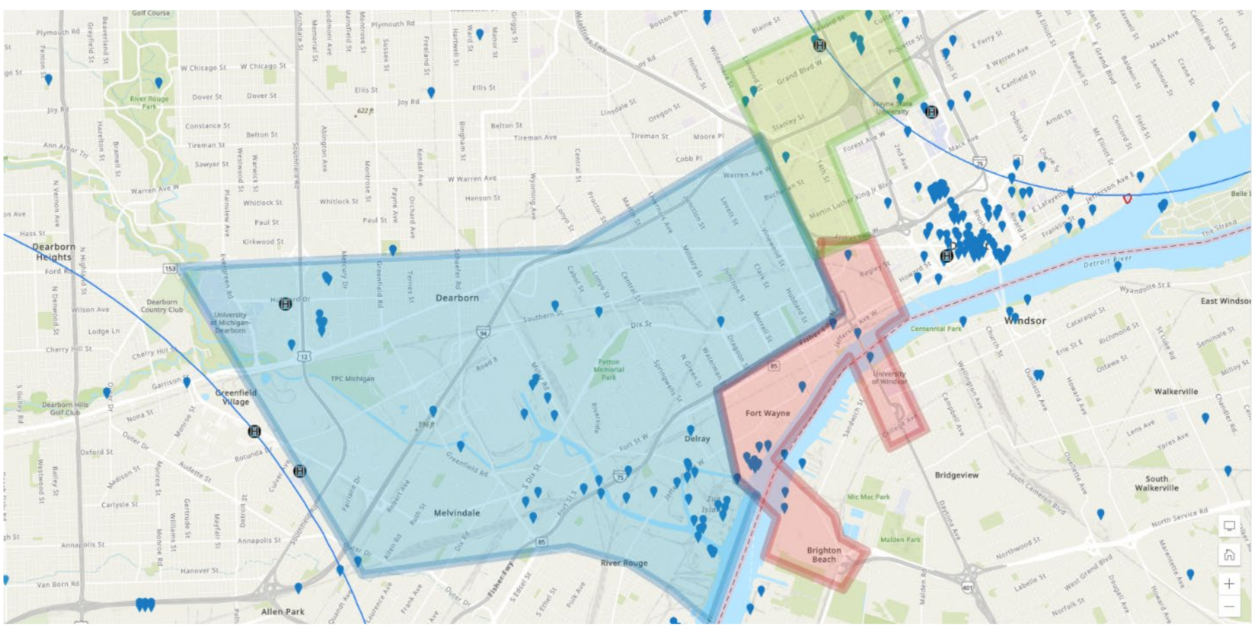


Figure 17: Obstacles in Areas 1 and 2 (authoritative source: FAA Digital Obstacle File)

Airspace Characterization

Now that the Operational Areas have been characterized, we must understand the air risks that may be present inside the corridors. Included in this characterization is an assessment of historical track data in order to pinpoint the high-density traffic “hotspots”. As explained above, preparing historical air traffic density maps is a way to help estimate air risks. While this method only provides a static view of the air risks, it is still a suitable and applicable approach to estimating air risk. A more dynamic way of computing air risks is currently under development. More specifically, computing the air risk output will be the actual probability of the UAS encountering a Mid Air Collision (MAC) with a crewed aircraft based on the UAS’ trajectory. In the interim, the results of the historical air traffic density analysis can provide a de facto practice to help identify locations of increased/decreased aircraft densities over a period of time and altitude. As a benefit, visualization of the data can present unique characteristics/insights not easily recognized when looking at the dataset itself. For instance, when visualizing data related to aircraft position, routes, or altitudes, one can see how the data can collectively illustrate certain aircraft behaviors (e.g., tight hovering patterns only rotorcrafts/helicopters can achieve that fixed wing airplanes cannot, as shown in Figure 18).

Figure 18: Visualization of Raw Track data. “Hovering” patterns are observed at locations such as US Customs and Border Protection (CBP) and Belle Island[3]

Visualization of the data can also present airspace structures that can account for known IFR/VFR routes, restricted airspace, or classes of airspace (e.g., “holes” or gaps produced in the airspace by routes may validate prohibited airspace over sensitive infrastructure); as well as depict how the natural environment may impact these aircraft behaviors due to weather phenomena, time of day, seasonal variations, etc.

[3] ATC SMEs have also indicated that routine DNR activity over the Detroit River for “boat spotting” due to the international border could account for the high concentration of air traffic density.

Air Risk Mitigation

Methodology

Defining Air Risk

Knowing where crewed aircrafts may be present based on historical data, especially in uncontrolled, low-altitude airspace below 1,200' AGL, is critical to understanding the likelihood of a reduced separation event between uncrewed and crewed aircraft. In this case, air risk is simply defined as the likelihood that a crewed aircraft will be in a desired UA operating area. Air risk in this context is not the likelihood of another UA being in a desired UA operating area. Based on historical crewed aviation traffic, UAS Static Air Risk Maps (USARMs) are generated by the DAIP to depict said air traffic density "hotspots" of where such reduced separation situations are more likely to occur. Figure 19 illustrates such hotspots in Areas 1 and 2.

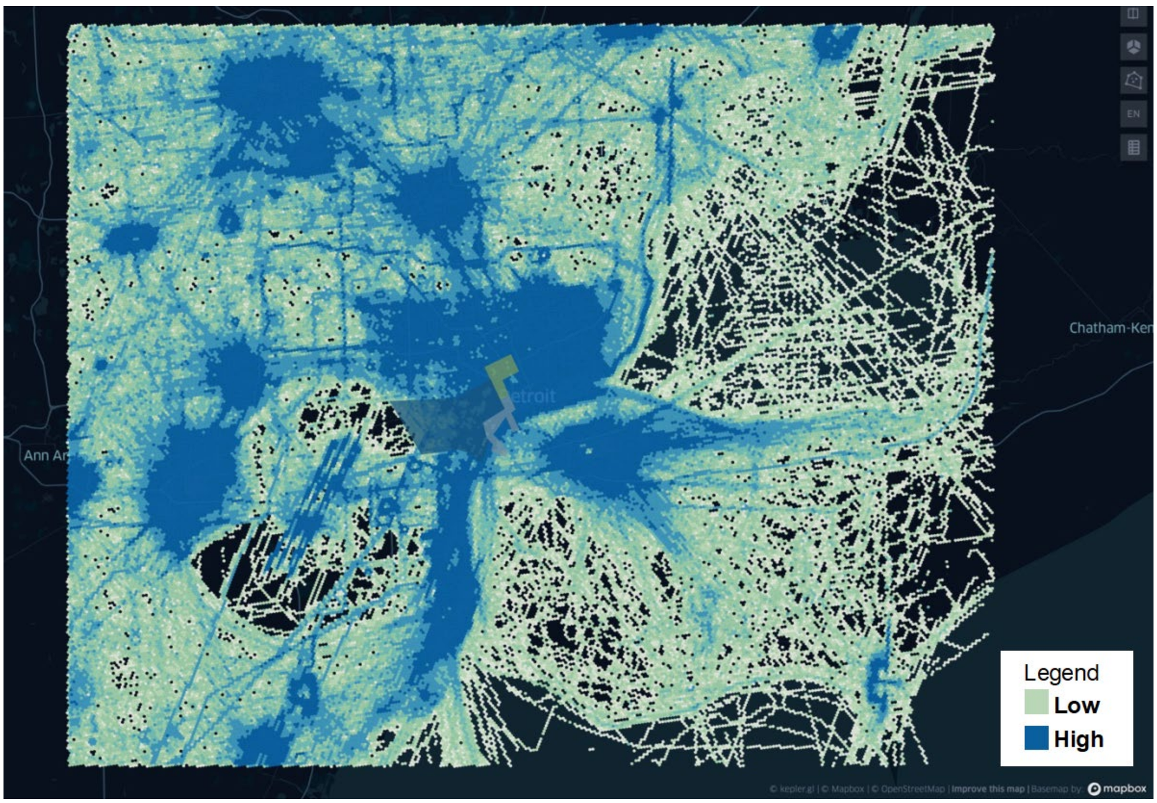


Figure 19: Example of a UAS Static Air Risk Map with Computed Air Traffic Density of <1,200' AGL in Areas 1 and 2

These heatmaps can be generated for specific regions, for any timeframe, and for any altitude range and ultimately presents the unmitigated air risks for a defined airspace volume. By computing air traffic density, we present the expected number of aircraft occupying a given portion of airspace at a given time, and again, this presents the most conservative view of risk because you view all the tracks as a trigger to a reduced separation event. An Operator's ConOps details the specific approved operating conditions (geographic boundaries, geofences, proximity to infrastructure or airports), technology (aircraft & supporting systems, data feeds, software systems), procedures, and mechanisms by which the UAS Operator would mitigate air risk and the likelihood of a reduced separation event. These elements may be voluntary or required as part of a condition & limitation of FAA waivers or exemptions.

Identifying & Quantifying Air Risk

The heatmaps generated for Areas 1 and 2 visualize the density of the air traffic below 1,200' AGL. To quantify the air risk **inside the corridors** using the air traffic density metric, 12 weeks of historical surveillance track data (June – August 2021) was analyzed to aggregate the total number of distinct tracks. In total, over 57,000 distinct crewed aircraft tracks were recorded below 1,200' in Areas 1 and 2. However, only 7,066 of those 57,000+ crewed positions were recorded below 500', with most of those positions being present outside of the corridors/along the Detroit River, indicating a lower probability of a drone colliding with a crewed aircraft in low altitude inside the corridors. This is a realistic outcome as GA pilots do not fly between buildings and typically do not fly below 500'. These low-altitude aircraft are most likely helicopter operations for tourism, transportation to/from hospitals, and Department of Natural Resource (DNR) activities. To see the breakdown in air traffic, see Table below.

Table 12: Number of Distinct Tracks/Altitude Band inside the Corridors for Areas 1 and 2

Altitude Band (MSL)	Corresponding Altitude Band (AGL)	Total Track Reports (Areas 1 & 2)
600-700	0-100	232
701-800	101-200	515
801-900	201-300	630
901-1000	301-400	701
1001-1100	401-500	1384
1101-1200	501-600	3604
1201-1300	601-700	10222
1301-1400	701-800	11009
1401-1500	801-900	7648
1501-1600	901-1000	6436
1601-1700	1001-1100	5983
1701-1800	1101-1200	5263

The major generation of air traffic in Areas 1 and 2 is the KDTW airport. Other than arriving/departing traffic from KDTW, most of the observed tracks are GA activity and low altitude commercial flight operations such as helicopter tours at KDET airport. The raw track outputs for these cooperative flight operations were validated against known published Detroit area helicopter routes (FAA Route Chart, 2022). Visualized track data and published helicopter routes are compared in Figure 20 and Figure 21. One can see strong correlation between the visualized raw tracks along the river, traffic around KDET, and north-south traffic (Figure 21) to the published routes (Figure 20).

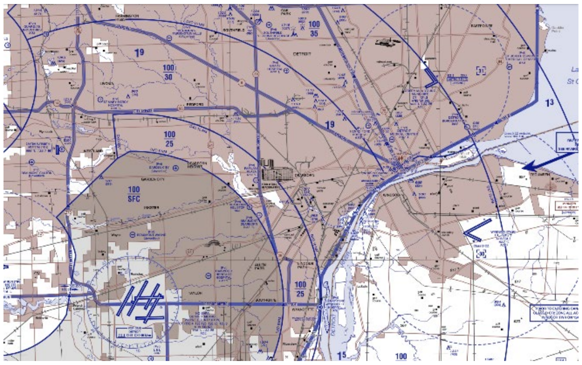


Figure 20: Published Detroit VFR Helicopter Route Chart (routes are depicted in solid purple lines)

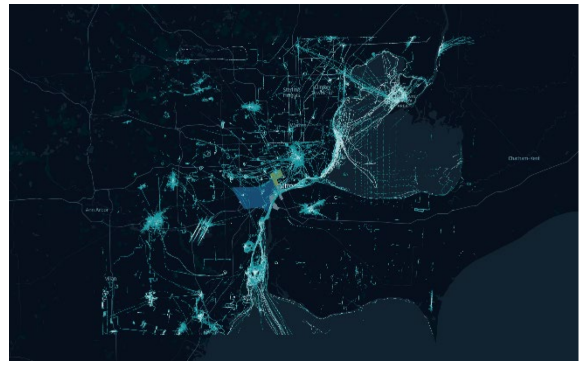


Figure 21: Track Data Visualization below 1,200' AGL in Areas 1 and 2

A UAS Operator's safety case must consider how their operations will mitigate the air risks in high traffic density locations, such as airports. A criteria-based approach described in the safety case could justify how operations are to be conducted (e.g., no operations will occur within 5nm from an airport having an operational control tower).

Mitigating Air Risk

As the USARM presents the "unmitigated" air risk picture, the BVLOS UAS operator must develop appropriate standard operating procedures (SOPs) as part of their holistic ConOps. These specific procedures will vary based on the specific operating area, aircraft performance characteristics, and aircraft technical capabilities to mitigate air risk (ex. return to home function).

Findings

Air risk in this study is associated with reduced separation events between drones and crewed aircraft, and not between uncrewed to uncrewed aircraft. The airspace in Areas 1 and 2 is complex with several factors that introduce hazards and risks and call for additional drone infrastructure to ensure safe operations and remove risk associated with integrating low altitude drones. The core identified risk factors were:

Mixed use of air traffic

- Commercial Air Carriers, General Aviation, Private/Business Jet operations, Helicopter operations, Governmental operations (e.g., Department of Natural Resources (DNR))

3 large airports within 20 miles of downtown Detroit, MI

- Detroit Metro Wayne County Airport (KDTW) - Class B Airspace
- Willow Run Airport (KYIP) - Class D Airspace
- Coleman Young Municipal Airport (KDET) - Class D Airspace

7 operational helipads/heliports in and around BVLOS Corridors

- Detroit Border Patrol Helipad (Government Use Helipad)
- WDIV-TV Channel 4 (News Helicopter Helipad)

- Detroit Medical Center Helipad (Medical Use Helipad)
- Henry Ford Hospital Helipad (Medical Use Helipad)
- Fairlane Plaza (Private Use Heliport)
- Dearborn Helistop (Private Use Heliport)
- Beaumont Hospital Helipad (Medical Use Helipad)

Areas of uncontrolled, low-altitude, airspace below 1,200' AGL

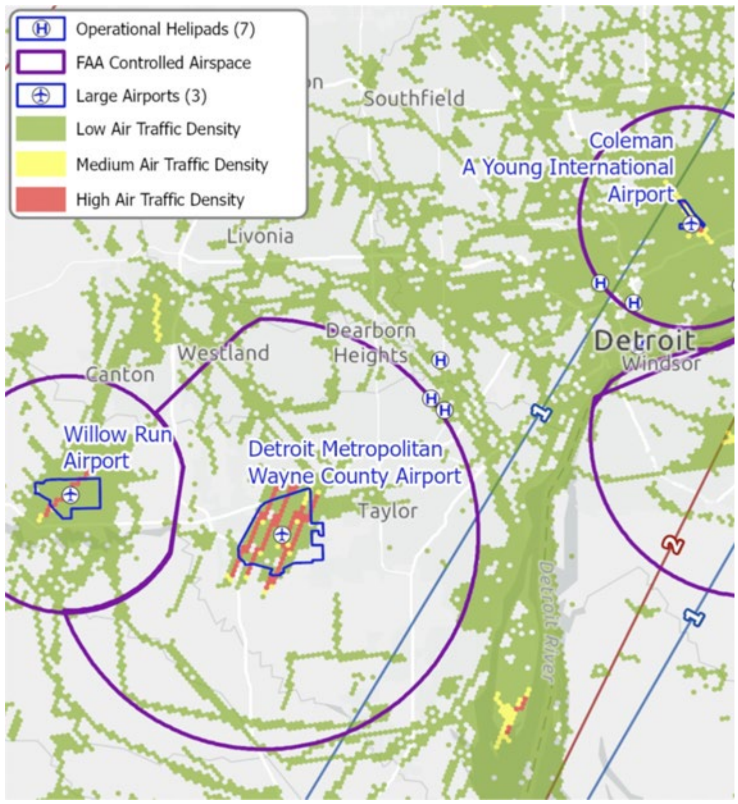


Figure 22: Historic low altitude air traffic density (UASRM) in Areas 1 and 2

Identifying and mitigating air risks require a diverse array of physical infrastructure and data services to manage the risk of reduced separation events. To start, FAA historical surveillance data can be used to discover key information regarding airspace use and air traffic patterns. These patterns provided insight into where to install surveillance systems and how to structure operating procedures to ensure the separation of drone and crewed aircraft, ultimately mitigating the risk of reduced separation events. For Areas 1 and 2, the corridors are outside the controlled airspaces of KDTW, KYIP, and KDET. Thus, surveillance tracks detected at these airports, and its positions detected “above” the corridor height definition, were not included in the total track count analysis; opposed to the track counts recorded in Area 3 at KTVC where airspace utilization in controlled *was* accounted for, hence the significantly higher track counts recorded in Area 3. Evidenced by the visualization of each crewed aircraft track in Figure 21, there are distinct patterns representing those of known published victor airways / approach & departure routes, to those aircraft in uncontrolled airspace that are typically flying under VFR, or patterns representative of aircraft characteristics that can only be achieved by rotorcraft vehicles / helicopters. The figure below zooms into Areas 1 & 2 to highlight said tracks in uncontrolled airspace, where many circular patterns are prevalent, and almost absent in controlled airspace.

Figure 23 Airspace Utilization / Patterns in Uncontrolled and Controlled Airspace

To support this feasibility assessment, 10 weeks of historical surveillance track data were analyzed to quantify the air risk for the corridor itself. Findings include:

- Over 53,000 distinct crewed aircraft track positions recorded below 1,200'
- Only 3,462 crewed positions were recorded below 500'
- Low track count in low altitudes (less than 500') trends to a lower probability of a reduced separation event between drones and crewed aircraft
- Using historical FAA surveillance data, UASRMs can be generated to:
  - Depict "hotspots" of higher air risk
  - Analyze air risk of specific regions, for any timeframe, and for any altitude range
  - Present the unmitigated air risk for a defined airspace volume
  - Identify areas to augment FAA surveillance to fully mitigate risk

Ground Risk

Introduction

Just as air risk is associated with drones colliding with crewed aircraft, ground risk is associated with the collision of drones with population, structures, or infrastructure. The geographic and demographic complexity across the different areas presented an interesting challenge for identifying and analyzing the quantity and distribution of various features and hazards that are associated with ground risk. As the manager of the National Airspace System, the FAA is accountable to the public to ensure that they are not exposed to undue risk posed by participants in the National Airspace System. This responsibility then requires the FAA to not only evaluate the risk posed to other participants in the airspace, but also evaluate the risk on the ground.

The key ground risk factors include:

Aviation Infrastructure	Community & Government Facilities
Transportation Infrastructure	Education facilities:
Critical Infrastructure / Utilities	Secure & Restricted Areas
Public Safety & Law Enforcement	Population Density
Healthcare facilities:	Traffic Volume

Methodology

For this feasibility analysis, the Project Team leveraged the capabilities of the Airspace Link AirHub® digital infrastructure platform to generate comprehensive ground risk assessments to support example use cases. To perform these assessments, the Airspace Link AirHub® platform first sourced numerous ground hazard data from authoritative providers at the federal, state, and local levels. Next, it combined all the data layers into one dataset and unified them across a common surface.

The final and most important step to produce data for a complete ground risk assessment was to apply risk classifications to the specific types of hazards, then use the platform to apply those classifications to all the hazards in the operational area to determine the ground risk exposure for potential operations.

The Airspace Link ground risk service has been successfully demonstrated in other projects to support Part 107 VLOS, Waivered BVLOS, and Part 135 operations in rural, suburban, and urban locations for flight routes supporting diverse use cases that range from hundreds of feet to dozens of miles.

In general, these ground risk assessments are used as a key criterion to inform the operation feasibility for the selected use cases. The specific risks that can be mitigated depend on the operator's ConOps, range from obstacle avoidance, minimization of population exposure, minimization of road crossings, geofencing from critical infrastructure, detection of optimal emergency landing areas, and more.

Findings

By following the process described in the methodology section above, clear qualitative and quantitative findings emerged from the analysis. These findings provide insight into the operation environment for UAS operators, support contextual analysis for specific locations, enable more intelligent decisions around relevant use cases for these areas, and aid with understanding and mitigating regulatory and safety constraints.

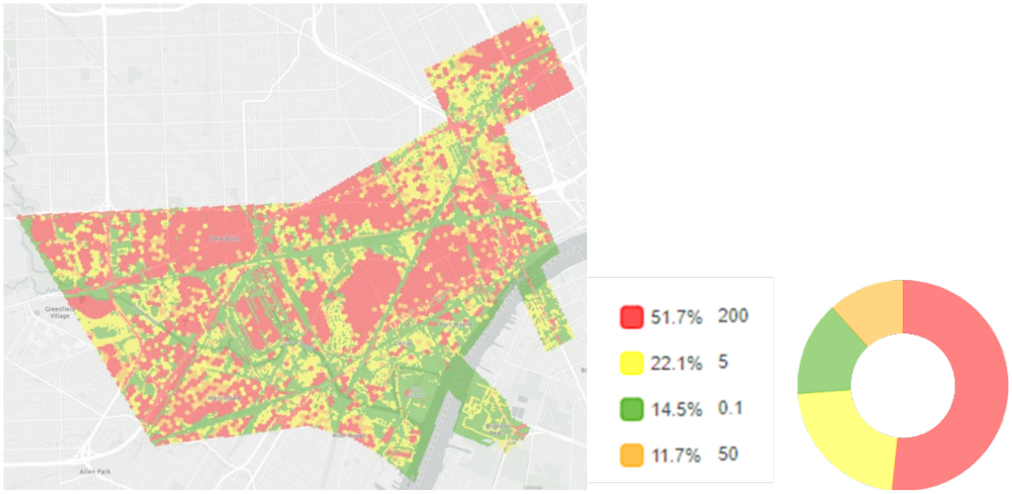


Figure 24: Risk classification areas within Areas 1 and 2

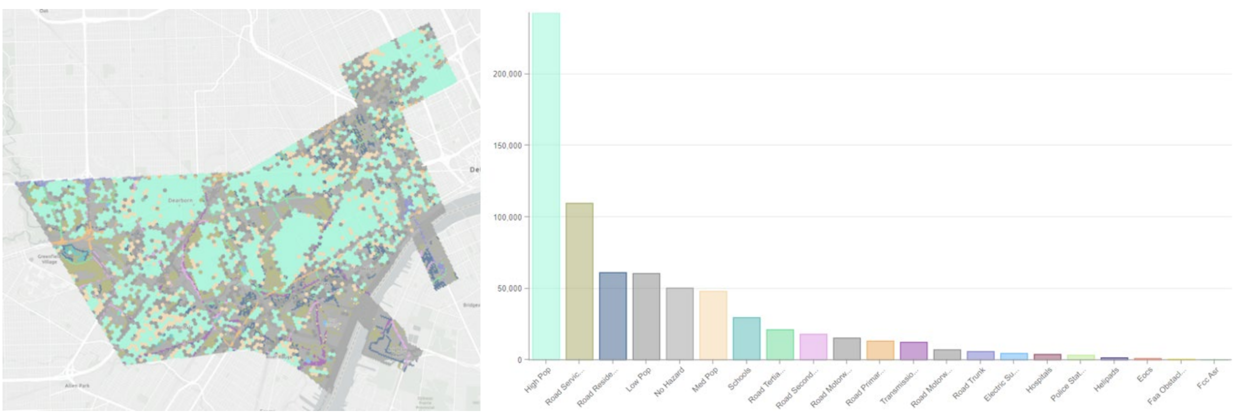


Figure 25: Hazards Identified within Areas 1 and 2

Qualitative Ground Hazard & Risk Insights of Areas 1 and 2

- Large distribution common urban/suburban risk factors such as high population density and road infrastructure that align with city neighborhoods.

Quantitative Ground Hazard & Risk Insights for Areas 1 and 2

- ~50% of area geography contains “High Risk” ground features (typical for urban areas)
- After previously mentioned ground hazards (population & roads), the most common ground hazards are energy infrastructure (transmission lines & substations), schools, hospitals, and public safety infrastructure.

While these ground risk findings are insightful by themselves, the true value of the analysis is unlocked when applying these findings to the UAS Drone Corridor assessment. This data enables stakeholders to understand how this specific operating environment may present challenges for certain drone use cases. Specifically for Areas 1 and 2, the large areas and distribution of population present an initial challenge for BVLOS drone operations. However, they also (alongside demographic information) show the market potential for advanced use cases such as package delivery for consumer goods, medical supplies, and supply chain logistics. For these use cases, having an accurate and authoritative understanding of the population and its distribution can assist in addressing the regulatory and safety constraints associated with these use cases. The large amount of utility infrastructure also presents a valid use case for drones to support maintenance, inspection, and security of these valuable community assets. These use cases, amongst others, could all benefit from accessing ground hazards and risk information as summarized in the points below.

Importance of Ground Hazards and Associated Risks:

- Understanding ground risk is important for all operators, but particularly so for commercial BVLOS use cases.
- An authoritative source of ground hazard and risk data would accelerate a key component of current BVLOS approvals.
- Ground hazard and risk data is applicable to regulatory **and** business use cases for drone businesses of varying sophistication.

Opportunity for the State of Michigan and MDOT

- The State of Michigan and MDOT are well positioned to be the authoritative provider of digital infrastructure in the form of airspace and ground risk data platform and associated service (data engineering, program management, etc.).
- This service would differentiate the State of Michigan, signaling its interest in supporting commercial drone operators by providing a valuable capability for operators of varying sophistication.
- The service would be utilized by operators to accelerate business and regulatory challenges regarding ground features and risks and could be made available in a more expeditious manner while larger physical and digital infrastructure deployments are in planning or implementation.

Drone Traffic Infrastructure

Air Risk Infrastructure & Risk Mitigation

While the FAA data supports general airspace risk identification results of the preliminary analysis leads the Project Team to recommend additional ground-based infrastructure as required to reduce the airspace risk to regulatory safety standards. This ground-based infrastructure would provide the surveillance, communications and command and control (C2) resources enabling operators with the means to electronically detect and avoid any crewed aircraft within their area of operation. The key component of the physical infrastructure includes:

Medium Range Radar
Augments FAA radar providing coverage and primary detection of aircraft at low altitudes and supports detect and avoid reduced separation event mitigation procedures.

Optical Sensors
Monitor the airspace for at risk aircraft using computer vision and Artificial Intelligence (AI) technology and report actionable real-time telemetry data to the pilot-in-command.

ADS-B Receivers
Detect cooperative aircraft broadcasting their identity and position to support, detect, and avoid/ reduced separation event mitigation procedures.

Wireless Communications Receivers
Provide C2 datalink capability to support communications between operator, drone, sensors, and C2 center throughout drone operations.

Ground Communication Networks
Provide the ground-to-ground communication network (i.e., backhaul network) to connect all ground-based infrastructure and cloud services.

Drone infrastructure Command and Control Center
Manages drone Infrastructure access, operations, and secure cloud services ensuring proper use and system health.

Additional information regarding the full details of the required infrastructure can be found in the Technology Implementation & Deployment section of this report.

Ground Risk Infrastructure & Risk Mitigation

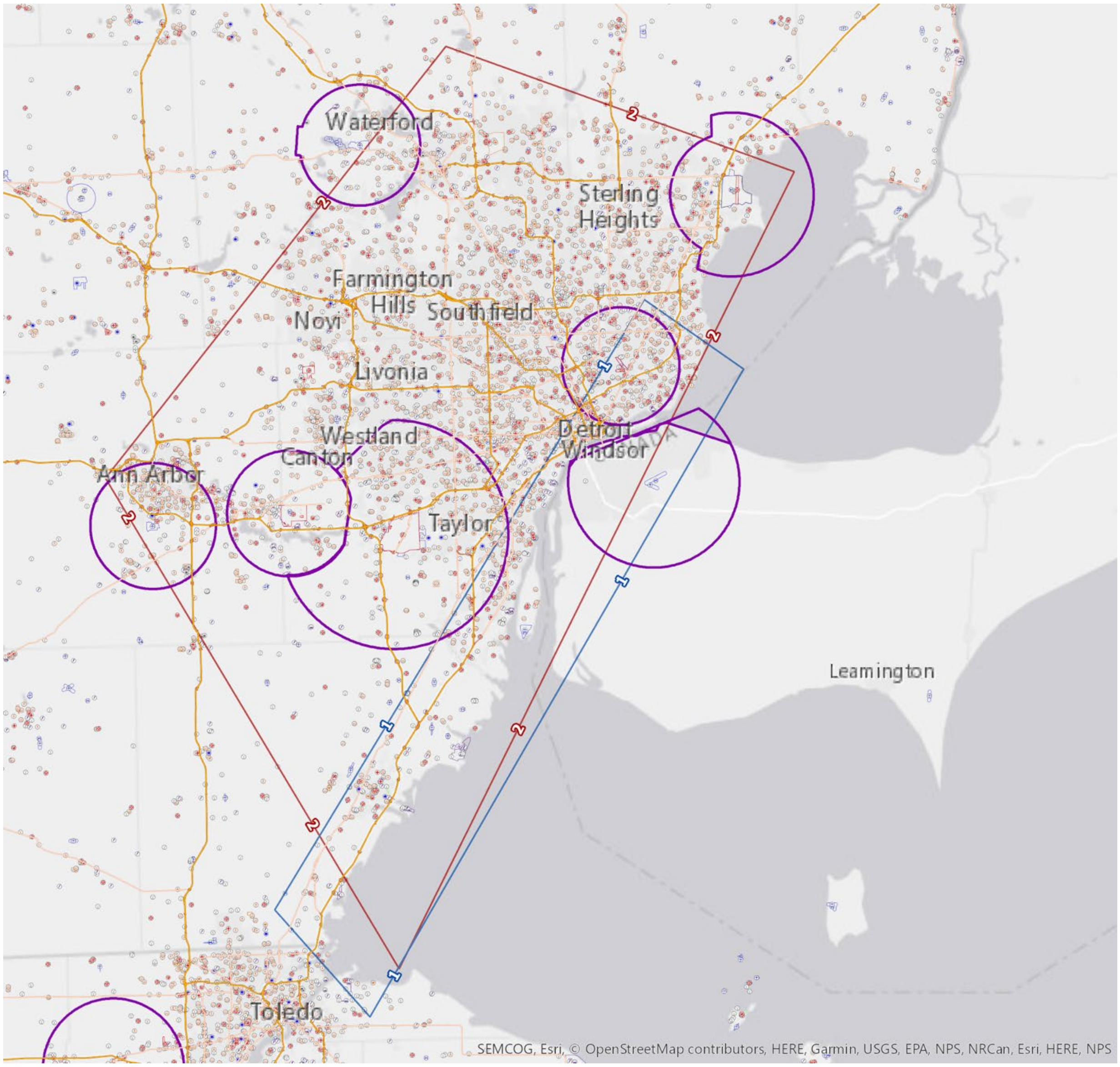


Figure 26: Ground Risk Features in Areas 1 and 2

The concept of digital infrastructure to enable ground hazard & risk identification and quantification is a new entrant to the world of aviation infrastructure and is of particular value for drone operations as described in the previous section on ground risk. Due to the FAA's current approach for BVLOS operations under approvals by exemption, operator mitigations for ground risk exposure will vary based on operation procedure, aircraft selection and certification, aircraft equipage, and other operational factors outlined in the operator's concept of operations. As described in the previous ground risk section, The State of Michigan and MDOT are well positioned to be the authoritative provider of digital infrastructure in the form of a ground risk data service to support operators in identifying ground hazards and their associated risk and incorporate the appropriate mitigation based on their ConOps. Examples of risks & their potential mitigations are outlined below.

Examples of Ground Risks & Mitigations:

- Risk: Road Crossing
  - Mitigation: Visual Observer to confirm no overflight of moving vehicle
- Risk: Population Density
  - Mitigation: reroute around population center to avoid operation over people
- Risk: Critical Infrastructure (Transmission Line)
  - Mitigation: None, example operation is a utility inspection flight
- Risk: Forested Area
  - Mitigation: Avoid, if possible, but mark as a potential ditch area for an emergency landing

Concept of Operations & Risk Mitigation

As drone shared-use infrastructure is implemented, drone operators can effectively leverage this Infrastructure to take advantage of the benefits it provides. These benefits include:

- Creating standard operating procedures for all operators.
- Creating operating requirements and limitations for all aircraft.
- Creating a single, reliable system in which performance is verified and continuously monitored.
- Providing operators with the necessary services for advanced, scalable, and efficient drone operations.
- Providing surveillance services as a means to see and avoid other users of the airspace more efficiently than a visual observer.
- Removing the physical and financial burden from the operators to provide the technology to mitigate air risk and ground risk.

To take full advantage of this shared-use infrastructure, operators must incorporate the data, services, and capabilities into their operating procedures and technology. This is often accomplished through a ConOps document, which outlines the type of operation being performed, the technology being used, identified hazards and their mitigations, and more. By integrating the shared-use infrastructure into the various sections of the ConOps, operators ensure the infrastructure is being utilized fully, and can be applied to support advanced operation regulatory approvals.

Safety Case & Regulatory Framework

There are many regulatory and safety requirements associated with enabling drone operators to conduct advanced BVLOS operations within the United States. Currently it falls on the operator to overcome the challenges and receive FAA approval to fly a drone. The operator must present a safety case to the FAA, which describes how they will manage risk to an acceptable level and generally requires:

- Technology in the form of FAA-accepted shared use infrastructure that provides the resources that unlock scalable and economically viable drone operations for all operators and use cases
- Risk Mitigations that apply the technology resource in a way that strategically or tactically reduces risks throughout the drone operation

Regulatory Pathways

The rules and regulations relevant to the operator and operation are dependent on the operator's ConOps, as specified below.

Part 107 Operations

Involve small drones of less than 55 pounds, which typically fly below 400 feet AGL in uncontrolled airspace (Class G). There are a limited number of regulations under Part 107 that can be waived for advanced operations.

Part 91 Operations

Developed for crewed aviation but can be a pathway for drone operations when the aircraft is greater than 55 pounds.

Part 135 Operations

Designed for air transportation of persons or property for compensation. A drone operator transporting property for compensation must hold a Part 135 Certificate.

Part 137 Operations

Designed for dispensing chemicals and agricultural products. A drone operator conducting these activities must hold a Part 137 Certificate. State laws must also be considered.

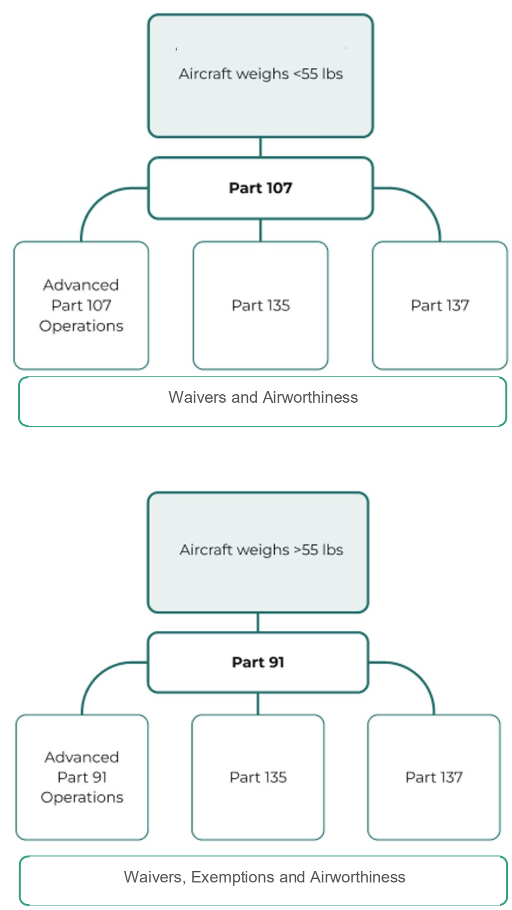


Figure 27: Regulatory Pathway Chart for UAS Operations

Safety Case Development

Regardless of the regulatory path to receive FAA approval for an advanced drone operation, the operator must present a safety case to the FAA which describes how risk will be managed to an acceptable level. When developing the safety case, the operator should use FAA guidance, which can be found within the following FAA Orders and manuals.

- Safety Management System (SMS) Policy: Establishes SMS policy and requirements and emphasizes Safety Risk Management (SRM) and Safety Assurance (SA) processes
- Safety Risk Management Policy: Establishes requirements to conduct SRM
- UAS Safety Risk Management Policy: Establishes a methodology for conducting SRM specifically for drone operations
- Air Traffic Organization (ATO) Safety Management System Manual: A collection of principles, policies, processes, procedures, and programs used to identify, analyze, assess, manage, and monitor safety risk

These orders and manuals were designed to be used by the FAA to establish their own processes. Still, they each provide invaluable information for applicants of waivers, exemptions, and authorizations as they provide key insight into what the FAA requires and how the information should be conveyed.

Shared-Use Infrastructure to Support Safety Case

When conducting a safety case, the operator is required to complete the following five-step risk assessment process per the FAA's guidance and processes described in the FAA Orders and Manuals:

- Describe the System
- Identify Hazards
- Analyze Risk
- Assess Risk
- Treat Risk

During the hazard identification step, each hazard's corresponding outcomes are identified and documented. For example, an operator must consider the hazard, "Aircraft in Proximity of Drone" in the safety case and document the worst credible outcomes, such as:

- Collision between a drone and aircraft in the air
- Collision between a drone and a person on the ground or moving vehicle when avoiding aircraft
- Collision between a drone and critical infrastructure on the ground when avoiding aircraft

The hazard "Aircraft in Proximity of Drone" results in high air and ground risk. However, an operator leveraging the drone infrastructure can provide a safety case showing a reduction of risk to an acceptable level by using surveillance sensors (medium-range radar, optical sensors, ADS-B receivers, etc.) to maintain air traffic awareness. Additionally, the operator can indicate how the drone infrastructure ground risk data ensures the drone flight plan factors in ground risk and routes around risk areas. These controls enable the operator to present a robust safety case to the FAA when requesting to conduct advanced drone operations and improve the probability of approval.

International Considerations for Area 1

Corridor Location

Overview

Area 1, as defined by MDOT AERO, gave the Project Team a unique and novel challenge that when solved, will establish precedence for commercial cross-border UAS operations across the U.S. The establishment of a UAS international connection presents multiple challenges over domestic options, primarily because of the increased number of regulatory agencies that are involved. While the domestic corridors (Areas 2 and 3) focus on FAA regulations and approvals, the international connection will require additional coordination with Transport Canada (TC) and NAV CANADA. More importantly, regulatory agencies that are relatively unfamiliar with commercial UAS, such as US Customs and Border Protection (CBP) and Canada's Border Security Agency (CBSA), are key players in gaining approval and implementation. With this in mind and to gain approvals in a timely manner, the Project Team has proposed area of operation locations of interest that are no greater than 1-2 miles apart, as a starting point. These items are examined in greater detail in part 2 of this report.

Reduce Initial Infrastructure Cost

Development costs of new inspection areas and facilities can range from several hundred thousand dollars to several million based on the size and scope of operations. Using existing and future CBP/CBSA Ports of Entry (POE) for the initial proposed cross-border corridor will significantly reduce the cost versus establishing new dedicated POEs designed exclusively for drone/Remotely Piloted Aircraft Systems (RPAS) operations.

Future Expansion

The inclusion of a second cross-border crossing that parallels the New Gordie Howe Bridge provides an opportunity to scale the facilities to meet the needs resulting from the increased activity levels. Each of the corresponding new Gordie Howe Ports of Entry have facility footprints that will allow the installation of additional technology and expanded border processing facilities.

Final Corridor Recommendation

After careful analysis of the first proposed cross-border corridor paralleling the Ambassador Bridge and the corresponding limitations at the current ports of entry, it became evident that it would serve the purpose of a test-bed location, however, any scalability or growth in activity would be extremely difficult. With that in mind, the Project Team analyzed possible alternatives that would allow for growth and the possible introduction of larger, more frequent UAV/RPAS operations including possible Urban Air Mobility Operations. A solution was found by incorporating a second corridor that parallels the Gordie Howe Bridge, which is currently under construction.

Regulatory Status

Overview

Implementing a BVLOS UAS cross-border corridor presents multiple regulatory challenges at the federal and international levels that must be addressed and mitigated to enable UAS flight operations within that corridor. The three primary U.S. Federal entities that must 'approve' such a system are the Federal Communications Commission (FCC), the FAA, and the Department of Homeland Security's CBP. Their Canadian counterparts are Innovation Science and Economic Development Canada (ISED), Transport Canada (TC), Nav Canada, and CBSA, all need to review and 'approve' such a system. Processes exist around many of the regulatory approvals with the FAA and TC when conducting BVLOS operations domestically. However, these processes have not been harmonized for international operations. These items are being addressed through the FAA/TC Cross Border Working Group to ensure safe integration into the NAS. The sections below examine the existing regulations and procedures and identify areas that need to be developed to ensure approval of a UAS Cross-border corridor is successful.

Federal Aviation Administration/Transport Canada

As of the date of this report, neither the FAA nor TC have developed regulatory guidance intended explicitly for international drone BVLOS operations. The FAA and TC have established a working group that is expected to release draft harmonized regulations for drone cross-border operations by the end of 2023. Until that time, operations under 107 (FAA) with a waiver granted to section 107.I (a) and Special Flight Operations Certificate for a Remotely Piloted Aircraft System (SFOC-RPAS) (TC) could be utilized with coordination from FAA and TC.

Figure 28: USA and Canadian Regulatory Agencies

U.S. Customs and Border Protection/Canadian Border Services Agency

CBP and CBSA are in the process of developing regulations, processes, and procedures to address UAV operations. Both are participating in the FAA Working Group. The development of regulations, processes, and procedures for CBP (and CBSA) are the key areas that will need to be harmonized for the success of a cross-border drone corridor and provide the best reason for including the proposed MDOT corridor as a test-case and operational proof of concept in the development of the new harmonized regulations. CBP and CBSA have existing regulations concerning FAR Part 73S Operators that could be used as a starting point for the development of new drone-focused regulations.

Way Forward

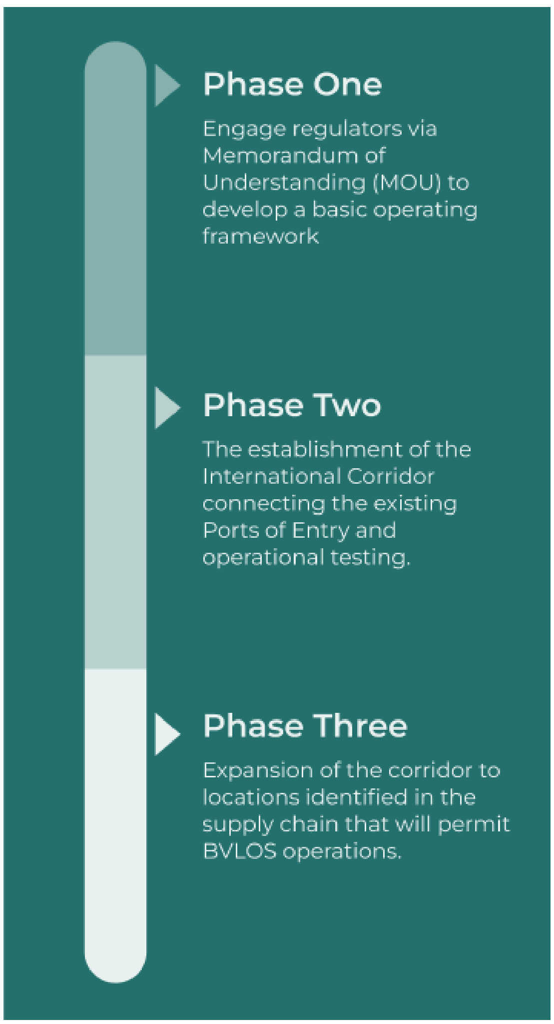


Figure 29: Phased Approach to Enabling UAS BVLOS Operations

Summary

The challenges associated with the establishment of a cross-border UAS corridor are significant, but achievable, and the rewards of successfully establishing such a corridor are groundbreaking. As previously mentioned, the development of regulations, policies, and procedures that are needed to achieve approval of a BVLOS cross-border corridor are in development and still several years away from being implemented. However, in discussions with the FAA/TC, CBP, and CBSA there has been unanimous support for this project going forward. By working through the FAA/TC Cross-Border Working Group and using the proposed cross-border corridor as a test case scenario MDOT and the operators using the corridor will be in the best position to capitalize when these regulations are released. Detailed analysis and additional recommendations are covered in detail within the dedicated International Considerations section of this report

Impacts

Introduction

MDOT's overarching goal for the UAS Connect Corridor project is to improve the quality of life for residents. As such, the Project Team assessed the projected impacts through the lens of three critical categories: The economy, the environment, and community benefits. This includes an overarching, birds-eye view of impacts residents and businesses may expect from the pilot, as discussed in the Use Cases section above (e.g., increased productivity, reduced emissions, etc.), quantitative estimates for each impact where appropriate (e.g., number of jobs created, estimated reduction in vehicle miles traveled, etc.), and scoring to demonstrate the relative size of each impact as compared to one another (e.g., the largest impacts in Areas 1 & 2 falls within the economy category).

Cityfi led the Project Team in the impact study, which is based on a 5-year time horizon for UAS adoption and considers low (10%) and high (30%) adoption scenarios. It is also limited to the infrastructure service footprint for the study areas and associated use cases. While the study used existing research for reference, its methodology and findings differ from previous studies such as: "Measuring the Effects of Drone Delivery in United States, Virginia Tech, 2020" and "Advanced Air Mobility Business Case Assessment: State of Ohio, NEXA White Paper, 2021" in the following ways:

- Previous studies have been based on longer time horizons for UAS full adoption, such as 25 years, which reflect more significant impacts in Vehicle Miles Traveled (VMT) reduction, creation of jobs, etc.
- This study accounts for the unique context/characteristics of each location (delimited by the area of study) instead of full drone adoption over larger geographies.
- This study did not perform community/local business engagement, instead leveraging stakeholder engagement conducted through the use case selection process.

Methodology

Economic Impact Assessment

Assuming that a percentage of ground transportation will be replaced by air mobility for medical, pharmaceutical, and manufacturing cargo, it is crucial to assess the effect that this will have on the economy of the studied areas. The analysis divides these impacts into the following variables:

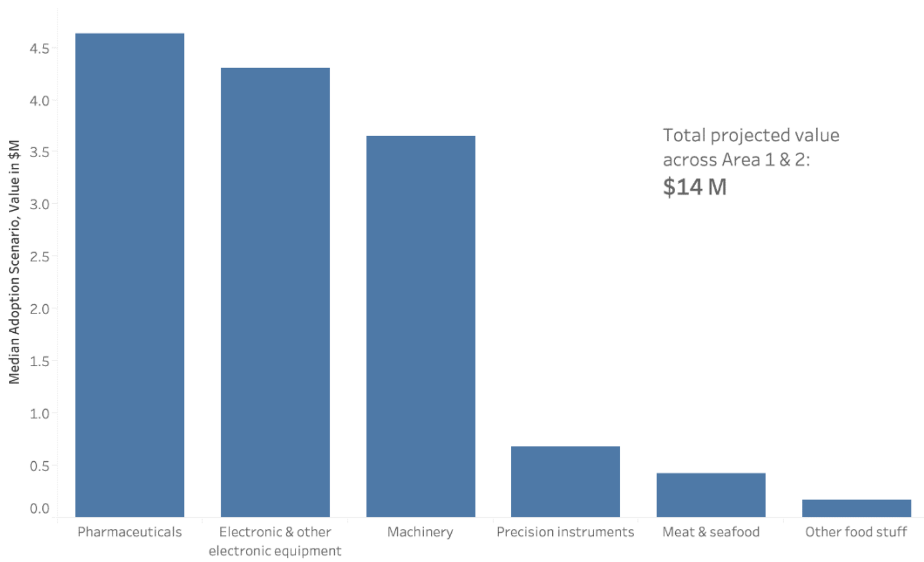
- Increase in productivity
- Creation of new skilled jobs
- Variation in per capita income
- Revenue/cost recovery

To calculate these variables, we started by identifying the ***increase in productivity*** by studying the current freight movement along the main highways in the region (domestic origin and destination), using data from the Freight Analysis Framework (U.S. DOT, 2022). We focused our study on six commodities: pharmaceuticals, machinery, electronic & other electronic equipment, precision instruments, meat & seafood, and other food stuff. From these data, we were able to retrieve the total annual tons and value in millions of dollars of the products transported in the area. Afterwards, to determine which percentage of the total freight would be replaced by drone transportation, we evaluated the commodity flow survey to assign a percentage of possible products that are feasible for drone transport, considering the following assumptions:

- There must be an urgency to deliver the product where drones can be more efficient than terrestrial transportation (Dyment & Leeby, 2021).
- Products should be within key aircraft performance related constraints: Load Capacity (Poundage – 15 or less), Speed – 30 mph or less, Delivery Distance – 4 miles (Airspace Link, 2022).

After the percentage per commodity was defined, we obtained the total tons and value in dollars of products that potentially could migrate to drone transportation for two scenarios of adoption (high and low) over the 5-year study period.

Economic Impact: Projected Value of Goods to Be Transported by UAS by Commodity



To identify the number of ***new skilled jobs created*** due to the introduction of UAS in the area, we identified the industries that would experience employment variations and organized them by those that are impacted directly (Professional/Scientific/Tech Services; Information; Transportation/Warehousing; Real Estate/Rental/Leasing; Retail trade industries) and indirectly (Utilities; Manufacturing; Finance/Insurance). Data was gathered around existing employment numbers and we performed an analysis to identify the approximate number of new jobs created, considering the increase in productivity in the analysis above.

Since our study considers the adoption of UAS in a span of five years, we infer that the ***per capita income of the area could be impacted in a positive way*** due to the increase in highly skilled jobs and associated higher wages. Therefore, we analyzed the per capita income for the state of Michigan and for Areas 1 and 2 and compared it against the average annual salary of the new jobs created in the area.

Environmental Impact Assessment

Historically, investments in transportation have not always addressed or fully valued the impact on the environment, to the ensuing detriment of other areas of life including the economy and community well-being. Our analysis focuses on the potential benefit of emissions reduction along with the potential cost of noise and visual pollution.

We approached the ***emissions reduction*** analysis by first estimating the impact the drone corridor might have on ground surface transportation in terms of vehicle miles traveled, or VMT. Building on that analysis, we used factors for emissions per vehicle mile versus emissions per drone mile and multiplied these values by our VMT reduction estimates to arrive at estimated emissions reduction for the low and high adoption scenarios within each geographic area. For emissions per vehicle mile, we use a round number estimate of CO_2 emissions for a passenger vehicle given the lightweight nature of the cargo for the UAS delivery use cases. For drones, while there will be some emissions when considering the lifecycle of advanced air mobility, such as battery charging and the extraction of parts, we assume these emissions to be negligible when realistically compared with vehicle emissions. For instance, our analysis of emissions per vehicle mile only considers carbon dioxide, whereas vehicles, especially trucks, also emit nitrogen oxides (NOx) and particular matter 10 microns in diameter (PM-10), two GHG emissions that negatively impact quality. Further, Michigan is pursuing electrification and carbon neutrality through the MI Healthy Climate Plan (Michigan.gov, 2022), so we can reasonably expect clean energy sources to service more and more electrification in the coming years.

To evaluate ***noise and visual pollution***, we conducted a literature review and evaluated the noise level expected in the corridor using a decibel level. In particular, the Project Team consulted the regulations regarding acceptable decibel levels for drone noise according to the National Environmental Policy Act (FAA, 2022) and a comparison of the noise level of different UAS vehicle types and models using a report commissioned by the FAA at the Choctaw Nation of Oklahoma's test site (Read et al, 2020). Still, we recognize that the real impact of noise may be more nuanced. For instance, some studies suggest that the novelty of the sound of drones may cause an increase in the perception of noise pollution even if noise volume, or decibel level, decreases (Christian & Cabell, 2017). As such, we also offer ideas for monitoring and managing these impacts over the course of implementation.

Community Impact Assessment

As ground transportation gets replaced by advanced air mobility for medical, pharmaceutical, and manufacturing cargo, we anticipate community impacts within the areas of health, safety, and wellbeing. Some of these impacts are direct, such as in the case of ***improved access to medical care***, and some are derived from other impacts. For instance, reducing vehicle miles traveled may be expected to reduce traffic congestion, which ***improves mobility*** and quality of life as residents are able to get around more easily. Similarly, the emission reduction due to VMT reduction is not only good from the environmental standpoint of mitigating climate change but also has health implications, as poor air quality leads to asthma and other respiratory-related illnesses. We also consider a potential ***reduction in traffic fatalities*** as vehicle trips are removed from the system. Finally, we expect ***enhanced community well-being*** as a result of the economic benefits that combine to create a more competitive job market and compelling place to live.

The community impact assessment is primarily qualitative, with descriptions of the significance of each impact within the Impact Scoring Interactive Tool (see appendices D-F). The community profile analysis focuses on population composition, growth rate, and socioeconomic status to understand the context for the anticipated impacts of the corridor. Another community impact that was essential to study was how the use of drones could impact the accessibility of pharmacy services to disadvantaged communities. To assess this, we calculated the population density by square mile, the lack of accessibility to public transportation, the vehicle accessibility by household, and the distance to the nearest pharmacy. Details of this study can be found in the technical appendix.

Impact Scoring

Through the combination of qualitative and quantitative research, we assigned ***impact scores*** that allow for a comparison of all impacts, whether economic, environmental, or community-based, in a single view. These scores are calculated as the cumulative expected impact over a 5-year time horizon, ranging from a possible total impact value of -10 to 10.

In order to assess the relative size of each potential impact (benefits and costs), we started by conducting a literature review and speaking with subject matter experts. This research enabled us to identify the general directionality of each impact (benefit versus cost), as well as where to focus the quantitative economic, environmental, and community analyses that would then feed back into the impact score. In addition to these three broad categories that impact all residents, we also included a fiscal category in the overall assessment in order to keep in mind separate costs and benefits that will be felt directly by MDOT (departmental revenue generation, operation and maintenance), as opposed to by the economy at large.

Findings

The findings below represent the median estimated scenario between the Project Team's low- and high-adoption models.

Economic Impact Assessment

Understanding the economic value and community impact resulting from top use cases is a key input in developing a roadmap on how to move this initiative forward. Some of the top impacts are outlined below.

Creation of Skilled jobs

A shift in deliveries from ground vehicles to drones would positively impact jobs in Michigan, stimulating new and existing industries by creating high-paying jobs in aviation, logistics, engineering, and finance. Studies have repeatedly shown a relationship between automation and greater employment at both a macroeconomic and company level. Analysis of possible new direct and indirect jobs, associated with the study area market potential resulted in an estimate of significant job creation, as shown in Figure 30.

Figure 30: Skilled Job Creation Metrics in Areas 1 and 2

Wage Growth

Areas 1 and 2 has an average annual per capita personal income of $18,970 (which for the year 2027 is projected to be $27,198), below the annual average for the State of Michigan and the US. The creation of direct and associated indirect jobs will have a positive impact on the per capita income of the area since the average annual salary of new skilled jobs (direct and indirect) is $78,317. This average annual salary is significantly higher than both the US and State of Michigan average annual salaries ($58,260 and $55,160, respectively), which strengthen our assumption of a positive economic impact (BLS, 2021).
The sectors that will receive the biggest positive impact due to the adaptation of UAS services will be the professional, scientific, and technological services, information, transportation, warehousing, and real estate industries.

Table 13: Wage Growth Metrics

Location	Description	2020
US	Per capita personal income (dollars) (Statista, 2022)	$59,147
State of Michigan	Per capita personal income (dollars) (BLS, 2021)	$52,724
Areas 1 & 2	Per capita personal income (dollars) (ESRI, 2021)	$18,970
Areas 1 & 2	Average salary of new direct/indirect created jobs (ESRI, 2021)	$78,317

Productivity Growth

A key finding is that delivery drones can significantly reduce costs and increase efficiencies in business logistics. This productivity increase would primarily result from transferring light cargo from ground delivery to drone and potentially accommodate increases in last-mile deliveries. Using an analysis of regional freight data and projected drone services supporting initial use cases, we have quantified a potential market of $69 M in freight revenue in a span of 5 years.

Environmental Impact Assessment

Vehicle Miles Traveled (VMT)

Reducing VMT lays the groundwork for several benefits, including emissions reduction, improved mobility, and reduction in traffic fatalities. The calculations and assumptions leading to the VMT reduction estimate can be found in **Appendix F**.

22.3M – Vehicle Miles Traveled Reduction

Emissions Reduction
Drones are effective in helping Michigan reach electrification and emissions reduction goals. The analysis finds an estimated emissions reduction shown above.

12,618 – Tons CO_2 Emissions Reduction

Noise and Visual Pollution
The Federal Aviation Administration defines a significant aircraft noise impact as an increase in the yearly Day-Night Average Sound Level (DNL) metric of 1.5 decibels (dB) or more at or above DNL 65 dB noise exposure or a noise exposure at or above the 65 dB level due to a DNL 1.5 dB or greater increase. (FAA, 2022) The team does not find a significant impact according to this definition. Still, MDOT and other operators can mitigate potential environmental and community costs by:

- Conducting public outreach activities to better understand how drones affect the environment and community from an auditory and visual perspective
- Considering noise when choosing drone hardware
- Careful planning of drone port locations
- Operational noise mitigation measures such as population avoidance and flight path distribution
- Setting delivery times to reduce residential disturbance
- Collecting feedback
- Responding to complaints

Community Impact Assessment

Improved Access to Medical Care
Initial use cases include pharmaceutical and medical deliveries which have a positive impact on the health and quality of life of the general community and especially at-risk groups that lack mobility or easy access to medications. Our analysis finds:

202,111 – Total population served by drones in the service area
36,795 – Citizens lacking vehicle access that would initially be served by drones
26,573 – Senior Citizens that would initially be served by drones

For more information on the improved access to medical care results, details can be found in Appendix E.

Overall Impact Scoring

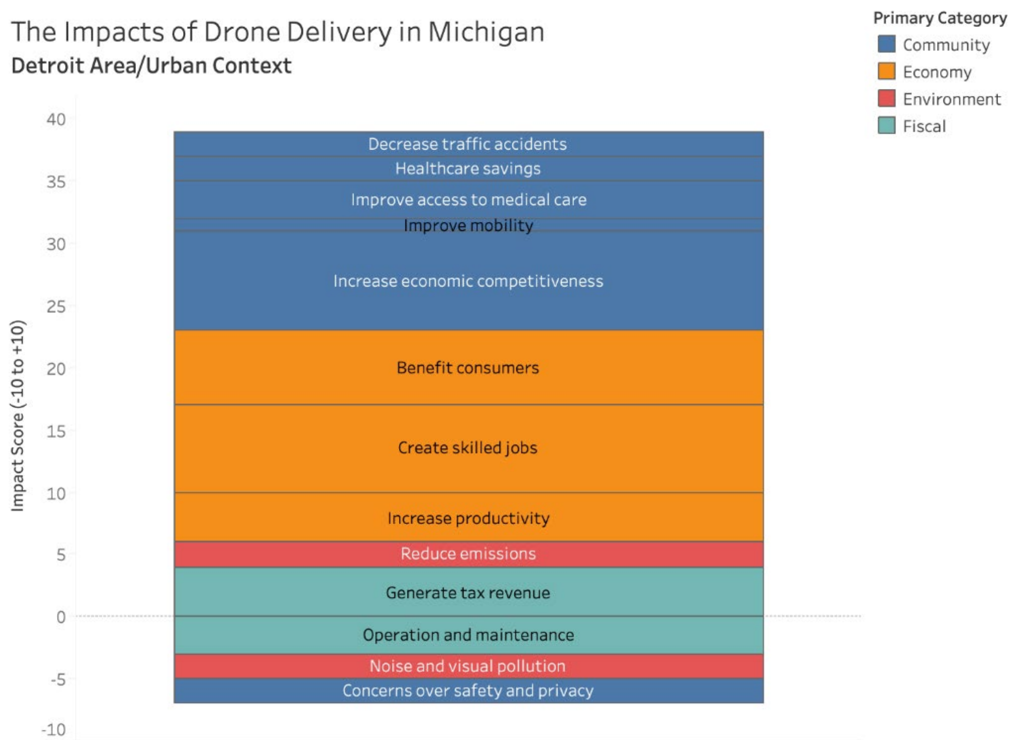


Figure 31: Drone Delivery Impact in the Detroit area

For Areas 1 and 2, the largest impacts fall within the Economy category. There are two broad reasons for this. First, there is a high amount of economic activity and freight movement within the manufacturing and medical use cases we studied that could be replaced or supplemented using delivery drones. Second, in addition to greater economic activity, there is a greater economic need in Areas 1 and 2, with the median per capita income falling well below the national average and the state of Michigan. Creating new skilled jobs would therefore have an outsized real impact on the residents in the area. From a community or social standpoint, these new skilled jobs may also enhance the general competitiveness of the area and quality of life for residents, as demand for talent drives overall growth and secondary employment in industries like hospitality and entertainment.

Readers can explore an interactive version of the Impact Scoring location comparison online. Details on each impact score and rationale can be found in a consolidated table in Appendix D.

Transportation Impact Assessment

Multi-Modal Interconnection Opportunities

Multi-modal connections and interfaces across the state and local transportation system are necessary to maximize the economic, environmental, and community benefits of the UAS corridor. Without such multimodal logistics environments and the associated economies of scale of using delivery drones, it can be difficult to realize productivity gains or benefits to consumers.

A multimodal interconnection environment streamlines connections between rail, ground vehicles, and aerial vehicles. Multimodal interconnections may be physical infrastructure, mobility services, and/or digital infrastructure and may include research and development, testing, and the full-scale operation of new logistics technologies. More information on this topic can be found in the 'Impacts' section of this report.

Methodology & Sources

Seamless intermodal operations require efficient operation of each component part as well as integrated operations among systems. The Project Team drew on its experience designing intermodal systems for a number of different mobility and advanced technology networks to identify and assess opportunities to leverage and areas of focus for additional research, demonstration, testing and development. The Project Team's experience with ports, rail stations, and regional transit hubs was also drawn upon as comparable proxies.

In addition to this subject matter expertise, the Project Team spoke with stakeholders interested in developing a multi-modal logistics environment to gain an understanding of specific opportunities in the geographic areas of interest. One compelling proposal was submitted by Aerotropolis and Willow Run Airport for MDOT's Program Development Portal Research Idea Form supported by MDOT Research Administration.

Findings

A multi-modal logistics facility offers a way to ensure critical goods get transported in a timely fashion. This is especially important in our current geopolitical and economic climate, where disruptions like supply shortages or labor strikes have become commonplace.

To maximize the benefits of a multi-modal interconnection environment, MDOT and partners should approach implementation by focusing on the following:

- Autonomous cars/trucks moving in the rail right of way
  - Testing new rail crossing signaling stations to better manage ground traffic
  - Testing right of way networks to improve movement of cargo and people
- Drones moving in the rail right of way
  - Testing integration of rail signaling stations to UAS traffic controls.
  - Testing low altitude airspace for package delivery
- Testing communication and surveillance networks to improve intermodal and multimodal transportation
  - Testing the movement of cargo between rail, trucks, and drones
  - Developing next generation intermodal transload facilities, including testing autonomous loading and unloading technologies
- Exploring and understanding infrastructure and design considerations
  - Logistics center design to facilitate autonomous/highly automated transload devices
  - Intermodal network connections such as ramp or intersection design to facilitate ground level final delivery
  - Zoning and urban design considerations for intermodal facilities incorporating UAS
  - Utility grid considerations for low/no emission intermodal facilities
- Understanding talent shortages and integrating diversity, equity, and inclusion in future workforce training
  - Cataloging the retraining/reskilling required to support the advanced air mobility industry
  - Identifying workforce partners for recruitment/job placement.

Airport

Modes	Payload -> Destination	Service Provider
Air Freight <-> UAS	Freight / Package to Customer	UPS
UAS		Bell Helicopter
		Volatus

Droneport / Nest

Modes	Payload -> Destination	Service Provider
Ground Freight <-> UAS	Retail Pickup to Customer	Google Wing
Currier <-> UAS		
POV <-> UAS		
UGV< -> UAS		

Big Box / Fulfillment Center

Modes	Payload -> Destination	Service Provider
Ground Freight -> UAS	Fulfillment to Customer	Amazon
		Walmart

Retail

Modes	Payload -> Destination	Service Provider
Ground Freight -> UAS	Retail to Customer	Matternet
UGV -> UAS		Flytrex
Currier <-> UAS		
POV <-> UAS		
UGV< -> UAS		

International Port of Entry

Modes	Payload -> Destination	Service Provider
Ground Freight -> UAS	Port to Port	UPS
UAS -> Ground Freight		
POV -> UAS		
UAS -> POV		

Private

Modes	Payload -> Destination	Service Provider
Facility -> UAS	Facility to Facility	Spright
Fleet -> UAS		
Ground Freight -> UAS		
UGV -> UAS		

Mobile

Modes	Payload -> Destination	Service Provider
Ground Freight -> UAS	Ground Vehicle to Customer	UPS
UAS		Workhorse

Figure 32: Potential Use Cases of Multi Modal Transportation with UAS

Area 3 Overview

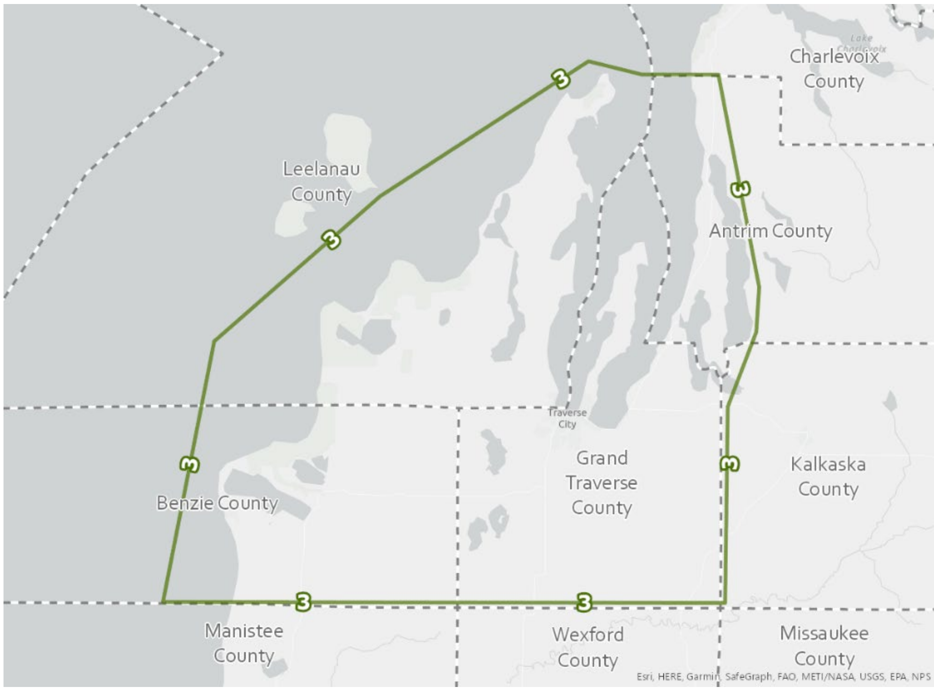


Figure 33: Geographic Boundary of Area 3

The Project Team collected key demographic, geographic, and economic information about the general study area to better understand their unique attributes and characteristics. This information provided the necessary context to develop use cases that support the area's strengths, provide the greatest benefits, and are transferable to other locations in Michigan that share the same attributes.

Figure 33 shows the third study area included in this case study. Figure 35 highlights the demographic, social, and economic details for the population within this study area.

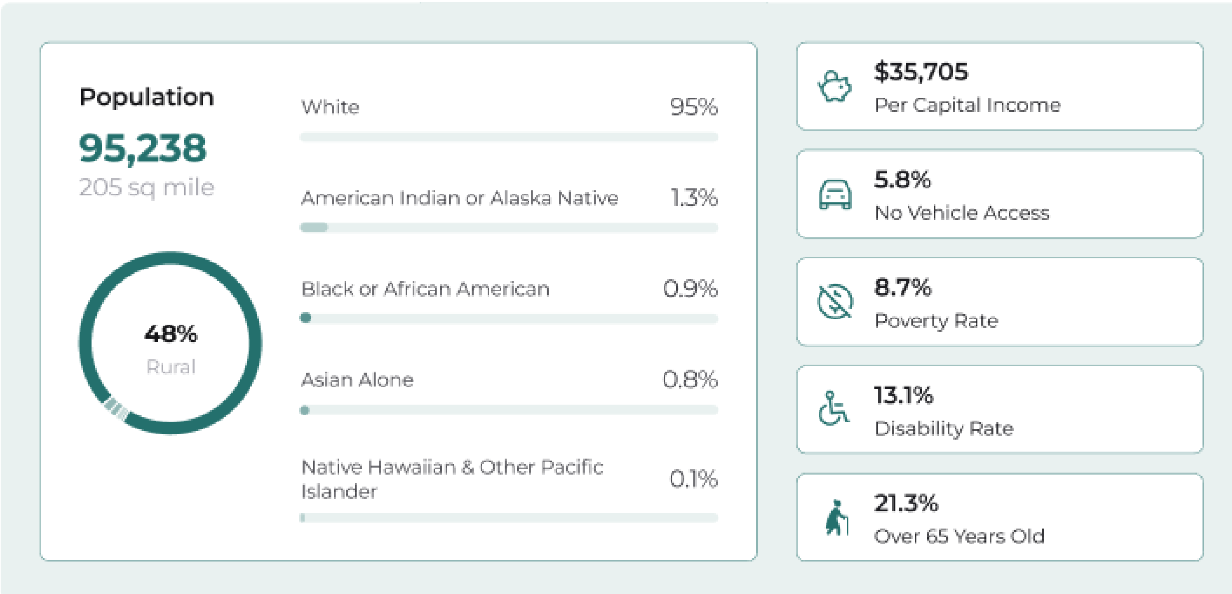


Figure 34: Demographic Overview of Area 3

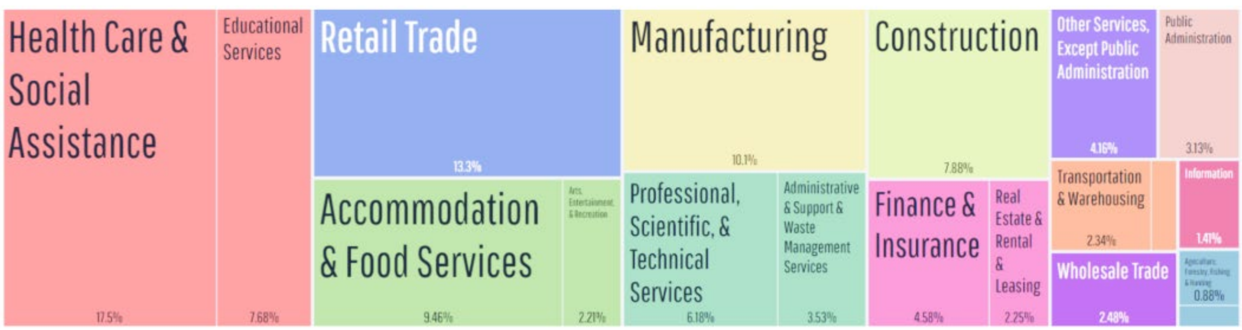


Figure 35: Job Classification in Area 3

Stakeholders

Introduction

When scaled, drones will impact people's day to day lives in direct and indirect ways that crewed aviation does not, considering the low-altitude airspace they will occupy. For this reason and countless others, this project depended on early, often and sustained engagement with stakeholders of all manners. How we identified those stakeholders most relevant to the preliminary portion of the study is described below in great detail. The method of communications with those stakeholders varied, including:

1. Email Communications
2. Media and Social Media communications
3. Briefing progress to existing Government and Industry bodies (i.e., the UAS Task Force, and the Council for Future Mobility and Electrification)
4. Hosting multiple UAS Summits, Town Halls, and other group conferences that were held hybrid in-person and virtual for accessibility

The Project Team's approach to this portion of the preliminary assessment includes the identification of initial key stakeholders, users, and use cases for the UAS Corridor that provide immediate and longer-term benefits to the communities near the locations of interest in Area 3. The Project Team researched a broad spectrum of potential BVLOS drone operational use cases for all areas and narrowed down use case candidates qualified by a best-fit analysis leveraging the attributes and strengths of the area (i.e., economy, geography, demographics, transportation infrastructure, utilities, air, and ground risk, etc.).

Methodology

The Project Team considered and weighed stakeholder impact (see Table 14). Stakeholders from existing associations, private/public partnerships (P3), regional or state transportation, and mobility initiatives who would benefit from or be vested in the success of establishing a UAS corridor became factors in the decision-making process. Additionally, the Project Team assessed whether there were industry clusters and/or major national or international employers with headquarters located within the recommended area of operations who would directly benefit from the establishment of shared-use UAS infrastructure. Equally important were the drone-as-a-service operator stakeholders who would ultimately need to be incentivized to establish operations in the prescribed area; as such, we conducted market analysis to understand the likelihood for commercialization of services, or at least the ease of transferability of testing capabilities in the area (could assets or IP be lifted/shifted into a similar region or application within the state).

Stakeholder Impact						
Objectives	Leverages **Existing P3 / Associations**	Leverages **Existing Transportation Initiatives**	Proximity to **Corporate HQs**	Proximity to **Industry Clusters**	Operators: Path to Commercialization	Operators: Transferability
Definition	Is the use case of benefit or interest to existing private, public partnerships or related associations.	Is the use case able to leverage funding, expertise, momentum or other capital of existing transportation initiatives.	Is the use case located in proximity to corporate HQs that are of particular significance to Michigan, or a relatively high quantity of corporate HQs.	Does the location of the use case have the potential to impact a known industry sector cluster, i.e., high-tech manufacturing.	Does the use case provide a clear path to commercialization for the operator.	Can the Operator easily transfer assets, experience or qualifications to new use cases/ locations.

Table 14: Stakeholder Impact Evaluation Methodology

Working with the stakeholders provided relevant insights, resources, and information throughout the project. These stakeholders are positioned to facilitate, through direct or collaborative roles as necessary, the process of implementing and leveraging the future drone infrastructure in Michigan.

The Project Team then used the list of qualified use cases to identify a stakeholder registry* creating a list of contacts and contact details (i.e., organization, title, role, area of interest, phone number, email, etc.) that would be used to further socialize and validate the use cases that aligned with their organization interests and geographic location within the corresponding study areas. The Project Team coordinated events along with the MDOT PMO to engage the stakeholders in reviewing the project vision, objectives, approach, and use case.

Stakeholder Registry								
Name	Contact (email/ phone)	Type (Internal/ External)	Org.	Title	Role	Influence (H,M,L)	Area (1,2,3)	Comms Cadence

Table 15: Stakeholder Registry

The Project Team also connected with its drone partner ecosystem and compiled an operator registry to identify qualified drone service providers within the United States that are well-positioned to support the use cases identified in the use case selection process. Information gathered on the service providers includes but is not limited to company name, market focus, headquarters location, regulatory certifications, customer partnerships, location of current test sites and operation sites, and more. This information was used to further qualify all use cases through the identification and validation of service availability for each ensuring that if MDOT should invest in UAS infrastructure in support of the preliminary use cases existing operators would be immediately available and incentivized to leverage the infrastructure.

UAS Operator Registry (excerpt)							
Company	Industry Role	Operator/ Airline Partnerships	Commercial Partnerships	Regulatory Certifications	Public Ticker	HQ Location (City)	...

Table 16: UAS Operator Registry (excerpt)

Lastly, the Project Team sought to understand the true user needs of the community through a partnership with local engagement organizations, as the community would ultimately accept and adopt the capability or see it as an infringement or worse. These community acceptance criteria are factored in heavily in the Impact Analysis section, pages 45-51, and Appendix D.

Once the initial set of use cases was identified, the Project Team applied a use case selection process to narrow down the candidates even further, applying a scoring method that uses the same qualifying criteria from Areas 1 and 2, that of aligning with the MDOT 2045 Mobility Plan and MDOT Aviation Systems Plan, Strategic Impact Criteria and Operational Criteria. For more, see Table 1: Use Case Evaluation and Identification Methodology, based on the MDOT Aviation Systems.

Objectives	2045 Mobility	MDOT Aviation Systems Plan					
	Operations within **Strategic Multimodal Corridors (SMC)**	Serves Population Center	Serves Business Center	Serves Tourism Center	Provides Access to General Population	Serves Isolated (including seasonally) Areas	Enables All Weather Access
Definition	Does the use case exist within or service an SMC (defined as integrated, multimodal system serving the movement of people, services, and goods that are vital to the economy).	Does the use case serve the most densely populated areas of the state (defined by 250 ppl per sq. mile).	Does the use case serve or positively impact businesses in areas of the state with increased business activity (defined employment projections of at least 3,000 by year 2040).	Does the use case serve or exist in ra easonable distance to tourist locations within Michigan (defined by counties with $75 million or more in visitor spending).	Does the use case serve non-business, non-recreational use within Michigan (i.e., law enforcement, healthcare organizations, educational institutions, etc.).	Does the use case serve islands that have year-round residents (Beaver, Bois Blanc, Drummond, Harsens, and Mackinaw Islands).	Does the use case enhance or positively impact all-weather operations and access.

Table 17: Use Case Evaluation and Identification Methodology, based on the MDOT Aviation Systems

Findings

After a preliminary analysis of the opportunities in Area 3, it became clear that the use cases would be associated with the land and maritime public safety and services. Use case examples that aligned with MDOT and Michigan's strategic goals included package delivery to rural points of need, servicing remote and seasonally isolated populations, and infrastructure and natural resource management services.

Through this analysis and engagement process, the Project Team was able to provide recommendations for the ideal use cases to prioritize for capability demonstrations and applications that would meet both the highest impact value to the area and the greatest appeal to commercial UAS providers in their market analysis. This, at its core, is the blueprint function of the analysis – a repeatable, data-driven approach to scaling UAS across the State.

The Project Team then used the list of qualified use cases to identify stakeholders that would be leveraged to further socialize and validate the uses cases that aligned with their organizational interests and geographic location within the corresponding study areas. The Project Team coordinated events along with the MDOT PMO to engage the stakeholders reviewing the project vision, objectives, approach and use case details with the stakeholders. Examples of initially identified stakeholders include but are not limited to those shown in Figure 36.

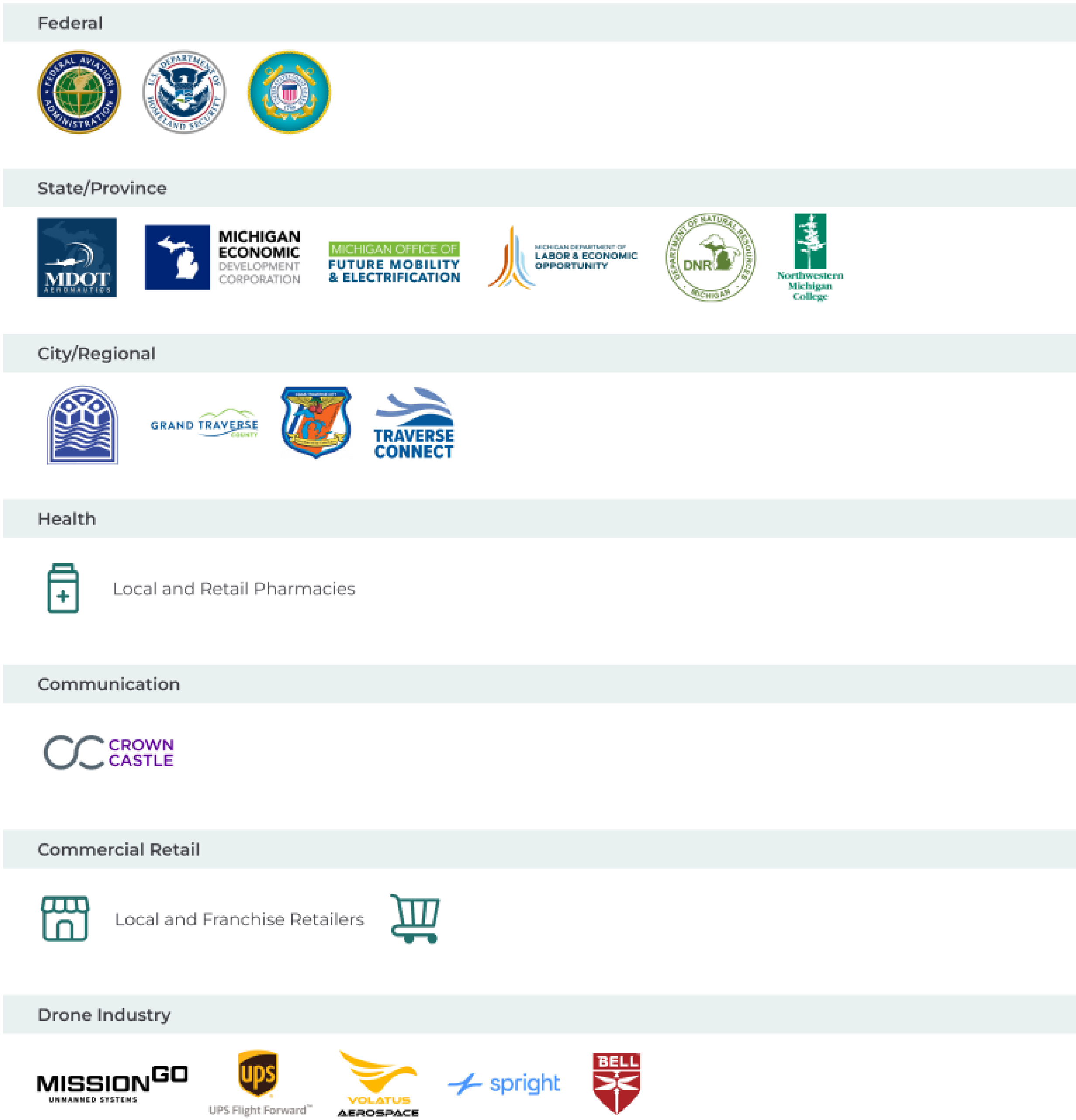


Figure 36: Potential Stakeholders of a UAS Corridor in Michigan (Area 3)

Use Cases

Overview

A critical and novel aspect of the blueprint is in the detailed, repeatable, and defensible process for determining a designated area or drone corridor location with the highest return on investment. To do so, the team identified use cases that would jump-start drone operations and provide immediate and long-term benefits to the communities within Area 3. This was done by researching and recording a broad spectrum of potential BVLOS drone use case candidates, then down-selecting via a best-fit analysis leveraging the attributes and strengths of this geographic area.

The major potential benefits of all use cases were identified, providing the information necessary to align use cases with community interests with the prospective outcome of the use case. The Project Team then down selected the candidates further with a scoring method that uses qualifying criteria in alignment with the MDOT 2045 Mobility Plan, MDOT Aviation System Plan, Strategic Impact Criteria, and Drone Operational Criteria.

MDOT Aviations System Plan Criteria
Serves Population Center
Serves Business Center
Serves Tourism Center
Serves Isolated (including seasonal) Areas
Enables All Weather Access
Provides Access to General Population
Strategic Impact Criteria
Leverages Existing P3 / Associations
Leverages Existing Transportation Initiatives
Proximity to Corporate HQs
Proximity to Industry Clusters
Operators: Path to Commercialization
Operators: Transferability
Economic, Community, and Environmental Impacts
Drone Operational Criteria
Existing Air Traffic Infrastructure
Airspace Characteristics & Risk
Land Use and Zoning
Ground Risk
Communications Infrastructure
Population Characteristics
Operator & Technology Maturity
Laws, Rules, and Regulations

Figure 37: Criteria Used to Determine Use Case Viability

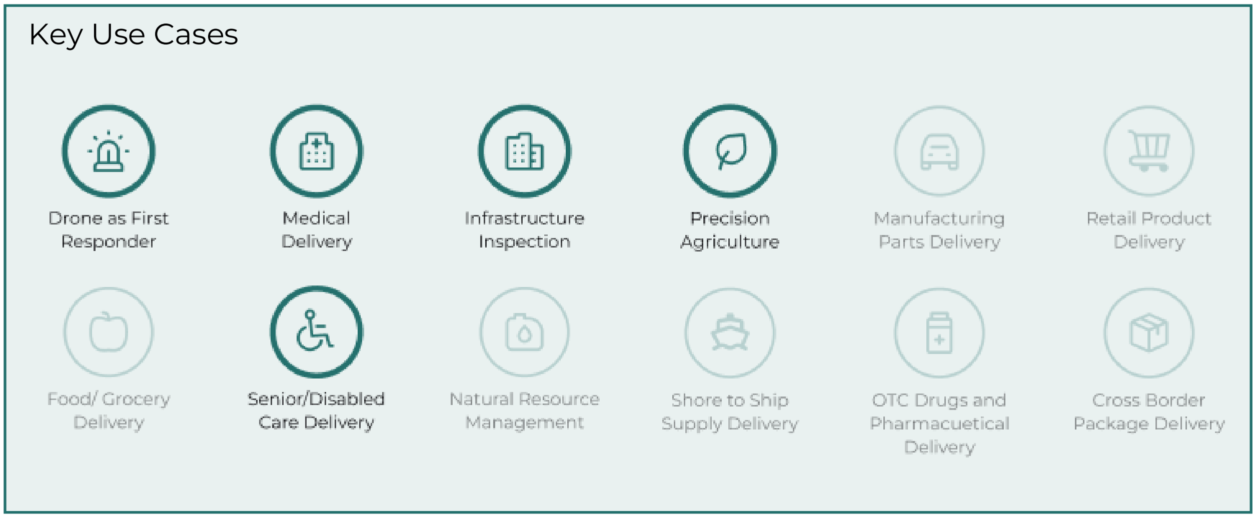


Figure 38: Identified Key UAS Use Cases

Potential Benefits

- Increased Productivity
- Reduce Emissions
- Services to Underserved and Rural Citizens
- Create New Skilled Jobs
- Reduce Traffic
- Open New Markets
- Introduce New Industry
- Increase Medical Access
- Extend Public Transportation
- Extend Current Infrastructure Resources
- Extend Small Business Markets
- Improve Health Care
- Reduce Traffic Injury and Fatalities
- Extend Public Services to At-Risk and Mobility Challenged
- Transportation Electrification

Figure 39: Identified Benefits of Key UAS Use Cases

One novel insight that emerged was the outsized value of selecting a single, champion use case to initiate planning and momentum around. This is perhaps antithetical to the accepted logic behind investing in shared-use emerging infrastructure, the colloquial "build it and they will come" approach. While the investment in public-use infrastructure must be able to service a wide variety of known and to-be-discovered uses, the Project Team discovered it was critical to select and socialize an initial use case that met all the scoring criteria, had strong, vested stakeholders and a clear business/community need that would be addressed to produce performance metrics. Taking the alternative approach often led to unclear requirements, lack of interest or stakeholder investment, and could stall or delay the momentum critical to being an-early adopter.

Risk

Air Risk

Introduction

As the regulator of the US Airspace and manager of the National Airspace System, the FAA is accountable to the public and aviation stakeholders to ensure the USA has the safest, most efficient aerospace system in the world. This mission and mandate require the FAA to ensure that any new addition to the National Airspace System does not present an unacceptable risk to the public or other airspace users. The risk exposure for the latter is what airspace awareness is meant to address. Airspace awareness, which is comprised of all air traffic and the operational environment, is based upon the notion that non-cooperative surveillance is required to detect crewed aviation that may intrude the operational volumes for UAS airspace. This enables airspace awareness for relevant stakeholders and supports an appropriate risk/threat mitigation timeline. In the mid/long-term, it is expected that on-board Detect and Avoid (DAA) capabilities will contribute substantially to requirements for UAS to stay well clear of other airspace users and to enable mitigation actions in cases of potential or expected conflicts.

Long term, DAA will provide the main tactical mitigation to the risk of reduced separation events with crewed aircraft or any other obstacle. However, in the shorter term, ground-based surveillance will continue to play a critical role in this safety function. Even once reliable DAA capabilities are available, we must assume that it will only contribute to tactical safety management as small UAS will not have the power nor payload capability to carry DAA that will perform reliably beyond 1-2 miles. It's important to note that not all UAS will carry airborne surveillance/on-board DAA systems. Thus, ground-based surveillance will still serve as a critical input to the DAA function for small UAS that cannot carry airborne surveillance. This assessment described herein validates the significance of ground-based non-cooperative surveillance infrastructure to facilitate airspace awareness and associated services.

Methodology to Characterizing Airspace

The approach to characterizing airspace and estimating its associated air risks for MDOT Areas 1-3 leverages Thales' existing quantitative analysis and visualization capabilities to provide a standardized and repeatable process to help identify areas of increased air risk for proposed operations in low altitude airspace (<1,200' AGL). Thales' DAIP is the tool used to support the analysis and visualization capabilities. The output of the aforementioned platform provides historical traffic density and actual track counts of cooperative traffic at specific altitudes. Collecting, processing, and visualizing cooperative traffic, however, provides only a partial view of the total airspace picture but is still very relevant to evaluating air risks. To complement the cooperative traffic view, the deployment of primary sensors to detect non-cooperative targets when there is no TRACON/terminal radar data available can help provide a more complete air traffic picture and overall situational awareness to end-users.

To evaluate air risk, airspace metrics are used specifically to estimate the likelihood of a reduced separation event between uncrewed and crewed aircraft. These violations or events are just one of the main factors in computing the UAS operation's air risk. Metrics are computed using the following sources:

- FAA System-Wide Information Management (SWIM) system track data from Air Route Traffic Control Centers (ARTCCs) and/or Terminal systems
- Track data from ARTCCs are attained from the FAA's SWIM Flight Data Publication Service (SFDPS)
- Track data from Terminal systems are attained from the FAA's SWIM Terminal Automation Information Service (TAIS)
- FAA Radar
- MDOT ground surveillance sensors

Airspace Metrics include:

- Traffic density/count (by altitude and time of the day)
- Unmitigated background potential reduced separation events per hour(s) of flight (by altitude and time of the day)

When no historically significant set of UA trajectories are available, a more generic method is used to characterize the unmitigated air risk associated to a specific airspace volume. The airspace volume under analysis is mapped using a mesh of H3 cells (hexagon), and using historical recorded crewed aviation traffic, to compute the number of reduced separation events assuming a UA is stationary at the center of each cell and a "hockey-puck" volume. The result, in terms of number of events per unit of time, in the form of a graphical map can help plan the mission to avoid "hot spots" and therefore minimize the risk of a reduced separation event between an uncrewed and crewed aircraft.

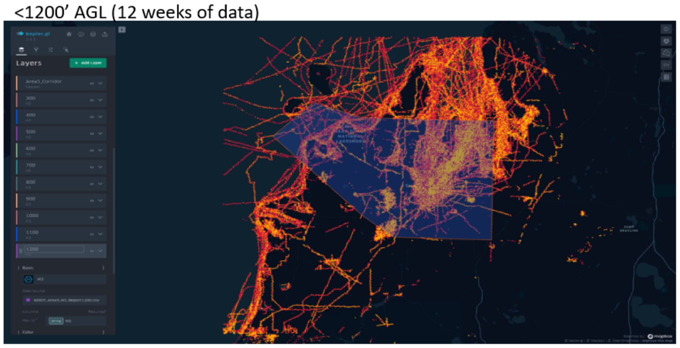
The figure below is a computed example around Area 3 using only SWIM terminal radar data. The method requires availability of significant recording of crewed aviation in the airspace. The air risk model can be complemented by using MDOT ground surveillance infrastructure.

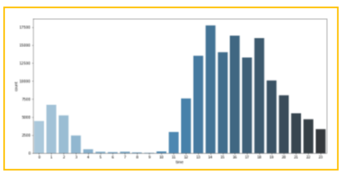
Airspace Characterization:

Included in this characterization is an assessment of individual manned aircraft tracks, pinpointing high-density areas, and presentation of a UAS Static Air Risk Map (USARM), derived from sufficient historical air traffic data.

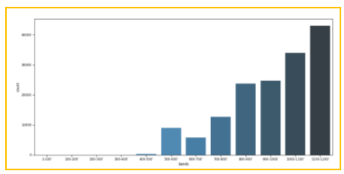
MDOT Areas of Interest – Density & Track Results

<1200’ AGL (12 weeks of data)





Total Tracks per Time (Zulu)



Total Tracks per Altitude Band (AGL)

- **153,556 distinct tracks** <1200’ AGL within the MDOT Corridor
- Total Tracks per altitude band:
  - 43,072: 1100-1200’
  - 34,007: 1000-1100’
  - 24,723: 900-1000’
  - 23,773: 800-900’
  - 12,746: 700-800’
  - 5,809: 600-700’
  - 9,047: 500-600’
  - 379: 400-500’
  - 0: 300-400’
  - 0: 200-300’
  - 0: 100-200’
  - 0: 0-100’

Note: corridor height is given as 400’ AGL. Higher altitude is provided to illustrate activity above the corridors. Assumption: 800’ MSL in the dataset is baselined to represent 0’ AGL

- Aircraft behavior and hotspots remain constant within each band
  - Includes KTVC
  - Concentration of manned traffic appear aligned with commercial aviation patterns around the airport
  - Remaining traffic is associated with general aviation representing recreation traffic along lake shoreline and bay as well as publicly operated aircraft (i.e. US Coast Guard) traffic in the same areas.

Figure 40: Airspace Characterization using Historical Track Data

The characterization of airspace is one component of the overall Operational Risk Assessment (ORA). The other components comprise of assessing ground risks and how well the area (i.e., service volume) can be covered by surveillance sensors and Command and Control (C2) capabilities. Figure 41 below illustrates this holistic approach to assessing not just the operational risks, but also the infrastructure analysis necessary for this feasibility study.

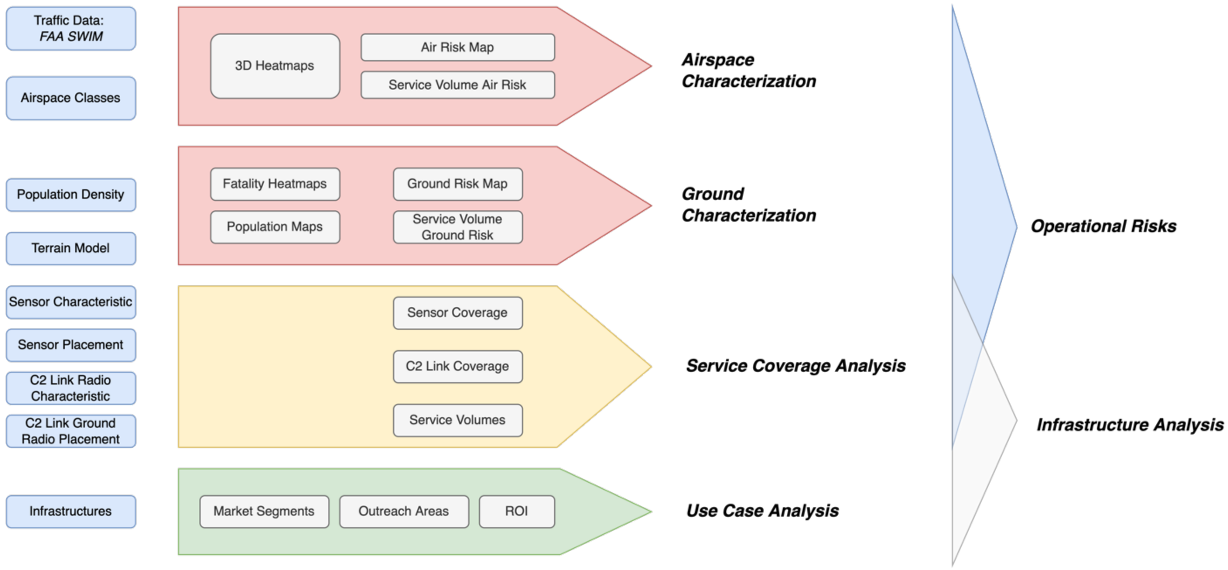


Figure 41: Airspace Characterization Process as part of the Overall Operational Risks and Infrastructure Analysis Process

In general, this repeatable process can be applied not just to the defined corridor boundaries provided by the Customer, but to any region in the NAS. The corridor boundaries are defined here as the MDOT Service Volumes (MSV) within the overall MDOT Areas of interest (Area 3). MDOT Service Volumes are generally described as the areas where both surveillance and command and C2 performance requirements are met. The MSV is a subset, or the union, of where C2 coverage and surveillance volumes overlap. From the MDOT Service Volumes, surveillance sensor and communications network infrastructure are assessed for coverage and availability.

The following separate analyses are conducted to provide the airspace characterization and service coverage picture:

- **Airspace Characterization**: Use of surveillance data to allow for the estimation of the air risk. For the purposes of this project, low altitude is defined here as navigable airspace less than 1,200 feet AGL. Airspace Characterization analyses will use this height as the upper threshold to bound the surveillance data.
- **Radar Coverage Analysis**: Analyzes the line-of-sight capability of the surrounding radar sites to inform the completeness of the surveillance data.

Computing air traffic density becomes a method to which air risk can be estimated. With this relationship, the computed air traffic density represents the most conservative view of the airspace picture and ultimately presents the unmitigated air risks for a defined airspace volume since aircraft tracks, in this context, are seen as intruders within the service volume.

Preparing the Dataset

The air traffic density analysis aims to examine historical cooperative traffic from 1,200 feet AGL to the surface in the service volume from the period of June 2021 – August 2021. Due to data for

Cherry Capitol Airport being unavailable data from Detroit Metro Wayne County was used as an analog. The June through August months were chosen as they represent a period of **peak traffic** activity around the Detroit metropolitan area during the calendar year. This same period was then used for the airspace characterization analysis in Area 3. Processing peak traffic is important as this provides a dataset that best represents the densest crewed traffic activity for a specific region and time period. To justify the period corresponding to peak traffic activity, the following FAA databases were used:

- Aviation System Performance Metrics (ASPM)
- Terminal Area Forecast (TAF)

The ASPM online access system provides data on IFR and VFR flights to and from the ASPM airports (including the Core 30 and OEP 35 airports), and all flights by ASPM carriers, including flights by those carriers to international and domestic non-ASPM airports. From the FAA's ASPM database, the Metric Module was used to collect information on aircraft departure and arrival times and flight delays at selected airports compared to the schedule and flight plan times. For the purposes of this project, Detroit Metro Wayne County (KDTW), Coleman Young Municipal (KDET), and Willow Run (KYIP) airports were selected. Due to availability of the metrics per airport, the only metrics considered in this report are those of KDTW.

The FAA's TAF database is the official FAA forecast of aviation activity for U.S. airports. It contains active airports in the National Plan of Integrated Airport Systems (NPIAS) including FAA towered airports, Federal contract towered airports, non-federal towered airports, and non-towered airports. Forecasts are prepared for major users of the National Airspace System (NAS) including air carrier, air taxi/commuter, general aviation (GA), and the military. For the purposes of this project, the Calendar Year (CY) 2021 TAF Report was used to collect counts of GA traffic since the ASPM system does not collect GA traffic counts.

From the ASPM database, peak flight operations and activity, along with GA Counts for calendar year 2021, binned by hour (Zulu), are depicted in the figures below. The red dashed outline around the total flight operations during months 6 (June) through 8 (August) highlight the peak activity.

Table 18: Number of Departures per Hour per Month at DTW Airport

Sum of Departures for Metric Computation

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	8	21	29	32	20	29	5	26	20	20	21	28
1	4	6	9	2	3	3	4	2	2	5	4	4
2	3	5	1	1	1	4	2	4	0	3	1	4
3	0	4	4	2	2	4	1	1	11	15	12	4
4	4	6	5	0	1	2	2	1	3	2	4	14
5	7	5	3	5	2	23	87	92	100	58	80	78
6	217	203	398	448	405	433	436	443	367	404	501	531
7	265	248	299	298	375	552	694	751	637	737	818	809
8	1198	1147	1328	1358	1561	1654	1676	1594	1640	1579	1579	1613
9	472	398	412	402	422	369	314	327	301	304	145	197
10	1323	1281	1560	1486	1546	1425	1500	1502	1322	1348	1285	1187
11	141	69	120	218	267	230	212	214	196	255	220	170
12	770	659	777	836	1046	1107	1105	1158	1249	1150	1107	1037
13	206	230	328	224	201	409	574	552	531	567	523	510
14	602	503	680	714	674	683	701	573	534	588	593	531
15	828	716	601	669	641	667	584	692	655	643	707	694
16	1029	864	1230	1278	1430	1284	1473	1402	1367	1318	1207	1190
17	212	214	263	229	242	371	366	376	407	534	466	411
18	136	112	209	210	214	436	465	464	497	593	653	579
19	598	410	496	647	586	272	212	173	156	148	156	225
20	818	734	995	720	734	864	981	881	823	835	710	676
21	852	790	986	1105	1258	1350	1066	1015	920	795	782	948
22	118	101	152	120	109	339	604	654	691	737	661	647
23	39	31	35	37	32	60	55	40	59	59	139	91
Grand Total	9850	8757	10920	11041	11772	12570	13119	12937	12488	12697	12374	12178

Table 19: Number of Arrivals per Hour per Month in DTW Airport

Sum of Arrivals for Metric Computation

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
40	13	94	126	197	191	225	215	152	166	186	201
9	7	6	6	18	11	20	16	5	1	15	20
6	8	5	2	5	2	3	2	15	19	12	7
1	3	5	2	2	2	2	2	2	5	7	21
14	10	32	32	27	46	45	33	46	32	18	16
148	116	193	192	169	252	227	226	157	177	194	204
91	76	77	81	150	228	321	284	297	312	277	235
801	898	1127	1074	1165	1069	1156	1201	1115	1072	1071	1099
588	412	342	332	304	427	404	307	245	212	200	225
592	442	719	726	734	929	890	874	877	868	819	679
206	184	175	239	379	322	307	317	294	356	260	227
607	476	685	780	839	826	993	1064	1161	1178	1120	1029
318	394	515	461	399	548	557	512	502	500	531	528
720	585	709	757	774	716	854	818	667	630	590	579
937	929	884	887	942	857	852	1086	966	953	942	834
823	684	971	990	1050	1071	1191	1024	1099	1110	1003	1131
199	209	293	243	263	389	419	474	479	514	512	500
557	409	472	586	553	675	682	623	624	682	701	680
720	659	816	720	833	562	470	306	314	390	440	446
1253	1090	1145	1072	1124	1238	1398	1419	1383	1433	1257	1241
678	628	902	942	895	1118	1030	1128	1005	948	873	1010
177	142	185	211	223	379	409	438	470	534	453	342
235	228	235	284	222	354	336	231	305	312	574	606
131	140	292	288	463	318	336	342	283	274	307	295
9851	8742	10879	11033	11730	12530	13127	12942	12463	12678	12362	12155

Table 20: Total Number of Departures and Arrivals per Month at DTW Airport

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Total Departures	9850	8757	10920	11041	11772	12570	13119	12937	12488	12697	12374	12178
Total Arrivals	9851	8742	10879	11033	11730	12530	13127	12942	12463	12678	12362	12155
Grand Total	19701	17499	21799	22074	23502	25100	26246	25879	24951	25375	24736	24333

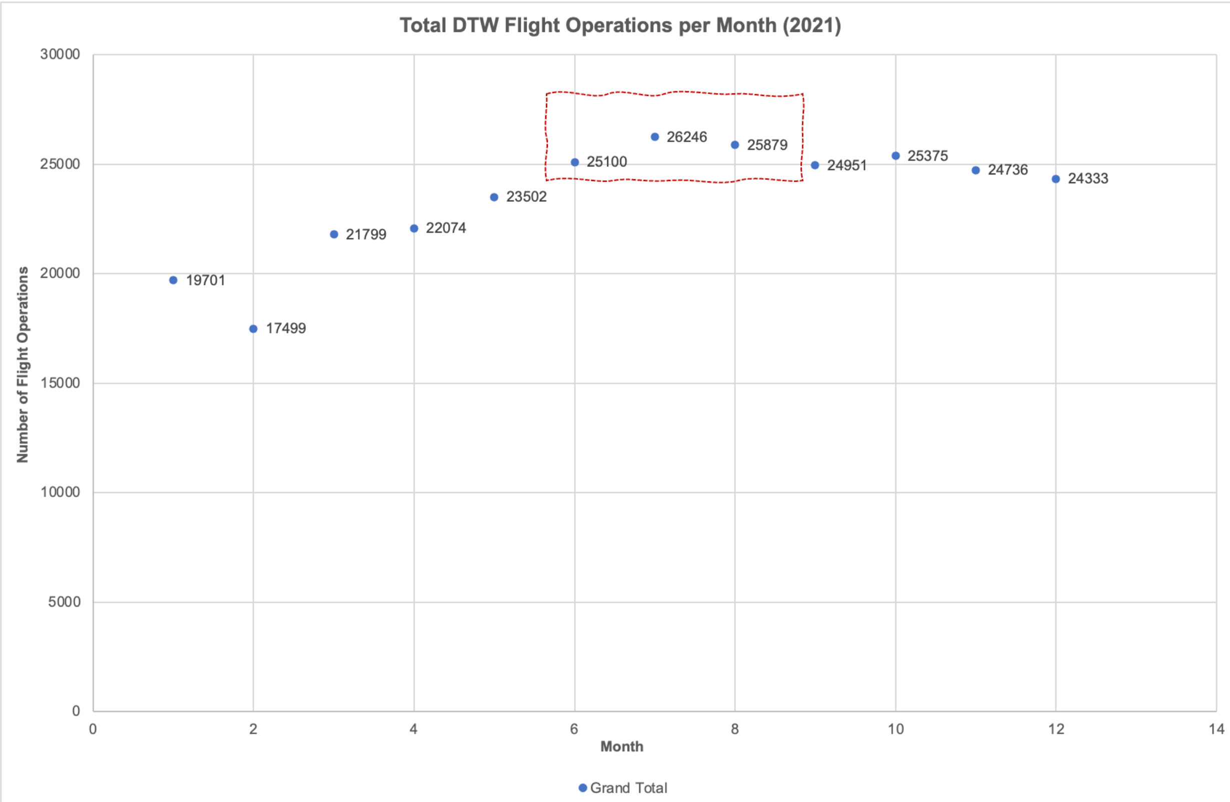


Figure 42: Peak Number of DTW Flight Operations in 2021

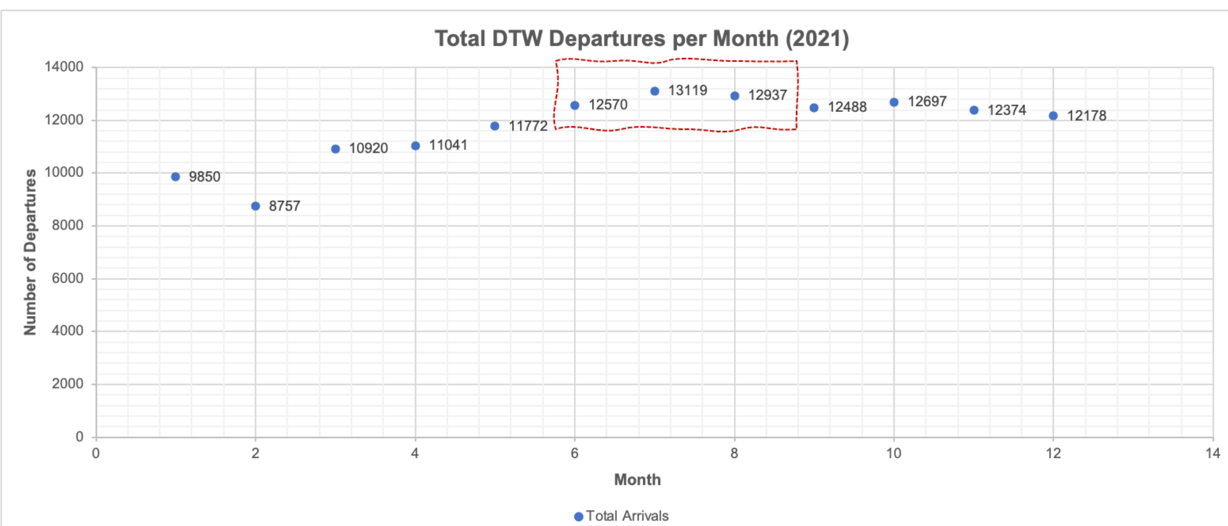


Figure 43: Peak Number of DTW Departures in 2021

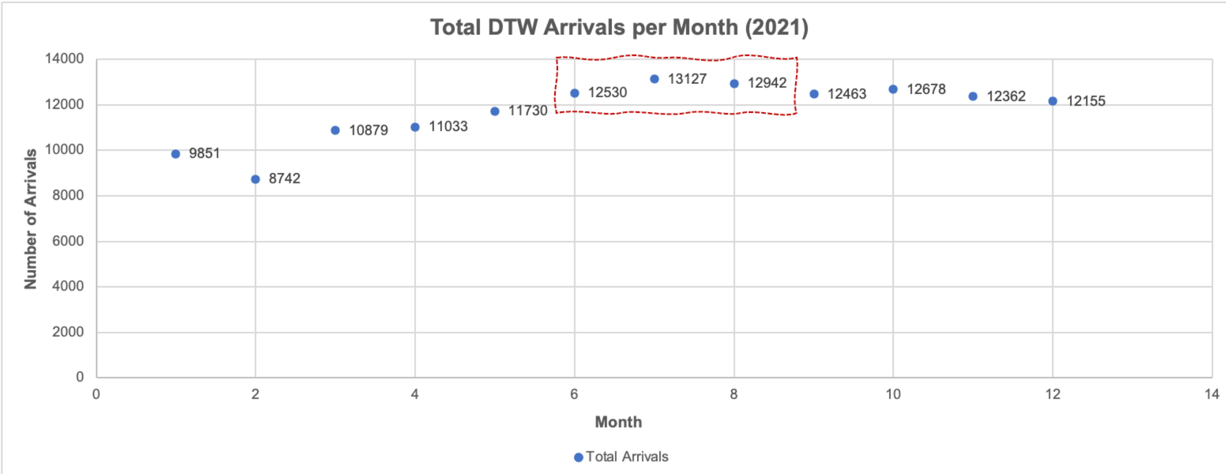


Figure 44: Peak Number of DTW Arrivals in 2021

Table 21: Summary of General Aviation Traffic in Detroit Area Airports

APORT_NAME	Sum of LOC_GA	Sum of ATN_GA
Detroit City	21781	22961
Detroit Metro Wayne Co	0	4245
Detroit Willow Run	23542	21105
Grand Total	45323	48311

Analysis Components – Data Quality

With the peak activity timeframe identified and justified, collection of all traffic data for the regions of interest is achieved using the DAIP. To ensure the quality of the analysis, the authoritative sources of air traffic data originate from the FAA; specifically, the FAA's System-Wide Information Management (SWIM) network. Thales has onboarded with the FAA as an official industry SWIM services consumer and has met all security and performance requirements required by the SWIM program office to consume all available data topics via the National Airspace System (NAS) Enterprise Messaging Service (NEMS). As such, and for the purposes of this task, all cooperative crewed surveillance track and position data (i.e., track reports) in terminal airspace are sourced from the SWIM Terminal Data Distribution System's (STDDS) Terminal Automation Information Service (TAIS).

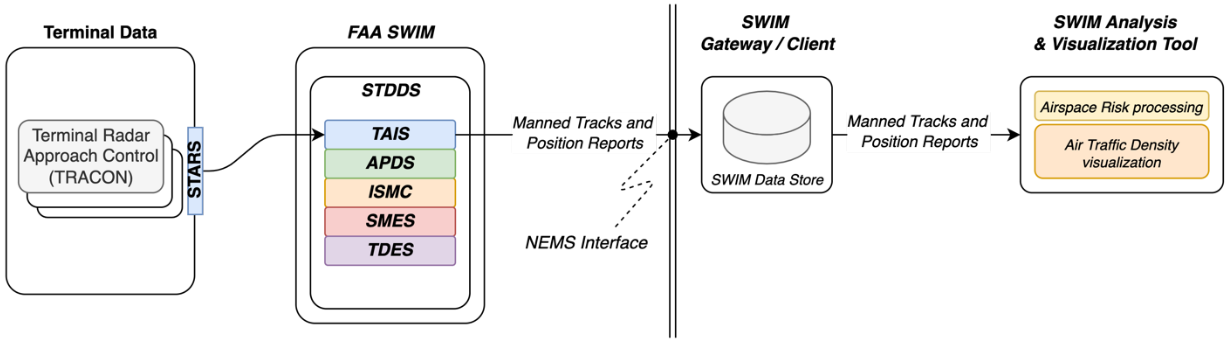


Figure 45: SWIM Data Information Flow[4]

In the figure above, terminal data originating from Terminal Radar Approach Control (TRACON) facilities are made available to the SWIM service via the Standard Terminal Automation Replacement System (STARS) interface, from which the TAIS service publishes operational live flight plan data, track data, sign-in/sign-out (SISO) data, alert data, Instrumental Meteorological Conditions (IMC) data, traffic count data, and performance monitoring data to authorized SWIM service consumers via NEMS. From the NEMS interface, the Thales SWIM Gateway consumes and logs all available information. The use of the Digital Aviation Integration Platform allows an end-user (e.g., data analyst) to query the ATM-truthed track report data to process target reports for a given geographical area, where visualization capabilities of the tool can output histograms of track counts, all binned by altitude band (in hundreds of feet), or hourly time slice. Air traffic densities and track information can also be overlaid onto a geographical map, or a Visual Flight Rules (VFR) aeronautical chart. For this study, it is important to note that the output of the traffic reports from the TAIS service, specifically the reported altitude, are provided in Mean Sea Level (MSL). Thus, the following assumption is made when preparing the airspace characterization analysis: due to the varying field elevation values in the vicinity of the KDTW and KDET, 600’ MSL is assumed to represent 0’ AGL for the dataset (inclusive of Area 3).

Operational Environment – MDOT Operational Areas and Characteristics

As an input to the Digital Aviation Integration Platform, the regions of interest must be known so air traffic data can be *pulled* from the collected SWIM data to create the Jun-August 2021 dataset. The customer has proposed three (3) MDOT areas of interest within the State of Michigan. Two (2) of these areas were identified earlier in this document. Area 3 is defined here as the greater boundary around Traverse City, MI, as depicted in Figure 46.

[4] The STDDS system is comprised of additional information services, such as the Infrastructure System Monitor and Control (ISMC), Airport Data Service (APDS), Surface Movement Event Service (SMES), and the Tower Departure Event Service (TDES).

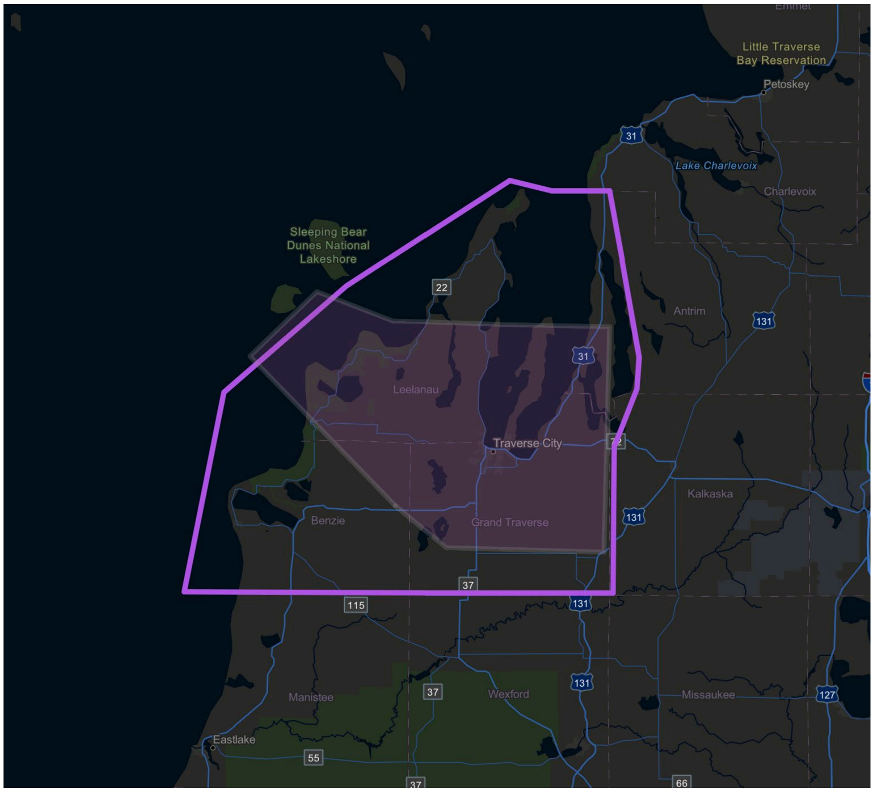


Figure 46: MDOT Area 3 (purple outline) and Corridor (purple polygon)

Operational Area 3 Characteristics

Zooming into Area 3, Figure 47 illustrates the corridor in relation to nearby airport facilities. Similarly, the corridor is overlaid onto a VFR Sectional Chart in Figure 48 to further illustrate its surrounding operational environment and aeronautical characteristics. Area 3 also presents airspace complexities, and this complexity is, again, influenced by the varying operational activity and ground-based infrastructure within this region. For instance, the operational area contains a mixed use of air traffic comprising of Commercial Air Carriers, General Aviation, Private/Business Jet operations, Helicopter operations, as well as Governmental operations (e.g., DoD, USGC) that could be present at low altitudes. The Class D Cherry Capital Airport (KTVC) is a medium sized airport serving these mixed-use airspace operators and unlike the major airports in Areas 1 & 2 that are outside of the corridors, Cherry Capital is solely contained within the corridor. Other smaller airports within the corridor are the Miller-Harrold Airport (18NV) – a Personal/Private Use Airport, and Empire (Y87), Lake Ann Airway Estates (4M0), and Green Lake Airports (Y88), which are all designated as *Public Use Airports.* During the data processing, these airports can contribute to the total track count for Area 3.

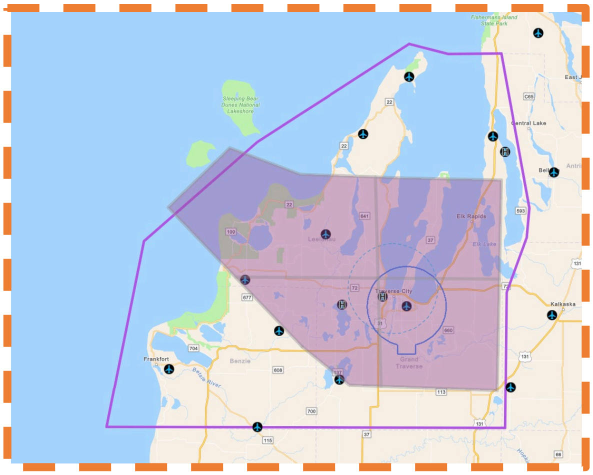


Figure 47: MDOT Operational Area 3 (purple outline) with Corridor Overlay (orange dotted outline represents the area to pull data from SWIM)

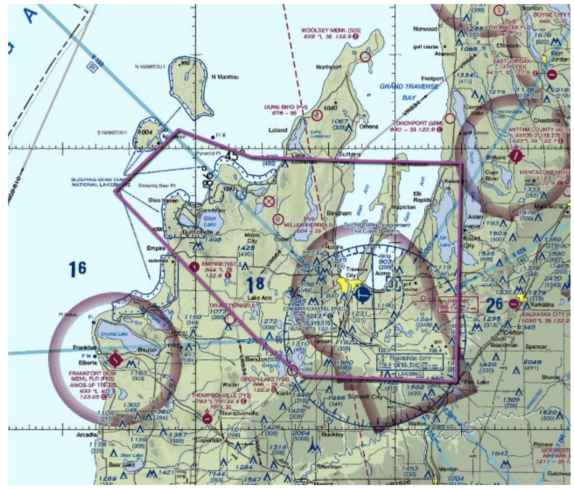


Figure 48: Traverse City Area / VFR Sectional Chart with Corridor Overlay

Outside of the Class D airspace are the Class G and E airspaces serving the majority of the GA community. Similar to Areas 1 & 2, the Area 3 corridor is defined with a ceiling/height of 400' AGL, where it also underlies the Class E airspace, which begins at 700' AGL. Two active and operational helipads/heliports exist within the Area 3 corridor itself. These helipads/heliports descriptions are presented in Table 22.

Table 22: Area 3 Helipad/Heliport Identification and Use

Helipad ID	Helipad/Heliport Facility	Operational Use
22MI	Munson Medical Center	Medical Use Helipad
MI94	TC Helicopter	Private Use Helipad

Area 3 also overlies terrain characterized as an Urban Area, where the total corridor population is 146,104. The presence of obstacles (i.e., buildings, towers, stacks, utility poles, antennas, windmills, etc.) within and around the corridor, as seen as blue icons in Figure 49, also present challenges to navigable airspace. Selection of one of the obstacles from the FAA's Digital Obstacle File reveals a tower that stands at more than 400' AGL; though the majority of these obstacles are either on the airport surface—an area that should be avoided—or within the Class D airspace. The onus falls on the UAS Operator to ensure separation from all obstacles.

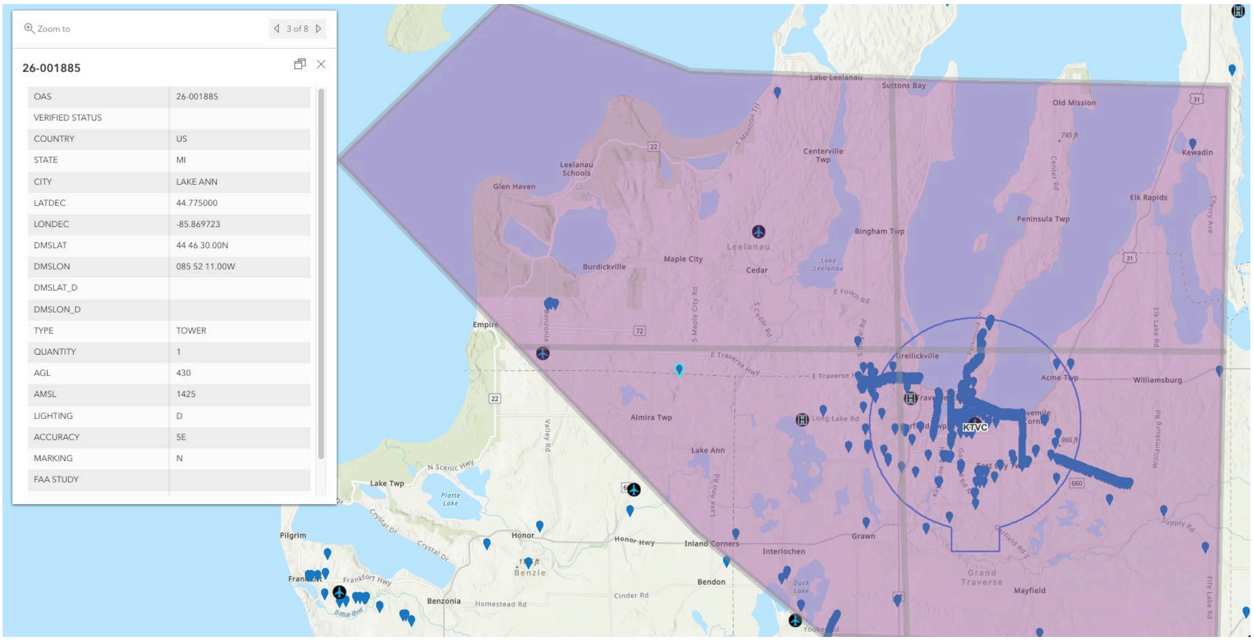


Figure 49: Obstacles in Area 3 (authoritative source: FAA Digital Obstacle File). A tower is highlighted as an obstacle that stands at 430' AGL.

Airspace Characterization

Now that the Operational Areas have been characterized, we must understand the air risks that may be present inside the corridors. Included in this characterization is an assessment of historical track data in order to pinpoint the high-density traffic "hotspots". As explained in 1.2.1, preparing historical air traffic density maps is a way to help estimate air risks, but this method only provides a static view of the air risks. Though only static, this is still a suitable and applicable approach to estimating air risk. A more dynamic way of computing air risks is work that is still in development. More specifically, computing the air risk output will be the actual probability of the UAS encountering a MAC with crewed aircraft based on the UAS' trajectory. In the interim, the results of the historical air traffic density analysis can provide a de facto practice to help identify locations of increased/decreased aircraft densities over a period of time and altitude. As a benefit, visualization of the data can present unique characteristics/insights not easily recognized when looking at the dataset itself. For instance, when visualizing data related to aircraft position, routes, or altitudes, one can see how the data can collectively illustrate certain aircraft behaviors (e.g., tight hovering patterns only rotorcrafts/helicopters can achieve that fixed wing airplanes cannot).

Visualization of the data can also present airspace structures that can account for known IFR/VFR routes, restricted airspace, or classes of airspace (e.g., "holes" or gaps produced in the airspace by routes may validate prohibited airspace over sensitive infrastructure); as well as depict how the natural environment may impact these aircraft behaviors due to weather phenomena, time of day, seasonal variations, etc.

Air Risk Mitigation

Methodology

Defining Air Risk

Knowing where crewed aircraft may be present based on historical data, especially in uncontrolled, low-altitude airspace below 1,200’ AGL is critical to understanding the likelihood of a reduced separation event between uncrewed and crewed aircraft. We simply define air risk as the likelihood that a crewed aircraft will be in a desired UA operating area. Air risk in this context is not the likelihood of another uncrewed aircraft being in a desired UA operating area. Based on historical crewed aviation traffic, UAS Static Air Risk Maps (USARMs) are generated by the DAIP to depict said air traffic density “hotspots” of where such reduced separation situations are more likely to occur. Figure 50 illustrates such hotspots in Area 3.

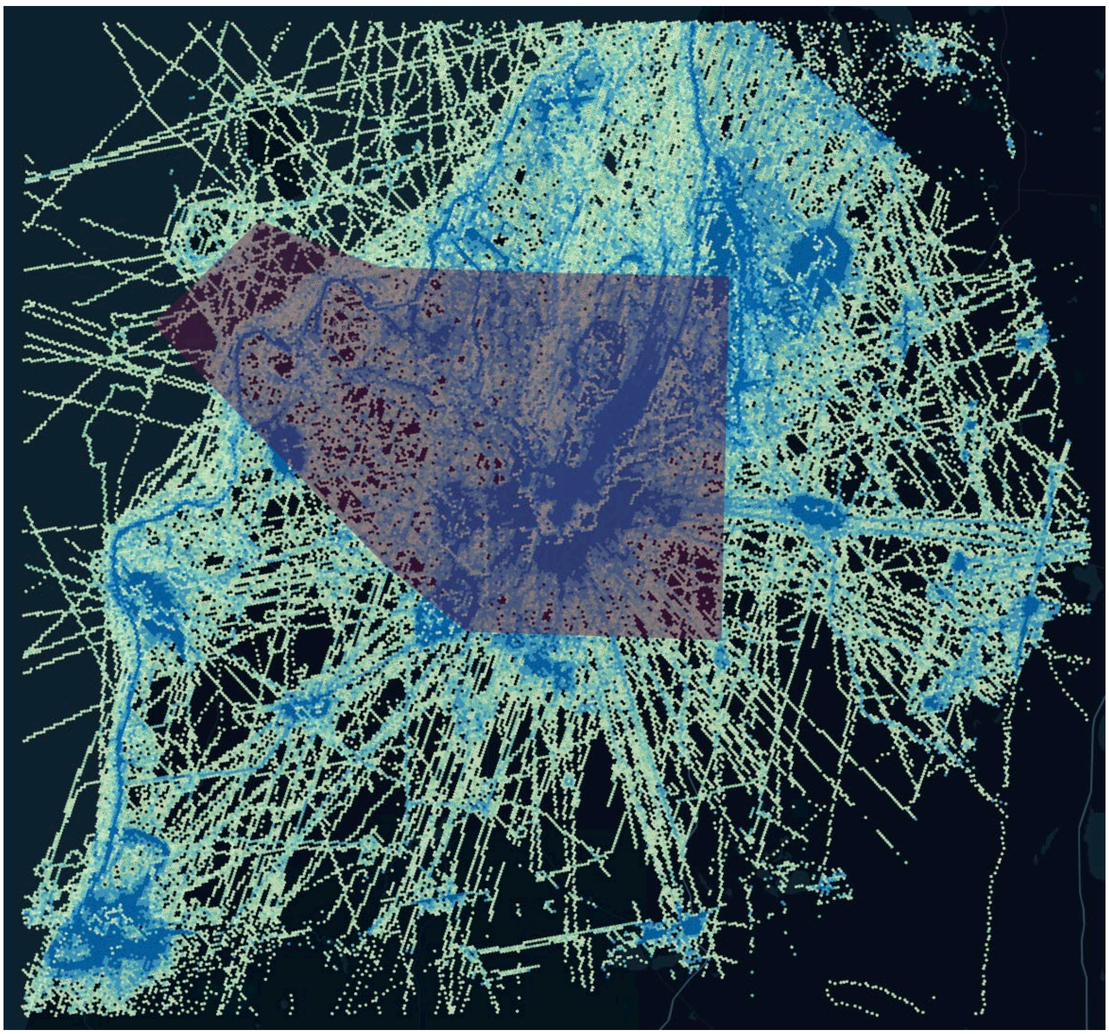


Figure 50: Example of a UAS Static Air Risk Map with Computed Air Traffic Density <1,200’ AGL in Area 3

These heatmaps can be generated for specific regions, for any timeframe, and for any altitude range and ultimately presents the unmitigated air risks for a defined airspace volume. By computing air traffic density, we present the expected number of aircraft occupying a given portion of airspace at a given time, and again, this presents the most conservative view of risk because you view all the tracks as a trigger to a reduced separation event. An Operator's ConOps details the specific approved operating conditions (geographic boundaries, geofences, proximity to infrastructure or airports), technology (aircraft & supporting systems, data feeds, software systems), procedures, and mechanisms by which the UAS Operator would mitigate air risk and the likelihood of a reduced separation event. These elements may be voluntary or required as part of a condition & limitation of FAA waivers or exemptions.

Identifying & Quantifying Air Risk
The heatmaps generated for Area 3 visualizes the density of the air traffic below 1,200' AGL. To quantify the air risk ***inside the corridors*** using the air traffic density metric, 12 weeks of historical surveillance track data (June – August 2021) was analyzed to aggregate the total number of distinct tracks. Similar to the results/findings in Areas 1-2, the number of distinct tracks captured in Area 3 also decrease dramatically below 400' as seen in Table 23

Table 23: Number of Distinct Tracks per Altitude Band Inside the Corridors for Area 3

Altitude Band (MSL)	Corresponding Altitude Band (AGL)	Total Track Reports (Area 3)
600-700	0-100	11,000
701-800	101-200	26,646
801-900	201-300	41,115
901-1000	301-400	51,235
1001-1100	401-500	51,318
1101-1200	501-600	55,190
1201-1300	601-700	59,161
1301-1400	701-800	66,496
1401-1500	801-900	73,195
1501-1600	901-1000	87,613
1601-1700	1001-1100	106,265
1701-1800	1101-1200	75,543

Figure 51: Track Data Visualization Below 1,200' AGL in Area 3

Unlike Areas 1 and 2, the number of distinct tracks counted in Traverse City is significantly higher. This is due to the total number of tracks to/from Cherry Capital Airport (KTVC) being counted in the dataset because the airport is wholly included in the corridor. A UAS Operator's safety case must consider how their operations will mitigate the air risks in high traffic density locations, such as airports. A criteria-based approach described in the safety case could justify how operations are to be conducted (e.g., no operations will occur within 5nm of an airport having an operational control tower).

Mitigating Air Risk
As the USARM presents the "unmitigated" air risk picture, the approach in which a UAS Operator who wishes to conduct BVLOS operations must consider developing their SOPs as part of their ConOps, which is predicated on the performance characteristics of the drone they intend to fly. The ConOps is the mechanism by which the UAS Operator would mitigate the air risk between its UAS and crewed traffic (e.g., return to home function).

Findings

For this study, air risk is primarily associated with drones colliding with crewed aircraft. The airspace in Area 3 is complex, with several factors that introduce hazards and risks, and call for additional drone infrastructure to ensure safe operations and remove risks associated with integrating low altitude drones. The core risk factors are:

Mixed use of air traffic

- Commercial Air Carriers, General Aviation, Private/Business Jet operations, Helicopter Operations, Governmental operations (e.g., Department of Natural Resources (DNR))
- Frequent USCG Helicopter Operations out of Cherry Capitol Airport

1 large airport within 2 miles of downtown Traverse City, MI

- Cherry Capital Airport (KTVC)- Class D & E Airspace

3 operational helipads/heliports in and around BVLOS Corridors

- Munson Medical Center (Medical Use Helipad)
- TC Helicopter (Private Use Heliport)
- Torchlake (Private Use Heliport)
- USCG Air Station Traverse City (Chery Capital)

Areas of uncontrolled, low-altitude, airspace below 1,200' AGL

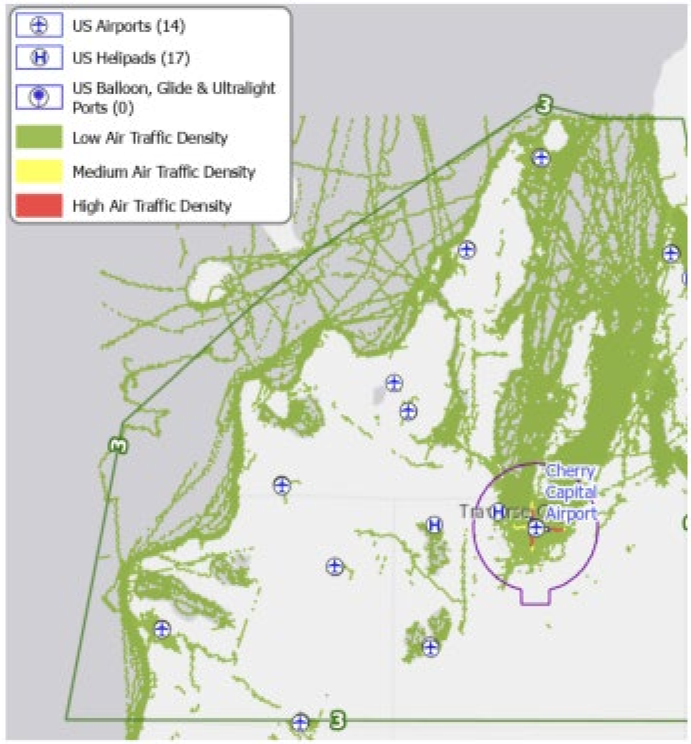


Figure 52: Low Altitude Air Traffic Density in Area 3

Identifying and mitigating air risks require a diverse array of physical infrastructure and data services to manage the risk of reduced separation events. To start, FAA historical surveillance data can be used to discover key information regarding airspace use and air traffic patterns. These patterns provide insight into where to install surveillance systems and how to structure operating procedures to ensure separation of drone and crewed aircraft, ultimately mitigating the risk of reduced separation events.

To support this feasibility assessment, 72 weeks of historical surveillance track data was analyzed to quantify the air risk for the corridor itself. Findings include:

- Over 700,000 distinct crewed aircraft track positions recorded below 1,200’
- Only 181,000 crewed positions were recorded below 500’
- Low track count in low altitudes (less than 500’) trends to a lower probability of a reduced separation event between drones and crewed aircraft
- Using historical FAA surveillance data, UAS (drone) Static Air Risk Maps (UASRMs) can be generated to:
  - Depict “hotspots” of higher air risk.
  - Analyze air risk of specific regions, for any timeframe, and for any altitude range.
  - Present the unmitigated air risk for a defined airspace volume.
  - Identify areas to augment FAA surveillance to fully mitigate risk.

Ground Risk

Introduction

Just as air risk is associated with drones colliding with crewed aircraft, ground risk is associated with the collision of drones with population, structures, or infrastructure on the ground. The geographic and demographic complexity of Area 3 presents an interesting challenge for identifying and analyzing the quantity and distribution of various features and hazards that are associated with ground risk. As the manager of the National Airspace System, the FAA is accountable to the public to ensure that they are not exposed to undue risk posed by participants in the National Airspace System. This responsibility then requires the FAA to not only evaluate the risk posed to other participants in the airspace, but also evaluate the risk on the ground.

The key ground risk factors include:

Aviation Infrastructure	Community & Government Facilities
Transportation Infrastructure	Education facilities:
Critical Infrastructure / Utilities	Secure & Restricted Areas
Public Safety & Law Enforcement	Population Density
Healthcare facilities:	Traffic Volume

Methodology

For this feasibility analysis, Airspace Link leveraged the capabilities of the Airspace Link AirHub® digital infrastructure platform to generate comprehensive ground risk assessments to support example use cases. To perform these assessments, the Airspace Link AirHub® platform first sources numerous ground hazard data from authoritative providers at the federal, state, and local levels. Next, it combines all the data layers into one dataset and unifies them across a common surface.

The final and most important step to produce data for a complete ground risk assessment is to apply risk classifications to the specific types of hazards, then use the platform to apply those classifications to all the hazards in the operational area to determine the ground risk exposure for potential operations.
The Airspace Link ground risk service has been successfully demonstrated to support Part 107 VLOS, Waivered BVLOS, and Part 135 operations in rural, suburban, and urban locations for flight routes supporting diverse use cases that range from hundreds of feet to dozens of miles.

These ground risk assessments are used as a key criterion to inform the operation feasibility for the selected use cases. The specific risks that can be mitigated depending on the operator's ConOps, range from obstacle avoidance, minimization of population exposure, minimization of road crossings, geofencing from critical infrastructure, detection of optimal emergency landing areas, and more.

Findings

By following the process described in the methodology section above, there are clear qualitative and quantitative findings that emerge from the analysis. These findings provide insight into the operation environment for UAS operators, support contextual analysis for specific locations, enable more intelligent decisions around relevant use cases for these areas, and aid with understanding and mitigating regulatory and safety constraints.

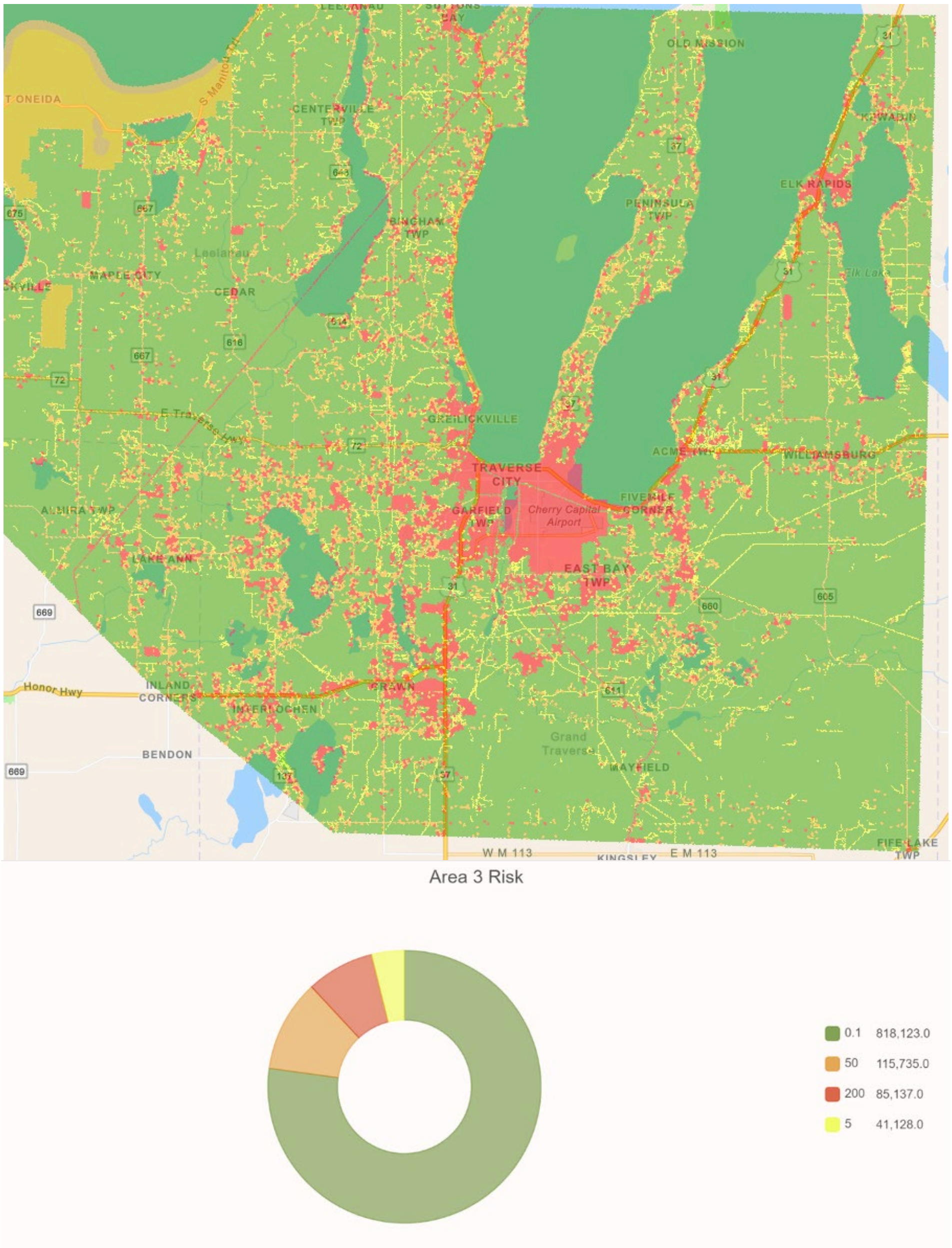


Figure 53: Ground Risk Surface and Distribution for Area 3

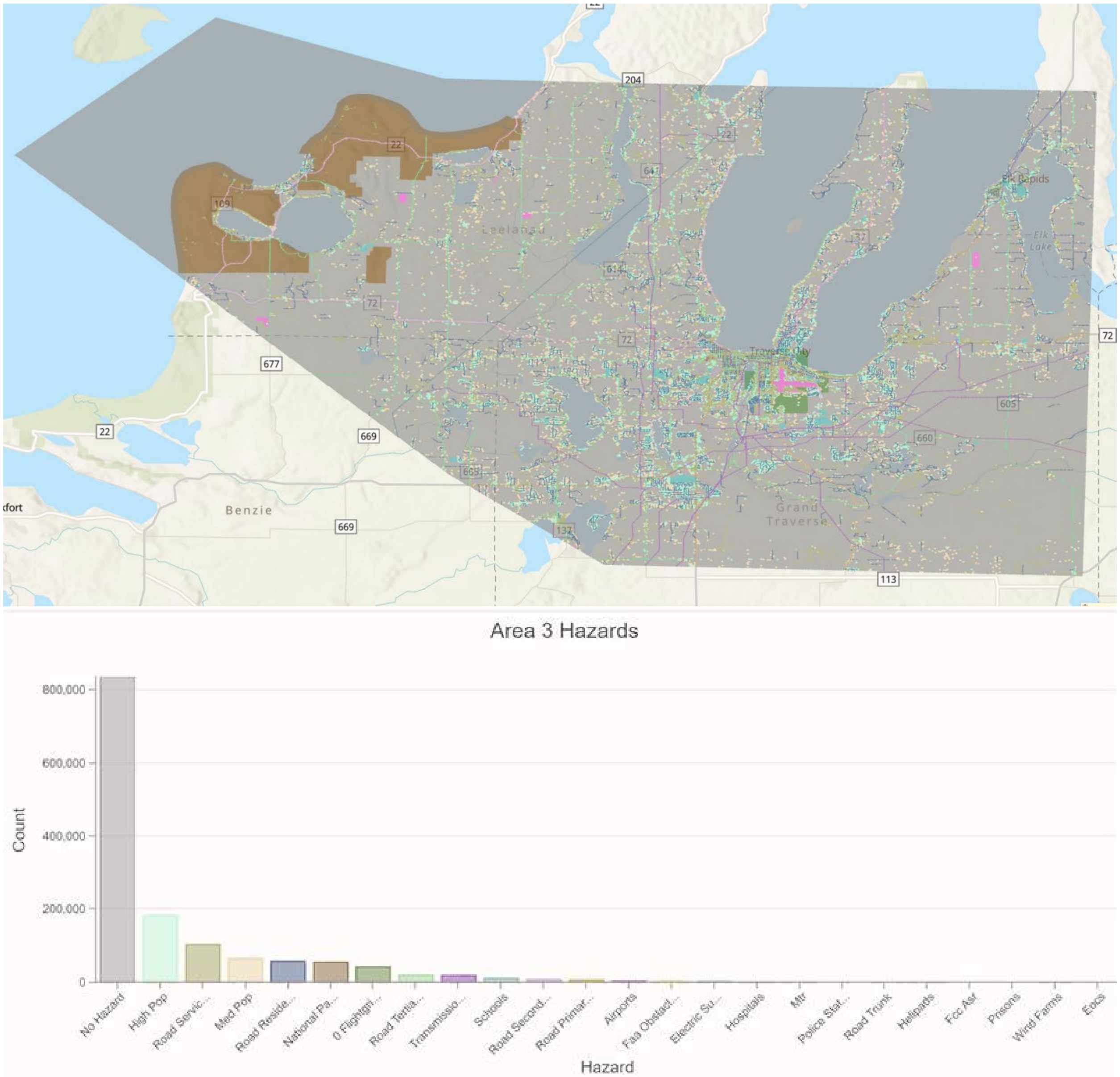


Figure 54: Hazard Distribution across Area 3

Qualitative Ground Hazard & Risk Insights of Area 3

- Large areas of no or minimal ground risk, and those areas of higher ground risk are regional population centers with rural land surrounding and the higher traffic roads between the population centers.

Quantitative Ground Hazard & Risk Insights for Area 3

- ~8% of area geography contains “High Risk” ground features (typical for rural areas)
- After previously mentioned ground hazards (population & roads), the most common ground hazards are national parks, energy infrastructure (transmission lines & substations), schools, and airports.

While these ground risk findings are insightful by themselves, the true value of the analysis is unlocked when applying these findings to the UAS Drone Corridor assessment. These data help stakeholders understand key details of the operating environment providing the insights necessary to mitigate the risks and challenges unique to each use case. Specifically for Area 3, the large rural areas and more disparate distribution of population present a unique opportunity for UAS operations given the demographic and economic attributes. These features may lend themself well to agricultural use of drones to support crop spraying and monitoring. Another high value use case may be to support the rapid delivery of high value & high impact packages such as medical supplies. The large amount of utility infrastructure also presents a valid use case for drones to support the maintenance, inspection, and security of these valuable community assets. For these use cases, having an accurate and authoritative understanding of the population and its distribution can assist in addressing the regulatory and safety constraints associated with these use cases. These use cases, amongst others, could all benefit from accessing ground hazards and risk information, as summarized in the points below.

Importance of Ground Hazards and associated Risks:

- Understanding ground risk is important for all operators and particularly so for commercial BVLOS use cases.
- An authoritative source of ground hazard and risk data would accelerate a key component of current BVLOS approvals.
- Ground hazard and risk data is applicable to regulatory **and** business use cases for drone businesses of varying sophistication.

Opportunity for the State of Michigan and Michigan Department of Transportation

- The State of Michigan and MDOT are well positioned to be the authoritative provider of digital infrastructure in the form of a ground risk data service.
- This service would differentiate the State of Michigan, signaling its interest in supporting commercial drone operators by providing a valuable capability for operators of varying sophistication.
- The service would be utilized by operators to accelerate business and regulatory challenges regarding ground features and risks and could be made available in a more expeditious manner while larger physical + digital infrastructure deployments are in planning in implementation.

Drone Traffic Infrastructure

Air Risk Infrastructure & Risk Mitigation

While the FAA data supports the general airspace risk identification, results of the preliminary analysis led the Project Team to recommend additional ground-based infrastructure to reduce the airspace risk to regulatory safety standards. This ground-based infrastructure would provide the surveillance, communications, and command and control (C2) resources enabling operators with the means to electronically detect and avoid any crewed aircraft within their area of operation. The key components of the physical infrastructure include:

Medium Range Radar
Augments FAA radar providing coverage and primary detection of aircraft at low altitudes and supports detect and avoid reduced separation event mitigation procedures.

Optical Sensors
Monitors the airspace for at risk aircraft using computer vision and AI technology and reports actionable real time telemetry data to the pilot-in-command.

ADS-B Receivers
Detects cooperative aircraft broadcasting their identity and position to support detect and avoid/ reduced separation event mitigation procedures.

Wireless Communications Receivers
Provides C2 datalink capability to support communications between operator, drone, sensors, and C2 center throughout drone operations.

Ground Communication Networks
Provides the ground-to-ground communication network (i.e., backhaul network) to connect all ground-based infrastructure and cloud services.

Drone infrastructure Command and Control Center
Manages drone Infrastructure access, operations and secure cloud services ensuring proper use and system health.

Additional information regarding the full details of the required infrastructure can be found in the “Technology Implementation and Deployment” Section of the this report.

Ground Risk Infrastructure & Risk Mitigation

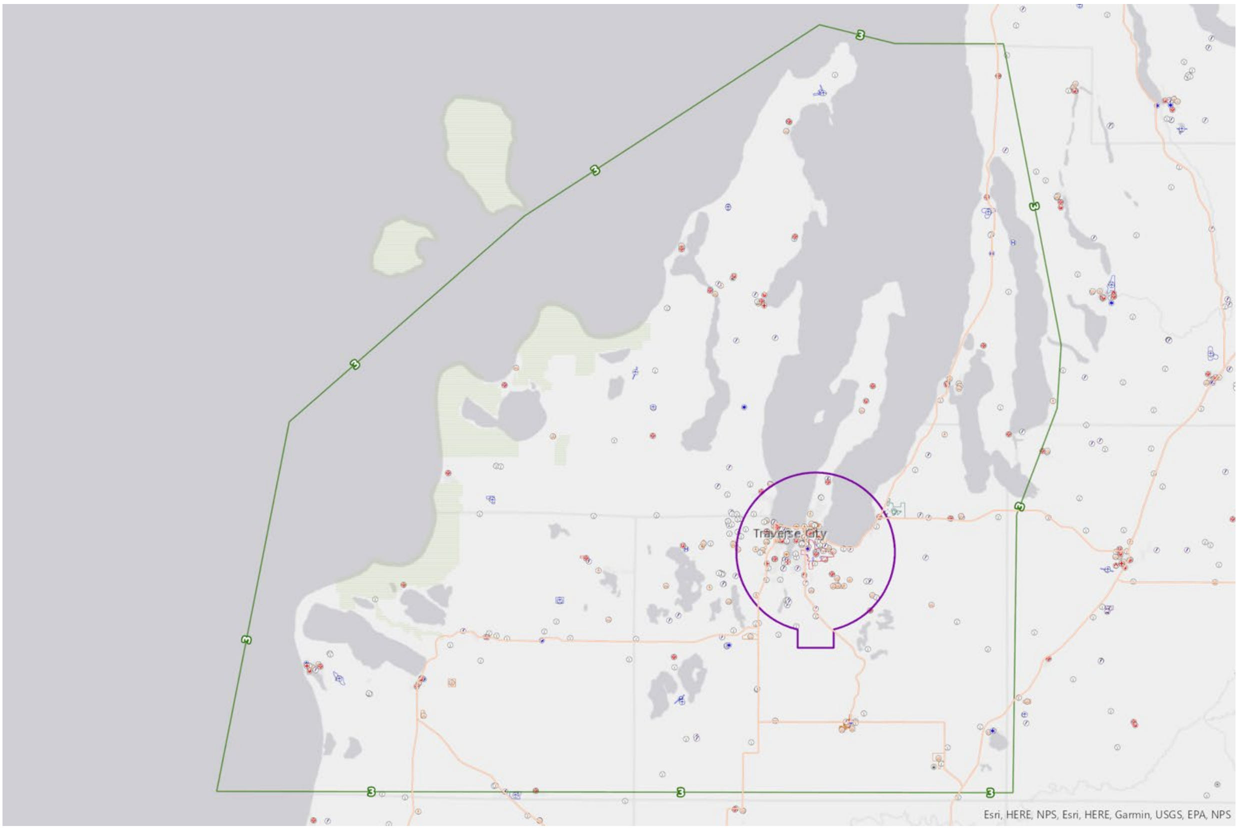


Figure 55: Ground Hazards within Area 3

The concept of digital infrastructure to enable ground hazard & risk identification and quantification is a new entrant to the world of aviation infrastructure and is of particular value for drone operations as described in the previous section on ground risk. Due to the FAA's current approach for BVLOS operations under approvals by exemption, operator mitigations for ground risk exposure will vary based on operation procedure, aircraft selection and certification, aircraft equipage, and other operational factors outlined in the operator's concept of operations. As described in the previous ground risk section, The State of Michigan and MDOT are well positioned to be the authoritative provider of digital infrastructure in the form of a ground risk data service to support operators in identifying ground hazards and their associated risk and incorporate the appropriate mitigation based on their ConOps. Example risks & their potential mitigations are outlined below.

Example Ground Risks & Mitigations:

- Risk: Road Crossing
  - Mitigation: Visual Observer to confirm no overflight of moving vehicle
- Risk: Population Density
  - Mitigation: reroute around population center to avoid operation over people
- Risk: Critical Infrastructure (Transmission Line)
  - Mitigation: None, example operation is a utility inspection flight
- Risk: Forested Area

- Mitigation: Avoid, if possible, but mark as a potential ditch area for an emergency landing

Concept of Operations & Risk Mitigation

As drone shared-use infrastructure is implemented, drone operators can effectively leverage this infrastructure to take advantage of the benefits it provides. These benefits include:

- Creating standard operating procedures for all operators.
- Creating operating requirements and limitations for all aircraft.
- Creating a single, reliable system in which performance is verified and continuously monitored.
- Providing operators the services necessary for advanced, scalable, efficient drone operations.
- Providing surveillance services as a means to see and avoid other users of the airspace more efficiently than a visual observer.
- Removing the physical and financial burden from the operators to provide the technology that mitigates air risk and ground risk.

To take full advantage of this shared-use infrastructure, operators must incorporate the data, services, and capabilities into their operating procedures and technology. This is often accomplished through a Concept of Operations document (or ConOps), which outlines the type of operation being performed, the technology being used, the identified hazards and their mitigations, and more. By integrating the shared-use infrastructure into the various sections of the ConOps, operators ensure the infrastructure is being utilized fully, and can be applied to support advanced operation regulatory approvals.

Safety Case & Regulatory Framework

There are many regulatory and safety requirements associated with enabling drone operators to conduct advanced BVLOS operations within the United States. Currently it falls on the operator to overcome the challenges and receive FAA approval to fly a drone. The operator must present a safety case to the FAA which describes how they will manage risk to an acceptable level and generally requires:

- Technology in the form of FAA-accepted, shared use infrastructure that provides the resources that unlock scalable, economically viable drone operations for all operators and use cases
- Risk Mitigations that apply the technology resource in a way that strategically or tactically reduces risks throughout the drone operation

Regulatory Pathways

Depending on the drone operator's ConOps, they will operate under existing rules and regulations as specified below. Depending on the drone operator's concept of operation (ConOps), they will operate under existing rules and regulations as specified below.

Part 107 Operations
Involve small drones less than 55 pounds which typically fly below 400 feet above ground level (AGL) in uncontrolled airspace (Class G). There are a limited number of regulations under Part 107 that can be waived for advanced operations.

Part 91 Operations
Developed for crewed aviation but can be a pathway for drone operations when the aircraft is greater than 55 pounds.

Part 135 Operations
Designed for air transportation of persons or property for compensation. A drone operator transporting property for compensation must hold a Part 135 Certificate.

Part 137 Operations
Designed for dispensing chemicals and agricultural products. A drone operator conducting these activities must hold a Part 137 Certificate. State laws must also be considered.

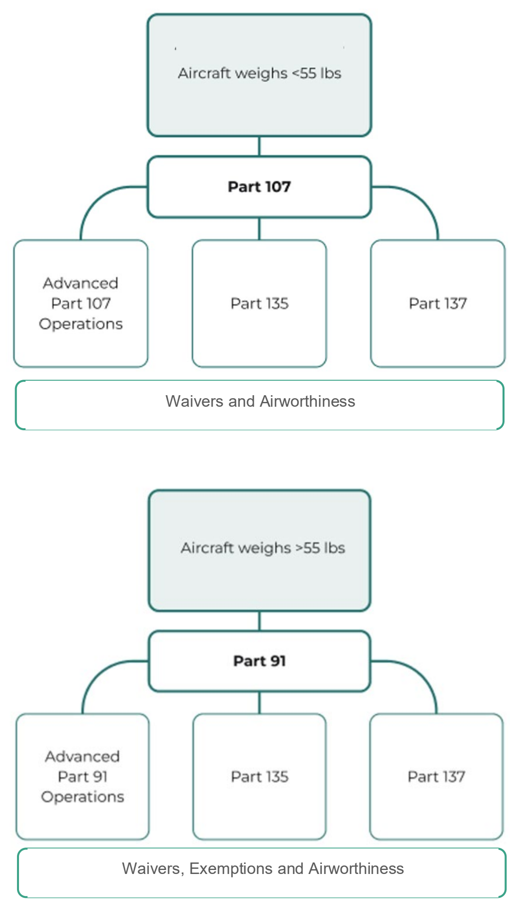


Figure 56: Regulatory Pathway Chart for UAS Operations

Safety Case Development

Regardless of the regulatory path to receiving FAA approval for an advanced drone operation, the operator must present a safety case to the FAA which describes how risk will be managed to an acceptable level. When developing the safety case, the operator should use FAA guidance which can be found within the following FAA Orders and Manuals.

- Safety Management System (SMS) Policy: Establishes SMS policy and requirements and emphasizes Safety Risk Management (SRM) and Safety Assurance (SA) processes

- Safety Risk Management Policy: Establishes requirements to conduct SRM

- UAS Safety Risk Management Policy: Establishes a methodology for conducting SRM specifically for drone operations

- Air Traffic Organization (ATO) Safety Management System Manual: A collection of principles, policies, processes, procedures, and programs used to identify, analyze, assess, manage, and monitor safety risk

These orders and manuals were designed to be used by the FAA to establish their own processes, but they each provide invaluable information for applicants of waivers, exemptions, and authorizations as they provide key insight into what the FAA requires and how the information should be conveyed.

Shared-Use Infrastructure to Support Safety Case

When conducting a safety case, the operator will need to complete the following five-step risk assessment process per the FAA's guidance and processes in the FAA Orders and Manuals:

- Describe the System
- Identify Hazards
- Analyze Risk
- Assess Risk
- Treat Risk

During the hazard identification step each hazard's corresponding outcomes are identified and documented. For example, an operator must consider the hazard, "Aircraft in Proximity of Drone" in the safety case and document the worst credible outcomes.

- Collision between a drone and aircraft in the air
- Collision between a drone and a person on the ground or moving vehicle when avoiding aircraft
- Collision between a drone and critical infrastructure on the ground when avoiding aircraft

The hazard "Aircraft in Proximity of Drone" results in high air risk and high ground risk. However, an operator leveraging the drone infrastructure can provide a safety case showing a reduction of risk to an acceptable level by using surveillance sensors (medium range radar, optical sensors, ADS-B receivers) to maintain air traffic awareness. Additionally, the operator can indicate how the drone infrastructure ground risk data ensures the drone flight plan factors in ground risk and routes around risk areas. These controls enable the operator to present a strong safety case to the FAA when requesting to conduct advanced drone operations and improve the probability of approval.

Impacts

Introduction

A fundamental goal of the UAS Connect Corridor project is to improve the quality of life for Michigan residents. As such the Project Team assessed the projected impacts through the lens of three critical categories: The economy, the environment, and community benefits. This includes an overarching, birds-eye view of what sorts of impacts residents and businesses may expect from the pilot, as discussed in the Use Cases section above (e.g. Increase Productivity, Reduce Emissions, etc.), quantitative estimates for each impact where appropriate (e.g. the number of jobs created the reduction in vehicle miles traveled, etc.), and scoring to demonstrate the relative size of each impact as compared to one another (e.g. the largest impacts in Area 3 fall within the Community category).

Cityfi led the Project Team in the impact study, which is based on a 5-year time horizon for UAS adoption and considers low (10%) and high (30%) adoption scenarios. It is also limited to the infrastructure service footprint for the study areas and associated use cases. While we used existing research for reference, our methodology and findings differ from previous studies such as: "Measuring the Effects of Drone Delivery in United States, Virginia Tech, 2020" and "Advanced Air Mobility Business Case Assessment: State of Ohio, NEXA White Paper, 2021" in the following ways:

- Previous studies have been based on longer time horizons for UAS full adoption, such as 25 years, which reflect more significant impacts in Vehicle Miles Traveled (VMT) reduction, creation of jobs, etc.
- This study accounts for the unique context/characteristics of each location (delimited by the area of study) instead of full drone adoption over larger geographies.
- This study did not perform community/local business engagement, instead leveraging stakeholder engagement conducted through the use case selection process.

Methodology

Economic Impact Assessment

Assuming that a percentage of ground transportation will be replaced by air mobility for medical, pharmaceutical, and manufacturing cargo, it is crucial to assess the effect that this will have on the economy of the studied areas. Our analysis divides these impacts into the following variables:

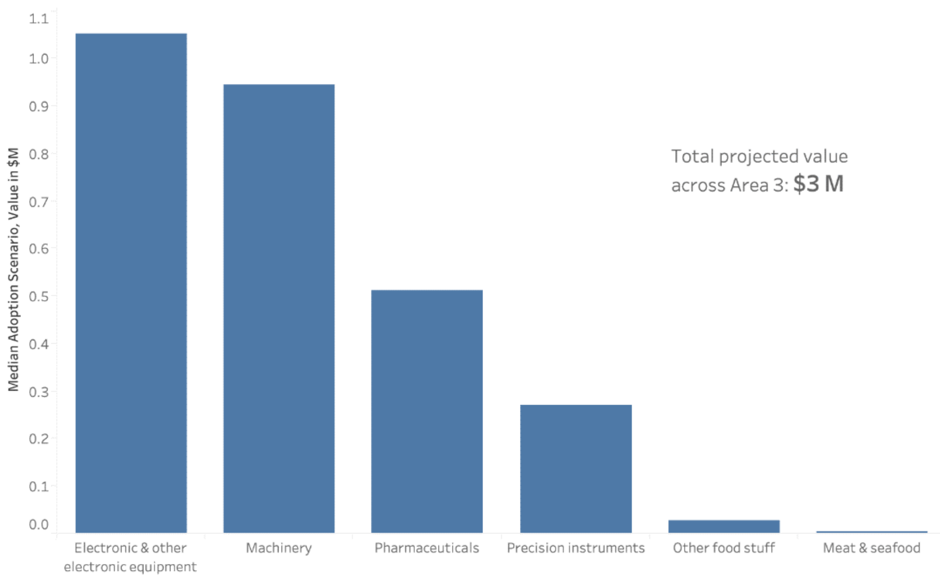
- Increase in productivity
- Creation of new skilled jobs
- Variation in per capita income
- Revenue/cost recovery

To calculate these variables, we started by identifying the ***increase in productivity*** by studying the current freight movement along the main highways in the region (domestic origin and destination), using data from the Freight Analysis Framework (U.S. DOT). We focused our study on six commodities: pharmaceuticals, machinery, electronic and other electronic equipment, precision instruments, meat, seafood, and other food stuff. From this data, we were able to retrieve the total annual tons and value in millions of dollars of the products transported in the area. Afterward, to determine which percentage of the total freight would be replaced by drone transportation, we evaluated the commodity flow survey to assign a percentage of possible products that are feasible to be transported by drones, considering the following assumptions:

- There must be an urgency to deliver the product where drones can be more efficient than terrestrial transportation (Dyment & Leeby, 2021)
- Products should be within key aircraft performance related constraints: Load Capacity (Poundage – 15 or less), Speed – 30 mph or less, Delivery Distance – 4 miles (Airspace Link, 2022)
- Products should be of high value (Dyment & Leeby, 2021)

After the percentage per commodity was defined, we obtained the total tons and value in dollars of products that potentially could migrate to drone transportation for two scenarios of adoption (high and low) over the 5-year study period.

Economic Impact: Projected Value of Goods to Be Transported by UAS by Commodity



To identify the number of ***new skilled jobs created*** due to the introduction of UAS in the area, we identified the industries that would experience employment variations and organized them by those that are impacted directly (Professional/Scientific/Tech Services; Information; Transportation/Warehousing; Real Estate/Rental/Leasing; Retail trade industries) and indirectly (Utilities; Manufacturing; Finance/Insurance). Data was gathered around existing employment numbers and we performed an analysis to identify the approximate number of new jobs created, considering the increase in productivity in the analysis above.

Since our study considers the adoption of UAS in a span of five years, we infer that the ***per capita* income** of the area could be impacted in a positive way due to the increase in highly skilled jobs and associated higher wages. Therefore, we analyzed the per capita income for the state of Michigan and for the study area and compared it against the average annual salary of the new jobs created.

Environmental Impact Assessment

Historically, investments in transportation have not always addressed or fully valued the impact on the environment, to the ensuing detriment of other areas of life including the economy and community well-being. Our analysis focuses on the potential benefit of emissions reduction along with the potential cost of noise and visual pollution.

We approached the ***emissions reduction*** analysis by first estimating the impact that the drone corridor might have on ground surface transportation in terms of vehicle miles traveled or VMT (See Appendix F for details). Using the VMT calculations, we then estimated emissions reduction using the formula:
Emissions reduction = VMT reduction x (emissions per vehicle mile (grams CO_2) - emissions per drone mile)

The emissions per vehicle mile that we used was a rounded estimate for a passenger vehicle (400 grams CO2), given the lightweight nature of the cargo for our delivery use cases (Environmental Protection Agency, 2018). For emissions per drone mile, while there will be some emissions when considering the lifecycle advanced air mobility such as battery charging and the extraction of parts, we assume these emissions to be negligible when realistically compared with vehicle emissions. This is especially true given our assumption of passenger delivery vehicles, since the true makeup of the vehicles is likely some combination of cars and trucks. Our analysis of emissions per vehicle mile also only considers carbon dioxide and not nitrogen oxides (NOx) or particulate matter, two vehicle exhaust emissions that are particularly bad for air quality. As such, we believe this simplified comparison evens out to be conservative.

To evaluate ***noise and visual pollution***, we conducted a literature review and evaluated the noise level expected in the corridor using a decibel level. In particular, the Project Team consulted the regulations regarding acceptable decibel levels for drone noise according to the National Environmental Policy Act (FAA, 2022) and a comparison of the noise level of different UAS vehicle types and models using a report commissioned by the FAA at the Choctaw Nation of Oklahoma's test site (Read et al, 2020). Still, we recognize that the real impact of noise may be more nuanced. For instance, some studies suggest that the novelty of the sound of drones may cause an increase in the perception of noise pollution even if noise volume, or decibel level, decreases (Christian & Cabell, 2017). As such, we also offer ideas for monitoring and managing these impacts over the course of implementation.

Community Impact Assessment

As ground transportation gets replaced by advanced air mobility for medical, pharmaceutical, and manufacturing cargo, we anticipate community impacts within the areas of health, safety, and wellbeing. Some of these impacts are direct, such as the use case of ***improved access to medical care***, and some are derived from other impacts. For instance, reducing vehicle miles traveled may be expected to reduce traffic congestion, which ***improves mobility*** and quality of life as residents are able to get around more easily which improves access to goods and services. Similarly, the emissions reduced from VMT reduction is not only good from the environmental standpoint of mitigating climate change but also has health implications, as poor air quality leads to asthma and other respiratory related illnesses. We also consider a potential ***reduction in traffic fatalities*** as vehicle trips are removed from the road system. Finally, we expect ***enhanced community wellbeing*** as a result of the economic benefits that combine to create a more competitive job market and compelling place to live.

The community impact assessment is primarily qualitative, with descriptions of the significance of each impact within the Impact Scoring interactive tool (see appendices D-F). The community profile analysis focuses on population composition, growth rate, and socioeconomic status to understand the context for the anticipated impacts of the corridor. Another community impact that was essential to study was how the use of drones could impact the accessibility of pharmacy services to disadvantageous communities. To assess this, we calculated the density of population by square mile, the lack of accessibility to public transportation, the vehicle accessibility by household, and the distance to the nearest pharmacy. Details for this study may be found in the technical appendix.

Impact Scoring

Through the combination of qualitative and quantitative research, we assigned ***impact scores*** that allow for a comparison of all impacts, whether economic, environmental, or community-based in a single view. These scores are calculated as the cumulative expected impact over a 5-year time horizon, ranging from a possible total impact value of -10 to 10.

In order to assess the relative size of each potential impact (benefits and costs), we started by conducting a literature review and speaking with subject matter experts. This research enabled us to identify the general directionality of each impact (benefit versus cost), as well as where to focus the quantitative economic, environmental, and community analyses that would then feed back into the impact score. In addition to these three broad categories that impact all residents, we also included a fiscal category in the overall assessment in order to keep in mind separate costs and benefits that will be felt directly by MDOT (departmental cost recovery, operation, and maintenance), as opposed to the economy at large.

Findings

Findings below represent the median estimated scenario between the Project Team’s low- and high-adoption models.

Economic Impact Assessment

Understanding the economic value and community impact resulting from top use cases is a key input in developing a roadmap on how to move this initiative forward. Some of the top impacts are outlined below.

Creation of Skilled jobs

A shift in deliveries from ground vehicles to drones would positively impact jobs in Michigan, stimulating new and existing industries in creating high-paying jobs in aviation, logistics, engineering, and finance. Studies have repeatedly shown a relationship between automation and greater employment at both a macro-economic and company level. Analysis of possible new direct and indirect jobs, associated with the study area market potential resulted in an estimate of significant job creation, as shown in Figure 57.

Figure 57: Skilled Jobs Metrics for Area 3

Wage Growth

Area 3 has an average annual per capita personal income of $36,367 (which for the year 2027 is projected to be $46,757), below the annual average for the State of Michigan and the US. It is projected that by 2027 Area 3 will have a 27% of senior population, above the national 19% average, this will most likely influence the demand of UAS services, and the creation of direct and indirect jobs associated with this industry. The average annual salary of new skilled jobs (in direct and indirect industries) is $78,317. The sectors that will receive the biggest positive impact due to the adaptation of UAS services will be the professional, scientific, and technological services; information; transportation; warehousing; and real estate industries.

Table 24: Per Capita Income Impact for Area 3

Location	Description	2020
US	Per capita personal income (dollars)	$59,147
State of Michigan	Per capita personal income (dollars)	$52,724
Area 3	Per capita personal income (dollars)	$36,367
Area 3	Average salary of new direct/indirect created jobs	$78,317

Productivity Growth

A key finding is that delivery drones can significantly reduce costs and increase efficiencies in business logistics. This productivity increase would primarily result from transferring light cargo from ground delivery to drone and potentially accommodate increases in last mile deliveries. Using an analysis of regional freight data and projected drone services supporting initial use cases, we have quantified a potential market of $14M in freight revenue in a span of 5 years.

Environmental Impact Assessment

Vehicle Miles Traveled (VMT)

Reducing VMT lays the groundwork for several benefits, including emissions reduction, improved mobility, and reduction in traffic fatalities. The calculations and assumptions leading to the VMT reduction estimate can be found in **Appendix F**.

19.8M – Vehicle Miles Traveled (VMT) Reduction

Emissions Reduction

Drones are effective in helping Michigan reach electrification and emissions reduction goals. The analysis finds an estimated emissions reduction shown above.

7,038 – Tons CO_2 Emissions Reduction

Noise and Visual Pollution

The Federal Aviation Administration defines a significant aircraft noise impact as an increase in the yearly Day-Night Average Sound Level (DNL) metric of 1.5 decibels (dB) or more at or above DNL 65 dB noise exposure or a noise exposure at or above the 65 dB level due to a DNL 1.5 dB or greater increase. (FAA, 2022) The team does not find a significant impact according to this definition. Still, MDOT and other operators can mitigate potential environmental and community costs by:

- Conducting public outreach activities to better understand how drones affect the environment and community from an auditory and visual perspective
- Considering noise when choosing drone hardware
- Careful planning of drone port locations
- Operational noise mitigation measures such as population avoidance and flight path distribution
- Setting delivery times to reduce residential disturbance
- Collecting feedback
- Responding to complaints

Community Impact Assessment

Improved Access to Medical Care

Initial use cases include pharmaceutical and medical deliveries, which have a positive impact on the health and quality of life of the general community and especially at-risk groups that lack mobility or easy access to medications. Our analysis finds:

147,484 – Total population served by drones in the service area
10,324 – Citizens lacking vehicle access that would initially be served by drones
39,820 – Senior Citizens that would initially be served by drones

For more information on the improved access to medical care results, details can be found in **Appendix E**.

Overall Impact Scoring

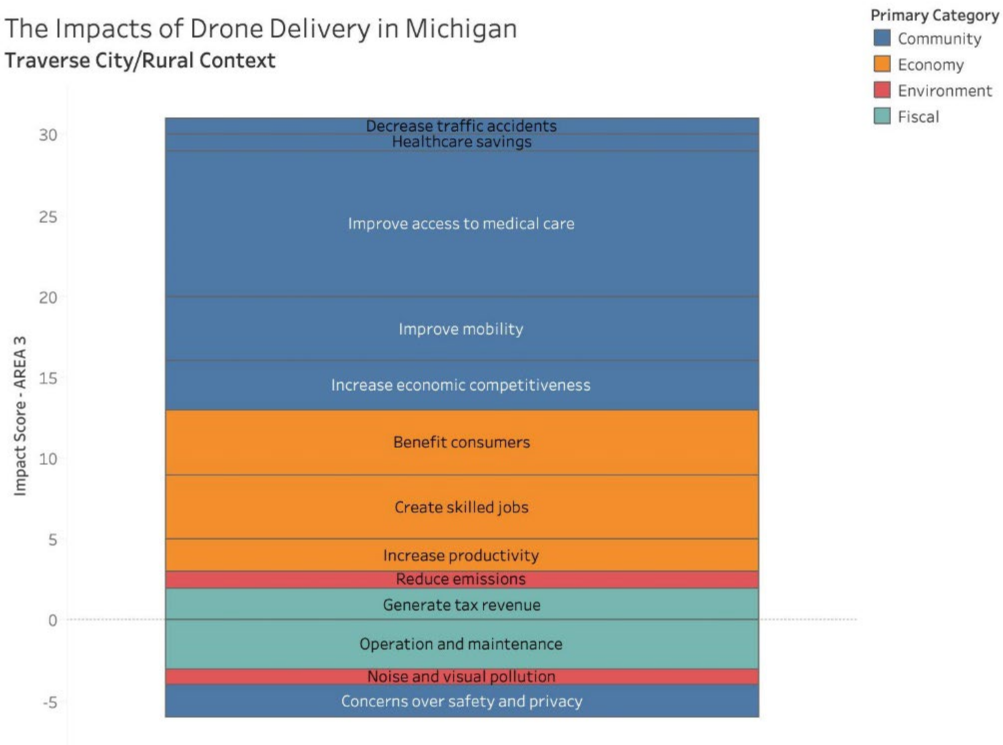


Figure 58: Drone Delivery Impact in Traverse City Area

For Area 3, the largest impacts fall within the Community category. In particular, the pharmaceutical and medical delivery use cases are significant in the rural context of Traverse City, given the high elderly population (24% as compared to 17% nationally). This is because seniors tend to have both a greater need for medications and more difficulty driving to a pharmacy, especially in inclement weather. Further, our study finds that 60% of the population in Area 3 live farther than ½ mile from a pharmacy. Delivery drones may thus supply needed medications more quickly and easily to a population that faces mobility challenges.

Readers can explore an interactive version of the Impact Scoring location comparison online. Details on each impact score and rationale can be found in a consolidated table in Appendix D.

Transportation Impact Assessment

Multi-Modal Interconnection Opportunities

Multi-modal connections and interfaces across the state and local transportation system are necessary to maximize the economic, environmental, and community benefits of the UAS corridor. Without such multimodal logistics environments and the associated economies of scale of using delivery drones, it can be difficult to realize productivity gains or benefits to consumers.

A multimodal interconnection environment streamlines connections between rail, ground vehicles and aerial vehicles. Multimodal interconnections may be physical infrastructure, mobility services, and/or digital infrastructure and may include research and development, testing, and the full-scale operation of new logistics technologies. More information on this topic can be found in the 'Impacts' section of this report.

Methodology & Sources

Seamless intermodal operations require the efficient operation of each component part as well as integrated operations among systems. The Project Team drew on its experience designing intermodal systems for a number of different mobility and advanced technology networks to identify and assess opportunities to leverage and areas of focus for additional research, demonstration, testing, and development. The Project Team's experience with ports, rail stations, and regional transit hubs was also drawn upon as comparable proxies.

In addition to this subject matter expertise, the team spoke with stakeholders interested in developing a multi-modal logistics environment to gain an understanding of specific opportunities in the geographic areas of interest. One compelling proposal was submitted by Aerotropolis and Willow Run Airport for MDOT's Program Development Portal Research Idea Form supported by MDOT Research Administration.

Findings

A multi-modal logistics facility offers a way to ensure critical goods get transported in a timely fashion. This is especially important in our current geopolitical and economic climate, where disruptions like supply shortages or labor strikes have become commonplace.

To maximize the benefits of a multi-modal interconnection environment, MDOT and partners may choose strategies for implementation by focusing on the following:

- Autonomous cars/trucks moving in the rail right of way
  - Testing new rail crossing signaling stations to better manage ground traffic
  - Testing right of way networks to improve movement of cargo and people
- Drones moving in the rail right of way
  - Testing new rail crossing signaling stations to better manage air traffic
  - Testing low altitude airspace for package delivery
- Testing communication and surveillance networks to improve intermodal and multimodal transportation
  - Testing the movement of cargo between rail, trucks, and drones
  - Developing next generation intermodal transload facilities, including the testing autonomous loading and unloading technologies
- Exploring and understanding infrastructure and design considerations
  - Logistics center design to facilitate autonomous/highly automated transload devices
  - Intermodal network connections such as ramp or intersection design to facilitate ground level final delivery
  - Zoning and urban design considerations for intermodal facilities incorporating UAS
  - Utility grid considerations for low/no emission intermodal facilities
- Understanding talent shortages and integrating diversity, equity, and inclusion in future workforce training
  - Cataloging the retraining/reskilling required to support the advanced air mobility industry
  - Identifying workforce partners for recruitment/job placement.

Airport

Modes	Payload -> Destination	Service Provider
Air Freight <-> UAS	Freight / Package to Customer	UPS
UAS		Bell Helicopter
		Volatus

Retail

Modes	Payload -> Destination	Service Provider
Ground Freight -> UAS	Retail to Customer	Matternet
UGV -> UAS		Flytrex
Currier <-> UAS		
POV <-> UAS		
UGV< -> UAS		

Droneport / Nest

Modes	Payload -> Destination	Service Provider
Ground Freight <-> UAS	Retail Pickup to Customer	Google Wing
Currier <-> UAS		
POV <-> UAS		
UGV< -> UAS		

International Port of Entry

Modes	Payload -> Destination	Service Provider
Ground Freight -> UAS	Port to Port	UPS
UAS -> Ground Freight		
POV -> UAS		
UAS -> POV		

Big Box / Fulfillment Center

Modes	Payload -> Destination	Service Provider
Ground Freight -> UAS	Fulfillment to Customer	Amazon
		Walmart

Private

Modes	Payload -> Destination	Service Provider
Facility -> UAS	Facility to Facility	Spright
Fleet -> UAS		
Ground Freight -> UAS		
UGV -> UAS		

Mobile

Modes	Payload -> Destination	Service Provider
Ground Freight -> UAS	Ground Vehicle to Customer	UPS
UAS		Workhorse

Figure 59: Multi Modal Use Cases for UAS

Conclusion & Road Map

Summary

The regulatory, safety, and operational challenges to scaling drone operations into the national airspace and communities across Michigan are arguably greater than what most operators and communities can afford to overcome on their own. This study not only demonstrates how these challenges can be met, but also provides the State of Michigan a blueprint that shows how it plays a key role as the US mobility innovation leader by spearheading the implementation of new shared transportation infrastructure. The study has also revealed that the adoption and advancement of drones for broad use cases can be directly integrated with other modes of transportation, reducing costs, and increasing benefits for all mobility solutions. By applying the blueprint across the drone integration framework, Michigan can build an infrastructure that provides a platform where operators, public organizations, communities, and customers are able to work together in building a sustainable drone ecosystem that reaches its full potential in generating the broad benefits of drones socially, environmentally, and economically.

MDOT is well positioned to take action following the completion of this study to lead the drone ecosystem towards the vision of broad and scaled adoption. Focusing on requirements and capability analysis of public and private operators, as well as the communities, local and state government entities, MDOT can directly target what operators and stakeholders need from the state in order to hit their technological, regulatory and operational milestones. Current capabilities vary by operator, city, or organization, and therefore their respective requirements will be varied. Leveraging the below framework, MDOT can implement an effective data-driven growth strategy that will support safe drone integration.

UAS Integration Framework

Drone technology has made remarkable advancements since uncrewed aircraft initially took to the skies leading to great progress in demonstrating benefits to our personal lives, communities, public organizations, and businesses across the globe. In the United States, public and private entities at various levels are actively working to advance the use of drones. The focus has been on mitigating fundamental regulatory, safety, environmental, social, security, technology, and infrastructure concerns to support broad use cases across various geographic locations at scale. These efforts have produced many architecture documents, maturity models, standards, and other frameworks that highlight an approach to further advance the potential of drones and their integration into the airspace.

The MDOT preliminary analysis builds upon the work of the public and private entities mentioned above thus ensuring a comprehensive assessment of the feasibility and impact of a drone corridor in Michigan. While the preliminary analysis provides a wealth of information associated with introducing UAS into the state of Michigan, and the safety and risk framework, regulatory framework and technology recommendations provide the processes and resources necessary to support the implementation of a UAS physical, digital, and operational infrastructure. The Project Team also came to the realization that there is a need for an overarching Integration Framework to tie it all together. Led by Airspace Link, the Project Team reviewed the MDOT project material along with a comprehensive evaluation of industry rules, standards, responsibilities, initiatives and best practices to develop the UAS Integration Framework designed to support coordination between all the stakeholders, align initiatives, activities and responsibilities, provision resources and to avoid a fragmented approach and reduce the complexity, accelerating the benefits and ensuring safe, legal UAS operations that are in harmony with the communities they serve. Ultimately the UAS Integration Framework provides Michigan a common language to harmonize capabilities and objective outcomes across framework levels to understand gaps, requirements, and associated benefits and risks of UAS.

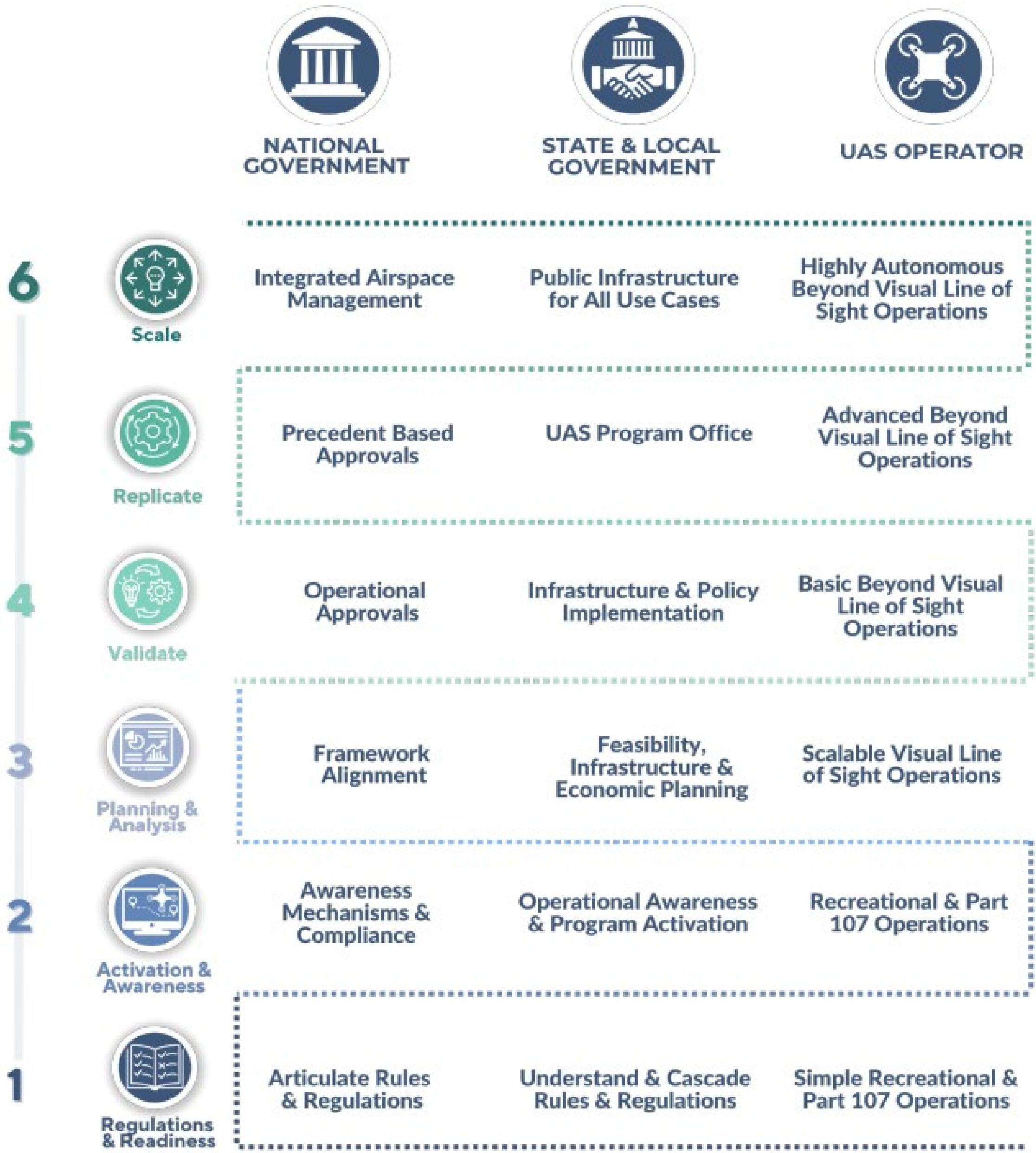


Figure 60: Drone Integration Framework Diagram Illustrating Key Details of Each Level

Applying the Framework

When community-focused solutions or infrastructure are provided by federal, state, or local government agencies, UAS operators are empowered to fly at a more complex level than they may be able to on their own. Conversely, governments may not be equipped to effectively manage inquiries and prioritize safety for residents when interfacing with advanced operators utilizing their own private processes and infrastructure. In the example scenario listed below, the government agencies in a shared geography are at varying levels of readiness. For example, two unique operators could propose the same ConOps to begin offering their services in the same geography. The difference in levels between stakeholders, namely federal, state, regional and local governments, illustrates a readiness gap and signals a risk to optimal regulatory, safety, and community outcomes.

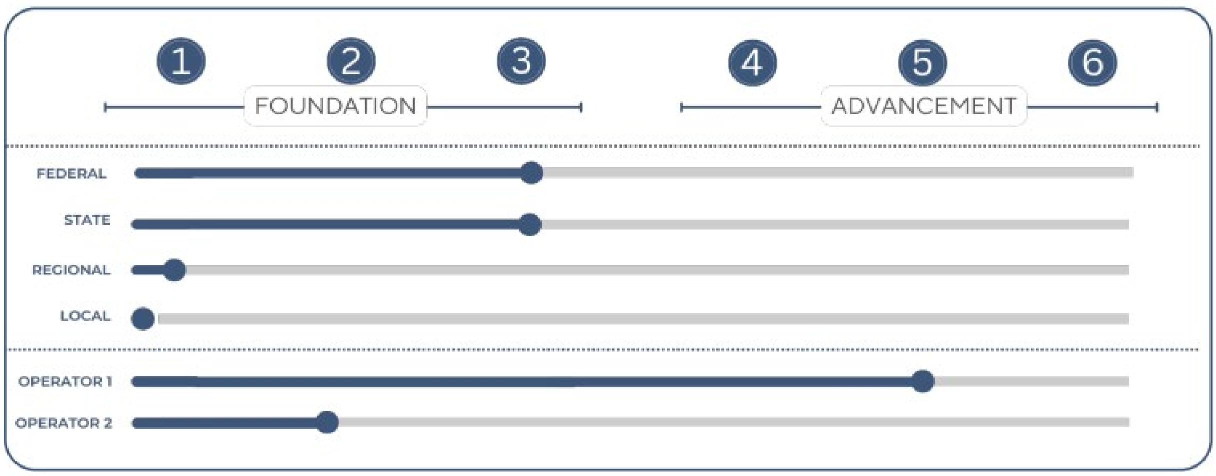


Figure 61: Example of Applied Levels of UAS Integration Framework

By applying the framework, it becomes clear to the local and regional governments that they will need to implement capabilities to proactively address awareness, safety, and security concerns that may arise as the operations continue to scale. These foundational capabilities will also position the regions as ideal geographies for further infrastructure investment and provide opportunities to progress advanced operations.

Level 1 Regulations and Readiness

Building a foundation of safety in UAS integration begins with all stakeholders understanding the airspace rules and regulations at the federal, state, and local levels. Public stakeholders will support programs that increase understanding and adherence to those regulations, reducing barriers to operators executing safe and compliant flights in harmony within the community. In the United States, Level 1 has the most comprehensive tools and support from a federal perspective, as it was the first step in establishing a safe roadmap for drone integration. These tools include the following.

Federal

UAS Data Exchange: The Federal Aviation Administration (FAA) introduced the Low Altitude Authorization and Notification Capability (LAANC) as the first step in integrating UAS into the National Airspace. LAANC allows pilots to apply for authorization when flying in controlled airspace, along with the additional benefits of:

- Awareness of where pilots can and cannot fly
- Access to controlled airspace at or below 400 feet
- Visibility into where and when drones will operate for Air Traffic Control

FAA DroneZone: Resources to help you stay compliant, register your drone, and apply for waivers. LAANC Providers, also known as UAS Service Suppliers, provide LAANC and support with unique services and capabilities. For example, after receiving LAANC authorization, pilots still need to check for NOTAMs/TFRs to ensure compliance.

Certifications: The Recreational UAS Safety Test (TRUST) by the FAA provides education and testing on important safety and regulatory information for operators flying UAS recreationally under the Exception for Recreational Flyers. Operators flying UAS less than 55 pounds for work or business, must follow 14 CFR Part 107 guidelines, including becoming an FAA Certified Drone Pilot and operate a drone registered with the FAA.

State and Local

State and local governments must have an in depth understanding of all federal rules and regulations along with state and local laws, and the means to communicate them to operators and their constituents. The understanding of the rules and regulations established in this initial phase equips the community with data to answer constituent questions, understand unique traits of their airspace, and begin to unlock low-altitude airspace as another community asset.

State and local agencies have begun creating policies, laws, and regulations within their jurisdictional authority regarding UAS. While they are not the final airspace authority, state and local governments have a role to play in furthering the safe integration of drones into their communities in a manner that’s in harmony with the FAA. For example, some of these policies seek to clarify privacy and zoning laws, as well as additional localized considerations to help manage and prepare for the growing drone economy in harmony with community interests.

Operator

UAS operators must understand the rules and regulations while supporting any given use case. With an ever-growing list of use cases from recreational enjoyment to the initial stages of utilizing drones for commercial use under Part 107 licenses, it can be overwhelming to locate and abide by all of the rules and regulations. While compliance is always the operator's responsibility, providing easily accessible tools and communication will continue to support safe and compliant operations by everyone in the community, and help operators and citizens avoid hefty fines and penalties. In addition to local community tools, private drone training programs continue to proliferate and broaden their offerings, providing safety information, and recreational and professional certifications.

Level 2 Awareness and Activation

While the majority of UAS operations are safe, legal, and conducted with good intentions, there may be situations where an operation is conducted by a bad actor. State and local governments have a role to play in responding to such incidents or fielding concerns from the community, such as concerns about privacy, a recreational flyer entering controlled airspace without authorization, or suspicious drone activity around critical infrastructure. When citizens are reporting those issues or asking questions about what they're seeing, they may not report directly to the FAA and the volume of reports may stress FAA resources or capacity to respond to inquiries in a timely manner. While the FAA is ultimately responsible for the airspace, increasing UAS activity is highlighting a growing need for the FAA and state, regional and local governments to work together in further clarifying roles, responsibilities, policies, and procedures to ensure a coordinated response.

A key step for local government in supporting these inquiries is understanding the rules and regulations with data readily available from Level 1 to confirm if UAS are allowed to fly in that area. Referencing those rules and obtaining awareness of these flights is required to effectively understand and respond to inquiries. One of FAA's responses for this need for enhanced awareness came in the form of Remote Identification (Remote ID). Remote ID is a crucial resource in local situational and operator awareness when responding to illegal or dangerous activities and is commonly called the "digital license plate" for drones. Remote ID allows authorized personnel to access information provided by the drone, such as identification and location. Ultimately, local Remote ID capabilities lay the foundation for safe and secure UAS operations. Future capabilities may be combined with Remote ID to support advanced operations such as flying over people, moving traffic, or beyond visual line of site.

While Remote ID is one aspect of the safe management and integration of drones, activation and awareness of internal operations for government entities also become increasingly critical at Level 2. From local law enforcement to image data collection or infrastructure inspection, the number of government operations executed daily across the globe is rapidly increasing. As those activations expand in parallel with private and commercial drone operations, the need for systems to increase awareness and coordination rises dramatically. While different departments of government may be using drones to support different use cases, the need to coordinate those operations internally and externally is universal. Community-focused tools designed to support communication and coordination are vital for driving harmony among all operations.

Level 3 Planning and Analysis

Unlike traditional aviation, typically operating within airport environments, UAS can operate, take off, and land throughout local communities, requiring additional coordination between federal, state, and local governments. Aligning federal, statewide, and local approaches ensures a seamless and unifying approach that expedites coordination and simplifies the complexity of the operators' landscape. Federal programs have been launched extensively over the past few years in the U.S. to support advanced planning through research and analysis, including the UAS Integration Pilot Program (IPP) and the continuation of that work through the BEYOND Program.

These programs are designed to drive meaningful dialogue on the balance between stakeholders, including national and local interests related to drone integration, and provide actionable information on the expanded and universal integration of drones into the National Airspace System. There are currently seven UAS test sites to support the FAA in integrating UAS into the National Airspace System, each playing a critical role in planning, analysis, and advancement efforts. In parallel, through obtained waivers and other certifications, operations are proliferating significantly beyond these sites.

State and Local Considerations

State & Local Governments will need to be informed of federal efforts, and in certain cases, participate in and influence these activities. Ultimately there is precedence for state and local agencies to begin their own planning and analysis projects to prepare for the rapidly evolving industry while simultaneously creating an attractive environment for investment from UAS operators.

Infrastructure investments have historically focused on highly tangible items like roads and bridges. Currently, the infrastructure enabling safer and scalable drone operations isn't clearly defined even as drone operations and regulations advance. State and local agencies such as Departments of Transportation, Metropolitan Planning Organizations, and Councils of Government, have an opportunity to begin analyzing and investing in enabling solutions for safer operations today and tomorrow, reducing operator barriers to entry within their geographies, all in a manner that aligns with their interests and is harmonized with the FAA.

Many agencies are investing in UAS service corridor planning as a first step in infrastructure investment. UAS service corridors provide full-service infrastructure and resources for UAS operations along these infrastructure service areas supporting safety and regulatory requirements. These initiatives can help increase community acceptance, remove the need for advanced waivers and one-off approvals within the service area, and begin to implement infrastructure for testing before a wider-scale rollout. Such feasibility studies and modeling initiatives can be conducted in parallel to traditional transportation and infrastructure planning, taking a comprehensive approach to UAS integration planning will support longer-term roadmap viability and ensure drones are successfully integrated with the community and all modes of transportation.

Designing infrastructure and regulations to foster growth in the industry will require close collaboration between private industry and all levels of government. The BVLOS ARC (Beyond Visual Line of Sight Advanced Rule Making Committee) for example brought together public and private stakeholders to collaborate on its report. Drones flying beyond an operator’s visual line of sight present unique challenges to the FAA’s existing regulatory framework and require additional consideration. Regional organizations have a role to play as well. For example, Metropolitan Planning Organizations (MPOs) are experts in guiding alignment on complex emerging topics like UAS integration and can ensure regions are preparing in harmony to promote interoperability and avoid fragmented approaches and siloed systems. Local communities are closest to their constituents and can help bridge the gap in alignment across interested parties.

Level 4 Validate

When implementing emerging technology, validation of proposed infrastructure, systems, and regulations is required to test new concepts before they can be responsibly replicated and scaled. The FAA has demonstrated the first step of this process during their UTM (Uncrewed Traffic Management) Field Testing at various IPP Test Sites. These field tests are designed to prove out new capabilities and proposed standards that support small UAS operations in the real world. The test outcomes help to support policy development and help the industry update standards to support routine BVLOS operations. In partnership with the FAA, the same rigor in validation testing is happening at the state and local levels to continue to move from planning and analyzing to implementing infrastructure and policy. UAS operators are essential in exercising and validating that infrastructure while advising on what will best support industry growth and consumer benefits.

Currently, many operators are challenged in meeting regulatory and safety requirements or scaling advanced operations due to the required resources and associated infrastructure required. Traditionally, airlines are not expected to commission and maintain their own navigation aids or maintain individual airports. Requiring drone operators to bring their own infrastructure is inefficient and expensive, leading to a lack of standardization and coordination, and, ultimately, industry stagnation. Additionally, at-hoc infrastructure only adds complexity to associated regulatory compliance processes associated with the validation of private infrastructure systems, making them costly, inefficient, and unscalable. It is quickly becoming evident that public or shared-use infrastructure is required to successfully scale and realize the full potential benefits that drones can offer.

Level 5 Replicate

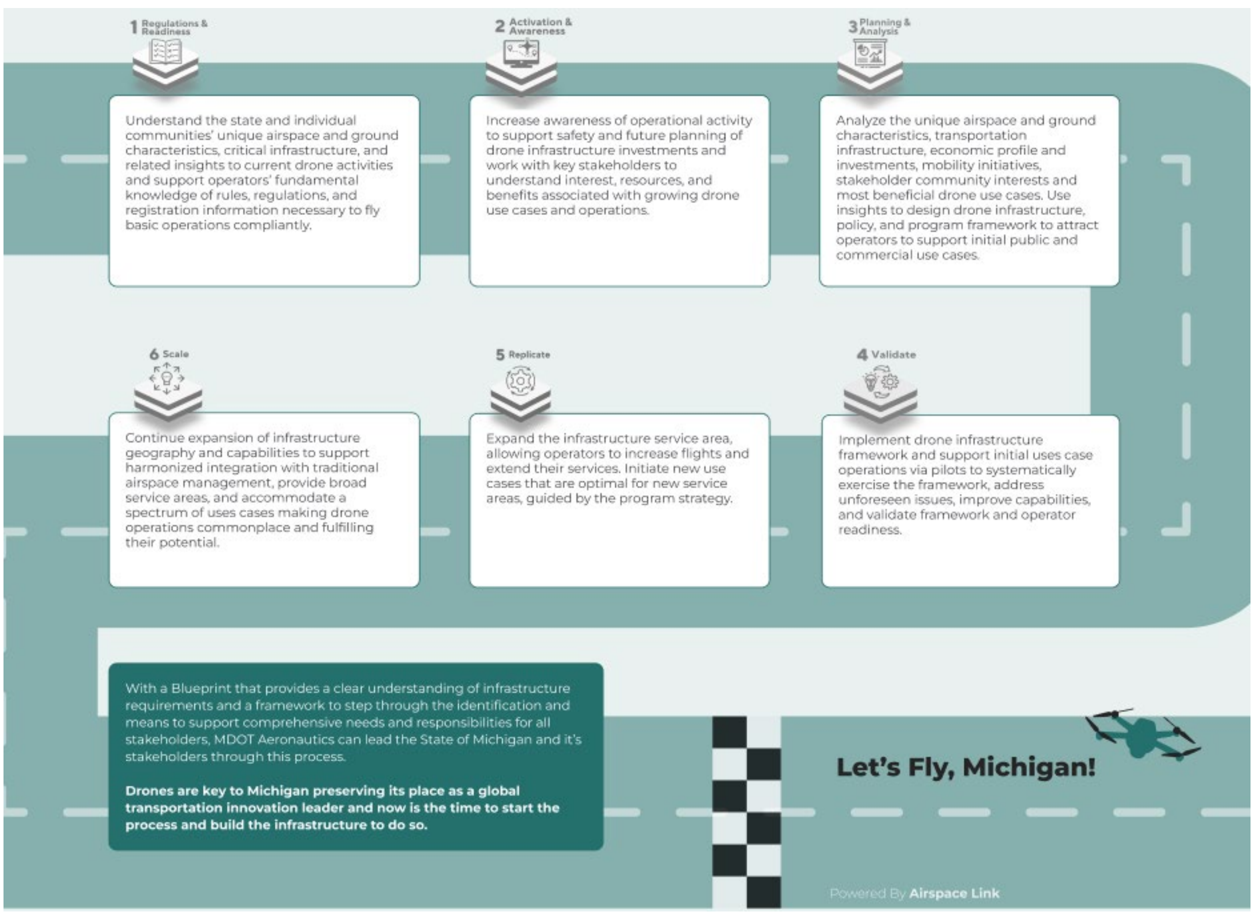
Validated systems, data, processes, and supported UAS use cases can be replicated into new markets to safely and effectively expand the infrastructure service area. Precedent-based approvals or pre-approved standards and systems significantly expedite processes and reduce the burdens on both the commercial and regulatory stakeholders. Many UAS operators are currently providing their own private infrastructure and have received waivers for specific aircraft certification and use case approval, operating in limited geographic areas at very complex levels. To replicate these successes at scale, stakeholders will need to move from one-off waiver-based approvals to integrated, coordinated efforts, leveraging standardized infrastructure, systems, and supporting tools.

For traditional airports, infrastructure replication is relatively standard. Expanding drone infrastructure into new geographies can be complex, given the unique attributes of each location, the broad areas of operation, and the importance of ground risk and localized information. Applying the knowledge of these unique attributes to the implementation strategy at a new location is an important step in the process and can be simplified through the use of a common process and infrastructure blueprint that can be configured or extended to support any combination of attributes.

Level 6 Scale

The long-promised vision of drones advancing economic, environmental, and societal objectives can only be fully realized when the infrastructure is in place to support comprehensive scaling of UAS operations. The infrastructure and regulations needed to enable ubiquitous drone operations will require a commitment from all stakeholders. Aligning all stakeholders on this unified approach to integration will simplify and expedite the execution of a shared vision of safe operations at scale and supporting the realization of the full potential of UAS for all communities. While everyone can benefit from the integration of drones at scale, communities that create favorable regulatory and business environments for the industry will likely siphon benefits, like job creation, from those who do not.

UAS Integration Road Map



Critical Steps to Safely Scale UAS

Unlock Aggregated Data and Analytics - Become an SDSP for Operators

Michigan has the distinct advantage of having aggregated a tremendous amount of airspace and ground risk data in the course of this Feasibility Analysis. To equitably attract industry partners, MDOT must become a world-class supplemental data service provider for advanced UAS operations. With the state acting as an SDSP, the vast amounts of airspace and ground risk data aggregated for the feasibility analysis will be paired with data engineering and program management services to lower the barriers to entry for waivers & operators.

Establish a Program Office – Drive Policy, Rules, and Regulations

This analysis is a critical first step in ensuring Michigan is first to scale commercial UAS– but many steps remain. We've learned from the progress of competing states that establishing a UAS Program Office is an invaluable step in creating one authoritative voice for local governments, State Authorities and Stakeholders, Commerce, UAS operators and the Federal Government to interact with. Major actions that benefit from the establishment of a UAS Program Office include, but are not limited to:

1. Providing clear, consistent and informed state policy and guidance to local governments and public & private UAS operators who wish to invest resources, participate in and/or leverage the network.
2. Being the single point of contact for the Federal Government in UAS integration into the NAS.
3. Oversight of implementation, operations and maintenance of the UAS infrastructure build to ensure public funds are used fairly, equitably and measurably advance Michigan to the desired end state.
4. Operationalizing the State's investment in analysis and infrastructure.
5. Ensuring compliance of use of Michigan's UAS infrastructure.

With this in mind, it is recommended that the State of Michigan takes steps to establish and resource a program office within MDOT Aeronautics, focused on Commercial UAS, to help inform policy-making that serves public interests and creates awareness. States legislation needs to be enacted in harmony with the FAA and extend their aviation current rules to UAS. The operator will know that this is a state that is in lockstep with federal regulators, and communities will have consistent, clear guidance on zoning and land use.

Allocate Budget – Fund and Emplace Critical Capital Infrastructure

Ultimately, the state must make a substantial, strategically planned investment in physical infrastructure. Communications, Navigation, and Surveillance (CNS) technology will ensure advanced UAS operations are feasible within integrated airspace above people. Combined with a robust and embedded digital infrastructure, will establish Michigan as the continued global leader in mobility. The Program Office (mentioned above) should manage the build.

Engage with Industry – Fund Technology Demonstrations

State-funded capability demonstrations have and will continue to run *in-parallel-to-and-in-support-of* the preliminary analysis, establishing an effective data loop of real-world application. Sustained, deliberate industry engagement led by the Program Office signals the state is making investments that will enable their operations and lower the barriers to entry.

Regulatory & Safety

Regulatory & Safety Framework

There are many regulatory and safety requirements associated with enabling drone operators to conduct advanced BVLOS operations within the United States. Currently, it falls on the operator to overcome the challenges and receive FAA approval to fly a drone. The operator must present a safety case to the FAA, which describes how they will manage risk to an acceptable level and generally requires:

- Technology in the form of FAA-accepted, shared-use infrastructure that provides the resources that unlock scalable, economically viable drone operations for all operators and use cases
- Risk Mitigations that apply the technology resource in a way that strategically or tactically reduces risks throughout the drone operation

Drone operators will operate under existing rules and regulations as specified below. The drone operator will operate under 14 CFR Part 107 or 14 CFR Part 91, depending on the concept of operation. In certain circumstances, operators may need to follow Part 135 or Part 137 rules.

Part 107 Operations
Involve small drones less than 55 pounds which typically fly below 400 feet above ground level (AGL) in uncontrolled airspace (Class G). There are a limited number of regulations under Part 107 that can be waived for advanced operations.

Part 91 Operations
Developed for crewed aviation but can be a pathway for drone operations when the aircraft is greater than 55 pounds.

Part 135 Operations
Designed for air transportation of persons or property for compensation. A drone operator transporting property for compensation must hold a Part 135 Certificate.

Part 137 Operations
Designed for dispensing chemicals and agricultural products. A drone operator conducting these activities must hold a Part 137 Certificate. State laws must also be considered.

Regardless of the regulatory path to receiving FAA approval for an advanced drone operation, the operator must present a safety case to the FAA, which describes how risk will be managed to an acceptable level. When an advanced drone operation has high air risk, an operator leveraging the drone infrastructure can provide a safety case showing a reduction of risk to an acceptable level by using surveillance sensors (medium range radar, optical sensors, ADS-B receivers) to maintain air traffic awareness. Additionally, when an advanced drone operation has high ground risk, the operator can indicate how the drone infrastructure ground risk data ensures the drone flight plan factors in ground risk and routes around risk areas. These controls enable the operator to present a strong safety case to the FAA when requesting to conduct advanced drone operations and improve the probability of approval.

When developing the safety case, the operator should use FAA guidance, which can be found within the following FAA Orders and manuals.

- FAA Order 8000.369C Safety Management System (SMS) Policy: Establishes SMS policy and requirements and emphasizes Safety Risk Management (SRM) and Safety Assurance (SA) processes
- FAA Order8040.4B Safety Risk Management Policy: Establishes requirements to conduct SRM
- FAA Order 8040.6 UAS Safety Risk Management Policy: Establishes a methodology for conducting SRM specifically for drone operations
- Air Traffic Organization (ATO) Safety Management System Manual: A collection of principles, policies, processes, procedures, and programs used to identify, analyze, assess, manage, and monitor safety risk

These FAA Orders and Manuals provide a formal, organization-wide approach to managing safety risk and assuring the effectiveness of safety risk controls for the FAA. These Orders and Manuals were designed to be used by the FAA to establish their own processes, but they each provide invaluable information for applicants of waivers, exemptions, and authorizations as they provide key insight to what the FAA requires and how the information should be conveyed. Following the guidelines within these FAA Orders and Manuals enable drone operators to provide a strong, FAA-accepted safety case when requesting approval for advanced drone operations.

Details of each regulatory and safety pathway are described within the Regulatory Pathways and Safety Case Development sections below. Drone operators must develop a comprehensive concept of operation and asses it thoroughly to determine the most suitable pathways to approval for advanced drone operations. Figure 62 provides a basic flow chart to guide drone operators when selecting suitable paths. Note that this flow chart provides typical paths based on FAA guidance but is not one-size-fits-all as certain concept of operations may require operators to deviate or combine multiple paths.

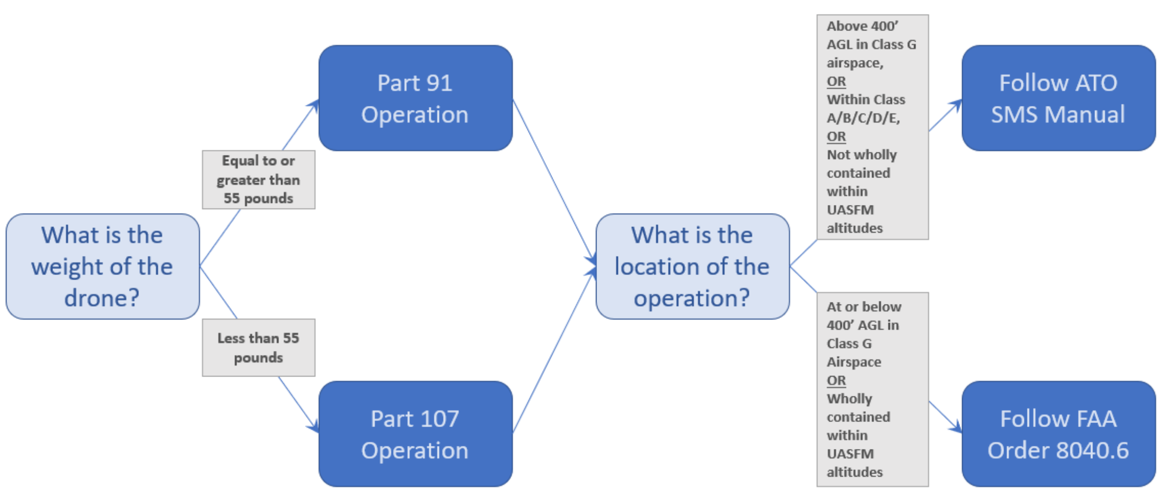


Figure 62: Regulatory and Safety Pathway Guidance for Operators

Information in the following sections include the current regulatory framework and FAA guidance. It is important to understand that regulatory pathways and FAA guidance are evolving. Over time, updates will occur, and new pathways and guidance will be developed.

Regulatory Pathways

14 CFR Part 107

Background

The FAA created 14 CFR Part 107 in 2016 to allow commercial drone operators to fly under a defined rule set. Previously, any drone operation for commercial purposes had to apply for permission from the FAA. Part 107 removed a time-consuming process to allow for basic drone operations provided the operation follow the outlined 3-step process:

- Ensure aircraft and operation fall under 14 CFR Part 107 rules (https://www.law.cornell.edu/cfr/text/14/part-107).
- The remote pilot must obtain a Remote Pilot Certificate issued by the FAA. To obtain a Remote Pilot Certificate, you must meet the eligibility requirements outlined in 14 CFR Part 107.61 and complete FAA Form 8710-13.
- All drones used for commercial operation must be registered with the FAA. This can be done on the FAA's DroneZone website (https://faadronezone-access.faa.gov). At the time of this report, registration is $5/drone and is valid for 3 years.

Waivers

Any operation that falls outside the Part 107 rule set requires a Part 107 waiver or exemption. A waiver is an official document issued by the FAA that approves certain operations of aircraft outside the limitations of a regulation. You may request to fly specific drone operations not allowed under Part 107 by requesting an operational waiver. Refer to Part 107.205 for the list of regulations that may be waived under Part 107 (https://www.law.cornell.edu/cfr/text/14/107.205). These waivers allow drone pilots to deviate from certain rules under Part 107 by demonstrating they can still fly safely using alternative methods.

To apply for a Part 107 waiver:
Determine appropriate waiver and create supporting documents. The FAA has a Waiver Safety Explanation Guidelines document located on the FAA's website (https://www.faa.gov/uas/commercial_operators/part_107_waivers) that outlines what should be included in a waiver submission. This includes operational details, drone details, pilot/personnel details, and operational risks and mitigations (safety case). The following supporting documents are recommended for a waiver submission:

1. Concept of Operation
2. Safety Risk Management Documentation
3. Responses to Waiver Safety Explanation Guidelines and Guiding Questions

Submit your waiver request and supporting documents on the FAA DroneZone website. The FAA generally reviews and decides on the waiver request within 90 days. However, this timeframe depends on the complexity and completeness of the initial application. As outlined in Part 107.205, the following are Part 107 regulations subject to waiver:

- 107.25: Operations from a moving vehicle or aircraft*

- 107.29(a)(2) and (b): Anti-collision light required for operations at night and during periods of civil twilight
- 107.31: Visual line of sight operation*
- 107.33: Visual observer
- 107.35: Operation of multiple sUAS
- 107.37(a): Yielding the right of way
- 107.39: Operation over people
- 107.41: Operation in certain airspace
- 107.51: Operating limitations for sUAS
- 107.145: Operations over moving vehicles

*The FAA will not waive this section to allow the carriage of property of another by aircraft for compensation or hire.

See and Avoid Compliance

See and avoid is a function that is a requirement for all aviators. Part 107.31, Visual Line of Sight Aircraft Operation, and Part 107.33, Visual Observer, address the see and avoid function as it relates to the Part 107 regulations. To operate beyond the remote pilot in command's visual line of sight, a Part 107.31 waiver is required and depending on the concept of operation, a Part 107.33 waiver may be required.

Airworthiness

Determination of airworthiness is required for all aircraft flying in the National Airspace System. This can be accomplished in different ways depending on the rules and regulations that are being flown under. For Part 107, the function of determining airworthiness is performed by the remote pilot in command. However, for advanced drone operations under a Part 107 waiver, such as beyond visual line of sight or operations over human beings, additional airworthiness requirements may apply. Refer to Part 107.39 and the Durability and Reliability section below for additional information.

14 CFR Part 91

Background

Part 91 outlines aircraft certifications and equipment requirements for the operation of aircraft in U.S. airspace. It prescribes rules governing maintenance, preventive maintenance, and alterations. If a drone operation does not fall under Part 107 rules or if it is determined that the operation is better suited for Part 91 based on the concept of operation, the drone operator may choose to pursue advanced UAS operations under Part 91.

See and Avoid Compliance

See and avoid is a function that is a requirement for all aviators. Part 91.113, Right-of-way rules, addresses the see and avoid function as it relates to the Part 91 regulations. To operate beyond the remote pilot in command's visual line of sight, a Part 91.113(b) waiver is required.

To apply for a Part 91.113(b) waiver, the drone operator must:

1. Complete an application for certificate of waiver or authorization using FAA Form 7711-2.
2. Develop supporting documentation.
3. Send completed FAA Form 7711-2 and supporting documents via email to 9-UAS-91.113Waivers@faa.gov.

The following paragraph includes guidance for filling out FAA Form 7711-2 and developing supporting documents. Additional guidance can be found on the FAA website, https://www.faa.gov/uas/advanced_operations/instructions-drone-operators-completing-faa-form-7711-2.

FAA Form 7711-2 guidance includes:

- Items 1-3: Provide current contact information.
- Item 4: State whether the applicant has an application for waiver pending at any other office of the FAA.
- Item 5: State whether the applicant has ever had its application for waiver denied, or whether the FAA has ever withdrawn a waiver from the applicant.
- Item 6: FAR section and number to be waived
    - In addition to the specific section and number for which you are seeking a waiver, indicate the following, either in this Item or under Item 7:
        - Identify if this operation is a Public Part 91 (PAO) or a Civil operation.
            - For PAO, does the operation meet 49 U.S.C. § 40125 requirements?
            - For Civil operations, what certification will the operation take part under?
        - List any certification request that has been initiated for the operation under the indicated part. (e.g., Part 135, Part 137)
        - List any other prior agreements or approvals provided by the FAA for your equipment or operation (e.g., COA, Equipment Certifications, licenses).
- Item 7: Detailed description of proposed operation (attach supporting documentation if needed)
    - Applicants should include the following topics in response to this item. A full Concept of Operations document is not required. Additional information that is not directly related to the safety case for the intended operation, and that does not address any of the following topic areas, is generally not necessary.
        - Spectrum
        - Inflight Operation
        - Cargo Information
        - Command and Control
        - Navigation Information
        - Aircraft and Crew
        - Operational Details
        - Assumption, Hazards, and Risks
- Item 8: Area of operation
- Item 9: Beginning and ending time (date and hour)
- Item 10: Aircraft details
- Items 11-16: These items need not be completed for UAS operations unless the operation

is in for an air show or race.

Additional Waivers and Exemptions

Within 14 CFR, the proponent may petition for an exemption from any rule issued by FAA under its statutory authority. A proponent may also petition the Administrator to issue, amend, or repeal a rule. Regulations governing the petition for exemption or rulemaking process are in Part 11 of Title 14 CFR.

Because Part 91 was developed for crewed aviation, uncrewed operations require relief from certain sections of Part 91 where drone operations cannot comply as written. Below is a list of common regulations in which a drone operation will require a waiver or exemption. 14 CFR 91.905 lists the Part 91 rules that are subject to waiver. Rules not in this list would require an exemption.

1. 61.3(a)(1)(i): Required pilot certificate for operating a civil aircraft in the US
2. 61.3I(1): Medical certificate
3. 91.7(a): Civil Aircraft Airworthiness
4. 91.9(b)(2): Civil aircraft flight manual, marking, and placard requirements
5. 91.119I:): Minimum safe altitudes: general
6. 91.121: Altimeter settings
7. 91.151: Fuel requirements for flight in VFR conditions
8. 91.203(a)&(b): Civil aircraft: Certifications required
9. 91.403(a)&(b): General
10. 91.405(a): Maintenance required
11. 91.407(a)(1)(2): Operation after MX, preventative MX, rebuilding, or alteration
12. 91.409(a)(1)(2): Inspections
13. 91.417(a)(b): Maintenance records

The proponent must send a petition for exemption 120 days before the exemption is needed. The FAA typically grants an exemption for 2 years. Per 14 CFR 11.81, the petition for exemption must include:

1. Your name and mailing address. You may include other contact information such as a fax number, telephone number, or email address
2. The specific section or sections of Title 14 of the Code of Federal Regulations from which you seek an exemption
3. The extent of relief you seek and the reason you seek the relief
4. How your request would benefit the public as a whole
5. Reasons why the exemption would not adversely affect safety, or how the exemption would provide a level of safety at least equal to the existing rule
6. A summary we can publish in the Federal Register stating:
    a. The rule from which you seek the exemption
    b. A brief description of the exemption you seek
    c. Any additional information, views, or arguments available to support your request
7. If you want to exercise the privileges of your exemption outside the United States, you must state the reason.

To file a petition for exemption, the request is submitted to the Federal Docket Management System (FDMS) electronically by accessing the public portal: https://www.regulations.gov/commenton/FAA-2007-0001-0001

This docket serves as the primary method of submitting public requests for consideration by the Federal Aviation Administration. Detailed instructions to filing a petition for exemption are found here: https://www.regulations.gov/comment/FAA-2007-0001-0001

Upon submission, save the tracking number generated following submission for your records. This tracking number will be the only confirmation until the petition has been posted.

Airworthiness

Drone operators conducting operations under Part 91 must consider 14 CFR Part 21 certification requirements. Part 21 defines three separate certifications: type, production, and airworthiness. This report focuses on type certification and airworthiness certification.

- **Type certification** is the approval of the design of the aircraft and all component parts (including propellers, engines, control stations, etc.).
- **Production certification** is the approval to manufacture duplicate products under an FAA-approved type design. It signifies that an organization and its personnel, facilities, and quality system can produce a product or article that conforms to its approved design.
- **Airworthiness certification** is necessary for operation of civil aircraft outside of 14 CFR Part 107 or without an exemption under the Special Authority for Certain Unmanned Systems (U.S.C. 44807). An airworthiness certificate can be either in the Standard or Special class and signifies that an aircraft meets its approved type design (if applicable) and is in a condition for safe operation.

A standard airworthiness certificate is the FAA's official authorization allowing for the operation of a type-certificated aircraft. A standard airworthiness certificate allows the aircraft to be operated and used with the most minimal restrictions and for compensation and hire. Because type certification is a prerequisite for a standard airworthiness certificate, most UAS do not currently meet the requirements for a standard airworthiness certificate. However, the FAA recently published a policy clarification to the “special class" category under §21.17(b) to issue type certificates for certain UAS. The FAA has developed a durability and reliability (D&R) process to establish criteria as an element of the proposed certification basis for these aircraft. This special class process establishes a defined path to type certification of UAS.

Another airworthiness certification option for UAS is a special airworthiness certificate. Special airworthiness certificates limit operation and use of the aircraft, often severely. The most common category of special airworthiness certificates for UAS are those in the experimental category.

Thus, UAS airworthiness certification pathways currently include:

1. Section 44807: Special Authority for Certain Unmanned Systems
2. D&R Process for UAS Type Certification
3. Special Airworthiness Certificate

These 3 pathways are summarized in the subsections below.

Section 44807: Special Authority for Certain Unmanned Systems

49 U.S.C. §44807 grants the Secretary of Transportation the authority to use a risk-based approach to determine whether an airworthiness certificate is required for a drone to operate safely in the national airspace system. Under this authority, the Secretary may grant exemptions to the applicable operating rules, aircraft requirements, and pilot requirements for a specific operation on a case-by-case basis. This grants drone operators safe and legal entry into the NAS, thus improving safety. An exemption under 49 U.S.C. §44807 can be useful if the drone exceeds 55 pounds, the drone does not yet have an airworthiness certificate, or the mission includes a non-waivable rule.

Steps to request FAA authorization to operate a drone for civil (non-governmental) purposes pursuant to 49 U.S.C. §44807 are as follows:

1. Prepare the petition, ensuring it includes the following at a minimum:
    a. Concept of Operations
    b. Operations Manual
    c. Emergency Procedures
    d. Checklists
    e. Maintenance Manual
    f. Training Program
    g. Flight History (flight hours, cycles, accidents)
    h. Safety Risk Analysis
        i. Required for complex operations for any proposal that includes the following, but not limited to:
            a) Flight over or in close proximity to people
            b) Flight beyond visual line of sight
            c) Operation of multiple drones
            d) Operations from a moving vehicle
            e) Package delivery
            f) Part 135 operations
            g) High speeds

2. Verify that all the necessary information is included. Refer to 14 CFR Part 11.81.
3. Submit the petition and supporting documentation on the public docket through the public portal: https://www.regulations.gov/commenton/FAA-2007-0001-0001.
4. Once the petition is approved, the FAA will instruct the proponent to submit a COA application via the COA Application Processing System (CAPS). The COA serves as operational approval for the specific airspace. COA applications associated with 49 U.S.C. §44807 exemptions must include:
    a. The exemption number corresponding to the Federal Register Docket ID for your petition for exemption
    b. The aircraft registration number used in the petition.
    c. The same name or company name that was used on the petition for exemption.

Special Airworthiness Certificate

Background

A special airworthiness certificate is an option for UAS that do not meet the airworthiness requirements for a standard airworthiness certificate. A special airworthiness certificate covers a wide variety of aircraft in seven different categories. Special airworthiness certificates limit operation and use of the aircraft, often severely. The most common category of special airworthiness certificates for drones are those in the experimental category (SAC-EC). FAA Order 8130.34D (https://www.faa.gov/regulations_policies/orders_notices/index.cfm/go/document.information/documentid/1031867) establishes procedures for special airworthiness certification of drones and optionally piloted aircraft. Special airworthiness certificates in the experimental category may be issued for:

1. Research and development
2. Showing compliance with regulations
3. Crew training
4. Exhibition
5. Market survey

Application

Per FAA Order 8130.34D, the following elements are typically required for a SAC-EC application:

1. The owner of the aircraft must register the aircraft according to 14 CFR Part 47 or Part 48
2. Define an operational area
3. Develop a Program Letter and Safety Checklist
4. Complete FAA Form 8130-6 for submission to the FAA

Applicants can submit the application using the ASKME Segment II Airworthiness Certification (AWC) tool. The FAA securely transmits the completed form so that it can be processed by an FAA Aviation Safety Inspector (ASI) or Designee.

Program Letter

The program letter outlines the program objectives and describes the purpose of the flight operation and should be developed using the guidance in FAA Order 8130.34D Appendix C and FAA Order 8130.2. The program letter does not need to include all the minute details, but it must be detailed enough to permit the FAA to prescribe the conditions and limitations necessary to ensure the safe operation of the aircraft.

Safety Checklist

For operations in Group II and Group III, the proponent is responsible for providing the responsible office with a completed safety checklist that reflects the configuration of the aircraft at the time of certification. The safety checklist is very comprehensive and should be completed in its entirety following the outline in FAA Order 8130.34D Appendix D. Refer to FAA Order 8130.34D Appendix E to determine Group Category. The FAA inspector will distribute the safety checklist to all FAA offices involved in the certification process.

UAS Risk Index

Because drones have large variances in size, weight, technology, and flight envelopes, the airworthiness certification process used in FAA Order 8130.34D is based on assessed risk.

The baseline parameters of the order are:

1. The use of FAA certificated pilots
2. The use of visual observers
3. Visual line of sight operations
4. Daytime operations in visual meteorological conditions (VMC) to permit VFR flight as required by § 91.319(d)(2)
5. The avoidance of densely populated areas

These baseline parameters provide a high degree of risk mitigation.

Appendix E in FAA Order 8130.34D, UAS Risk Index, is used by FAA to assist in determining the appropriate certification tasks for a particular drone. The risk index indicates that programs deemed to have lower risk can satisfy the pertinent regulatory standards by completing fewer airworthiness certification tasks than programs deemed to have a higher risk.

Table 25, Risk Categories, from appendix E of FAA Order 8130.34D identifies four categories that are used to assess risk. The categories are composed of operational and performance parameters. Each category is broken down into incremental elements that are assigned points. Higher-risk elements are assigned more points.

The total score from Table 25 is used by FAA to determine the risk group. The degree of risk increases from Group I to Group III. Therefore, a Group I aircraft can meet the pertinent regulatory standards by completing fewer tasks than aircraft in higher-risk groups. Refer to FAA Order 8130.34D Appendix E to review Applicant Tasks in Table E-4. Some certification tasks were not included in Table E-4 because they will apply to all risk categories. These items include the FAA Form 8130-6, program letter, aircraft registration, aircraft markings, and certificated pilots.

Table 25: Risk Categories

Risk Category	Incremental Element	Value	Points
Maximum Takeoff Weight	Up to 4.5 lbs	0	
	4.5 up to 55 lbs	5	
	55 lbs up to 300 lbs	10	
	300 lbs up to 1,000 lbs	15	
	Greater than 1,000 lbs	25	
Maximum Speed	Less than 87 kts (100 mph)	0	
	87 kts to 250 kts	10	
	Greater than 250 kts	20	
Maximum Operating Altitude	Less than 200 ft AGL	0	
	200 ft AGL up to 500 ft AGL	5	
	500 ft AGL up to 5,000 ft AGL	10	
	5,000 ft AGL up to 17,999 MSL	15	
	Class A and above	25	
Flight History	Known – previous flight time ≥ 50 hrs	0	
	Known – previous flight time < 50 hrs	2	
	Unknown – first flight	6	
		Total Score	

Table 26: Special Considerations

	Yes	No
Night Operations		
IMC		
Beyond or Extended Visual Line of Sight (BVLOS/EVLOS)		
Chase Aircraft		
Operations Closer Than 2 Miles From Towered Airport		

Note: *If "Yes" is checked for any of these items, Group III requirements will be applied. FAA Order 8900.1 may impose additional requirements (such as a safety case) for these items.*

Table 27: Group Categories

Group Category	Total Score
Group I	0 to 16
Group II	17 to 39
Group III	40 and above

Overview of the SAC-EC Certification Process

An overview of the SAC-EC certification process is illustrated in Figure 63.

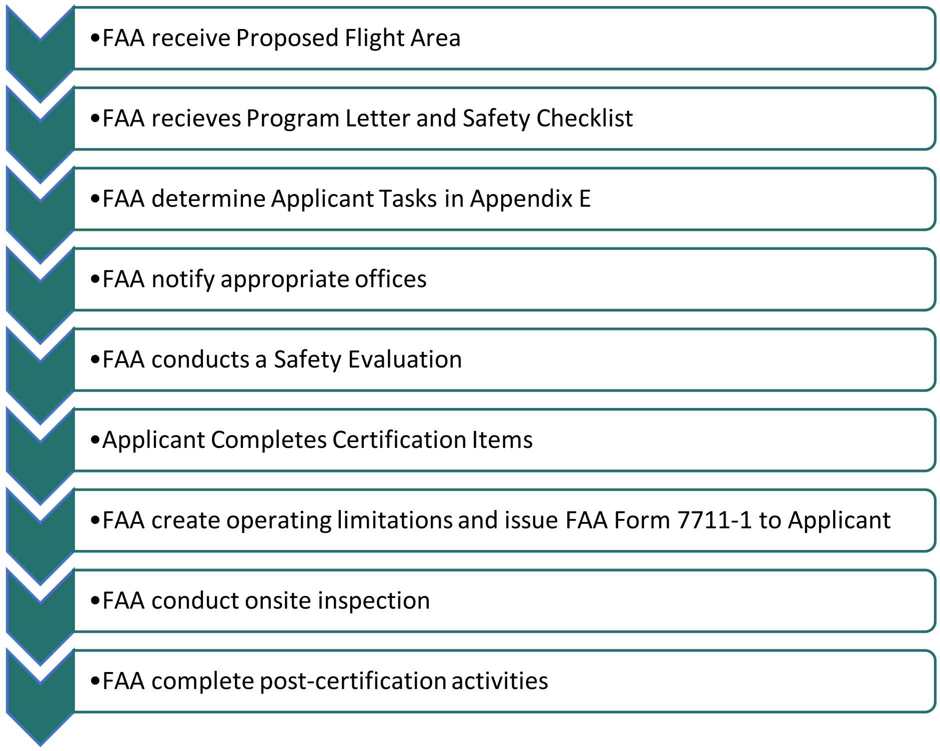


Figure 63: SAC-EC Certification Process

Upon application for an original airworthiness certificate, an ASI will coordinate the original airworthiness certification of a drone with the appropriate FAA offices and serves as a single point of contact between the applicant and the FAA. The ASI ensures the program letter, safety checklist, documents, manuals, and communications from the applicant are provided to the appropriate FAA offices. These offices include:

1. The Technical Support Branch (AUS-420) of the UAS Safety and Integration Division (AUS-400)
2. The General Aviation Operations Branch (AFS-830) of the General Aviation and Commercial Division (AFS-800)
3. The Emerging Technologies Team (AJV-115) of the Air Traffic Organization
4. Geographically responsible FAA office (MIDO or FISDO) performing the certification
5. Geographically responsible airworthiness ASI

Next steps include the following. Refer to FAA Order 8130.34D Chapter 3, Section 2 for additional information on each step.

1. Conduct Safety Evaluation - Aircraft owner/operator briefs FAA on the application
2. FAA issues operating limitations and COA for flight demonstration
3. Conduct onsite inspection - FAA visits to review documentation, inspects the drone, and witnesses flight demonstration
4. FAA issues airworthiness certification

Durability and Reliability Type Certification
(Applies to Part 91 and in certain cases, Part 107)

The FAA published a policy clarification to use the "special class" category under §21.17(b) to issue type certificates (TC) for certain drones. The FAA has developed a durability and reliability (D&R) process to establish criteria as an element of the proposed certification basis for these aircraft. This special class process establishes a defined path to type certification of drones and is the first of its kind developed worldwide. The D&R process involves applicants demonstrating to the FAA that a UAS (uncrewed aircraft system) is reliable, controllable, and safe. This process is used to provide the FAA with basic assurance that the aircraft will function as intended and can be used as a type certification solution for drone operations under Part 107 or Part 91.

The means of compliance for durability and reliability-based type certificate is divided into three major sections:

1. Durability and reliability testing
   a. Test cycles are fully representative of end-state operations with test points to verify safe operation at the operational limits and corners of the vehicle envelope.
2. Likely failure and specific demonstration tests
   a. Induced failures and specific tests where operationally representative cycles alone may not provide sufficient detail.
3. Design criteria
   a. A list of design criteria that applicants will review to assess their UAS. Applicants will provide the assessment and a certifying statement of compliance to the Aircraft Certification Office.

Compliance with all three sections is expected to be eligible for a TC through this process.

ASTM F3478-20 outlines the process for development and implementation of a flight demonstration program for the durability and reliability type certification process. Demonstration plans developed in accordance with this document will include all necessary content and key considerations to support an effective flight demonstration program aimed at approval or certification of UAS by the FAA through D&R demonstration.

Certificate of Authorization

Chapter 6 of FAA Order JO 7200.23C outlines the steps in which the FAA processes a Certificate of Authorization (COA) application for drone operations under 14 CFR Part 91. Proponents requesting the use of a drone outside of restricted and warning areas must obtain a COA if exceptions documented in FAA Order JO 7200.23C are not met. The proponent must submit an application/renewal for a COA using the online application system at https://caps.faa.gov. Applications (including renewals) should be submitted at least 60 business days before the proposed start of drone operations to allow a comprehensive operation and technical review. COAs must have a termination date not more than 2 years from the effective date unless renewed or extended.

The steps in which the FAA processes a COA application are as follows:

1. When the application is received, an initial review will be conducted, and any initial mitigations will be included prior to sending the draft COA forward for processing and note that the

application is ready for air traffic coordination.
2. The Service Center and ATC facility will determine any additional mitigations that are necessary for the Air Traffic Control Special Provisions portion of the COA.
3. Uncrewed requests for VFR operations wholly contained in Class G airspace do not need to be coordinated or approved by the overlying air traffic facility. Additionally, a copy of the COA does not need to be sent to the ATC facility.
4. Air Traffic Managers (ATMs) will ensure any operational requirements necessary for the safe operation of the drone in the facility's airspace are provided so that they can be included in the COA. Examples of items to consider during the review may include, but are not limited to:
   a. Impact of drone Operating Areas on local operations.
   b. Verify the lost link procedures will not interfere with other traffic.
   c. Any operational issues that may impact local air traffic procedures and operations.
5. Once the Service Center/ATC coordination is complete, the processor will complete the COA for final processing.
6. Once the final COA is signed, it will be distributed by the appropriate Service Center to the ATC facilities and the proponent.

Refer to Chapter 6 of FAA Order JO 7200.23C for additional information, such as On-Airport COAs and exceptions to the COA requirement.

14 CFR Part 135

An operator that provides air transportation of persons or property for compensation or hire is required under the Federal Aviation Regulations to hold a commercial operating certificate. Operators of business aircraft that wish to conduct operations for compensation or hire are generally certificated under Part 135. As a certificate-holding entity, the operator must comply with FAA requirements regarding areas that include flight operations, maintenance, and training. Currently, the existing Part 135 certificate process applies to drone operators seeking to conduct package delivery operations and is the only pathway forward for drone operators seeking to conduct this type of operation.

The Part 135 regulations establish requirements for operators such as:

1. Aircraft maintenance requirements
2. Pilot licensing
3. Minimum insurance coverage
4. Crew duty time limitations

To conduct Part 135 operations, the operator must be certified. There are four types of Part 135 certificates that can be applied for based on the type of operations that the applicant wishes to conduct:

1. Part 135 Single Pilot. A single-pilot operator is a certificate holder that is limited to using only one pilot for all Part 135 operations.
2. A Single Pilot in Command certificate is a limited Part 135 certificate. It includes one pilot in command certificate holder and three second pilots in command. There are also limitations on the size of the aircraft and the scope of the operations.
3. A Basic operator certificate is limited in the size and scope of their operations. Maximum of five pilots, including second in command. A Maximum of five aircraft can be used in their operation.
4. A Standard operator holds a certificate with no limits on the size or scope of operations.

However, the operator must be granted authorization for each type of operation they want to conduct.

Once an applicant determines the correct type of certificate to obtain, they can apply. The certification process utilizes a phase and gate system that has 5 phases and 3 gates:

1. Pre-application
   a. The completion of the Pre-application Phase also completes Gate 1 of the certification process.
2. Formal Application
   a. The completion of the Formal Application Phase also completes Gate 2 of the certification process.
3. Design Assessment
4. Performance Assessment
   a. The completion of the Performance Assessment Phase also completes Gate 3 of the certification process.
5. Administrative Functions

All items in a phase must be successfully completed prior to continuing past a gate and into the next phase of the process. An applicant will not be certificated until the FAA is confident that the prospective certificate holder can fulfill the required responsibilities and will comply with 14 CFR in an appropriate and continuing manner. For additional information on the Part 135 certification process, refer to the FAA website, https://www.faa.gov/licenses_certificates/airline_certification/135_certification/cert_process

14 CFR Part 137

The regulation for operating drones to dispense chemicals and agricultural products including disinfectants, is 14 CFR Part 137, Agricultural Aircraft Operations. Not all substances fall under this regulation, so first check to see if the proposed operation meets the FAA's criteria for Part 137. If the substance you plan to dispense does meet the criterion described in Part 137.3, refer to the Advisory Circular 137-1B, Certification Process for Agricultural Aircraft Operators, for guidance on the requirements that must be met before dispensing it. Under 14 CFR Part 137, the following operations are considered agricultural by nature:

1. Dispensing economic poison such as pesticides, plant regulators, a defoliant, or chemicals used as disinfectants for viruses.
2. Dispensing any other substance intended for plant nourishment, soil treatment, propagation of plant life, or pest control.
3. Engaging in dispensing activities directly affecting agriculture, horticulture, or forest preservation. Dispensing of live insects is not included.

To conduct a Part 137 operation, the following steps must be completed:

1. Apply for an Agricultural Aircraft Operator Certificate (AAOC). Advisory Circular (AC) 137-1B describes how to apply for an AAOC under Part 137.
2. Petition for an exemption. Refer to the Additional Waivers and Exemptions Section in this report for guidance.
   a. Drones weighing less than 55 pounds (including the weight of the substance being

dispensed) are operated under 14 CFR Part 107 and require exemption from §107.36, Carriage of hazardous material, and depending on the concept of operation, exemption from additional Part 137 regulations.

b. Drones weighing 55 pounds or more are operated under 14 CFR Part 91 and require exemption from several 14 CFR Part 61, 91, and 137 regulations. Specific regulations are determined based on the concept of operation.

To receive an AAOC, Part 137 applicants must successfully satisfy each of the five phases in the evaluation process. Phases include:

1. Preapplication Phase
2. Formal Application Phase
3. Document Compliance Phase
4. Demonstration and Inspection Phase
5. Certification Phase

For part 137 operations using a UAS, prior to the Formal Application Phase, the applicant must have petitioned for an exemption, and prior to the Demonstration and Inspection Phase, a grant of exemption must have been issued to the applicant.

Safety Case Development

FAA Order 8000.369C: Safety Management System Policy and Requirements

FAA Order 8000.369C, Safety Management System, establishes the SMS policy and requirements for the FAA. This order furthers safety management by evolving to a more process-oriented system safety approach with an emphasis on SRM and Safety Assurance (SA) processes. It sets forth the basic principles of management to guide the FAA in safety management and safety oversight activities. The order outlines a common approach to implementing and maturing an integrated Safety Management System (SMS).

The purpose of FAA Order 8000.369C is to:

1. Establish the Safety Management System policy and requirements for the FAA.
2. Explain the SMS components and requirements. The four main components of SMS are: Safety Policy, Safety Risk Management, Safety Assurance, and Safety Promotion. They provide a means of defining SMS within the FAA and a systematic approach to describing and achieving the desired safety performance.
3. Standardize terminology for safety management, where appropriate.
4. Define the roles and responsibilities of the FAA organizations, FAA SMS Executive Council, and FAA SMS Committee regarding safety management.
5. Require FAA organizations to establish guidance defining SMS implementation activities for their own organizations and for their industry segment.
6. Establish the commitment to continuous improvement of SMS.

Refer to Chapters 2-4 of FAA Order 8000.369C for detailed information on each of the above-mentioned objectives. This order is used as a foundation to support a safety risk management policy described in detail in FAA Orders 8040.4B and 8040.6.

FAA Order 8040.4B: Safety Risk Management Policy

FAA Order 8040.4B, Safety Risk Management Policy, supports FAA Order 8000.369C on SMS and establishes requirements for how to conduct SRM in the FAA. The objective of SRM, as described in FAA Order 8040.4B, is to provide information regarding hazards, safety risk, and safety risk controls/mitigations. SRM consists of conducting a system analysis; identifying hazards; and analyzing, assessing, and controlling safety risks associated with the identified hazards so that risk is managed to acceptable levels.

FAA Order 8040.4B supports the FAA SMS by providing the ability to consistently conduct SRM and provide safety risk information to decision-makers. SRM, as described in FAA Order 8040.4B outlines standardized principles that enhance the FAA and industry's ability to coordinate risk-based decision-making across organizations. Safety Policy and Safety Promotion are not addressed in this order but are discussed in detail in FAA Order 8000.369C, Safety Management System. However, Safety Assurance is described in this order due to its importance in triggering SRM through the identification of potential hazards or ineffective safety risk controls, as well as its role in monitoring safety risk controls.

The design of FAA Order 8040.4B is to prescribe common SRM language and communication standards. Furthermore, the policy recognizes that organizations have unique missions and requirements, so it allows flexibility in how SRM is conducted and the tools and techniques that are employed. However, the process requires consistency in the application of SRM principles.

Conducting Safety Risk Management

FAA Order 8040.4B, Chapter 2 describes the steps to conduct safety risk management. The SRM steps outlined in 8040.4B Chapter 2 are used as a foundation to support the UAS SRM Policy documented in FAA Order 8040.6. The following paragraphs in this section describe SRM according to FAA Order 8040.4B.

The objective of SRM is to provide critical information for decision-makers by identifying hazards, analyzing safety risk, assessing safety risk, and developing controls to reduce safety risk to an acceptable level. In general, SRM is conducted when making planned changes to the aerospace system and when potential and previously unidentified hazards and/or ineffective risk controls are discovered. SRM is used to evaluate the need for, as well as develop, safety risk controls in the aerospace system. Effective SRM requires early and ongoing involvement by appropriate stakeholders.

SRM and Safety Assurance

While the focus of this policy is on SRM, it is important to understand how the SRM and Safety Assurance functions work together within an SMS. Refer to Figure 64, which illustrates the SRM and Safety Assurance Processes. There are two basic triggers for applying SRM. The first is planned changes, and the second is the discovery of potential hazards or ineffective controls from the Safety Assurance process. The SRM process provides system analysis, the identification of hazards, and the analysis and assessment of safety risk. When appropriate, safety risk controls are developed and, once they are determined to be practicable in mitigating safety risk to an acceptable level, employed operationally.

Safety Assurance is used to ensure the safety risk control strategies that have been employed are achieving their intended safety risk mitigation objectives. If the controls are not adequately mitigating safety risk, they are modified, and/or additional safety risk controls are developed through SRM. This is one-way SRM, and Safety Assurance are integrated. Another way these functions work together is through the identification of potential new hazards or ineffective controls using Safety Assurance functions, which are then analyzed and assessed using SRM. While the Safety Assurance functions generally follow the flow shown in Figure 64, the functions may not be performed in the sequence as illustrated.

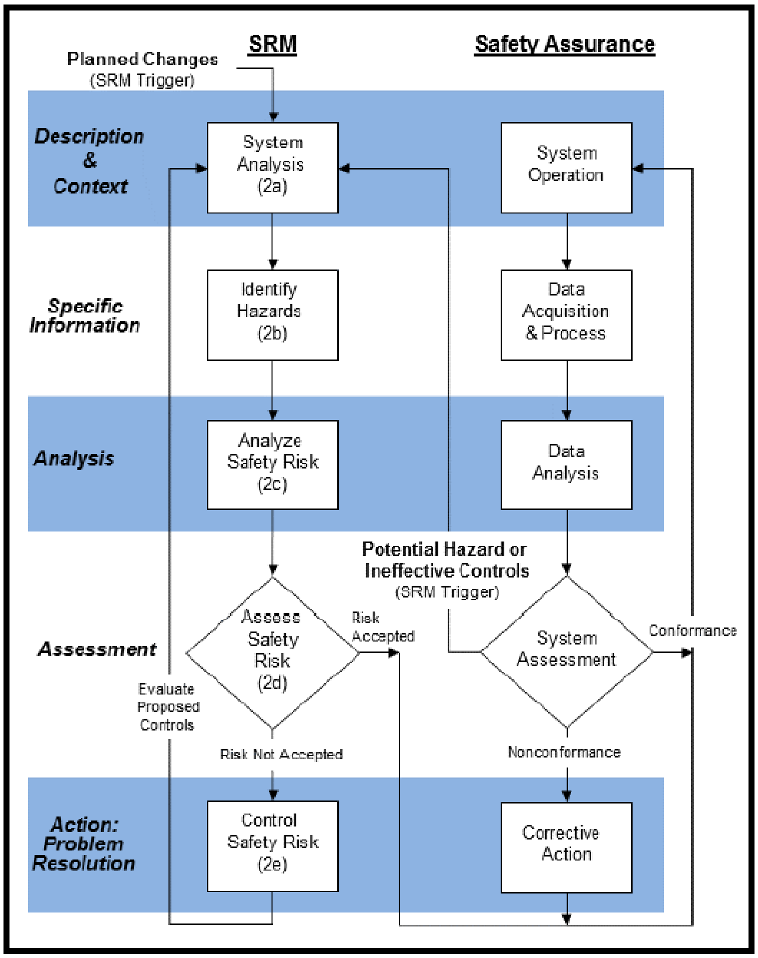


Figure 64: SRM and Safety Assurance Processes

SRM in the Operational Environment

SRM is an integral part of evaluating safety in the operational environment. Operational data provides information for evaluating failure modes, frequencies, and consequences. As such, it supports safety risk estimation by providing real-world information.

Sometimes, previously unidentified hazards are discovered, or known hazards are found to have more safety risk than was initially predicted. Analysis and assessment processes may uncover safety risks that would not have met risk acceptance criteria when the product or system was first put into service. This can present a difficult situation, especially if controls to mitigate the risk associated with the newly identified hazard require changes that cannot be immediately implemented. For this reason, SRM in the operational environment often necessitates allowing safety risk to exist in the system that is higher than would have been initially accepted while controls are being developed and implemented to lower the safety risk.

SRM Process

A thorough understanding of the components of safety risk must entail an examination of the factors that increase or decrease the likelihood of system events (errors or failures) that can result in unwanted outcomes (accidents or incidents). The analysis must also consider the type of outcomes possible to estimate potential severity. The steps of the SRM process are described below. While the steps of the process are described sequentially, they may be accomplished in parallel.

System Analysis

The system analysis step aims to understand and describe the system to the extent necessary to identify potential hazards. It is a comprehensive approach to examining an issue or change in terms of what is affected by the issue or change. A thorough system analysis is a foundation for conducting a sound safety analysis. The system analysis provides information that serves as the basis for identifying and understanding hazards, and their causes and associated safety risk. When describing and analyzing the system, it is important to:

1. Define and document the scope (i.e., system boundaries) and objectives related to the system.
2. Gather the relevant available data and information regarding the issue or change to be analyzed. This includes:
    a. Available incident and accident data
    b. Previous applicable analyses and assessments
    c. Related requirements, rules, and regulations
3. Develop a safety risk acceptance plan that includes evaluation against safety risk acceptance criteria, designation of authority to make the required safety risk decisions involved, and assignment of the relevant decision-makers.
4. Describe and model the system and operation in sufficient detail for the safety analysts to understand and identify the hazards that can exist in the system, as well as their sources and possible outcomes.
5. Look at the system in its larger context. A system is often a subcomponent of some larger system(s). For example, a change to the design of an aircraft may affect the maintenance and/or operation of that aircraft type.
6. Consider the following in the analysis, depending on the nature and size of the system:
    a. The function and purpose
    b. The system's operating environment
    c. An outline of the system's processes, procedures, and performance
    d. The personnel, equipment, and facilities necessary for the system's operation

Identify Hazards

When identifying hazards in this step, consider the system analysis. A hazard is a condition that could foreseeably cause or contribute to an aircraft accident. During the hazard identification step, hazards and each hazard's corresponding outcomes are specifically identified and documented.

The hazard identification step considers all reasonably possible sources of hazards. Remember that elements in the system analysis may be sources of hazards. The Bow-Tie method or Bow-Tie diagram is an example of a tool that can be used to assist in the identification of hazards. Depending on the nature and size of the system under consideration, hazard sources could include:

1. Ambient environment (physical conditions, weather)
2. Equipment (hardware and software)
3. External services (contract support, electric, telephone lines)
4. Human-machine interface
5. Human operators
6. Maintenance procedures
7. Operating environment (airspace, air route design.)
8. Operational procedures.
9. Organizational culture
10. Organizational issues
11. Policies/rules/regulations

Analyze Safety Risk

The objective of this step is to determine the initial safety risk associated with the effects of each identified hazard. The safety risk associated with a hazard is the combination of the severity and the likelihood of the potential outcome(s) of the hazard. Where appropriate, existing controls are taken into account prior to safety risk determination.

The definitions and risk matrices documented in 8040.4B Appendix C should be considered for use, as appropriate depending on the operator's Concept of Operation. Regardless of which definitions/criteria are used, this step includes the following common characteristics.

1. The safety risk of a hazard is the function of the severity and likelihood of the hazard's potential outcomes. The safety risk associated with the hazard must be determined and documented in terms of severity and likelihood.
    a. Severity is the potential consequence or impact of a hazard in terms of the degree of loss or harm. It is a prediction of how bad the outcome of a hazard can be. There may be many outcomes associated with a given hazard, and the severity should be determined for each outcome.
    b. Likelihood is the estimated probability or frequency, in quantitative or qualitative terms, of the outcome(s) associated with a hazard. It is an expression of how often an outcome of a hazard is predicted to occur in the future. When sufficient empirical data exists, statistical probabilities should be used.
2. Limit assumptions as much as practical. If any assumptions are made, the assumptions and their rationale must be documented.
3. Any known limitations of the safety risk analysis should be described. Limitations may also include the margin of error of the analysis if it can be calculated.

Assess Safety Risk

In this step, each hazard's associated safety risk is assessed against the risk acceptance criteria identified in the safety risk acceptance plan and plotted on a risk matrix based on the severity and likelihood of the outcome. The objective of this step is to determine the safety risk level acceptability. A risk matrix provides a visual depiction of the safety risk and enables prioritization in the control of the hazards. Appendix C of 8040.4.B provides risk matrices to be used in this step of the process.

Control Safety Risk

Additional safety risk controls to reduce the safety risk to a level acceptable to the decision maker may need to be designed or developed and evaluated by the team conducting the assessment. The analysis is conducted to predict the residual safety risk as if the proposed controls had been put in place. The prediction of the residual safety risk is assessed to determine if the safety risk acceptance criteria are met. Further analysis is performed to ensure that no new hazards have been introduced or that existing safety risk controls have not been compromised based on the proposed safety risk controls. If the residual risk is not acceptable, the proposed safety risk controls are redesigned, or new safety risk controls are developed as necessary, and the analysis is re-conducted. This is done until the proposed safety risk controls enable the safety risk acceptance criteria to be met.

Safety Risk Acceptance

Once the assessment is complete, the findings and alternatives for safety risk mitigations or controls are documented. If the safety risk associated with the identified hazard(s) are not accepted, the assessment is sent back for additional analysis or identification of additional proposed alternatives for safety risk mitigations or controls. When a team accepts safety risk, it does not mean that the safety risk is eliminated. Some safety risk will remain, so the team has determined that the prediction of the residual safety risk is acceptable. By accepting risk, the management official is deciding to authorize the operation without additional mitigation at the present time.

Hazards may also be identified through the Safety Assurance functions used to monitor the system. In these situations, it is necessary to determine whether the continued operation is acceptable (and for how long) while new safety risk controls are introduced.

A methodology for monitoring and tracking the residual risk and assessing the safety risk against defined safety risk acceptance criteria should be defined for hazards with associated predicted safety risk that is medium or high. This methodology is documented in a monitoring plan, which is included in the documentation of the safety risk assessment. The monitoring plan describes who is responsible for tracking and monitoring and how it will be done. Specifically, the monitoring plan describes the tracking and monitoring activities, including their frequency (how often they will be performed), their duration (how long the monitoring activities will be conducted), and the data necessary to evaluate the effectiveness of safety risk controls. In addition, the monitoring plan includes a description of the safety performance targets that will be used to assess the safety performance of existing controls and any newly implemented safety risk controls.

Safety Performance Monitoring and Hazard Tracking

Safety performance monitoring and hazard tracking include documenting safety risk controls, confirming the implementation and effectiveness of safety risk controls, and updating the residual risk levels, as appropriate.

Safety performance monitoring measures the effectiveness of existing and new safety risk controls, as well as provides information regarding the accuracy of the prediction of residual risk resulting from the risk analysis and assessment. Safety risk controls are determined to be effective when safety performance targets identified in monitoring plans are met. Safety performance monitoring is primarily accomplished through the Safety Assurance functions. Hazard identification and tracking are foundational requirements for effective SRM. Hazard tracking is the process of tracking and managing information regarding a hazard through the life cycle of identification and iterations of assessment and control.

Documenting Assessments and Decisions

Safety risk acceptance decisions made because of the safety risk analysis must be recorded with the safety analysis documentation. Standardized documentation of safety risk acceptance facilitates consistent decision making and assists future decisions based on related analyses. The documentation should bring together the relevant information to enable the management officials to understand the issue or system, its associated safety risk, and safety risk controls implemented (or proposed) to reduce the safety risk such that the residual safety risk is acceptable. The document should contain sufficient detail to enable the reader to comprehend what steps have been taken to identify safety issues and the corrective steps taken or proposed. The documentation should include:

1. Identification of individual or team who conducted the analysis to include names, contact information, organizations, and roles in performing the analysis
2. Description of the Issue or Change and the Current System
3. Identification of Hazards and Existing Controls
4. Analysis of the Associated Safety Risk
5. Analysis of Proposed Safety Risk Controls
6. Comments or Other Opinions
7. Reviews (if applicable). Description of any peer reviews conducted.
8. Safety Risk Acceptance and Approvals (if applicable)

FAA Order 8040.6: Unmanned Aircraft Systems Safety Risk Management Policy

FAA Order 8040.6, UAS SRM Policy, supplements FAA Order 8040.4B by establishing a methodology for conducting SRM for UAS requests to operate. This order establishes the methods by which the FAA manages requests to operate UAS and how the Office of Aviation Safety (AVS) performs SRM in accordance with FAA Order 8040.4 for UAS operations under waivers, exemptions, or authorizations. FAA Order 8040.6 describes the scope, roles and responsibilities, triage, governance, and SRM triggers, and includes a template for documenting the steps of SRM. The order establishes the safety review process for UAS requests and provides a generalized list of common hazards and possible mitigations that should be considered with each applicable assessment. The use of methods within FAA Order 8040.6 enables individuals and organizations to address safety risks associated with UAS operations in the NAS in a more consistent, coordinated, and timely manner. FAA Order 8040.6 supplements but does not supersede requirements contained within FAA Order 8040.4.

In general, SRM is conducted when making planned changes to the NAS. This order focuses on safety risks to the NAS and nonparticipants on the ground. Regulations are risk controls and requests for appropriate action from applicable regulations are considered planned changes to the NAS. Figure 65 shows the five basic triggers for UAS-related SRM. FAA Order 8040.6 and thus, the following subsections outline the safety review procedures for the request for appropriate action from an applicable regulation(s) for a UAS operation.

Safety Issue			Planned Change	
Potential Hazard (Identified by UAS related event/occurrence)	**Ineffective Control** (identified by UAS related event/occurrence)	**Non-Conformance** (e.g. noncompliance with UAS related regulation)	**Request** for appropriate action from an applicable regulation(s) for a UAS operation	**New/change** to UAS related regulation (e.g. part 107)

Figure 65: SRM Triggers

Governance and Triage

FAA applies the following governance model (Figure 66) and triage steps to coordinate across FAA organizations, consistent application of SRM, and uniformity of FAA responses to applicants for UAS requests. In the event proposed operations introduce new unidentified hazards, SRM must be applied. SRM will be conducted in accordance with the applicable SRM order(s) such as FAA Order 8040.6, FAA Order 8040.4, and/or the ATO SMS Manual. The governance model in Figure 66 and the triage steps help determine which process applies. Chapter 4 FAA Order 8040.6 identifies how AVS meets requirements for situations in which FAA Order 8040.4 applies.

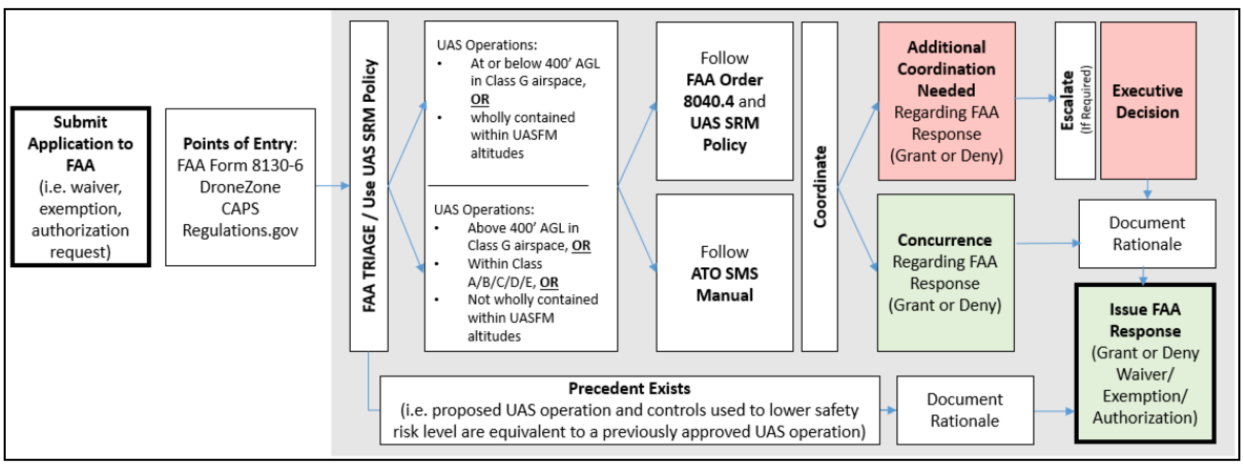


Figure 66: UAS Request Governance

Triage steps include:

1. Has the safety risk associated with the operation been previously addressed and verified?
   a. Are there differences or changes from the precedent setting UAS approval?
      i. If no, SRM may not be necessary.
      ii. If yes, SRM on the differences and changes is required.
2. Is there potential for the proposed UAS operation to introduce additional risk into the NAS?
3. Is the safety risk associated with the previously approved operation still valid (if applicable)?
4. Which SRM process applies?

In the fourth triage step, the applicant will determine whether FAA Order 8040.4, 8040.6, or the ATO SMS Manual applies by comparing the characteristics of the proposed UAS operation to the conditions of the ATO/AVS agreement, which is described below.

1. AVS is responsible for using FAA Order 8040.4, this order, and any service/office approved detailed risk analysis process to conduct SRM for any request for UAS operation:
   a. That occurs at or below UAS Facility Map (UASFM) altitudes, wholly within UASFM altitudes, or at or below 400 feet above ground level (AGL) in Class G airspace; and,
   b. Do not create new requirement(s) for air traffic service provisions through the operation or through mitigations for the operation. When air traffic service provision requirements are required, AVS will coordinate with the ATO on all such operations upon receipt of the application.
2. The ATO is responsible for determining the altitude values that populate the UASFM and applying SRM in accordance with the ATO SMS Manual for any request for UAS operation that occurs above 400 feet AGL in Class G airspace or within Class A/B/C/D/E airspace not wholly contained within UASFM altitudes (e.g., transitioning UAS), or when the provision of air traffic services during UAS operations are altered or required.

SRM for UAS Requests

For FAA to approve a UAS related request for appropriate action, its decision-makers must be informed of the severity and likelihood of the hazards, with all mitigations in place, so that they may determine whether the residual risk level is acceptable. The SRM process and resulting documentation provides decision-makers with a clear and accurate picture of the safety risk, informing their decision to grant, approve, or deny a request. FAA can either perform the SRM or verify the applicant has completed the safety analysis. If the SRM is verified, FAA must concur with the SRM analysis.

Once the SRM has been completed or verified, the analysis is documented and maintained in accordance with FAA Order 8040.4. The Sample Safety Risk Management Form for UAS Requests in Appendix D of 8040.6 can be used to document the analysis. The UAS industry and data sources are still evolving, therefore, safety analysts or teams should use the best available data and subject matter expertise to make their determinations and document the rationale. FAA Order 8040.6 Chapter 4 expands upon but does not supersede the information contained within FAA Order 8040.4.

UAS SRM Process

A thorough understanding of the safety risk components requires an examination of the factors that increase or decrease the likelihood of system events (e.g., errors or failures) that can result in unwanted outcomes (e.g., accidents or incidents). The UAS SRM Process in FAA Order 8040.6 includes:

1. Identify Safety Analysts or Team Members
2. System Analysis
3. Identify Hazards, Causes, and Outcomes
4. Analyze Safety Risk
5. Validity of Mitigations
6. Assess Safety Risk
7. Additional Safety Risk Controls and Residual Safety Risk
8. Safety Performance Monitoring and Hazard Tracking
9. Documenting Assessments and Decisions
10. Residual Safety Risk Acceptance
11. Safety Risk Documentation
12. Safety Performance Monitoring

Identify Safety Analyst or Team Members

Depending on the request under consideration, the safety risk analysis may be conducted by an individual or a team. It is important that the person or team conducting the analysis have the appropriate subject matter expertise and that all necessary AVS and FAA stakeholder organizations are involved. If a team is necessary, it must include representatives from the various organizations who have regulatory responsibility or shared responsibility for the regulations presented in the waiver or exemption, and members must have experience in assessing risk related to the type of UAS request/operation assessed.

System Analysis

The applicant provides the technical and operational information needed for the safety analyst or team members to verify or perform SRM. The following information and documentation should be provided by the UAS applicant:

1. Concept of Operations (ConOps)
2. Operational Risk Assessment (ORA)
3. Safety Case that includes a description of each hazard and mitigation
4. Operational procedures, manuals, and test documentation

The applicant's submission should contain:

1. Hazards identified and potential effects of the hazards before mitigations
2. Mitigation rationale statement of how each mitigation is expected to reduce the severity, and the likelihood of the hazard's effects
3. Test results to validate the mitigations, if available
4. Predicted residual risk after mitigations
5. Applicants determined level of risk and rationale

The safety analyst or team reviews the ConOps, ORA, and/or safety case, or other risk assessment tool to ensure completeness and accuracy. Additional hazards not originally outlined in the applicant's documentation may be identified by SRM analysts or the team. The safety analyst or the team documents the system assessment with information pertaining to each of the following elements of the operation:

1. Aircraft
2. Airman or Operator
3. Airspace
4. Operating Environment

When an application does not provide adequate information, FAA may send a Request for Information to the applicant requesting the information necessary to complete the safety risk assessment.

Identify Hazards, Causes, and Outcomes

During this step, the SRM analyst or team must identify hazards, causes, and outcomes. A hazard is a condition that could foreseeably cause or contribute to an aircraft accident. The safety analyst or team identifies the hazards using information from the applicant, the system assessment, and the common hazards in 8040.6 Appendix A. Hazards controlled by the rule being relieved must be assessed. For exemptions, 14 CFR §11.81 requires that an alternative of compliance not adversely affect safety or a level of safety at least equal to that provided by the rule being relieved. Waivers authorizing deviations from regulations can be issued if the UAS operation can be safety conducted under the terms of that certificate of waiver. The safety analyst and team must also identify and document the causes of the hazards. The list of hazards in 8040.6 Appendix A is a starting point. All hazards applicable to the operation must be identified and recorded. UAS hazards with the worst credible outcomes listed below must be considered:

1. Collision between a UAS and a crewed aircraft in the air
2. Collision between a UAS or its detached cargo and a person on the ground, or moving vehicle
3. Collision between a UAS or its detached cargo and critical infrastructure on the ground

The safety analyst or team must also consider less severe outcomes of those listed above. Often, less severe outcomes have higher likelihoods, and a higher risk level, than that of catastrophic outcomes with lower likelihoods. For example, although a Near Mid-Air Collision (NMAC) between a crewed aircraft and a UAS would probably not be catastrophic, it is much more likely to occur thus, raising the residual risk level. These less severe outcomes must be assessed and documented within the safety risk analysis. Possible UAS hazards include, but are not limited to:

1. Unable to detect and avoid
2. Human error
3. Adverse operating conditions
4. Technical issue with UAS
5. Deterioration of external systems supporting the UAS operation

Analyze Safety Risk

During this step, the safety analyst or team must determine the initial risk levels expected with the proposed UAS operation. The initial risk is based upon the proposed operation including applicant controls and existing controls. Existing controls are always considered prior to determining credible outcomes. For both the initial and residual risk, the safety analyst or teams rely upon information provided by the UAS applicants (e.g., the system assessment) and their own SMEs to determine the severity and likelihood of the hazard's outcomes. The safety analyst or team's rationale for how they arrived at their determination is just as important as the severity and/or likelihood determination itself. The severity and likelihood definitions and risk matrix are used to better define the safety impact of the proposed UAS operation. Severity and likelihood definitions are as follows:

1. Severity – The potential consequence or impact of a hazard in terms of degree of loss or harm. Refer to Table 28 and 8040.6 Appendix C Table C1.
   a. What are the credible outcomes? (i.e., catastrophic, hazardous, major, minor, minimal)
   b. Why? (e.g., data, line of thought, expertise, rationale for how the safety analyst or team arrived at their determination)
   c. How do existing controls and additional mitigations change the aircraft, airman/operator, or airspace/operating environment, such that the severity is reduced?
2. Likelihood – The estimated probability or frequency, in quantitative or qualitative terms, of the outcome(s) associated with a hazard. Refer to 29 and 8040.6 Appendix C Table C2: Likelihood Definitions – General Aviation Operations/Small Aircraft and Rotorcraft. When sufficient empirical data exists, statistical probabilities should be used (e.g., airspace and ground density data).
   a. What is the likelihood of the credible outcomes? (e.g., frequent, probable, remote,

extremely remote, extremely improbable)

b. Why? (e.g., data, line of thought, expertise, rationale for how the safety analyst or team arrived at their determination)

c. How do mitigations change the aircraft, airman, airspace/operating environment, such that the likelihood is reduced?

Table 28: Severity Definitions

Minimal 5	Minor 4	Major 3	Hazardous 2	Catastrophic 1
Negligible safety effect	– Physical discomfort to persons – Slight damage to aircraft/vehicle	– Physical distress or injuries to persons – Substantial damage to aircraft/vehicle	Multiple serious injuries; fatal injury to a relatively small number of persons (one or two); or a hull loss without fatalities	Multiple fatalities (or fatality to all on board) usually with the loss of aircraft/ vehicle

* Excludes vehicles, crew, and participants of commercial space flight.

Table 29: Likelihood Definitions - General Aviation Operations/Small Aircraft and Rotorcraft

	Qualitative	Quantitative – Time/Calendar-based Occurrences Domain-wide/System-wide
Frequent A	Expected to occur routinely	Expected to occur more than 100 times per year (or more than approximately 10 times a month)
Probable B	Expected to occur often	Expected to occur between 10 and 100 times per year (or approximately 1-10 times a month)
Remote C	Expected to occur infrequently	Expected to occur one time every 1 month to 1 year
Extremely Remote D	Expected to occur rarely	Expected to occur one time every 1 to 10 years
Extremely Improbable E	Unlikely to occur, but not impossible	Expected to occur less than one time every 10 years

Validity of Mitigations

The safety analyst or team must consider the validity of mitigations as part of the layered approach to mitigating risk. What evidence is there that proves the mitigations are effective (e.g., test data, third party verification)? How are the mitigations dependent on each other? How much credit should be given for the mitigations? Is there a single point failure? This information must be included in the SRM documentation.

Assess Safety Risk

A risk matrix provides a visual depiction of the safety risk and enables prioritization in the control of the hazards. Figure 67 from 8040.6 Appendix C is the risk matrix used during this step. The safety analyst or team uses the determined severity and likelihood to plot the initial risk level on the risk matrix. The safety analyst or team documents initial risk level, the rationale of how the severity and likelihood was determined and compares the level against the risk acceptance criteria.

Likelihood \ Severity	Minimal 5	Minor 4	Major 3	Hazardous 2	Catastrophic 1
Frequent A	[Green]	[Yellow]	[Red]	[Red]	[Red]
Probable B	[Green]	[Yellow]	[Yellow]	[Red]	[Red]
Remote C	[Green]	[Green]	[Yellow]	[Yellow]	[Red]
Extremely Remote D	[Green]	[Green]	[Green]	[Yellow]	[Red] * / [Yellow]
Extremely Improbable E	[Green]	[Green]	[Green]	[Green]	[Yellow]

High Risk [Red]
Medium Risk [Yellow]
Low Risk [Green]

* High Risk with Single Point and/or Common Cause Failures

Figure 67: Risk Matrix General Aviation Operations/Small Aircraft and Rotorcraft

Additional Safety Risk Controls and Residual Safety Risk

During this step, the safety analyst or team assesses the need for additional controls (i.e., conditions and limitations in exemptions and special provisions in waivers) to reduce the risk of the operation to an acceptable level. Conditions and limitations and special provisions are intended to document specific safety risk controls presented by the FAA. The safety analyst or team must record a description of the additional safety risk controls that were considered prior to analyzing and assessing the residual safety risk. The safety analyst or team documents the new severities, likelihoods, and residual risk level on the risk matrix taking into account the additional safety risk controls.

Safety Performance Monitoring and Hazard Tracking

When the safety risk assessment is complete, tracking and monitoring is required in accordance with FAA Order 8040.4 for medium and high residual risk levels. The intent of tracking and monitoring is to ensure the risk controls are valid and verify the predicted residual risk of the approved operation. The safety analyst or team provides a description of the data to be collected, at specific intervals for a specific duration, defines safety performance targets for each hazard, and the Point of Contact responsible. The safety performance targets are used to verify the residual risk levels.

Documenting Assessments and Decisions

The safety analyst or team documents the safety risk assessment utilizing the form in 8040.6 Appendix D, related documents, and any other relevant information and provides it to the risk acceptor. The safety risk assessment documentation is important for the risk acceptor to make a decision.

Residual Safety Risk Acceptance

Accepting risk is a management decision. By accepting risk, the management official is deciding to authorize the operation with the residual safety risk levels presented. Previously accepted risks may be referenced during future safety risk assessments. The decision to accept safety risk will result from the level of risk that the operation presents. The risk acceptor must have confidence that the mitigation strategies will reduce the safety risk to an acceptable level. The risk acceptor accepts the risk by signing the safety risk management document.

Safety Risk Documentation

Once SRM is completed, the information must be documented in accordance with FAA Order 8040.4.

Safety Performance Monitoring

Per the monitoring plan, safety performance monitoring is conducted to verify the risk assessment and the safety controls.

Air Traffic Organization Safety Management System Manual

The Safety Management System is a formalized and proactive approach to system safety. It directly supports the mission of the FAA, which is “to provide the safest, most efficient aerospace system in the world.” The ATO SMS is an integrated collection of principles, policies, processes, procedures, and programs used to identify, analyze, assess, manage, and monitor safety risk in the provision of air traffic management and communication, navigation, and surveillance services.

The ATO SMS Manual (2019) informs ATO employees and contractors about the goal of the ATO SMS, describes the interrelationship among the four components of the SMS and instructs readers on the process of identifying safety hazards and mitigating risk in the National Airspace System. The ATO SMS Manual and its complements, such as the Safety Risk Management Guidance for System Acquisitions, ATO Safety Guidance documents, and other FAA safety documents, are used to carry out the safety mission of the FAA and the requirements of the SMS.

The Air Traffic Organization Safety Management System is supported by numerous levels of policy and requirements, as depicted in Figure 68. Some relevant programs that pre-date the ATO SMS are detailed in other FAA publications and processes. This SMS Manual only references those documents when necessary.

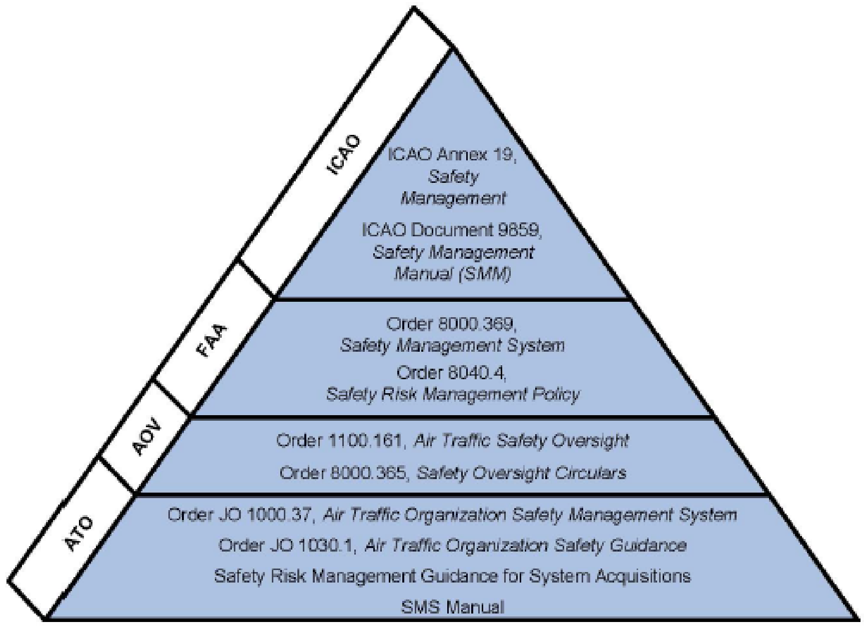


Figure 68: SMS Policy and Requirements Hierarchy

FAA Order 8040.6, Unmanned Aircraft Systems Safety Risk Management Policy, dictates that sUAS operations above 400 feet AGL are risk assessed using the Air Traffic Organization's Safety Management Manual processes and definitions. The ATO SMS Manual's five-step risk assessment process is shown in Figure 69.

SRM Process

Chapter 3 of the ATO SMS Manual provides a linear Safety Risk Management process to follow, guidelines to identify safety hazards and mitigate their risks, and requirements for the development of consistent and thorough safety analyses. Chapter 3.2 describes when a safety analysis may or may not be required. The proponent will begin by assessing the NAS change and determining which of the following two categories it falls under. Refer to the ATO SMS Manual Chapter 3.2 for additional guidance on category determination. Categories include:

1. Not requiring any safety assessment
2. Requiring a complete safety analysis by a SRM panel and a SRM document

Using the steps in Chapter 3 to perform a safety analysis will not always result in an exhaustive study of air traffic procedures, operations, or National Airspace System equipment (i.e., hardware and software). The appropriate level of detail in a safety analysis depends on the complexity, size, and potential effect of the NAS change or existing safety issue.

The performance of a safety analysis is broken down into a five-phase process called the DIAAT, illustrated in Figure 69. Consistent with International Civil Aviation Organization (ICAO) guidelines and best practices, these five SRM phases apply to all SRM activity, whether the activity pertains to Air Traffic Organization operations, maintenance, procedures, or equipment development. Systematically completing the steps outlined in the five phases supports a thorough and consistent safety analysis.

DIAAT phases are summarized in the following subsections. Refer to the ATO SMS Manual Section 3.3 through Section 3.7 for a detailed description of the DIAAT phases.

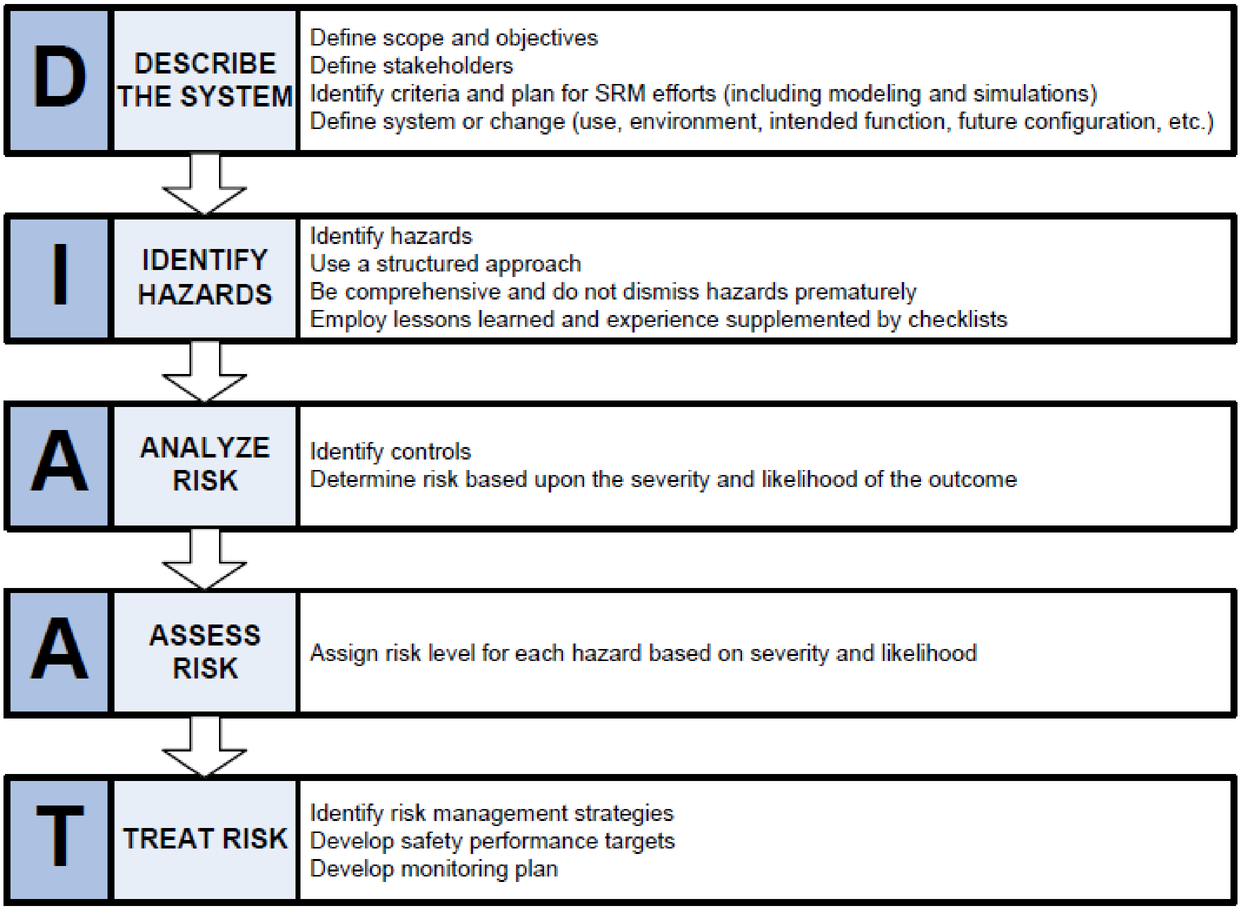


Figure 69: Five-Step DIAAT Process

Describe the System

As part of any initial decision-making and follow-on analysis, developing a detailed description of the NAS change and its affected elements is important. When deciding on the correct scope and level of detail of the safety analysis, determine the information required about the NAS change and/or current system.

System descriptions need to exhibit two essential characteristics: correctness and completeness. Correctness means that the description accurately reflects the system without ambiguity or error. Completeness means that nothing has been omitted and everything stated is essential and appropriate to the level of detail.

The system description provides information that serves as the basis for identifying all hazards and associated safety risks. The system/operation must be described and modeled in sufficient detail to allow the safety analysis to proceed to the hazard identification stage.

The 5M Model (Figure 70) can be used to capture the information needed to describe the system and aid in hazard identification. The 5M Model uses a Venn diagram to depict the interrelationships among its five elements. To adequately bound and describe a system, it is important to understand the relationships between the elements of the 5M Model.

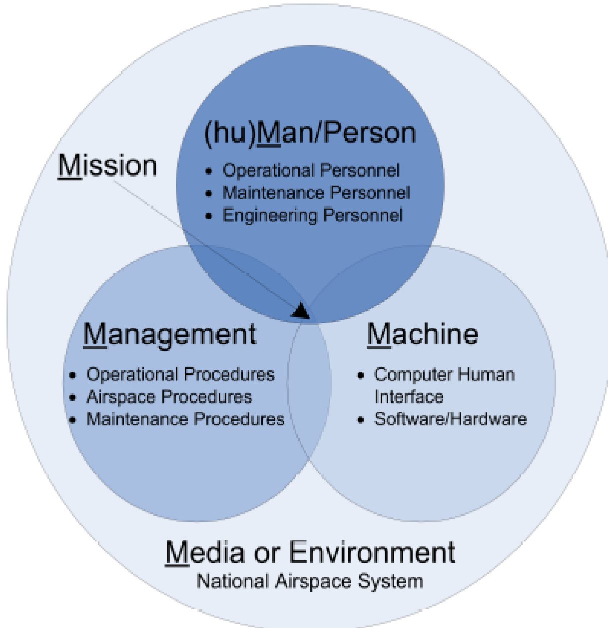


Figure 70: 5M Model

The 5M Model illustrates five integrated elements that are present in any system:

1. **Mission:** The clearly defined and detailed purpose of the NAS change proposal or system/operation being assessed
2. **(hu)Man/Person:** The human operators, maintainers, and affected stakeholders
3. **Machine:** The equipment used in the system, including hardware, firmware, software, human-to-system interfaces, system-to-system interfaces, and avionics
4. **Management:** The procedures and policies that govern the system's behavior
5. **Media:** The environment in which the system is operated and maintained

The 5M Model and similar techniques are used to deconstruct the proposed NAS change in order to distinguish elements that are part of or affected by the proposed NAS change. These elements later help to identify sources, causes, hazards, and current and proposed risk mitigation strategies.

Identify Hazards

During the hazard identification phase, identify and document safety issues, their possible causes, and their corresponding effects. A hazard is defined as any real or potential condition that can cause injury, illness, or death to people; damage to or loss of a system, equipment, or property; or damage to the environment. A hazard is a prerequisite to an accident or incident.

The proponent is responsible for identifying and mitigating hazards with unacceptable risk (i.e., high-risk). Likewise, the proponent should determine if hazards with acceptable risk (i.e., medium and low-risk) can be further mitigated. The hazard identification stage is integral to all preliminary safety analyses and follow-on, in-depth analyses in determining the appropriate means to address any safety risks associated with a National Airspace System change.

The hazard identification stage considers all possible causes of hazards. Depending on the nature and size of the system under consideration, the causes may include:

1. NAS equipment failure or malfunction
2. Operating environment to including physical conditions, airspace, and air route design
3. Human operator failure or error
4. Human-machine interface problems
5. Operational procedures limitations or design
6. Maintenance procedures limitations or design
7. External services

The process of describing the system using a tool like the 5M Model is designed to facilitate brainstorming for sources of hazards. The next step in the hazard identification process is to develop a preliminary hazard list (PHL). The PHL may be a combination of hazards, causes, effects, and system states. The items listed in the PHL all have the potential to be placed into the hazard analysis worksheet (HAW). It is at the panel's discretion to decide which items belong in the HAW during the Identify Hazards and Analyze Risk phases of the SRM process.

When hazards are identified, the HAW, a worksheet used to document a safety analysis, is required as part of the ATO SRM process. When developing the HAW, it is crucial to consider the hazards inherent to all aspects of an operation without regard to risk.

Using the HAW helps panels overcome the tendency to focus on safety risk in one aspect of an operation and overlook more serious issues elsewhere in the operation. Its broad scope guides the identification of issues requiring analysis with more detailed hazard identification tools.

Analyze Risk

An accident or incident rarely results from a single failure or event. Consequently, risk analysis is seldom a binary process. Risk and hazard analyses can identify failures from primary, secondary, or even tertiary events.

During the risk analysis phase:

1. Evaluate each hazard identified during the "Identify Hazards" phase and the system state from the "Describe the System" and "Identify Hazards" phases to determine the controls.
2. Analyze how the operation would function should the hazard occur.
3. Determine the hazard's associated severity and likelihood and provide supporting rationale.

A control is anything that currently reduces a hazard's causes or effects. Understanding controls affect the ability to determine credible effects. Policies, procedures, hardware, software, or other tools can only be considered controls if they are part of the operating National Airspace System and have demonstrated effectiveness.

Effect refers to the real or credible harmful outcome that has occurred or can be expected if the hazard occurs in the defined system state. A single hazard can have multiple effects. Credible means that it is reasonable to expect that the assumed combination of conditions that define the system state will occur within the operational lifetime. Credible effects should be determined with respect to controls. Document all identified credible effects.

The credibility of an effect is a nuanced and key consideration in the analysis. A thorough understanding of this concept can save time in determining the risk level of a specific hazard. Often, there needs to be clarity when distinguishing the possible effects of a hazard from the credible effects; possible is not necessarily the same as credible. When determining the credibility of the effect, it is important to recall and understand the Defenses in Depth Model, review history, rely on quantitative data, and visualize the occurrence of the accident or incident.

Risk is the composite of predicted severity and likelihood of the potential effect of a hazard. While the worst credible effect may present the highest severity, the likelihood of this effect is often very low. A less severe effect may occur more frequently and therefore present a higher overall risk than the more severe effect. The ways to reduce the risk for the two effects may be different, and both must be identified. Consider all credible effects and their associated risks in order to identify the highest risk for the safety hazard.

Attempt to obtain and document objective evidence (e.g., historical evidence of similar NAS changes, testing data, modeling, or simulation results) to support the assessed level of risk. If quantitative data are not available, document the research methods, including the data sources reviewed, in addition to qualitative assessments. Because different system states can affect both severity and likelihood in unique ways, determine whether the hazard will exist in several system states and assess the risk accordingly.

Severity

Severity is the consequence or impact of a hazard’s effect or outcome in terms of degree of loss or harm. It is independent of likelihood and must be determined before likelihood is calculated. Assess all effects, consider controls when determining severity, and use the measure yielding the most conservative estimate (i.e., the higher severity). Table 30 is the UAS severity table used in the ATO SMS process to assess the severity of a hazard when performing SRM. Provide a rationale for the chosen severity level in the HAW.

Table 30: Severity Table

	UAS Hazard Severity Classification ***Note: Severities related to ground-based effects apply to movement areas only***				
	Minimal 5	Minor 4	Major 3	Hazardous 2	Catastrophic 1
	Conditions Resulting in any one of the following:				
Uncrewed Aircraft Systems	Discomfort to those on the ground Loss of separation leading to a measure of compliance greater than or equal to 66 percent	Low Risk Analysis Event severity, two or fewer indicators fail Non-serious injury to three or fewer people on the ground	Medium Risk Analysis Event severity, three indicators fail Non-serious injury to more than three people on the ground A reduced ability of the crew to cope with adverse operating conditions to the extent that there would be a significant reduction in safety margins Crewed aircraft making an evasive maneuver, but proximity from Uncrewed Aircraft remains greater than 500 feet	High Risk Analysis Event severity, four indicators fail Incapacitation to uncrewed aircraft system crew Proximity of less than 500 feet to crewed aircraft Serious injury to persons other than Uncrewed Aircraft System crew	A collision with a crewed aircraft Fatality or fatal injury to persons other than the Uncrewed Aircraft System crew

Likelihood

Likelihood is defined as the estimated probability of a hazard's effect or outcome in quantitative or qualitative terms. More specifically, the concept of likelihood can be separated into two components: likelihood/probability and frequency. Frequency is how often a given effect occurs; it is a known value determined by monitoring a hazard and its effects to identify initial, current, or residual risk. Conversely, likelihood is an expression of the probability of a hazard's effects occurring (i.e., a rate of how often a given effect is expected to occur), which is used to estimate initial and predicted residual risk. Provide a rationale for likelihood estimations in the HAW.

Analyze the likelihood of all credible effects to:

1. Determine the highest potential risk.
2. Identify all system states that expose the risk.

Remember that less severe effects may occur more frequently, producing a higher risk, which is why it is important to determine the likelihood of all credible effects. Consider controls when determining likelihood because they may minimize the likelihood of an effect.

Calculating Likelihood with Quantitative Data

To estimate the likelihood, first determine the expected number of times the credible effect will occur (i.e., the number of times that the hazard will occur in the system state that will expose the risk). Then, divide that value by the known number of affected operations, flight hours, or operational hours in which the effect is exposed (i.e., the number of operations, flight hours, or operational hours affected by the proposed NAS change or the existing hazard). Finally, compare the result of this calculation (Figure 71) to the ranges presented in Table 31 to determine the likelihood rating.

$$\text{Likelihood} = \frac{\text{Expected number of occurrences of the effect}}{\text{Known number of affected operations}}$$

Figure 71: Likelihood Equation

Table 31: Quantitative Likelihood of Effect Standards

	Operations: Expected Occurrence Rate (per operation / flight hour / operational hour[3])
	Quantitative (ATC / Flight Procedures / Systems Engineering)
Frequent A	(Probability) ≥ 1 per 1000
Probable B	1 per 1000 > (Probability) ≥ 1 per 100,000
Remote C	1 per 100,000 > (Probability) ≥ 1 per 10,000,000
Extremely Remote D	1 per 10,000,000 > (Probability) ≥ 1 per 1,000,000,000
Extremely Improbable E	1 per 1,000,000,000 > (Probability) ≥ 1 per 10^{14}

Determining Likelihood with No Data

For some NAS changes, the necessary data are not available. There may not be a similar enough change/procedure/situation in the NAS to provide similar data from which to estimate a rate of occurrence. In situations where modeling is not feasible, pure subject matter expertise is the only input available, providing a qualitative approach to determining likelihood. This approach is only recommended when all avenues of data collection have been exhausted or when the change proponent is attempting to implement a new operation for which no data exist. 32 presents calendar-based approximations of NAS-wide effect occurrences.

Table 32: Qualitative Likelihood of Effect Standards

	Operations: Expected Occurrence Rate (Calendar-based)
	(Domain-wide: NAS-wide, Terminal, or En Route)
Frequent A	Equal to or more than once per week
Probable B	Less than once per week and equal to or more than once per three months
Remote C	Less than once per three months and equal to or more than once per three years
Extremely Remote D	Less than once per three years and equal to or more than once per 30 years
Extremely Improbable E	Less than once per 30 years

Assess Risk

In this phase, identify each hazard's associated initial risk and plot each hazard on a risk matrix. When assessing and mitigating safety risk, first determine the risk level prior to the implementation of any safety requirements. Initial risk describes the composite of the severity and likelihood of a hazard, considering only controls and documented assumptions for a given system state. It describes the risk before any of the safety requirements are implemented.

Record all hazards and their associated risk levels. Hazards are assigned one of three risk levels:

1. High-Risk: This is an unacceptable risk, and the NAS change cannot be implemented unless the hazard's associated risk is mitigated to medium or low. The predicted residual risk must be monitored and tracked in relation to the safety performance targets. The predicted residual risk must be confirmed with objective evidence suggesting an impact to the hazard's causes or effects.
2. Medium-Risk: Although the initial medium risk is acceptable, it is recommended and desirable that safety requirements be developed to reduce the severity and/or likelihood. The risk must be monitored and tracked in relation to the safety performance targets. The predicted residual risk must be confirmed with objective evidence suggesting an impact to the hazard's causes or effects.
3. Low-Risk: This is an acceptable risk without restriction or limitation. It is not mandatory to develop safety requirements for low-risk hazards; however, develop a monitoring plan with at least one safety performance target.

The risk matrix shown in Figure 72 is used to determine risk levels. The rows in the matrix reflect the likelihood categories, and the columns reflect the severity categories. Plotting the risk for each hazard on the matrix helps to prioritize treatment. Adhere to the following guidelines when plotting risk for each hazard:

1. Plot a hazard's risk according to its associated severity and likelihood.
2. Plot the hazard in the box where the severity and likelihood of the effect associated with the hazard intersect.
3. If the plotted box is red, the risk associated with the hazard is high; if the box is yellow, the risk associated with the hazard is medium; and if the box is green, the risk associated with the

hazard is low. As shown in the split cell in the bottom right corner of the matrix, hazards with catastrophic severity and extremely improbable likelihood can be medium or high risk, depending on the cause, as explained in the ATO SMS Manual Section 3.6.2.1.

Severity / Likelihood	Minimal 5	Minor 4	Major 3	Hazardous 2	Catastrophic 1
Frequent A	Low	Medium	High	High	High
Probable B	Low	Medium	High	High	High
Remote C	Low	Medium	Medium	High	High
Extremely Remote D	Low	Low	Medium	Medium	High
Extremely Improbable E	Low	Low	Low	Medium	High* / Medium

*Risk is high when there is a single point or common cause failure.

Figure 72: Risk Matrix

The current edition of FAA Order 8040.4, Safety Risk Management Policy, prescribes the use of a risk matrix that is different from the ATO SMS Manual risk matrix depicted in Figure 72. The order also applies with regard to the acceptability of risk levels at the agency level when crossing Lines of Business.

As a reminder, FAA Order 8040.6, Unmanned Aircraft Systems Safety Risk Management Policy, dictates that sUAS operations above 400 feet AGL are risk assessed using the ATO's SMS Manual and definitions. Thus, for sUAS operations above 400 feet AGL, use the risk matrix and risk assessment policy in the ATO SMS Manual.

Treat Risk

In this phase, identify appropriate means to mitigate or manage the safety risk. Treating risk involves:

1. Identifying appropriate safety requirements.
2. Defining safety performance targets or a sound alternate method to verify the predicted residual risk for each hazard.
3. Developing a monitoring plan that prescribes tasks and review cycles for comparing the current risk to the predicted residual risk.

To address safety risk, identify and evaluate means that either manage the risk or reduce it to an acceptable level. The four risk management strategies are risk control, risk avoidance, risk transfer, and risk assumption. Assess how the proposed risk management strategy affects the overall risk. Consider using a combination of actions to best manage or reduce the risk to an acceptable level. When determining the appropriate strategy, consider how the safety performance target will be used to evaluate the safety performance of the chosen course of action.

Risk Management Strategies:

1. Risk Control Strategy - Development of safety requirements, defined as planned or proposed means to reduce a hazard's causes or effects. Examples include policies or procedures, redundant systems and/or components, and alternate production sources.
2. Risk Avoidance - Averts the potential occurrence and/or consequence of a hazard by either selecting a different approach or not implementing a specific proposal. This technique may be pursued when multiple alternatives or options are available.
3. Risk Transfer - Shifts the ownership of risk to another party; the recipient may be better equipped to mitigate the risk at the operational or organizational level.
4. Risk Assumption - Simply means accepting the risk. The risk acceptor assumes responsibility for the risk as it is. When a risk acceptor agrees to implement a NAS change, he or she agrees to implement it based on the predicted residual risk being medium or low and assumes responsibility for the risk.

All safety requirements identified by the SRM panel and included in the HAW are considered recommendations for review and approval by the appropriate signatories.

Predicted residual risk is the risk that is estimated to exist after the safety requirements are implemented or after all avenues of risk reduction have been explored. The predicted residual risk is based on the assumption that controls are in place and/or all safety requirements are implemented and are valid. If safety requirements are not documented in the HAW, the predicted residual risk should be the same as the initial risk.

If the risk cannot be reduced to an acceptable level after attempting all possible risk reduction strategies, either revise the original objectives or abandon the proposed NAS change. The NAS change can only be implemented if an acceptable proposal is identified. Similarly, if a NAS change was implemented without safety requirements and the predicted residual risk was not met, the safety analysis must be revisited, which may require the development of safety requirements.

Refer to Section 5 of the ATO SMS Manual for additional information on preparing and performing a safety analysis and developing Safety Risk Management Documentation.

International Considerations

Overview

Implementation of a BVLOS UAS cross-border corridor presents multiple regulatory challenges at the federal and international levels that must be addressed and mitigated to enable UAS flight operations within that corridor. The three primary U.S. Federal entities that must 'approve' such a system are the Federal Communications Commission (FCC), the Federal Aviation Administration (FAA), and US Customs and Border Protection (CBP) on the US side of the border as well as their Canadian counterparts, the Innovation Science and Economic Development Canada (ISED), Transport Canada (TC), Nav Canada, and the Canada Border Services Agency CBSA). Processes exist around many of the regulatory approvals with the FAA and TC when conducting BVLOS operations domestically. However, these processes have not been harmonized for international operations and associated concerns and regulatory gaps are being addressed through the FAA/TC Cross Border Working Group to ensure safe integration into the National Airspace System (NAS). The sections below examine the existing regulations and procedures and identify areas that need to be developed to ensure that approval of a UAS Cross-border corridor is successful.

While the International Drone Corridor Option is the most complex and challenging, it offers an opportunity to establish the building blocks for the future supply. It is important to note that while existing and proposed regulations have been extensively examined, many of the needed regulatory and procedural challenges are still in the development stage. Due to the unique challenges of establishing an international Cross-border Corridor and the ongoing work with many of the regulators, there may be additional and unexpected issues that still need to be addressed in this analysis.

Existing Regulations Applicable to Cross-Border Operations

In accordance with Schedule A, The Statement of Work Contract Activities, Section 1.2.B.2.c and Section 1.2.C, the Project Team has assessed relevant regulatory approval considerations relating to the location of the approved international corridor (Area 1).

As a specific BVLOS UAS Connected Corridor is being selected for development, there are many regulatory considerations, both state and federal, that must be considered, addressed, and potentially mitigated during the development of the technological solution to enable UAS flight operations within that corridor. The three primary U.S. Federal entities that must 'approve' such a system are the Federal Communications Commission (FCC), the Federal Aviation Administration (FAA), and US Customs and Border Protection (CBP) on the US side of the border as well as their Canadian counterparts Innovation, Science and Economic Development Canada (ISED), Industry Canada (IC), Transport Canada (TC), Nav Canada, and the Canada Border Services Agency (CBSA).

Processes exist around all the regulatory approvals that are available when the operations are strictly domestic. However, international operations are still in the development stage with (FAA) and Transport Canada (TC), as well as for CBP and CBSA.

The Project Team has reached out to the FAA, TC, NAV CANADA, CBP, and CBSA by working through the International Division of the FAA's UAS Integration Office and corresponding agency Headquarters. Current ICAO guidance documents do not include autonomous operations or non-certified UAS operations; however, there has been a request for ICAO to include these operations in future work of the RPAS Working Group. Guidance from JARUS has been incorporated in the existing regulations developed by the FAA and TC for domestic operations and thus are not specifically examined but are referenced where applicable. Gaps in the regulatory structure needed to establish a cross-border corridor are discussed in greater detail later in this section.

Note: Regulatory requirements for domestic operations are referenced but not included in their entirety. Only those differences required for cross-border operations are examined.

FAA Existing Regulations

As of the date of this report the FAA has not developed regulatory guidance specifically intended for international UAS BVLOS operations, other than for UAS systems that have received a Certificates of Waiver or Authorization (COA). A COA is an authorization to a public operator for a specific UA activity. After a complete application is submitted, FAA conducts a comprehensive operational and technical review. If necessary, provisions or limitations may be imposed as part of the approval to ensure the UA can operate safely with other airspace users following the existing regulatory guidance for the type of operation. Unfortunately, this process would not be applicable to the types of operations being considered in this study.

The FAA and Transport Canada have formed an Interagency working group to examine all aspects involving cross-border UAS operations. The working group has established a work plan that is expected to release draft harmonized regulations for UAS cross-border operations by the end of 2023. Implementing these new regulations, including the modification of existing regulations will take additional time. It is important to note that even though the regulatory guidance needed to establish a BVLOS cross-border corridor is years away, the current initial operation being proposed by this study is for a line-of-sight corridor which would be accomplished with an exemption request. The FAA and TC have indicated, at the highest levels of the organization, support for the cross-border corridor initiative being examined in this study. An opportunity exists to explore entering into Memorandums of Understanding (MOU) that would allow the project to serve as a test-case and operational proof of concept in the development of the new harmonized regulations.

Transport Canada Existing Regulations

Transport Canada, like the FAA, has a mature set of regulations and guidance material available for UAS/RPAS operators seeking to operate within the borders of Canada. Like the FAA, TC does not have existing guidance for cross-border operations but is working to address the issue through the Cross-Border Working Group.

Existing regulations governing domestic UAS/RPAS operations are covered in Part IX of the Canadian Aviation Regulations SOR/96-433. Operators wishing to conduct BVLOS operations are required to obtain a Special Flight Operations Certificate. Subpart 3 of the regulation covers Special Flight Operations for Remotely Piloted Aircraft Systems and provides the regulatory guidance needed to apply for the Special Flight Operations Certificate. Additional guidance is available in the Advisory Circulars 903-001 (Remotely Piloted Aircraft Systems Operational Risk Assessment) and 903-002 (Application Guidelines for a Special Flight Operations Certificate for a Remotely Piloted Aircraft System (SFOC-RPAS).

As with the FAA, it is impossible at this time to determine the exact regulations that would govern a BVLOS Cross-Border Corridor until the completion of the FAA/TC Working Group's efforts to harmonize regulations is completed. Transport Canada has expressed a willingness to work with MDOT to explore how to make the BVLOS Cross-Border Corridor a reality.

DHS Component/DoD Regulatory Considerations/CBSA

Historically, cargo entering the United States from any foreign territory has been subject to a physical examination by the U.S. Government to verify that it complies with U.S. laws and regulations. After September 11, 2001, a new combined organization of Border Patrol, the Immigration and Naturalization Service, Agriculture Inspection, and the U.S. Customs Service became Customs and Border Protection (CBP) in the Department of Homeland Security. The CBP has taken on a leading role in defending Homeland Security and protecting the country against terrorists and weapons of mass destruction.

An important part of the CBP mission remains the facilitation of legitimate trade. In addition to its own regulations, CBP enforces over 400 laws on behalf of over 40 other U.S. Government agencies. (https://www.cbp.gov/border-security/ports-entry/cargo-security/examination) Many of these regulations being enforced remain invisible to the shipper, however, there are some specific requirements set forth by CBP that are important to establishing a cross-border UAS corridor. These regulations cover advanced passenger or cargo information and reporting requirements and vary based on operation type (i.e., Part 91, 121, 135). Additional regulatory requirements are set forth for Customs Brokers and Importers that may be applicable based on the categorization of UAS operations by CBP.

CBP is working with the FAA to examine the best way to safely and securely accommodate cross-border UAS operations and is an active member of the FAA/TC Cross-Border Working Group. In the past, the CBP participants of the working group were almost exclusively focused on the homeland security aspects of cross-border UAS operations, but there has been a renewed commitment on the part of CBP to address the lawful use of UAS/RPAS systems in legitimate trade. New members of the working group were added and now represent all major interests of CBP including the Office of Field Operations, the Office of Information and Technology, the Air & Marine Operations, and the Border Patrol.

To ensure the success of a cross-border UAS corridor, it is necessary to harmonize the development of regulations, processes, and procedures for the CBP and CBSA. This makes the proposed MDOT corridor a valuable test case and operational proof of concept for the creation of new, harmonized regulations.

FCC Regulatory Considerations

The FCC regulates interstate and international communications by radio, television, wire, satellite, and cable in all 50 states, the District of Columbia, and US territories. This includes but is not limited to the frequencies for air-ground communications, air-to-air communications, surveillance, and any other emitters used in the UAS network. Use of these frequencies requires approval or certification of the system. Once the certification process has been completed and a certificate has been issued, the FCC will issue an FCC ID. An FCC ID is assigned to all devices subject to certification. An FCC ID will be needed for the air-ground communications system equipment. Spectrum use modalities may include Title 47 Part 15 of the CFR unlicensed transmissions or other FCC-compliant methods with a path to FCC spectrum approval. Part 15 sets out the regulations under which an intentional, unintentional, or incidental radiator may be operated without an individual license. It also contains the technical specifications, administrative requirements, and other conditions relating to the marketing of Part 15 devices.

In addition to the FCC, the FAA, under 14 CFR Part 90 of the Federal Aviation Regulations, states the conditions under which radio communications systems may be licensed and used in the Public Safety, Industrial/Business Radio Pool, and Radiolocation Radio Services. These rules do not govern the licensing of radio systems belonging to and operated by the United States. Rules as to eligibility for licensing, permissible communications, frequency available, and any special requirements are set forth in §90.103.

The FCC continues to work with the FAA on all spectrum issues for UAS operators. The FAA/TC Cross-border Working Group will include spectrum harmonization as part of their work plan to harmonize UAS operations between the two countries.

Innovation, Science, and Economic Development Canada

Innovation, Science, and Economic Development Canada (ISED) provides the same services for Canada that the FCC provides for the US. In contact with representatives of Transport Canada, they advised that ISED works closely with TC to ensure that UAS/RPAS spectrum issues are addressed. TC has advised that should the cross-border UAS corridor move past the feasibility stage into development; they would work with MDOT and their contractors to ensure that the requirements set by ISED could be met.

Bilateral Agreements

The United States and Canada have had a long and healthy relationship, and bilateral agreements currently exist between the FAA and Transport Canada and a Customs Mutual Assistance Agreement (CMAA) between CBP and CBSA.

The existing bilateral agreements between the United States and Canada allow both organizations to further information sharing with respect to the development of regulations; existing and future research and development initiatives; common approaches to program implementation; and leveraging opportunities to broaden stakeholder engagement. The FAA and TC jointly chair the UAS/RPAS Cross-border working group and have assembled a team of representing the key regulators from both sides of the border that will be needed to develop the regulations and procedures that will allow the development of a BVLOS Cross-Border Corridor. Should this initiative move from the feasibility stage to the implementation stage, it is essential to engage this working group as early as possible to ensure MDOT and the contractor have access to the most up-to-date regulatory guidance.

Work covered by this working group falls under the existing US/Canadian Bilateral Agreement, and FAA legal is looking into whether the document will net to be modified or not. Since UAS are considered aircraft by the FAA and Transport Canada it is believed that these activities will fall within the existing Bilateral Agreement and will not require extensive modifications.

Operational Procedures

Existing guidance and operational procedures for BVLOS cross-border operations have not been developed as of this report date, and with limited exceptions cross-border autonomous UAS operations are prohibited. This feasibility study examined key areas integral to the success of a BVLOS Cross-Border Corridor, including but not limited to:

1. Existing operational practices covering UAS operations.
2. Willingness of FAA/TC and CBP/CBSA to participate in the development of the required procedures needed to establish an international corridor.
3. How will CBP/CBSA categorize UAS operations?
4. How will inspections of the packages delivered by UAS be completed?
5. What automated systems can be used to satisfy electronic waybill requirements?
6. How and by whom will the data be submitted to Customs?
7. Is there sufficient space at existing Ports of Entry to accommodate drone delivery and package inspection?
8. Secondary monitoring requirements to ensure the integrity of the drone corridor and prevent the unlawful introduction of illegal goods or persons.

Our findings indicate that many of these questions remained unanswered, however, CBP has expanded their panel of experts working with the FAA/CBSA Cross-Border Working Group to address many of these issues. The development of regulations, processes, and procedures for CBP (and CBSA) are the key areas that will need to be harmonized for the success of a cross-border UAS corridor and provides the best reason for including the proposed MDOT corridor as a test case and operational proof of concept in the development of the new harmonized regulations. Findings from this work would be included in the corridor ConOps.

International Considerations – Corridor Location

Overview

The establishment of a UAS international connection presents multiple challenges over domestic options because of the increased number of regulatory agencies that are involved. While the domestic corridors (Areas 2 and 3) focus on FAA regulations and approvals, the international connection will require additional coordination with Transport Canada (TC) and NAV CANADA. More importantly, new regulatory agencies that have not had as much experience with UAS, such as US Customs and Border Protection (CBP) and Canada's Border Security Agency (CBSA), are key players in gaining approval and implementation. This should be kept in mind in order to gain approvals in a timely manner, the Project Team has proposed locations of interest that are no longer than 1-2 miles, as a starting point.

Initial Proposed Corridor

An international cross-border Connected UAS Corridor will be the first of its kind in North America. While challenging to design and implement, its impact on the future of supply chains around the globe is monumental. The rewards of successfully accomplishing this task will solidify the MDOT's leadership position in the future of supply chain innovation.

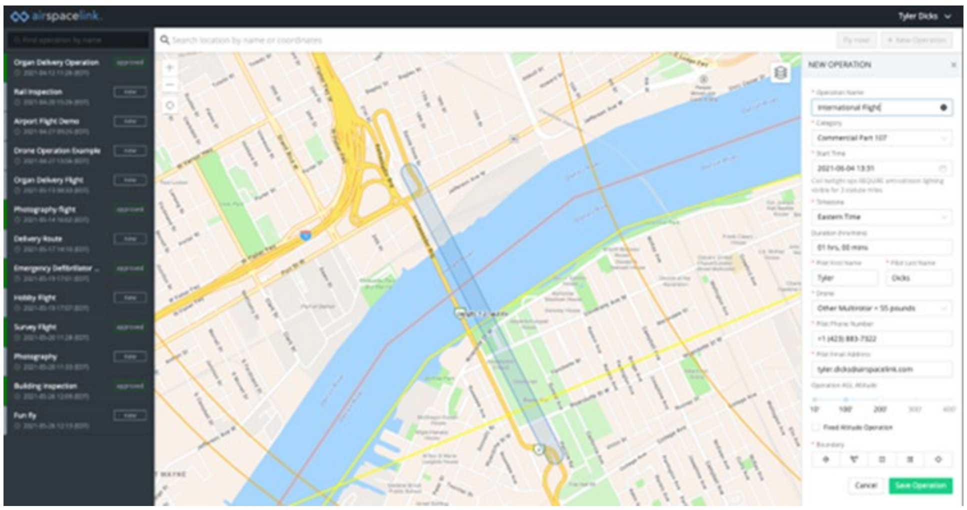


Figure 73: Initial Proposed Location for International UAS Connected Corridor

In order to gain approval for the new cross-border corridor our initial proposal calls for the establishment of a cross-border UAS corridor that will link the two existing CBP and CBSA facilities that are located to service the Ambassador Bridge. This short corridor was selected after considering several factors including but not limited to:

- Corridor must start/terminate at each country's respective ports of entry (POE).
- CBP and CBSA will want to make sure that UAS operations and inspections are conducted in accordance with existing CBP and CBSA requirements for other forms of transportation (i.e., vehicle, pedestrian, vessel, and aircraft.)
- Procedures for UAS operations into/out of existing airports are still in the development stage and final guidelines for these types of operations are still years away.
- The distance to existing airport ports of entry is significant and utilizing existing airports would introduce operational inefficiencies that would negatively impact the feasibility of establishing a cross-border corridor
- Establishing a corridor that is adjacent to existing infrastructure (Ambassador Bridge) is in alignment with recommendations presented by the BVLOS ARC

These areas are discussed in greater detail below:

Corridor Start/Terminate Locations and Port of Entry Criteria

According to CBP in fiscal year 2021, over 491,000 passengers and pedestrians and over 87,000 truck, rail, and sea containers carrying goods worth approximately $7.7 billion entered the United States through 328 U.S. land, sea, and airports of entry (POE), according to U.S. Customs and Border Protection (CBP) on a daily basis. https://www.gao.gov/products/gao-22-105421

By using existing CBP/CBSA POEs the initial proposed cross-border corridor will significantly reduce the cost versus establishing new dedicated POE's designed exclusively for UAS/RPAS operations. Costs for providing the required inspection areas and facilities in a new operation can range from several hundred thousand dollars to several million based on the size and scope of operations. By utilizing a drone docking station mounted on a portable trailer (as seen below) or vehicle there is improved flexibility on the location of the UAV/RPAS operational area and can be customized as needed to fit any unforeseen circumstances. Section 1.6.1.3 covers the analysis of the Space and Operational requirements in greater detail.

Figure 74: Drone Docking Station Mounted on a Portable Trailer

CBP and CBSA Operations Requirements and Procedures

CBP and CBSA will want to be sure that UAS operations and inspections are conducted in accordance with existing CBP and CBSA requirements for other forms of transportation (i.e., vehicle, pedestrian, vessel, and aircraft) As of the date of this report CBP and CBSA have not announced how they plan to process UAS/RPAS operations. A fundamental question regarding UAS is still being considered; with UAS be treated as aircraft and processed accordingly, or will they be treated as a new entity? If we examine the complexities involved should CBP/CBSA decide to treat UAS/RPAS operations as aircraft and require inspections at existing airport POEs, then the feasibility of such operations in the near future becomes more difficult for several reasons.

- While existing ports of entry would be capable of processing UAS/RPAS operations the complexities involved in establishing safe corridors between two active airports significantly increasing the risk of these operations.
- Monitoring of UAS/RPAS operations transiting between two existing active airport POE's would require a dedicated "International Corridor" that would overlap proposed domestic UAV/RPAS corridors and significantly increase the chance of mixing cleared vs. non-cleared operations in the same airspace. These present significant challenges to ensure that the requirement for 100% inspections in incoming cargo is completed prior to domestic operations.
- The area that would need to be covered by falling out or landing short contingency procedures would increase dramatically presenting an unacceptable risk for CBP/CBSA.

Given that CBP/CBSA and other Customs Organizations around the globe have not finalized their categorization of UAS/RPAS operations, this presents an opportunity to work with them to develop a cross modal inspection model that would utilize and build on existing infrastructure. By setting aside a specific area at each port of entry to accommodate UAS/RPAS operations and working with industry to develop operational procedures to process incoming UAS/RPAS operations the challenges listed above would be eliminated.

Airport Operations Requirements and Procedures

Procedures for UAS operations into/out of existing airports are still in the development stage and final guidelines for these types of operations are still years away. While many advancements have been made to accommodate UAS/RPAS operations in the vicinity of airports, current regulatory framework prohibits operation within the "zero grid area" without an approved airspace waiver.

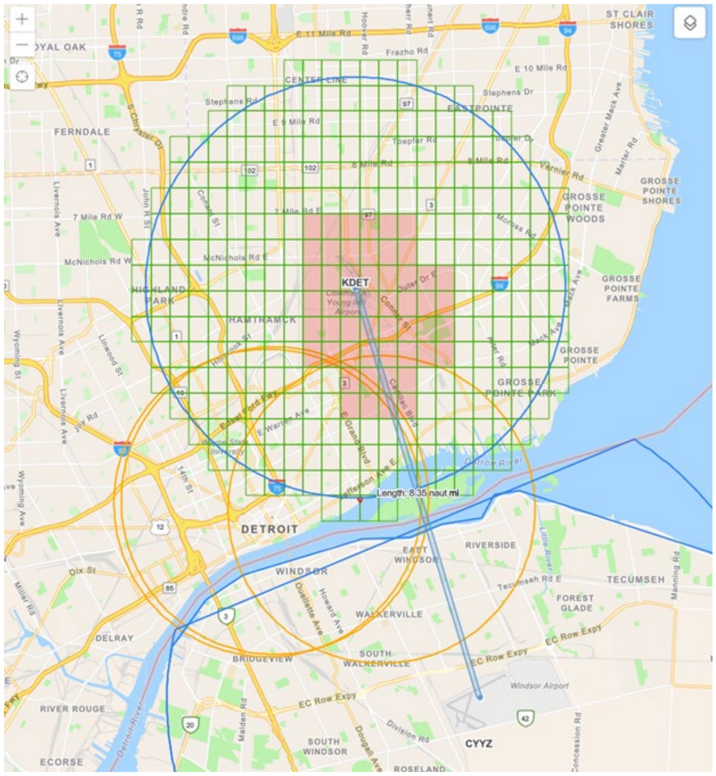


Figure 75: Corridor Alignment Linking the Two Existing Aviation Ports of Entry

In order to be granted a waiver or exemption, we would need to develop and submit for approval an alternate method of compliance that demonstrates the UAS operation achieves an equivalent level of safety with the existing air traffic. To date the FAA has granted only a few such waivers. In the future it may be beneficial to explore this type of operation, particularly if the corridor is expanded to accommodate Urban Air Mobility.

The distance to existing airport ports of entry is significant and utilizing existing airports would introduce operational inefficiencies that would negatively impact the feasibility of establishing a cross-border corridor. A corridor that would connect the two closest international Airports, Coleman A Young International Airport and Windsor International Airport, would be approximately eight miles long. This compares to slightly over one mile for the proposed corridor connecting the two vehicular ports of entry adjacent to the Ambassador Bridge.

BVLOS ARC Alignment

Establishing a corridor that is adjacent to existing infrastructure (Ambassador Bridge) is in alignment with recommendations presented by the BVLOS ARC. In June of 2021, The FAA published the Charter for the UAS Beyond Visual Line-of-Sight Operations Aviation Rulemaking Committee (ARC). The purpose of the ARC was to provide recommendations to the FAA for performance-based regulatory requirements to normalize safe, scalable, economically viable, and environmentally advantageous UAS BVLOS operations that are not under positive air traffic control (ATC). This ARC will take a holistic approach in recommending a performance-based, technology agnostic regulatory framework for BVLOS operations.

In the final report that was issued in March of 2022, one of the key recommendations advocated for BVLOS operations in the shielded area of critical infrastructure such as the Ambassador Bridge (*Advisory and Rulemaking Committees UAS BVLOS ARC Final Report*, 2022). The corridor is being proposed for initial as well as follow-on operations in compliance with the ARC recommendation.

Analysis of Space and Operational Requirements

The corridor being considered for the initial trial stages of the cross-border UAS/RPAS corridor is adjacent to the existing Ambassador Bridge and connects the current CBP/SBSA Ports of Entry. The Ambassador Bridge is North America's number 1 international border crossing. On average, the Ambassador Bridge handles around 8,000 trucks and 68,000 travelers daily. As such, operations at the existing Ports of Entry leave little room for the introduction of a new mode of transport (UAS/RPAS) on anything other than a test case basis. However, for a test case scenario, it offers the most beneficial option available. Given that regulatory reform that will allow for large scale UAS/RPAS operations is still several years away, establishing the cross-border corridor with the existing POEs offers an ideal testbed and can be accomplished despite the existing space restraints. (Section 1.6.1.4 examines the final buildout locations.)

While operations at the existing POEs will still require the approval of Senior Management at each location as well as respective Headquarters approvals, several areas have been identified that would accommodate low operational volume, low payload mass, and high time sensitivity operations.

CBP Port of Entry

As mentioned earlier in this section, utilization of trailer or vehicle mounted "Nests" for the UAS/RPAS operations would allow a safe/secure operating environment with a relatively small footprint. The locations proposed would be suggested areas for consideration by the CBP Port Director but the actual location, should this project move ahead, would be their decision to make.

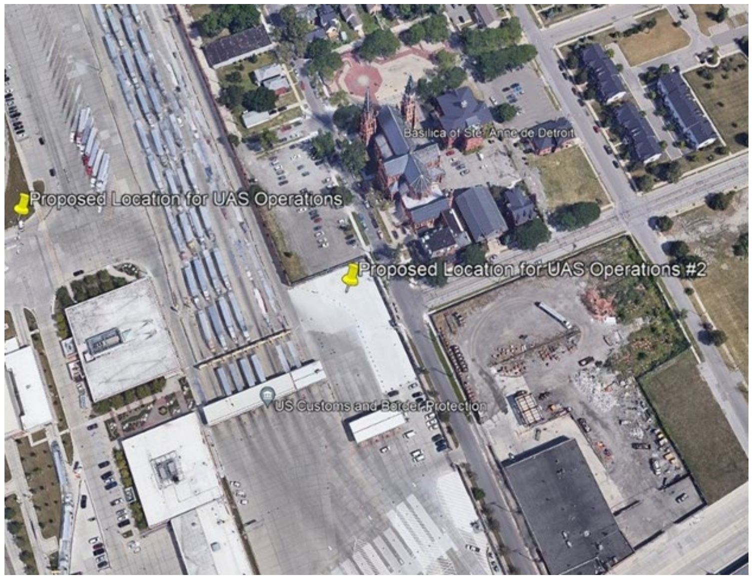


Figure 76: CBP Port of Entry Proposed Locations

The areas depicted in the aerial photo above offer a remote setting still within the boundaries of CBP's processing area for inbound international arrivals. Additionally, little if any facility modifications would be required. This is an important factor given the requirement that the cost of any facility modification would need to be borne by the requesting operator.

CBSA Port of Entry

The same principles were used to determine proposed UAS/RPAS operating locations at the CBSA Port of Entry in Windsor.

Figure 77: CBSA Port of Entry Proposed Locations

However, given that as of date of this study, there is no plan for a corresponding connecting drone corridor in the City of Windsor, these locations would be the termination/starting point for the UAS/RPAS operations and as such would require an area for interface between the UAS/RPAS operator and the general public. This could have an impact on the overall location chosen by the POE Director.

Should the UAS/RPAS Cross-Border Corridor project move forward, a comprehensive nesting survey would be required to determine the optimal location for consideration by the respective port directors. One area of significant importance is access to electric utilities for the operation of the nests. A comprehensive review of each POE utility infrastructure would be required to determine the most cost-effective operational location.

Self-contained nesting units such as the trailer or vehicle mounted automated drone hangar (or comparable models) may offer the best solution for an initial operational trial. These units are fully self-contained and would not require any infrastructure improvements thus greatly reducing the cost.

One area that this study was unable to fully analyze is the impact of any possible right-of-way or use restrictions that may exist with the existing Ambassador Bridge location. The Ambassador Bridge is one of two privately owned border crossings in Michigan, and the lease agreements with their tenants (CBP and CBSA) are not available for public review. Given that the introduction of a cross-border UAS corridor and subsequent inspection facilities remains in line with the existing uses of the tenant spaces no problem is anticipated, however, should the project move forward this is an area that will need additional coordination and consideration.

Border Crossing Concerns

The initial corridor selection for an international cross-border corridor was chosen considering the development of the drone corridor in Area 2 and establishing an international connection. The original scope of work did not contain date an equivalent Canadian corridor. As such many of the considerations examined in previous sections of this document have not been fully examined on the Canadian side of the border. Follow-on work, or a separate project by the Canadian Government or the Provence of Ontario to develop a corridor that would connect to Areas 1 and 2 would have a significant positive impact on many of the areas previously discussed in this section.

Final Corridor Recommendation

After careful analysis of the first proposed cross-border corridor paralleling the Ambassador Bridge and the corresponding limitations at the current ports of entry, it became evident that it would serve the purpose of a test-bed location, however, any scalability or growth in activity would be extremely difficult. With that in mind, the team started to analyze possible alternatives that would allow for growth and the possible introduction of larger, more frequent UAV/RPAS operations including possible Urban Air Mobility Operations. A solution was found by incorporating a second corridor that parallels the Gordie Howe Bridge that is currently under construction.

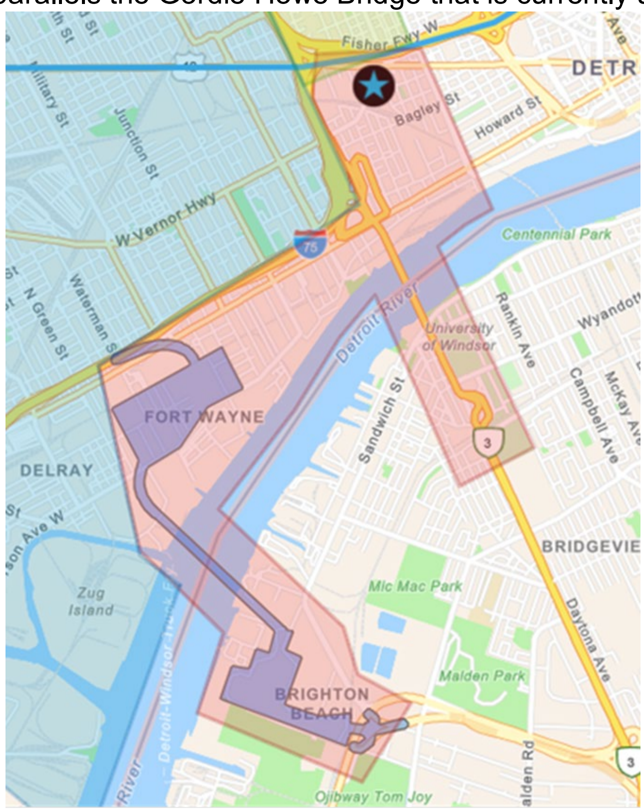


Figure 78: Final Corridor Recommendation Area

This second cross-border corridor would not be used until the bridge and associated infrastructure was completed, currently forecasted for the end of 2024. This timing aligns with when the development of regulations on cross-border UAS/RPAS operations that are expected to be released by the FAA and Transport Canada.

This second cross-border crossing has been included in the airspace and risk analysis referenced earlier in this document. The rational for choosing to add this location and the efficiencies listed with the initial crossing location remain the same as the original corridor paralleling the Ambassador Bridge. However, this provides a real opportunity for scaling the activities as activity levels increase. Each of the corresponding Ports of Entry have footprints that will allow the installation of additional technology and expanded border processing facilities. Additionally, discussions should begin with US Customs and Border Protection and Canadian Border Services Agency to determine if the existing CBP and CBSA facilities will remain despite the proposed demolition of the Ambassador Bridge. Potentially these facilities could be utilized for follow-on advanced air mobility operations.

Costs and Reimbursement

Without a corresponding drone corridor in Windsor that would connect to the cross-border corridor, it is impossible to accurately determine the required facility modifications and the associated costs. Should the cross-border corridor proceed, it envisioned that proof-of-concept operations would begin with a limited scope and could easily be accommodated at the existing Ambassador Bridge POEs with limited capital expenditures. If the proof-of-concept test results are favorable and the project increases in scale and activity, consideration should be given to conducting an engineering design survey to determine the footprint and associated infrastructure improvements that would be needed. The Gordie Howe Bridge website provides an overview of the proposed new POEs and highlights that each facility was designed to allow for the installation of additional technology and the expansion of border processing facilities.

- Size: approximately 68 hectare/167-acre site
- Inbound border inspection facilities for both passenger and commercial vehicles
- Outbound inspection facilities
- Commercial exit control booths
- The footprint allows for the installation of further technology and the addition of expanded border processing facilities
- Once constructed, this port will be one of the largest ports of entry in North America

- Size: approximately 53 hectare/130-acre site
- Inbound border inspection facilities for both passenger and commercial vehicles
- Outbound inspection facilities
- Toll collection facilities for both the US-bound and Canada-bound traffic
- Maintenance facility
- The footprint allows for the installation of further technology and the addition of expanded border processing facilities
- Once constructed, this port will be the largest Canadian port along the Canada-US border and one of the largest anywhere in North America

Should CBP and CBSA move all operations to the new Gordie Howe Bridge location MDOT may want to explore repurposing the existing POEs at the Ambassador Bridge and converting the site into a dedicated UAS/RPAS processing facility. This would again require a full-scale engineering design survey and cost benefit analysis to accurately determine the respective costs and associated infrastructure modifications.

In either case it is most likely that MDOT or other Government sponsor would need to enter into one of the existing CBP Public-Private Partnership Programs and ultimately be responsible for the costs associated with these modifications.

International Considerations – Additional Monitoring Interface

Overview

The complexities that arise with the consideration of UAS and AAM on an international basis, present significant regulatory and infrastructure challenges that were examined as part of this feasibility study. The infrastructure, inspection, and monitoring needed to support the operations and ensure compliance with Customs regulations on both sides of the border are significant and the processes and procedures required to implement UAS operations or AAM on an international basis are still in their development stages. However, one aspect that needs to be addressed is how monitoring of the cross-border corridor will integrate into the overall Air Domain Awareness system that exists today. While these requirements will most likely not be required for the initial visual line of sight trials proposed for the first phase of the corridor, they are considerations that need to be addressed should the corridor be upgraded to BVLOS or if the UAS/RPAS systems connect to other BVLOS corridors being explored.

To date the major focus of existing Air Domain Awareness actions have been centered around the detection and enforcement of illegal drones crossing the borders. The creation of a cross-border drone corridor will set the groundwork for legal cross-border operations and necessitates a way to detect which UAS operations are operated lawfully vs. those that are not.

As part of the feasibility study, we examined what additional monitoring interfaces would be required and included as part of the cross-border C2 system. These interfaces would provide the agencies responsible for air domain awareness the information needed to integrate legal cross-border UAS operations into their overall aviation domain picture. The technical requirements are still in development as this study is being conducted, but certain guiding principles can be used to anticipate the needs of these agencies. Should this project move forward from the feasibility stage to implementation close consultation with agencies on both sides of the border will be needed to establish the actual detail of the technical interfaces required. Additionally, a close examination of the ConOps and any modifications that may be required to address procedural concerns in the UAS operations will be needed. *(Note: Due to the sensitivity of many of these systems, contractors working in this area will most likely need to possess or be able to acquire a government sponsored contractor security clearance at the level determined by the supporting agencies. This should be factored into any follow-on bid documents to ensure compliance with procurement procedures and best practices.)*

HSPD 16 and the corresponding National Strategy for Aviation Security specify the responsibilities of the many agencies involved. https://www.dhs.gov/sites/default/files/publications/nspd-47.pdf

Requirements from Government Stakeholders

US CBP

In addition to the Department of Defense the Air Domain Surveillance and Intelligence Integration Plan, a supporting plan to the National Strategy for Aviation Security dated March 26, 2007, assigns CBP the responsibility for detecting and identifying potential air threats to the United States, including aircraft involved in the aerial transit of contraband into the United States (https://irp.fas.org/offdocs/nspd/adsii.pdf). The core of CBP's Air Domain awareness architecture consists of the Air and Marine Operations Center (AMOC) and its specially equipped airborne platforms, which fuse a variety of sensor systems and databases to produce a single, integrated air picture. The current air picture is very effective at detecting most airborne threats but is not designed to be able to track smaller targets such as most UAV/RPAS systems in use.

CBP is currently working with DHS Science and Technology (S&T) and other partners to improve their capability to detect and mitigate uncrewed aircraft systems in the United States with a special emphasis on the borders. The program, which is still in the test and evaluation stages, has two main focuses. Countering UAS/RPAS systems and creation of a joint ATM/UTM Air Domain

Awareness picture. This work is expected to be completed by the end of 2023.

Until the work being undertaken by DHS S&T, and the work of the FAA/Transport Canada cross border working group are completed, it is impossible to provide the exact technical specifications that would be needed to meet the monitoring requirements of CBP and other agencies. However, this also opens an opportunity to be part of the testing process. The current primary monitoring and C2 plan being proposed in this document meets or exceeds many of the current areas that are being evaluated and could offer a beneficial testbed for the working group.

Canadian CBSA

Unlike the US CBP, CBSA does not have a direct counterpart organization to the US CBP Air & Marine Operations Center. However, they do work collaboratively with US colleagues to ensure shared domain awareness of the border environment, taking the form of several joint operations/joint initiatives at various locations along the shared border. Thus, no secondary monitoring capability is anticipated at this time. Information shared with previously identified stakeholders will most likely be used to generate the domain awareness that will be shared with CBSA.

DHS Science & Technology (S&T)

A secondary monitoring capability would not be required; however, the current work of S&T in the Air Domain will directly impact and help to define what the technical requirements are for other agencies.

S&T is working with various federal partners and select vendors on an ongoing initiative to test, evaluate, and implement state-of-the-art aerial surveillance technologies, sensors, and capabilities in lowland plains, urban, mountainous, and maritime environments along the northern border. The primary objective of these tests and evaluations is to assess and demonstrate the capabilities of Air Domain Awareness (ADA) technologies such as radar systems, cameras, radio frequency detection systems, acoustic devices, and other selected electronic capture equipment to determine how effectively they can provide surveillance in the diverse environments and terrains that surround the northern border.

Over the next year, S&T and its partners will hold a series of ADA demonstrations at testing sites along the northern border. Each site will have unique geographies that will challenge the capabilities of the technologies being evaluated. At the conclusion of these demonstrations, S&T will develop comprehensive reports detailing the technologies that were tested, their capabilities, and how they each performed in the field. These reports will then be shared with all federal agencies and organizations looking to procure and implement ADA technologies at the northern border and other key points of entry around the country.

Until the work being undertaken by DHS S&T, and the work of the FAA/Transport Canada cross border working group are completed, it is impossible to provide the exact technical specifications that would be needed to meet the monitoring requirements of CBP and other agencies.

TSA

TSA's current primary focus centers around the threat that UAS/RPAS systems pose to the existing aviation ecosystem from a homeland security viewpoint. The Transportation Security Operations Center (TSOC) serves as the main aviation domain awareness center for TSA. Since CBP has a presence at the TSOC it is not likely that a secondary monitoring capability would be required at this location.

DoD

The Department of Defense DoD) for the United States and the Department of National Defense in Canada share many of the same requirements for a combined air domain awareness picture that were addressed with CBP and CBSA. Also, the requirements for additional monitoring interface are not likely to be required for the initial visual line of site being proposed at this time.

The United States and Canada through the North American Aerospace Defense Command (NORAD) work together to detect and deter, validate, and warn of attacks against North America in the air, space, and the maritime domains. Monitoring systems that monitor the area being proposed include the Canadian NORAD Region and the Continental U.S. NORAD Region specifically the Eastern Air Defense Sector (EADS) and the Combined Air Operations Center (CONR).

Because the cross-border corridor does not penetrate an Air Defense Identification Zone (ADIZ) there are not as many requirements as the same operation conducted on the southern border. DoD is a participant in the Air Domain Awareness initiative currently underway with DHS S&T, and as such final secondary monitoring requirements will be determined at the completion of that work.

Summary of Requirements

While these requirements listed above will most likely not be required for the initial visual line of sight trials proposed for the first phase of the corridor, they are considerations that need to be addressed should the corridor be upgraded to BVLOS or if the UAS/RPAS systems connect to other BVLOS corridors being explored.

As mentioned above, work continues integrating a workable UAS/RPAS air domain awareness picture into the existing monitoring systems of CBP and DoD. Until this work is finished it is impossible to provide the exact technical interface requirements for monitoring cross-border UAS/RPAS activity. However, by starting the initial cross-border corridor as a visual line of site operation, an opportunity exists to participate with these agencies through the FAA/Transport Canada Cross-Border working group to fully define what would be the acceptable means of compliance as operations increase and expand to BVLOS. The information gained through the first phase visual corridor being used as a testbed, combined with the evaluation of the monitoring systems being deployed for area 2, offers the best path for acceptance and validation of the needed security and monitoring requirements.

Development Required for Successful Cross-Border Implementation – Way Forward

As previously mentioned, as of the date of this report regulatory guidance for cross-border operations are in the development stage and are two years or more away from being completed. Regulators from the key agencies on both sides of the border recognize that the development of a cross-border corridor is important to their work and could serve as a test-case to assist in refining their regulatory approach and developing processes and procedures that are needed to accomplish lawful cross-border UAS operations. All have pledged their support for the initiative, with one entity willing to assign a dedicated project manager to work with MDOT should this move from the feasibility stage to the development stage. Initial phasing of the follow-on implementation contract is visioned as using a 3-phase approach.

- Phase 1 – Continue engagement with the FAA/Transport Canada Cross-Border Working Group via Memorandum of Understanding (MOU) between the FAA/Transport Canada and MDOT. Work with CBP and CBSA to develop a basic operating framework that addresses the issues raised in this study. Capitalizing on existing CBP and CBSA harmonization efforts developed to enhance US and Canadian economic competitiveness while enabling lawful trade and travel, extend/expand these programs to autonomous UAS operations serving as the building blocks for UAS regulatory framework. Identification of additional secondary monitoring requirements for CBP, CBSA, and other select agencies to ensure the integrity of the corridor will be addressed. This work will be concurrent with the harmonization efforts between the FAA, Transport Canada, and Nav Canada that are focused on airspace and operational parameters. (Suggested Milestone: Begin coordination 1st Qtr. 2023)

- Phase 2 – The establishment of the International Corridor connecting the existing Ports of Entry and operational testing. This step will allow operational issues to be identified and corrected as well as ensuring that secondary monitoring systems are providing the information and situational awareness needed by the regulators. (Suggested Milestone: 3rd Qtr. 2023)

- Phase 3 – Expansion of the corridor to locations identified in the supply chain that will permit the drone to leave the distribution point, travel to the port of departure and the port of entry, and then continue to other locations such as the Michigan Central Station currently under development. Development of a BVLOS corridor in Windsor that will connect to the Cross-Border Corridor and link stakeholders on both sides of the border. (Suggested Milestone: 3rd Qtr. 2024)

International Approvals

FAA Approval of the System

A fundamental goal of the FAA with UAS is to strive in reaching the next level of safety and efficiency and to demonstrate global leadership in how to safely integrate new users and technologies into our aviation system. Accountable to the American public and our aviation stakeholders is key.

Systems seeking FAA approval must demonstrate how they help achieve the next level of safety. Historically in the aviation industry, Radio Technical Commission for Aeronautics (RTCA) has provided the foundation for virtually every modern technical advance in aviation. As a Standards Development Organization (SDO), RTCA works with the FAA to develop comprehensive, industry-vetted, and endorsed standards that can be used as means of compliance with FAA regulations.

To achieve FAA approval and a path towards scalable FAA approvals/use, leveraging industry accepted standards, such as RTCA, increases confidence in FAA approvability, safety, scalability. The initial build out of the BVLOS UAS Connected Corridor should seek standards compliance and may have limited FAA approval with operational constraints to meet the early objectives. As the system demonstrated that it is efficient and safe, further expansion of the system can be achieved.

FAA Currently prohibits international operations of UAS systems as referenced in FAR 107.
Several levels of FAA approval are required for overall operational approval and the eventual fully operational corridor. These approvals will be determined by the types of operations that will be conducted in the corridor. The initial operations proposed for the UAS Connected Corridor (s) are identified in Section 3.1.1 of this document. These operations include package delivery, BVLOS and visual flights, and DOT-specific inspection and public safety services. These advanced operations fall outside the purview of Part 107 commercial UAS rules and therefore FAA waivers will be required.

Factors to consider while reviewing an application for an operational waiver include, but are not limited to, the aircraft to be flown in the operation, the operational location, the unique hazards of the proposed waivered operation, and the risk mitigations proposed by the applicant. Furthermore, applications will need to include, at a minimum, a detailed description of:

- Type of proposed UAS operation
- UAS aircraft and system description
- Operational procedures and limitations
- Operational location and Airspace evaluation
- Risk analysis including hazards, risks, and risk mitigations

This is to ensure that the FAA understands the proposed UAS operation, location, limitations, and proposed procedures. Additionally, a risk analysis document that entails each hazard's effects before mitigations are applied must be provided in the waiver application, as well as the severity and likelihood of each hazard's effects after mitigations are applied. FAA Orders 8040.4 and 8040.6 provide examples and instructions to FAA internal evaluators on the methods and approach for performing a risk assessment and definitions which may be used for severity and likelihood. The rationale must include supporting data provided by the applicant to substantiate how each mitigation reduces the severity or likelihood.

Transport Canada Approval of the System

Transport Canada, like the FAA, has a mature set of regulations and guidance material available for UAS/RPAS operators seeking to operate with the borders of Canada. Like the FAA, TC does not have existing guidance for cross-border operations but is working to address the issue through the Cross-Border Working Group.

Existing regulations governing domestic UAS/RPAS operations are covered in Part IX of the Canadian Aviation Regulations SOR/96-433. Operators wishing to conduct BVLOS operations are required to obtain a Special Flight Operations Certificate. Subpart 3 of the regulation covers Special Flight Operations for Remotely Piloted Aircraft Systems and provides the regulatory guidance needed to apply for the Special Flight Operations Certificate. Additional guidance is available in the Advisory Circulars 903-001 (Remotely Piloted Aircraft Systems Operational Risk Assessment) and 903-002 (Application Guidelines for a Special Flight Operations Certificate for a Remotely Piloted Aircraft System (SFOC-RPAS).

As with the FAA, it is impossible at this time to the exact regulations that would govern a BVLOS Cross-Border Corridor until the completion of the FAA/TC Working Group's efforts to harmonize regulations is completed. Transport Canada has expressed a willingness to work with MDOT to explore how to make the BVLOS Cross-Border Corridor a reality.

DHS Component/DoD Regulatory Considerations/CBSA

The regulatory approval considerations for regulators on both sides of the border will be challenging to address. They differ significantly when examining UAS delivery operations versus AAM. Given the importance of enhancing US economic competitiveness while enabling lawful trade and travel, the successful outcome of an International UAS Corridor is dependent on establishing a close working relationship with US CBP, the CBSA, and Department of Defense (DoD) components such as North American Aerospace Defense Command (NORAD). The establishment of an initial cross-border UAS Connected corridor will consider the interests of key stakeholders and the initial users identified in Section 1.6.2 of this document.

One location of interest within both Geographic Areas 1 and 2 has already been identified by the key stakeholders. The Project Team suggests starting with limited UAS package delivery use cases that are conducted with visual line of sight, before extending these to advanced BVLOS operations. Focusing on use cases between the CBP Port of Entry in Detroit and CBSA Port of Entry in Windsor are of interest from the initial users and stakeholders we have identified and could serve as the proving grounds to ensure that the requirements of the two border agencies are met before advancing to additional (and broader) operations.

The key to success with the International Corridor Proposal will be to develop harmonized operating rules with US Customs and Border Protection (CBP) and the Canadian Border Security Agency (CBSA) to ensure the needs of these agencies are addressed.

Summary

The challenges associated with the establishment of a Cross-Border UAS Corridor are significant, but the rewards of successfully establishing such a corridor are groundbreaking. As mentioned numerous times in this study, the development of regulations, policies and procedures that are needed to achieve approval of a BVLOS Cross-Border corridor are in development and still several years away from being implemented. However, in discussions with the FAA/Transport Canada, CBP, and CBSA, there has been unanimous support for this project going forward. By working through the FAA/Transport Canada Cross-Border working group and using the proposed Cross-Border Corridor as a test case scenario MDOT and the operators using the corridor will be in the best position to capitalize when these regulations are released.

Technology Implementation & Deployment

System Architecture

The MDOT BVLOS system architecture is described using an internal enterprise model Thales uses to address Uncrewed Traffic Management (UTM) worldwide. The model is the result of the analysis and comparisons of several available UTM ConOps, including but not limited to the FAA, ICAO, SESAR U-Space, Airservices Australia FIMS, and UK Catapult and. The model is being leveraged by the Project Team to recommend the most effective fundamental technology and deployment strategies to MDOT.

Operational Context

Details regarding use cases and associated operational context are provided in the preliminary analysis section of the this report for each study area. The table below outlines the first use cases that the Project Team recommends be the focus of system testing, validation, and initial operations.

Table 33: Use Cases

Use Case	Customer / Partner Agency	Study Area
Medical Delivery	Henry Ford Health, Spectrum Health	2,3
Manufacturing Parts Delivery	Ford Auto	1,2
OTC Drugs and Pharmaceutical Delivery	Henry Ford Health, Spectrum Health	2,3
Cross Border Package Delivery	Major Automotive Manufactures	1
Drone as First Responder	Traverse City, Grand Traverse County, USCG	3
Infrastructure Inspection	Traverse City, Grand Traverse County, State of Michigan	3
Senior/Disabled Care Delivery	Wayne County, City of Detroit, Traverse City, Grand Traverse County, State of Michigan	2,3
Precision Agriculture	Private Ag Operators, State of Michigan	3

Stakeholders and Personas

From an operation, monitoring, and control perspective, the following stakeholders are the entities envisioned to participate in the MDOT BVLOS system.

Table 34: Stakeholder Identification, Roles & Responsibilities

Stakeholders/Personas	Roles/Responsibility
Operator	An Operator is the user preparing and submitting an operation to the BVLOS system. Provides efficient management of human, ground and airborne vehicles, and equipment to provide best possible business value to their customers.
Remote Pilot	The Remote Pilot is the user executing the operation and can change the operation status while an operation is in flight. A Remote Pilot can be the Remote Pilot-In-Command (RPIC). Conducts a UAS operation in the safest and efficient way practicable.
Electronic Observer (EO)	A person on the ground co-located with the RPIC who monitors the operational volume for intruder aircraft and informs/alerts the RPIC about the intruder and proposes evasive maneuverers. The EO monitors the status of services and can declare if surveillance and C2 link services are lost.
Mission Manager (Local Authority)	The Authority is the user processing authorization requests from UAS operators within a stakeholder organization and can create/manage dynamic restrictions/UAS Volume Reservations (UVRs). The Authority can be an Airspace Authority as part of the ANSP, a Public Safety Authority if part of a Public Safety entity, or a Government Authority if part of the Local/State Government. An Authority can have jurisdiction at the central (e.g., nationwide) or the local (e.g., county) level.
UTM Traffic Control Operator	The user responsible for monitoring the UAS traffic within the UTM Area
UTM Traffic Flow Manager	A user responsible for the safety and efficiency over a generic portion of airspace; mainly in charge of strategic and pre-tactical functions.
Risk Manager	A user responsible for the analysis and publication of the air and/or ground risks associated to a specific airspace volume.
Service Manager	The Service Manager is a user that monitors all metrics associated to the SLA, monitors operator operation demand and can verify the demand can be reached. The Service Manager maintains system capacity and can receive service tickets related with the SLA.
Registry Manager	A user managing the Registry of the system (i.e., approving/denying new operators on the system)
Law Enforcement Officer	A user in charge of enforcing laws, and can access the system to identify UAS and associated information
Maintainer/Admin (Level 1 support)	A user that follows maintenance procedures and troubleshoots to restore service upon failure. This user manages the maintenance plan, and can add/remove maintenance activities, as well as dispatch local maintenance teams to verify/restore remote infrastructure.
Level 2 support	A user that can look at log files and has the ability to

	restart a service if necessary. This user can escalate issues to level 3 support if necessary.
Level 3 support	A user that analyses Level 3 tickets and can propose workarounds/fixes to the root cause of the incidents.
Help Desk Representative	A user that analyses support tickets from external users and from the public. The Help Desk Representative can also classify support tickets by level and assess the priority of the support tickets. This user communicates the status of the support tickets to the client.

MDOT BVLOS System Context

The MDOT BVLOS system, illustrated in Figure 79, is predicated on deployed, operationally proven components engineered to provide BVLOS services, systems monitoring, test and validation, and operations support to Areas 1-3 within the State of Michigan. The remainder of this section provides a detailed description of the design and operations of the Thales proposed system and includes:

- A decomposition of the BVLOS system architecture into fundamental components, major hardware, and software components
- Interrelationships between major hardware and software components
- A service-to-function mapping
- An approach to interfacing with other systems and communications requirements

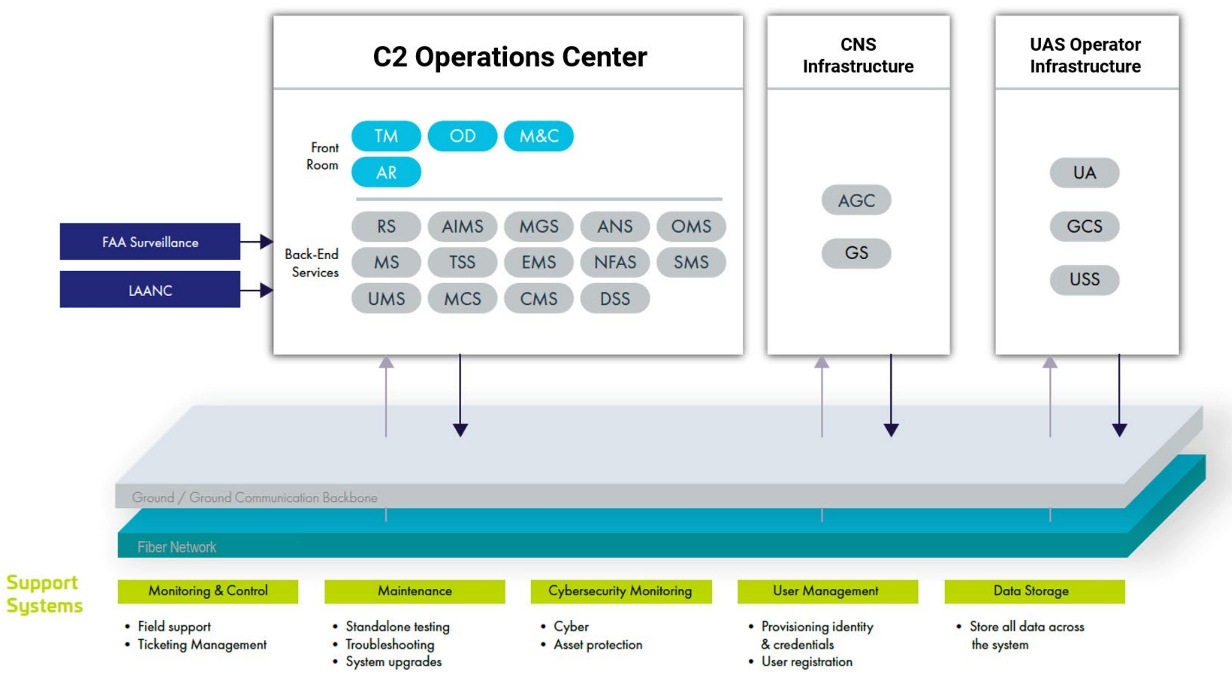


Figure 79: MDOT BVLOS System Architecture

The MDOT BVLOS system architecture features four operational systems to provision BVLOS services, support, and logistics. Each system leverages a communication backbone and a fiber network to deliver real-time and near real-time data exchanges between the systems. These include the C2 Operations Center; Communications, Navigation and Surveillance (CNS) Infrastructure, the UAS Operator Infrastructure and the Support Systems, as shown in Figure 79

C2 Operations Center

The C2 Operations Center is the core of the MDOT BVLOS system. It is comprised of the **C2 Operations Center Front Room** component which hosts the physical components that allow users to monitor and control all aspects of the system, and the **C2 Operations Center Back-End Services** which are implemented by a proven cyber-secured cloud (C2 Operations Center Cloud) infrastructure.

CNS Infrastructure

The CNS infrastructure includes the **Air/Ground Communication Infrastructure** enabling communications between the UAV and GCS, the **Ground/Ground Communications** which provides the backhaul network, and the **Ground-based Surveillance Infrastructure** providing detection and tracking of cooperative and non-cooperative crewed aircraft.

UAS Operator Infrastructure

The UAS Operator Infrastructure is composed of the UA, GCS, and optional USSs that elect to participate and operate within the BVLOS network. The UAS Operator Infrastructure is provided by UAS Operator flying the mission using the services provided by the MDOT BVLOS system and it is not described further in the remainder of the document.

Support Systems

Support Systems are comprised of all the transversal applications to monitor, control, and test the MDOT BVLOS system and are co-hosted by the same cloud as the C2 Operations Center Back-End Services.
The features and benefits of this architecture include:

- A full complement of support systems including monitoring, control, maintenance, test (which can also be achieved offline), training, and data archiving that ensures Operators and the MDOT can safely and effectively operate and maintain the system
- Scalable solution that provides end-to-end situational awareness through real-time monitoring of surveillance and communications infrastructure that can support the development of safety cases and approvals

Functional Descriptions

Thales will provide the necessary functions that satisfy the requirements for safe and efficient integration of BVLOS operations through the MDOT BVLOS system. Key functions include:

- UAS/Operator/Pilot Registration
- Operations Management through the C2 Operations Center

- LAANC Services provided via C2 Operations Center
- Provision of ground-based DAA
- Contingency Management by acting on actionable information such as infrastructure/system performance statuses plus NOTAM information

Table 35: Mapping between C2 Operations Center Services and Functions

Service	Functions
Registration Service (RS)	Operator Registration
	UAV Registration
	UAS Operator Approval
Aeronautical Information Management Service (AIMS)	Aeronautical Information Collection
	Aeronautical Information Distribution
	Traffic Flow Restriction Publication
	Airspace Restriction Creation
	Surveillance Coverage and Service Volume Publication
Authorization & Declaration Service (ADS)	Operation Authorization
	Operation Validation
Operation Management Service (OMS)	Operation Planning - Create Operation Intent
	Submit Operation Intent
	Operation Intent Modification
	Flight Event Notification
	Submit Operation Cancellation
	Operation Cancellation
	Operation Completion Acknowledgement
UAS Monitoring Service (UASMS)	Pre-process UAV Telemetry
	UAS Conformance Monitoring
Traffic & Surveillance Service (TSS)	Surveillance Data Processing
	UAV Position Collection
	Traffic Distribution
Emergency Management Service (EMS)	UAS Alerting and Coordination
	Emergency Chat
	Flight Information Service Provision - Distribute Conformance Monitoring Alerts to Authorities
	Flight Information Service Provision - Distribute Authorization Status

	Flight Information Service Provision - Distribute System Health and Status Information
User Management Service (UMS)	Identity & Credential Provisioning
	User Authentication
	Client Authentication/Authorization
	UAS Operator User Creation
	Authority User Creation
	System Performance Reporting (manual)
Monitoring & Control Service (MCS)	System Health Data Collection
	System Control
	System Health Data Distribution
	System Health Data Processing
	System Health Data Display
Maintenance Support Service (MSS)	Perform Test/Troubleshoot/System Upgrade
Cybersecurity Monitoring Service (CMS)	Cybersecurity Monitoring
	Cybersecurity Incident Response
Data Storage Service (DSS)	Data Storage
Customer Support Ticket Service (CSTS)	Support Ticket Request
	Ticket Management
	Dispatch Maintenance Action
G/G Communications Infrastructure	Ground/Ground Communication
C2 Link Management Service (C2LMS)	C2 Link Management
A/G Communications Infrastructure	Air/Ground Communication
Ground-based Surveillance Infrastructure	Detect and Track Cooperative Aircraft
	Detect and Track Non-cooperative Aircraft

Functional Architecture Decomposition

UAS Infrastructure Command and Control Operations Facility

UAS Infrastructure Command and Control Operational Location

Site	Type	Emplacement (Lat/Long)
Command and Control Operations - Michigan Central Station	Existing physical infrastructure (building)	-83.077751, 42.328725

The UAS Infrastructure Command and Control Operations Center provides the facility and resources necessary to support statewide UAS infrastructure operations and services. Key evaluation criteria considered for the location of the C2 Operations Center include resilient power utilities, water utilities, direct access to fiber optics network, physical security controls, structural suitability for staff workspace and equipment, committed facility funding and investments, immediate proximity to service area, and immediate proximity to stakeholders, activities or initiatives the C2 Operations Center supports. Preliminary review of potential locations for the C2 Operations Center resulted in the identification of a representative candidate site at Michigan Central. While Michigan Central meets all the initial selection criteria a more exhaustive site selection study is recommended to be conducted as part of the infrastructure design process.

The Michigan Central location is also ideal in housing the Regional UAS Operationalization and Commercialization Center (RUOCC) for the Southeast Region of Michigan. The RUOCC would provide the facilities necessary for UAS industry stakeholders (i.e., UAS OEMs, Service Providers, Pilots, et) to conduct full testing and operational approval activities for the use cases of interest that are well suited to the region while also providing an immediate path to commercialization within the area once approval is obtained. Additionally, locating the RUOCC at Michigan Central would foster collaboration between UAS initiatives and other transportation innovation activities that ensures comprehensive integration of UAS with all modes of current and future transportation. The location is also optimal given its proximity to current and future cross border assets (i.e., Windsor Bridge, Gordy Howe Bridge, Canada Pacific Tunnel, Windsor Detroit Ferry Crossing, et) and facilities (US Customs Port of Entry) that are key to cross border UAS operations. Finally, Michigan Central is also strategically located within immediate proximity to the initial corridor service area proposed for Areas 1 and 2.

The preliminary review for the RUOCC in Area 3 led to identifying Northwestern Michigan College (NMC) campuses as a viable representative site candidate. As with the Michigan Central site Northwestern Michigan campus locations and facilities meet all key evaluation criteria and leverages current academic programs and activities well aligned with the objectives of a RUOCC including mature aviation and UAS programs. Additionally, NMC has already taken steps in integrating UAS into other academic domains such as plant science which aligns well with the use cases (i.e., precision agriculture, public safety, maritime, et).

An example floor plan is shown in Figure 78 to provide a conceptual representation of what a C2 Operations Center or RUOCC Center Facility and Floor plan may look like. Exact details would require conducting a design process involving key stakeholders (i.e., Facility Owner, Operations and Maintenance Team, System Engineers, et).

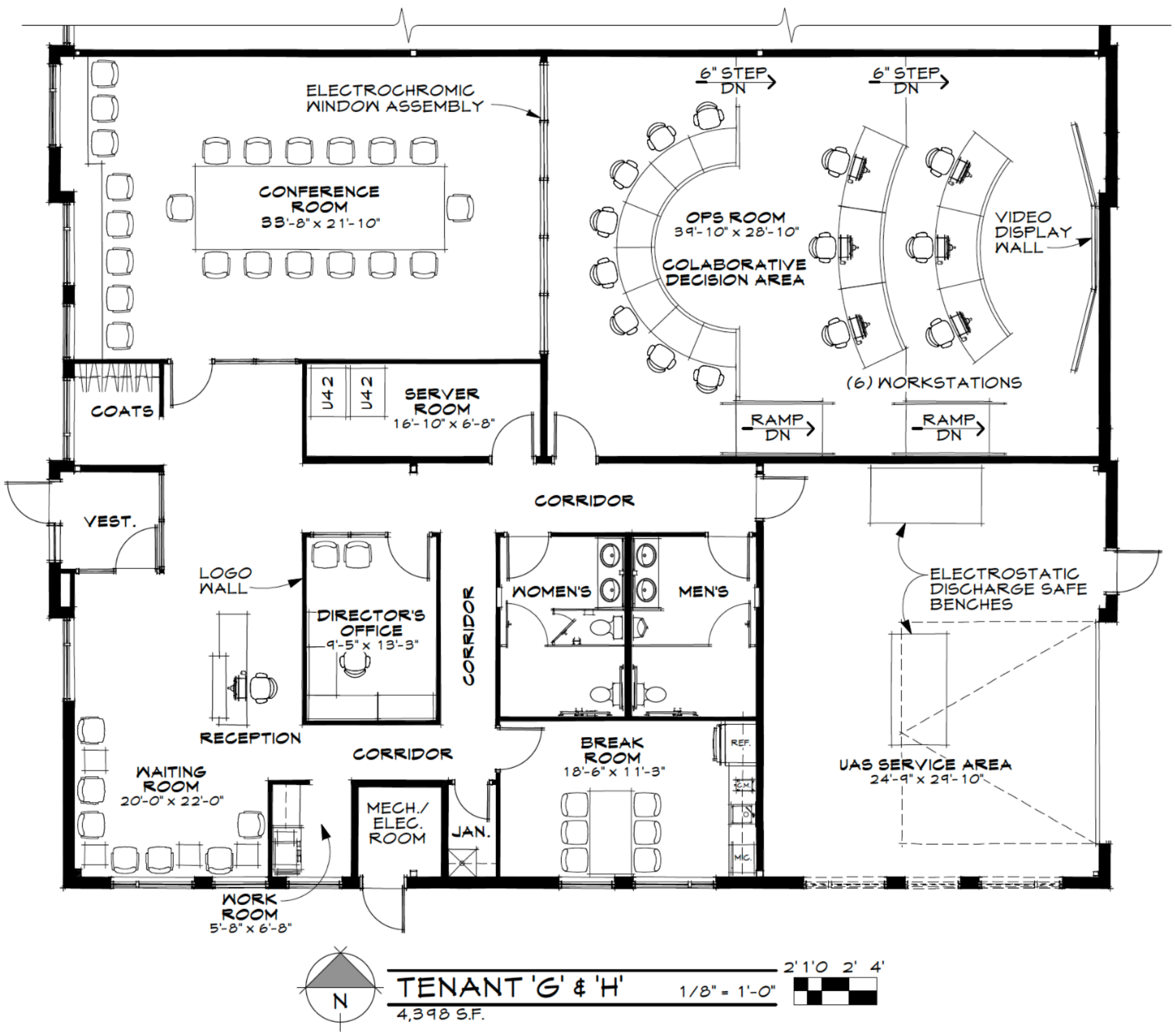


Figure 80: Example of Floorplan for C2 Center and Space Utilization

The main areas of the C2 Operations Center are the operations center, a conference room, a UAS service area, a server room, a waiting area, a break room, and the restrooms. Badge access is envisioned into the operations room, the conference room, the server room, and into and out of the drone repair area. The perimeter of the building will also be secured with the exception of the main entrance.

Operations Room

The Operations Room includes a horseshoe table with seating for 8 people at the Collaborative Decision Area, and 6 workstations for the RPICs (Remote Pilot-In-Command). Both the Collaborative Decision Area and the workstations have a direct line of sight to the large video display wall through the use of a tiered floor approach, while utilizing ramps to maintain ADA compliance. The Collaborative Decision Area of the Operations Room is envisioned to have audio/visual conferencing capabilities, a projector, and a web camera.

Server Room

The Server Room is just west of the Operations Room and is climatically separate from the rest of the building. It is envisioned to have secured access door with restricted permissions. It has been specified to include two full-size 42U server racks with a dedicated server room climate controlling air conditioner (not shown in model). The Server Room is large enough to accommodate an additional full-size server rack and scale through the various phases to match the build out of the MDOT BVLOS. The air conditioning unit will be specified to adequately cool the expanded Server Room.

Conference Room

The Conference Room allows for the seating of 14 individuals around the conference table, and 8 additional seats with a continuous work surface along the west wall. The seating along the west wall serves dual purposes: additional seating for large conferences; and a work area for people to use who are visiting the facility. The Conference Room will also double as a viewing area for tours with an electrochromic window overlooking the Operations Room. Lastly, the Conference Room will be fully equipped with audio/visual equipment and video conferencing capabilities for presentations and collaboration.

UAS Repair Area

Utilizing the existing overhead door on the East side of the facility, the UAS service area is able to service large platforms, if needed, and can also serve as a storage area for tools, equipment, battery chargers, and hazardous items. Two electrostatically protected workbenches with necessary tools and equipment are included for electronics repair.

Table 36: Example C2 Room Breakdown

Room	Position	IP Ports	VoIP	Power Receptacles	Collaboration Table	Conference Table	Small Table	Desk	Chairs	Video Conferencing	4’ x 8’ ESD Bench	Standard ESD Bench	ESD Chair
Lobby	Receptionist	1	1	4				1	1				
	Waiting Area			6			4		7				
Break Room	All			8			1		6				
Ops Room	Collaboration Area	8		8	1				8	1			
	Workstations	6	6	12				6	6				
Director’s Office	Director	1	1	6				1	3	1			
Conference Room	Conference Table	6		16		1			22	1			
UAS Service Area	UAS Service Bench	1		4							1		1
	Electronics Repair Bench			4								1	2

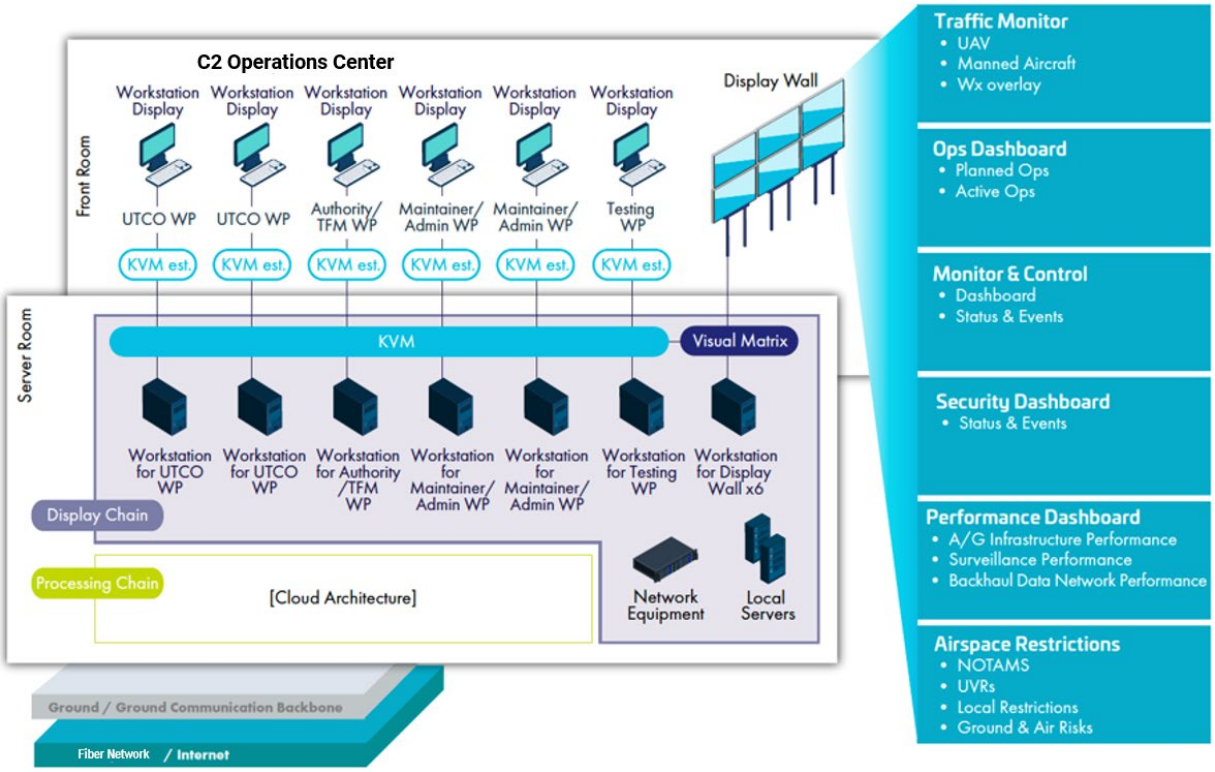


Figure 81: Example C2 Workstation Networking

Video Display Wall System

Functional description:

- Display the contents of several sources of information available in the operations center
- Administered by a local supervisor position fitted with a 31.5” display and wireless control facility for remote users (e.g.: display of the Video Wall information in a remote location like the adjacent offices).

Table 37: Example C2 Display Equipment

Component	Description	Qty	Location	Working Position
19" 42U* server rack	Servers, switches, Routers Equipment rack	1	Server Room	
Video Wall Management subsystem	Graphical/Video CPU and Interfaces Management	1		
KVM extender		2		
LAN Switch 24 ports		2		
Time Distribution System	NTP Time Server	1		
Supervision and Control Position	32" screen with keyboard and mouse	1	Operations Room	Ops Table
Video Wall Control	Wireless Control Position	1		Ops Table
Video Wall	55" screen	6		Ops Table
Display	55'' UHD screen with keyboard and mouse	4		Ext. Tables
Video conference	Camera	1		
Display	75'' HD Smart screen (1920 x 1080 60 Hz)	1	Conference room	
Video conference	Camera 55'' UHD	1 1		

C2 Operations Center Back-End Cloud Services

The MDOT BVLOS C2 Operations Center services are provided as software-as-a-service (SaaS).

Thales has invested heavily in secure, cloud-based applications that incorporates many advancements that we have seen in aerospace, space, ground transportation, security, and defence to find specific ways to make sense of our customers' data. The Project Team foresaw a major shift in the industry from closed systems to an internet of things (IoT) where connectivity and data sharing would be essential. This shift towards "big data" and cloud-based solutions has formed the basis for our approach to UTM and other key aviation related digital services.

The global approach is structured around closely interconnected themes:

- Big data (data management and storage)
- Data Analytics (processing, enrichment, and value creation)
- Visual Analytics (interactive visualization of datasets)
- Domain specific later: application and services (Uncrewed Traffic Management, Air Traffic Flow management, etc.)

These applications are built around large numbers of microservices, logically structured in a 3-layer platform. Microservices collect and process data sources such as surveillance, aeronautical information, community-based constraints, and terrain information and sources (radar, satellites, UAV) that generate large amounts of data. This ensures scalability, reactivity to customer needs, and maintainability. The collection, integration, processing, and storage of these data elements drove the need for new storage and processing technologies as well as innovative algorithm solutions to take advantage of all the available sources. Table 38 shows the main technologies employed to implement the services described in the following sections:

Table 38: Example Technologies Applicable to C2 Operations Center Back End Services

COTS	Description
Continuous Integration/Continuous Development (CI/CD) Pipeline	
Jira	Jira is used to plan, track, and release the system software
Jenkins	At the core of the CI/CD pipeline, Jenkins is an extensible automation server, used to perform both continuous integration and continuous delivery hub
SonarCube	Main tool to measure and guarantee code quality and security
Ansible	Automation of application deployment to cloud infrastructure
Terraform	Used to create, change, and improve cloud infrastructure
Operational	
PostgreSQL	Main repository for the registry, user management and all operation related data
Zabbix	Monitoring and Control tool
Kafka	High scalable and resilient message broker
Kubernetes	Host, scale, and manage all containerized application (containers are in Docker format)
Spark	Used for batch and real time analytics on stored data
Elasticsearch	Search and analytics engine used to manage centralized logfiles
Grafana	Used to create effective and user-friendly dashboards

COTS	Description
Docker	Used to build containers running on Kubernetes
Azure Monitor	Tool suite for all that is related to monitor resources in the Azure cloud
Keycloak	Identity, Authentication, and Authorization engine
Azure Data Lake	Allow scalable storage and organization of any structured and unstructured data; highly integrated with analytics tool as Spark and Storm
Azure DNS / Directory	Solution domain name server used to resolve all system endpoints (URL) from internet client
Azure API Management	Allow scalable API management: accelerated API discovery, allow for data and services to be selectively exposed to users
RabbitMQ	AMQP/MQTT message broker

MDOT BVLOS C2 Operations Center Cloud Description

Figure **82**, below, shows the cloud infrastructure hosting all MDOT BVLOS C2 Operations Center services.

MDOT SWNC C2 services.

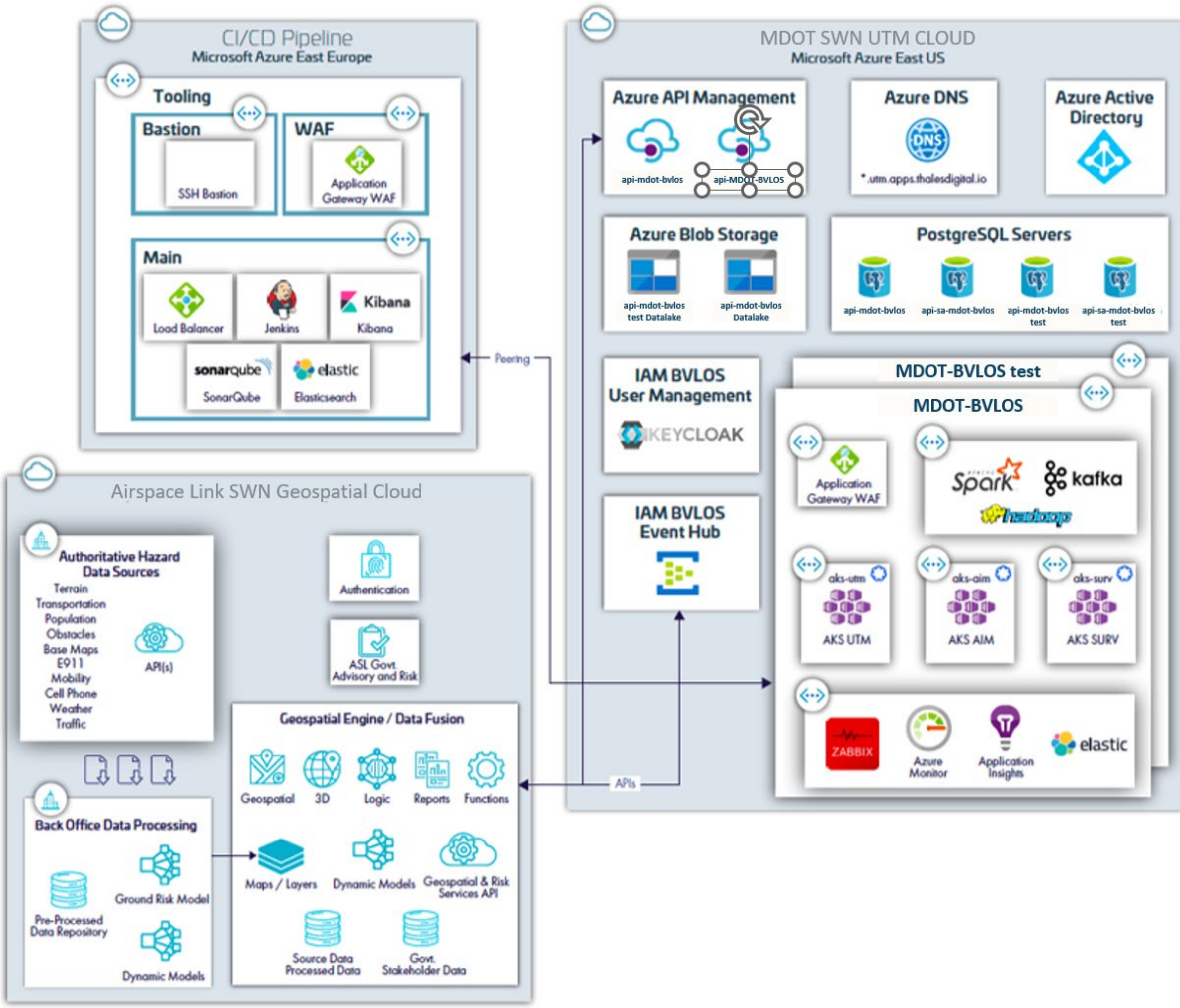


Figure 82: **MDOT BVLOS C2 Operations Center Cloud Architecture**

Thales CI/CD Pipeline

The Project Team solution for UAS integration maximizes the availability of new technologies by implementing a continuous integration and development (CI/CD) pipeline, deployed within the Microsoft Azure East Europe region, which allows for remote maintenance and software upgrades of the MDOT BVLOS system via a secure cloud-to-cloud peering connection. The CI/CD environment is highly automated, allowing a new software baseline to be automatically deployed without any local intervention once the new code is tested and validated according to the quality management process. The CI/CD pipeline allows for the introduction of new capabilities, upgraded features, and bug fixes throughout the lifecycle of the program.

Thales MDOT BVLOS Network UTM Cloud

The MDOT BVLOS Network UTM cloud is the set of Azure cloud resources instantiated in the US to host the UTM product implementing all operational and the test capabilities required by the MDOT BVLOS C2 Operations Center. The cloud security configuration and data segregation policy ensure MDOT BVLOS data are isolated and stored in the U.S. and can be accessed only by personnel in the U.S. or otherwise authorized by the MDOT.

The Project Team proposes to deploy two cloud environments - operational and test. A software release process will be developed and agreed with MDOT to align software lifecycle practices with the overarching safety management system. New releases of software will be evaluated on the test platform before deployment onto the operational platform. Leveraging cloud functionality, these environments can be automatically deployed and only operated as needed thus the test environment will only be running when needed to reduce cloud resource consumption and cost.

The C2 Operations Center test services are used both for troubleshooting of locally raised issues and as a validation platform for a new software baseline before deployment to the operational platform. Strict quality rules require all new software to undergo code quality rule checking and unit testing. Quality thresholds need to be satisfied for the code to be merged into product baseline and deployed to the Quality Assurance environment.

Airspace Link MDOT BVLOS Geospatial Cloud

Conducting BVLOS operations at low altitude requires new geospatial data sources and increases to the level of detail to existing data sources (e.g., terrain), compared to traditional Air Traffic Management systems. Consequently, integration between geospatial services and more traditional airspace information management services is necessary to support UAS operational planning and ground risk assessment. Airspace Link's C2 Operations Center components supplement Thales' services with specific applications and experience dedicated to geospatial information management services.

Implementation Services for the MDOT BVLOS C2 Operations Center

This section describes the cloud-hosted software applications and services that will comprise the MDOT BVLOS Network and be managed through the C2 Operations Center.

The following table lists the services that the MDOT BVLOS C2 Operations Center will offer, via APIs, to registered users.

Table 39: C2 Services Available to Registered Users

Services	Description
Operational Services	
Registration Service (RS)	A service that allows a UAS operator and/or pilot to register themselves and their UAS, and UAS-related data including equipage, performance, and any certification/airworthiness classification. The Registration Service should also include a query capability enabling authorized stakeholders (e.g., Authority, Regulators, Police/Public Safety personnel) and other UTM services to request registration data.
Aeronautical Information Management Service (AIMS)	A service that enables the distribution of aeronautical information/data necessary for the safety, efficiency, economy, and regularity of a UAS operation. Aeronautical information can include static (i.e., airport-heliport/facility, airspace classes and boundary/CTZ, UAS Facility Maps, SUA/FUA/SAA, National Security UAS Flight Restriction Areas/No-fly Zones, etc.) and dynamic airspace restrictions/constraints (TFR, NOTAM, SUA/FUA activation, UVR/emergency volume restriction).
Authorization & Declaration Service (ADS)	Authorization Service: A service that allows a UAS Operator to obtain airspace authorization(s) from the designated Authority(ies) as required by the rules and regulation published by the country. Notification service: A service that allows a UAS Operator to voluntary notify the authorities about an operation in areas when authorization is not required (i.e., uncontrolled airspace). The overall Authorization/Notification service includes the following functions: -Authorization and Notification Request -Operation validation and authorization request routing to the relevant authorities -Authority HMI access -Operation/authorization query, filter, report -Authorization approval/denial/revocation -Operation clearance management
Operation Management Service (OMS)	A sub-service within the Mission Management Service that allows the exchange, sharing, and synchronization of operation data among all stakeholders
UAS Monitoring Service (MS)	Monitoring service encompasses both Conformance Monitoring and CNS monitoring. Conformance Monitoring is a service that provides real-time monitoring and alerting to a UAS operator of non-conformance to intended operational volume(s), route/trajectories (i.e., path), violation of airspace restrictions, and to rules and regulation. CNS Monitoring is a service that provides real-time monitoring and alerting of required CNS infrastructure status within the UTM service area.
Traffic and Surveillance Service (TSS)	The Tracking and Surveillance service provides a seamless air traffic situational picture including both UAS and crewed aviation traffic; this service feeds the monitoring and the separation management service (e.g., GBDAA). The service includes the following functions:

Services	Description
	-Tracking: locating, identifying, and tracing individual UAS -Traffic distribution -Surveillance: target location, identification and independently tracing information from the aircraft/UAS -Multi-sensor fusion/classification The Traffic Information Service is a sub-service that provides the UAS operator with information on other known or observed air traffic which may be in proximity to the position or intended route of the UAS flight to alert and to help the UAS operator to avoid a reduced separation event.
Emergency Management Service (EMS)	A service that allows a UAS operator, pilot, and authority to communicate and collaborate about an emergency occurring during the flight. This service includes the following functions: -Emergency Reporting (for operator/pilot/public to report an emergency situation) -Emergency Message Broadcasting -Chat
Notification / Flight Advisory Service (NFAS)	A service that provides on-demand, periodic or event-driven information and message exchange of UTM operations occurring within the UTM airspace volume to all users including the UAS operator and authorities.
Support Services	
User Management Service (UMS)	A service that allows all stakeholders to register to the UTM system in order to receive services. This service also provides identity and access management (IAM) and credential management.
Monitoring & Control Service (MCS)	A support service that provides the monitoring of individual health information for communication, navigation, and surveillance (CNS) infrastructure.
Cybersecurity Monitoring Service (CMS)	A support service that provides the monitoring of potential internal and external vulnerabilities, and the overall system cybersecurity status measured against standardized security controls and protocols.
Data Storage Service (DSS)	A support service that provides the capability to capture and archive all data (e.g., recordings, playback) in transit between systems/across the APIs.

Registration Service

The Registration service will allow UAS operators to register themselves and their aircraft with the MDOT BVLOS, in a 1:M relationship (i.e., one operator can register multiple aircraft). All personally identifiable information (PII) data collected is stored in the U.S. and used by the MDOT BVLOS Network to validate users and authorize operations.

User Management Service

The User Management service is implemented using Keycloak. Keycloak is a proven Open Source Identity and Access Management providing Single-Sign On, LDAP and Active Directory integration, support for Standard Security protocols such as OpenID Connect, OAuth 2.0, SAML 2.0 and User federation. Keycloak Authorization Service supports fine-grained authorization policies and access control mechanisms such as:

- Role-based access control
- User-based access control
- Context-based access control

This allows the system to grant access to protected resources in a configurable and flexible way.

Operation Management Service

The Operation Management service is the entry point for all operational-related functions.

The service implements the following:

- Verification that the operation intent is properly formatted
- Storage of the operation
- Operation status management
- Route operation intent to the validation and the authorization/notification service
- Support operations query and sharing from authorized users

Authorization & Declaration Service

The Authorization and Notification Service allows the system to validate and authorize operations based on a set of rules that can grow as the BVLOS technologies and associated regulations and standards mature.

At the core of Project Team's UTM vision is the ultimate capability for UAS Operator to plan any operation in any UTM assigned airspace and obtain an authorization automatically, no matter how complex the operation is. Although this is possible today for simple operations, such as FAA Part 107 flights below UASFM threshold, the team believes that the progressive implementation of performance and risk-based sets of rules will enable more advanced automatic authorizations.

This service is composed of a rules engine and an orchestrator that, based on the country and type of operation, verifies if the operation intent supplied by an operator, either directly or via a USS, complies with a set of predefined rules. It then determines if the operation can be automatically approved and the authority(ies) responsible for the authorization. If the operation requires manual authorization, an authorization request is sent to one or more authorities involved in the approval process.

The FAA's LAANC service requires Part 107 Further Coordination requests to the be sent to the FAA via the LAANC-AP service for manual approval when the operation does not meet auto-approval criteria.

The UTM product roadmap includes two additional concepts toward this goal:

- Local authority(ies)
- Performance-based rules

A local authority is an entity that can approve a complex operation not currently meeting the criteria for an electronic submission by country rules, but that can be legally flown under an operator-specific certificate such as a COA, a Part 107 waiver, or in the future what the FAA ConOps refers to as a Performance Authorization. The authorization process is applicable within the operator approved airspace volume(s). The local authority concept allows the definition and implementation of a set of performance-based rules in a controlled and safe manner.

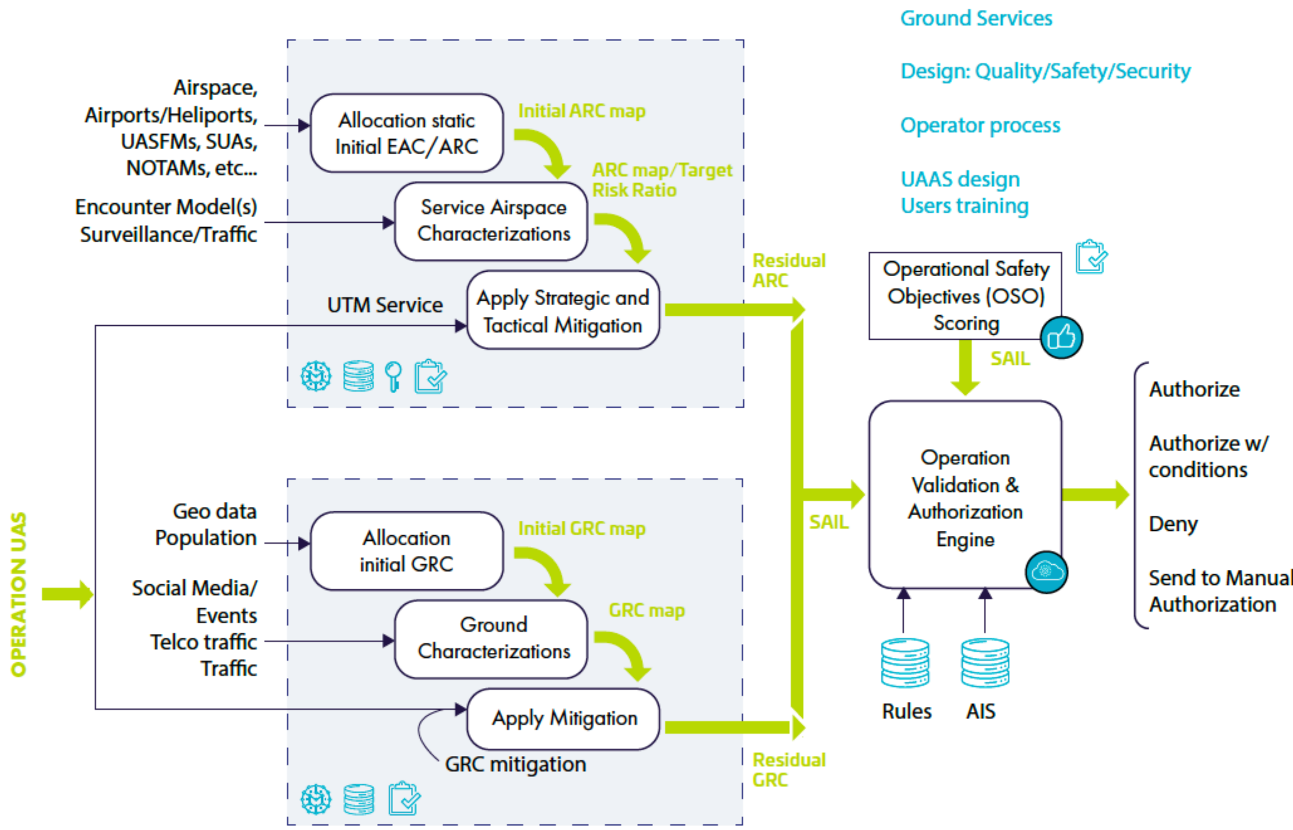


Figure 83: Concept for a Performance-Based Authorization Rules Engine

A performance-based set of authorization rules is a set of rules allowing an operation to be authorized when the risks associated to the operation are below a configurable risk target derived from a safety assessment. The idea, derived from the JARUS SORA 12-steps risk assessment process, requires the capability to automatically assess the operations air and ground residual risks and the availability of the data in electronic format for the system to assess the safety and robustness level of the service, processes, and procedures used by the operator to execute the flight.

Like SORA, the FAA's UAS Safety Risk Management (SRM) Policy Order 8040.6, discusses the essential elements that must be addressed to be granted a waiver for BVLOS operations. The same elements can be used in real-time to quantify risks associated to a specific BVLOS operation to determine if the operation should be authorized.

Safety risk analysis is based around the determination of the severity and the likelihood of hazards, all UAS operational conditions being equal. The severity of the hazards can be considered constants, so likelihood is the key factor to be estimated (e.g. the probability of an encounter between UAS and a crewed aircraft).

The likelihood of the hazards is highly dependent on the specific environment and airspace context and can change dramatically depending on a variety of factors, such as time of day. A static process like the SRM will never capture such variability and will tend to always determine the worst-case scenario, potentially not allowing the full capacity of the airspace to be used.

To illustrate the point, the likelihood of a reduced separation event can be reduced using two techniques:

- A measurement approach using surveillance to detect and track all surrounding aircraft and obstacles
- A probabilistic approach based on the forecast of surrounding aircraft and obstacles

While the first approach requires the MDOT BVLOS to deploy a ground-based surveillance infrastructure, the second approach requires the collection and analysis of a huge amount of data. Therefore, Thales believes a hybrid approach is best suited. This will save on the cost of instrumenting all possible BVLOS operational areas while also collecting data and experimenting in a specific location.

The following capabilities are proposed:

- Validation and routing of Part 107/44809 authorization requests to the FAA (as part of the LAANC service)
- Implementation of an initial set of COA rules
- Manual authorization of COA operations requests by a C2 Operations Center Authority user

The initial set of COA rules are proposed to include:

- Verification the operator is allowed to use the COA via the Registry service
- Verification the operation volume is compatible with the COA geographic limitations
- Verification the UAS used is registered and compatible with COA

Notification/Flight Advisory Service

This service provides APIs for the UAS operator and pilot to receive informational alerts associated with their planned operation during the pre-flight phase, as well as notifications during in-flight operations. The following is a sample list of notifications and/or advisories provided in this service:

- Operation authorization status and results
- Strategic de-confliction requests
- Operation non-conformance warning/alert
- Operation cancellation requests
- Emergency restrictions notification
- Restriction update notification

AIM and Notification/Flight Advisory services

Providing all participating UAS operators with a single authoritative source of up-to-date and consistent aeronautical information and relevant airspace restrictions is an important safety mitigation. As an example, it reduces the risk of an operator missing a flight restriction or multiple UAS operators trying to deconflict operations while not using the same airspace restriction data as the baseline for the deconfliction.

The AIM and Notification/Flight Advisory services maintain a database of all necessary airspace information to plan and conduct a safe flight, to include:

- Airspace Class
- Airspace Boundary
- Airports/Heliports
- UAS Facility Maps (UASFM)
- National Safety UAS Flight Restrictions (NSUFR)
- SUA
- TFR
- Local restrictions and emergency volume reservations

The AIM service gathers the authoritative airspace data from the following sources, which are the same as those prescribed by the FAA for the LAANC system:

- FAA Aeronautical Data Distribution Service (ADDS)
- FAA UAS Data Distribution Service (UDDS)
- FAA Web NOTAM
- FAA SUA schedule

Automated test scripts are used to check the data for correctness before being published to the API. The system allows for manual intervention in case of errors.

The Notification/Flight Advisory service allows local agencies/governments to create and distribute emergency or locally created restrictions in a timely manner to participating users of the MDOT BVLOS Network. Information can be queried by all authorized users. Upon creation of a new, or modification to an existing restriction, the system verifies the impact on all open UAS operations planned in the system service volume and informs affected operators of the need to cancel or amend their operation.

Monitoring and Emergency Management Services

These services directly support C2 Operations Center users maintaining the safety and efficiency of the MDOT BVLOS airspace volume. The position of each UAV is monitored against the shared operation intent 4D volume(s) to warn about potential loss of UAS control. An operational dashboard is provided to support decision about availability of the A/G communications and Tracking/Surveillance services. A chat feature allows C2 Operations Center users to collaboratively resolve emergencies and non-nominal situations with UAS operators and in the future with ATC (as required).

Tracking and Surveillance

Tracking and Surveillance component inherit decades of Thales experience delivering Air Traffic Control safety critical systems to hundreds of countries worldwide.

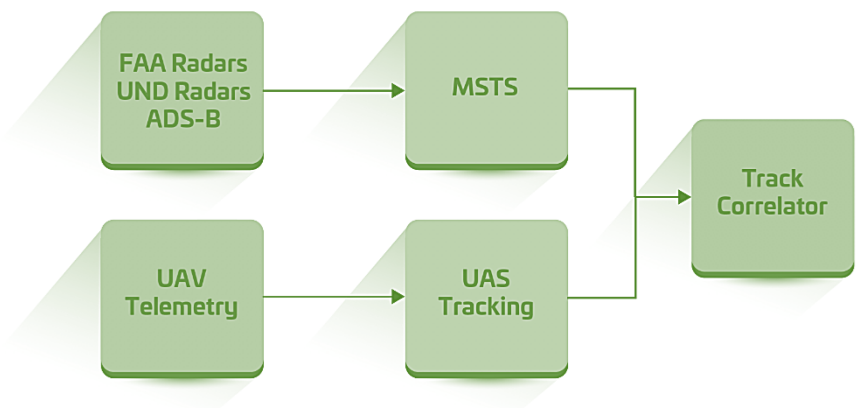


Figure 84: **Tracking and Surveillance**

The tracking and surveillance function combine all received data pertaining to a single aircraft into a single surveillance track.

The surveillance function supports wide range of services:

- Surveillance track distributions in broadcast and/or radar synchronized and/or area modes
- Sensor management and sensor state distribution,
- Flight plan and UAS Operation data enrichment association,
- Bias registration,
- Multiple levels of filtering criteria (e.g., volume processing, 24-bit ICAO address exemption list, GBS flag).

The Multi Sensors Tracking System (MSTS) is dedicated to co-operative and non-cooperative crewed aviation traffic and designed to support Air Traffic Management separation services, while the UAS tracking components handles co-operative and non-cooperative UAS.

Filtering
The sensor acquisition allows the filtering of the validated messages based on off-line, user-defined geographical and height filters considering the detection characteristics of each surveillance source and the operational condition of use. These filters are generally based on the surveillance source range, area of interest, and blanking areas. An off-line user-defined global surveillance area is applicable to all surveillance sources.

Surveillance Source State Monitoring
The surveillance source state management is performed at the sensor data acquisition. It calculates the technical state of each surveillance source. The Technical Supervisor may use this technical state for maintenance decisions and/or operational decisions, such as to use or not surveillance data received from a specific surveillance source (i.e., to detach a surveillance source).

The technical state of each sensor is continuously check by analyzing the data received from the surveillance sources. The Real Time Quality Control (RTQC) is assessed for each surveillance radar interface: the continuous checks include data format compliancy, data counting for pre-overload and overload, radar head status management (when possible), radar period assessment, Mode 3A code validity assessment, test target and site monitor failure, time drift, bias evaluation.

Statistics and Alerts on Received Sensor Data
Various statistics are performed on the received sensor data and raises alerts when these are out of defined bounds.

Statistics gathered are:

- The count of plots, tracked plots, and tracks received per surveillance source for a specified period (user-defined for each source).
- The computed time delay on the radar lines

Alerts are raised when:

- An excessive reception rate of plots, tracked plots, and tracks is detected
- An excessive number of invalid plots, tracked plots, and tracks is detected
- A radar data overload is detected in a sector and/or in an antenna revolution
- A radar time drift detection (above a user-defined threshold) is detected

General Processing

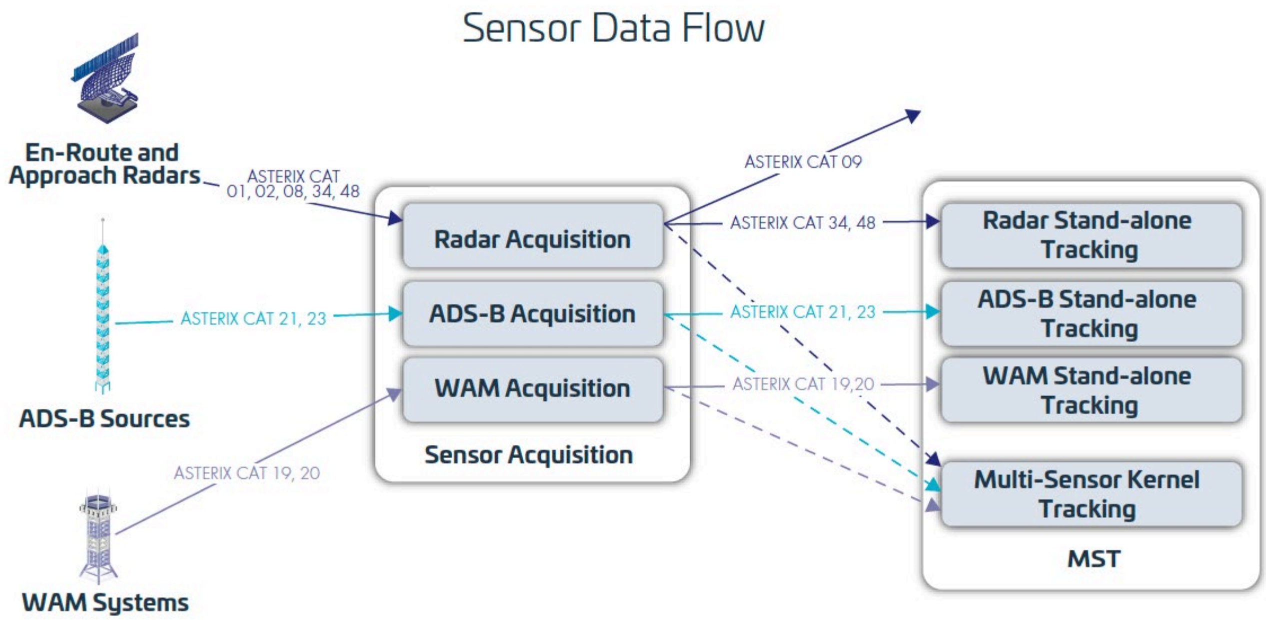


Figure 85: Sensor Data Flows

The Multi Sensor Tracking function processes radar reports, ADS-B reports, WAM reports and Mode S DAPs (when and if available) in the following way:

- Multi-radar stand-alone tracking: dedicated processing on radar data is performed to check the consistency and integrity of incoming radar reports.
- ADS-B stand-alone tracking: dedicated processing on ADS-B data is performed to check the consistency and integrity of incoming ADS-B reports (blunder detection). This processing is used in parallel with a consistency check with a multi-radar stand-alone track state vector to realize data sources cross-checking.
- WAM stand-alone tracking: dedicated processing on WAM data is performed to check the integrity of incoming WAM reports. This processing is used in parallel with a consistency check with a multi-radar stand-alone track state vector to realize data sources cross-checking.
- DAPs checking: each DAP related to the aircraft kinematics information used in tracking function is checked for reasonableness. DAPs from Mode S radar are checked according to the multi-radar stand-alone track state vector, DAPs from ADS-B are checked using an ADS-B stand-alone tracking. When DAPs are provided by a WAM system, they will be processed in the same manner as Mode S in a multi-sensor (radar and WAM) environment. In a WAM only environment, DAPs are checked using WAM stand-alone tracking.

After the consistency check has been performed, the multi-sensor data (radar reports, ADS-B reports, WAM reports and Mode S DAPs) is then processed in the Multi-Sensor Kernel Tracking function.

- Multi-sensor track update: After an association step, sensor reports update the surveillance track, using the position measurement of the sensor report, according to the sensor type:
- Measurement vector of a radar report is composed of the range, azimuth, and barometric altitude components.

- Measurement vector of an ADS-B report is composed of the latitude, longitude, and either geometric or barometric altitude.
- Measurement vector of a WAM report is composed of the latitude, longitude, and either geometric or barometric altitude.

The multi-sensor IMM filter uses the kinematics DAP either by:

- Integrating consistent on-board kinematics data directly in the filters, or
- Using the DAPs to dynamically adapt or trigger existing data fusion algorithms.

The intent is to provide the best tracking result using radar, ADS-B and WAM reports by optimizing the fusion after matching the surveillance track to the sensor reports. Bias registration is based on automatic assessment and is used for correcting the radar reports before tracking. The manual mode and command operator for mode switching are supported. The QNH correction of the barometric altitude is performed within QNH areas, below the transition level.

The proposed radars will utilize Asterix category 034 messages for built-in test reporting and Asterix category 048 messages to report target states to the MSTS.

Traffic Distribution

The traffic distribution allows external users to access the output of the tracking and surveillance service. This capability provides selective data distribution based on user access rights.

Government Stakeholder Tools

Figure 86: **Authoritative Stakeholders**

C2 Operations Center government stakeholders will be supported with the cloud-hosted and web-based AirHub Connect solution. AirHub Connect merges the needs of state and local government stakeholders with the operational planning and authorization capabilities in the proposed UAS flight operation planning tools or existing LAANC USS applications. AirHub Connect will provide stakeholders such as emergency responders, public administrators, legal officials, and event managers the means to create, schedule and publish dynamic ground-based hazards, advisories, and event/incident notification information.

Information generated by stakeholders using AirHub Connect is directly fed into the geospatial engine via APIs to be broadcasted to the BVLOS system or LAANC USS applications and applied to map visualizations of the operational environment. The information also feeds into risk modelling, risk mitigation, flight planning, and pre-flight checks. The advisories and notifications may include information about sensitive facilities (i.e., prisons, critical utility assets, stadiums), events related to dense populations or security (festivals, outdoor sports events, official gatherings), and activities (i.e., infrastructure inspections, emergency management, official exercises) that a stakeholder deems to be a pertinent factor to managing UAS activities.

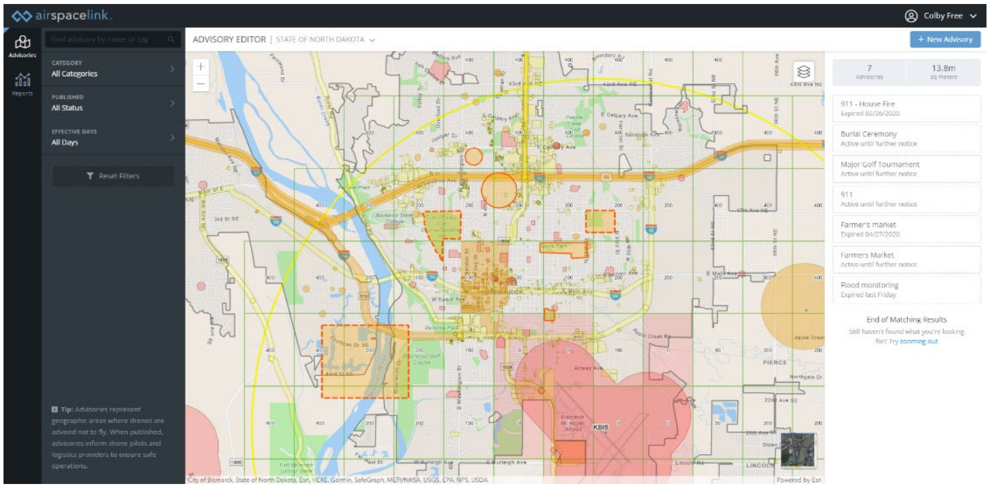


Figure 87: AirHub Connect C2 Stakeholder Advisory and Notification App

Environment Hazard & Ground Risk Data Sourcing and Modelling

The Project Team evaluates several domestic UAS regulations, guidelines, and studies to identify data requirements and developed a low-cost, high-efficacy method to source and process data to be applied to SORA-based air-to-ground, ground-to-air, and air-to-air hazard identification and risk analysis. The data requirements are categorized into three primary groups that can be applied to Holistic Risk Modelling (HRM): System, Operational Plan, and Operational Environment. The requirements list is mapped to candidate data and data sources to be evaluated and deemed viable based on key criteria (i.e., coverage, completeness, integrity, fidelity, resolution, format, authoritative source, etc). Many of the data requirements that called for external sources fall into the Operational Environment category.

Figure 88: **Authoritative Hazard Data Sources**

External Data sources are organized into three primary categories: Public, Commercial, and System. Public sources are comprised of data sets that originate from federal, state, local and tribal entities that are designated the official authority of the data, content, and subject matter.

When public data are not available, the process then turns to commercial data putting them through a similar viability assessment including additional commercial factors such as cost, company health and licensing constraints. Examples of commercial data include mobility, traffic, and micro weather data. System sources account for the majority of the dynamic, near real-time data (i.e., telemetry, network health), operational outcomes (i.e., events, incidents) and relevant messages and notifications from stakeholders.

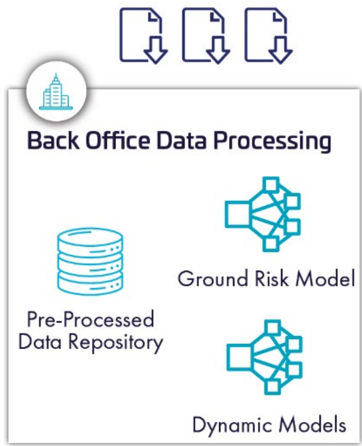


Figure 89: **Back Office Data Processing**

After identifying the sources, the process applies automated and scalable methods to access and transfer the data from the authoritative source via APIs or file repositories to a back-office cloud based repository for updates, pre-processing and publication to hazard data services to be used directly or for holistic risk modelling.

Geospatial Cloud

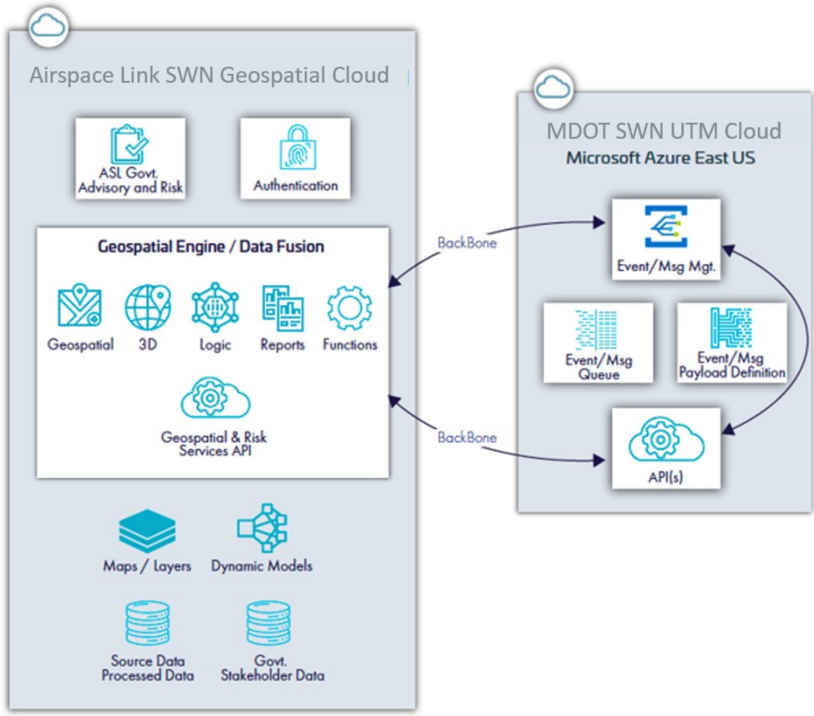


Figure 90: **Geospatial Engine Interoperability**

The Geospatial Cloud serves a Geospatial Engine as a full-featured feature data store supporting API query, tile-based mapping layers (raster and vector), geospatial decision making and other advanced geography-based workflows. Geospatial data is received via a system event bus, or API, transformed and stored for future static analysis or used to make quick spatial decisions based on operational or telemetric parameters. This geospatial data plays a key role in flight planning and pre-flight checking.

Each geographic feature or collection may be recalled through a map layer served through OGC compliant formats such as WFS and WMTS, popular raster and vector tile formatting schemes (open source protocol buffer [.pbf] specification), or community supported standards like GeoJSON. Data may also be re-exported into common exchange formats such as CSV, XML, Excel, and KML. Targeted geographic records are available on demand through RESTful APIs allowing data to be filtered by spatial intersection and compliant SQL 92 clauses. Additionally, data may be represented with stakeholder specific styles or data filters to ensure users only see data specific and tailored to the execution or reporting of the mission.

Real-time and near real-time data made available to the Geospatial Cloud via events initiates targeted geospatial processing, running code in response to each trigger. Each event trigger runs in parallel and processes the trigger individually, scaling precisely with the size of the workload. Examples of geospatial operations may include:

- Flagging geofence breaches
- Overlaying hazard and telemetry data in real-time
- Supporting tactical deconfliction based on stored and interpolated geographic data
- 3D modelling and visualization

Features submitted via the event-bus are also stored and made available for future or delayed dynamic modeling operations.

MDOT BVLOS User Tools

This web applications in the following figures show the operator planning function and the authority view. These can be used to plan operations as an alternative to direct integration between UAS operator planning software and the C2 Operations Center using the APIs.

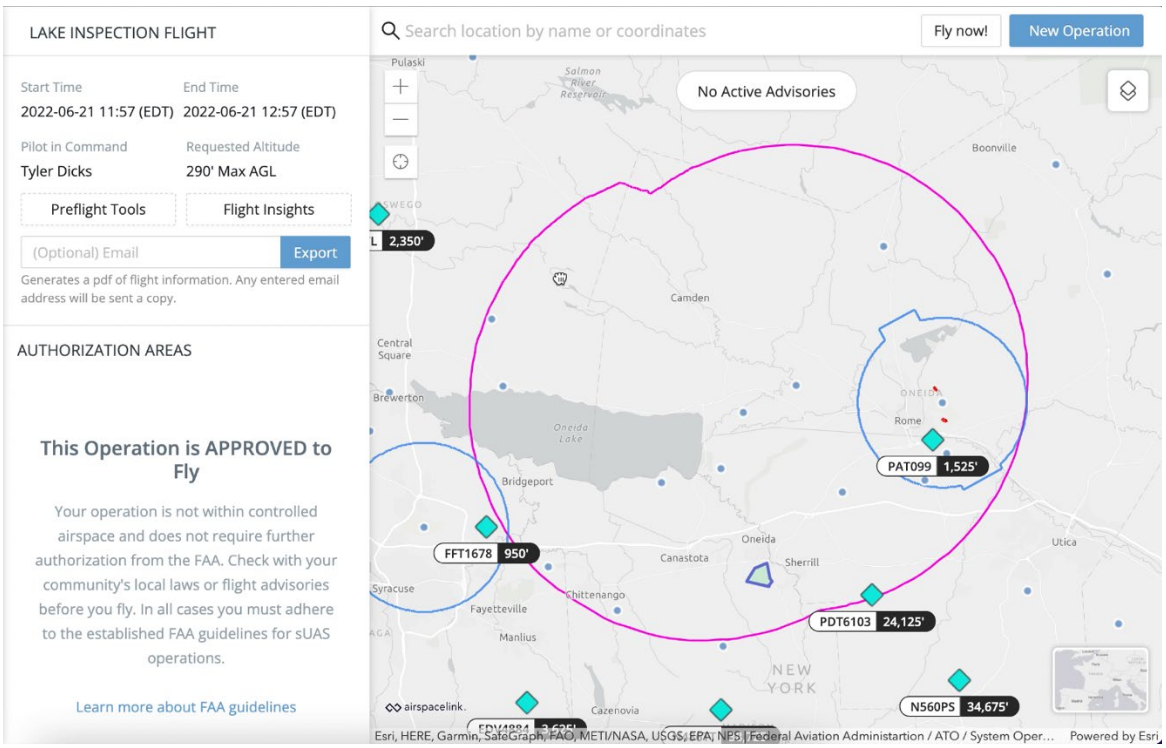


Figure 91: UAS Operator Planning Interface

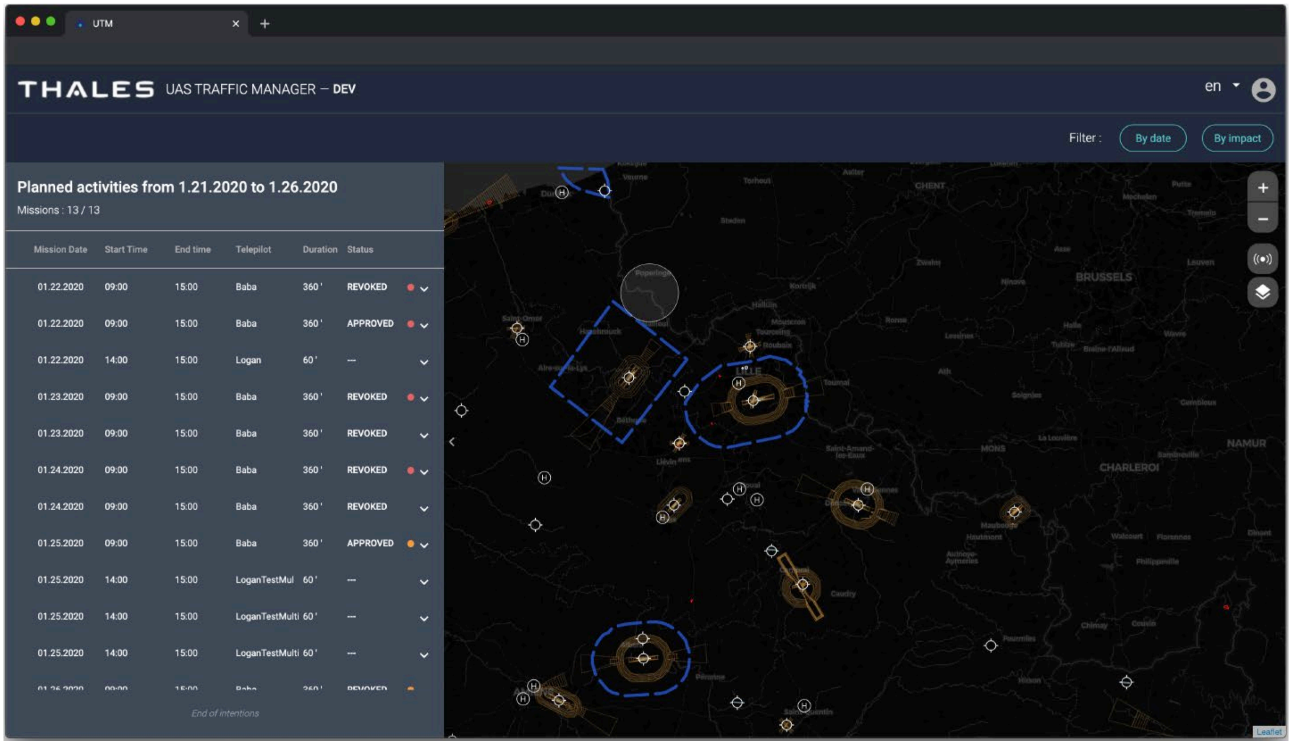


Figure 92: Authority View

Monitoring and Control

To guarantee that efficient and safe operations can be flown routinely, especially BVLOS, the monitoring and control of service performance to include the health of all system equipment, services, and cyber threats is a key capability.

The function is achieved using a combination of Cloud native monitoring and services such as Azure Application Insight and Azure Monitor, Zabbix – an enterprise grade open-source monitoring tool, and a distributed log analysis pipeline based on Elasticsearch.

Using the Simple Network Monitoring Protocol (SNMP) and a proxy application (agent) supporting Linux, MacOS and Windows operating systems, Zabbix monitors virtually all equipment connected to the backhaul data network, the A/G communication, and the ground surveillance infrastructures.

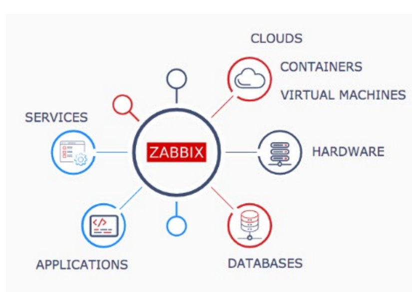


Figure 93: Zabbix Monitoring Service

The tool is highly configurable: event definition, filtering, and correlation can all be configured using a web interface and a flexible event notification mechanism allows users to configure e-mail-based alerts for virtually any event.

A discovery service allows the function to react to network changes due to connection of ‘mobile’ network nodes, such as a new ground control station, or a mobile or temporary ground surveillance sensor.

Cloud resources, APIs, and microservices are best monitored using cloud native tools offering highly scalable capability that can grow along with the overall system.

All C2 Operations Center services are integrated with Azure Application Insight, which monitors the following:

- **Request rates, response times, and failure rates** – to find out which application and tools are most used, at what times of day, and where your users are. See which pages perform best. Identify and troubleshoot resource problems.
- **Dependency rates, response times, and failure rates** – to find out whether external services are slowing the system down.
- **Exceptions** – Analyze the aggregated statistics or pick specific instances and drill into the stack trace and related requests. Both server and browser exceptions are reported.
- **User and session counts**
- **Diagnostic trace logs** – Troubleshoot services by correlating trace events with user requests.

Data recorded and application logfiles centrally stored in the cloud are continuously processed to extract performance related events that are not reported directly by external client such as ground control stations or ground sensors.

Data Storage and Performance Monitoring

Built around Azure Data Lake Storage (ADLS) technology, the data storage permanently stores all data as it is received by the system before domain specific processes take place.

The concept of ‘raw’ storage is well-known to the big data community and ensures information hidden in the data is not lost and can be discovered or mined at later stage using a data processing pipeline or ETL (Extract Transform Load) process.

Because data received are not homogeneous and information extraction use-cases are numerous, there is no tool that fits all use cases, normally platforms are open and do not provide a single specific data processing tool.

The FAA’s UAS Safety Risk Management (SRM) Policy Order 8040.6, paragraph 2.h “Safety Performance Monitoring and Hazard Tracking” clearly identifies the need of a performance monitoring as a key ingredient of the conduct of safe BVLOS operations.

To support this objective, the following analytics will be built around the data lake:

- Air/Ground Communication performance monitoring

- Ground Surveillance performance monitoring
- Airspace monitoring and characterization
- System services performance monitoring

Thales understands that the final list of data and metrics to be computed and monitored will be the result of a collaborative effort involving the FAA as part of the SRM process and as such this service will need to evolve and be finalized at later stage. The remaining part of this section provides a preliminary list of metrics that can be monitored by the C2 Operations Center.

Air/Ground Communication performance monitoring

Air/Ground Communication Metrics are used to monitor the performance of the A/G Comm Infrastructure and to evaluate the likelihood of a lost comm event.

Metrics include:

- UAV-GCS link continuity
- UAV-GCS link coverage
- UAV-GCS throughput (msg/sec, bytes/sec)
- UAV-GCS link latency

Note that the UAV-GCS link coverage metric computation depends on the modality used.

Once the baselines are established, continuous analysis of regular and dedicated period operation recording will be performed to verify and update metrics.

These metrics can be computed by analysis of the UAV-GCS command and control packets. Note that proprietary message formats and protocols can require specific decoding software.

Ground Surveillance Performance Monitoring

Ground surveillance metrics are used to monitor the performance of the ground surveillance infrastructure and indirectly to evaluate the robustness of the GBDAA service when used as a mitigation for reduced separation events.

Metrics includes:

- UA telemetry continuity
- Sensor detectability
- Sensor track completeness
- Sensor accuracy
- Sensor false alarm rate
- Load expectation
- Service availability

Detectability measures if the sensor can consistently observe targets of the specified size at the desired rate at all locations within coverage.

Track completeness measures the performance of the sensor tracker in providing continuous state updates on a target. This is separate from detectability as it quantifies switching track identification numbers and the time between the loss of one track and the start of another. While poor detectability will cause poor track completeness, other phenomenon can cause track completeness to degrade even with acceptable detectability.

Accuracy measures how close a sensor's reported track state is to the true position of the target.

False alarm rate measures how many tracks are falsely reported as a target of interest when they are in truth targets of non-interest. This is a classification measure and as such is directly tied to the ConOps of the corridor.

Load expectation is a black box metric useful for capturing unexpected or poorly understood phenomenon. It establishes a baseline of track load over time and monitors for large deviations from this expectation. It should not be relied upon heavily but can capture unusual effects such as animal migrations or the introduction of new interference sources to the environment.

Service availability is a measure of how much of the Tracking/Surveillance service coverage volume is usable how much of the time. Sensor availability measures how much coverage is operational. Operational availability measures how much of the coverage is currently occupied based on sensor reports.

System services performance monitoring
Measuring and displaying system performances on graphical dashboards helps to both maintain overall airspace safety and support a continuous collaborative improvement process where all system stakeholders can see the impact of their decisions on the system at a holistic level.

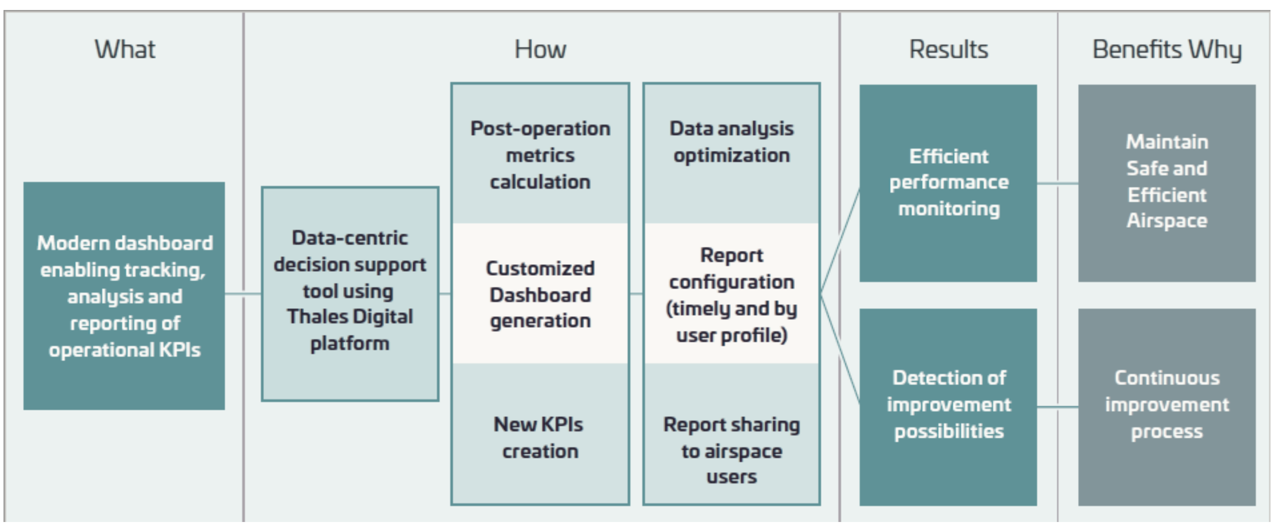


Figure 94: Operational Dashboard Helps Improving Operations

Figure **95** shows an operational dashboard's example from an Air Traffic Flow Management application that can be expanded to address specific needs of MDOT. Useful system performance metrics include the following:

- Number of operations by type, altitude, and operator
- Number of rejected/invalid operation submitted by type and operator
- Number of operations cancellations by type and operator
- Number of operation amendments by type and operator
- Number of registered operators, pilots, UASs
- Number of registered users
- Number of successful/unsuccessful user/client authentication
- Average operation durations by type and operator
- Average service response time by APIs
- Average service requests by operator, APIs
- Number of non-conformant operations by type and operator
- Probability of non-conformant operation by type and operator
- Number of rogue operations by type and operator
- Probability of rogue operation by type and operator
- Number of separation warning/alerts
- Service availability by service
- Number of non-nominal event reported by type and operator
- Operation volume size by type and operator
- Operation volume usage by type and operator

Figure 95: Air Traffic Operational Dashboard Example

Air/Ground (A/G) Communications Infrastructure

C2 connectivity is vital to the success of the connected corridor. Reliable and field-proven C2 links must be considered. As such, there are varying modalities that can achieve C2 connectivity for UAS infrastructure, including LTE and traditional CPNC solutions. Thales proposes MDOT to consider each modality described in turn. Similar to the selection approach of ground-based surveillance, selection of the C2 solution will be based on a formal site assessment and installation to test the equipment coverage.

LTE/Mobile Communications Networks

4G/5G/LTE communication is expected to be a readily accessible and appropriate communication means for supporting UAS operations in the future. The Corridor development will be an important contributor to the understanding of how the FAA will view this communication means and how the network availability and performance contribute to the safety case. The Project Team expects this to serve as a command and control (C2) modality to be supported in future phases – particularly for smaller UAS in urban/suburban areas. For the initial phase, an LTE module could be utilized (e.g., mounted on a drone) to collect cellular signal metrics from communication network / towers within the Corridors, while maintaining a C2 link using CNPC as the recommended primary C2 modality for BVLOS operations.

Command and Non-Payload Communications (CNPC) System

The Project Team recommends/proposes a Control and Non-Payload Communications (CNPC) system to be the primary C2 modality. The CNPC solutions proposed below operates on the ISM band and C-band, and are supplied by uAvionix, and are described in turn.

ISM Band Capability

The uAvionix CNPC solution operating on the ISM band comprises the microLink airborne radio system and the skyStation ground radio system (GRS) manages skyLine server. The ARS and GRS communicate to provide the C2 Link System. The solution incorporates a dual-radio architecture within the ARS and GRS components, which provides path (spatial) diversity, frequency diversity, and polarization gain. The Dynamic Medium and Multiple access, time, and position synchronized implementation supports hundreds of simultaneous co-located links without creating interference among them. Figure 96 illustrates a typical CNPC architecture using the uAvionix microLink and skyStation.

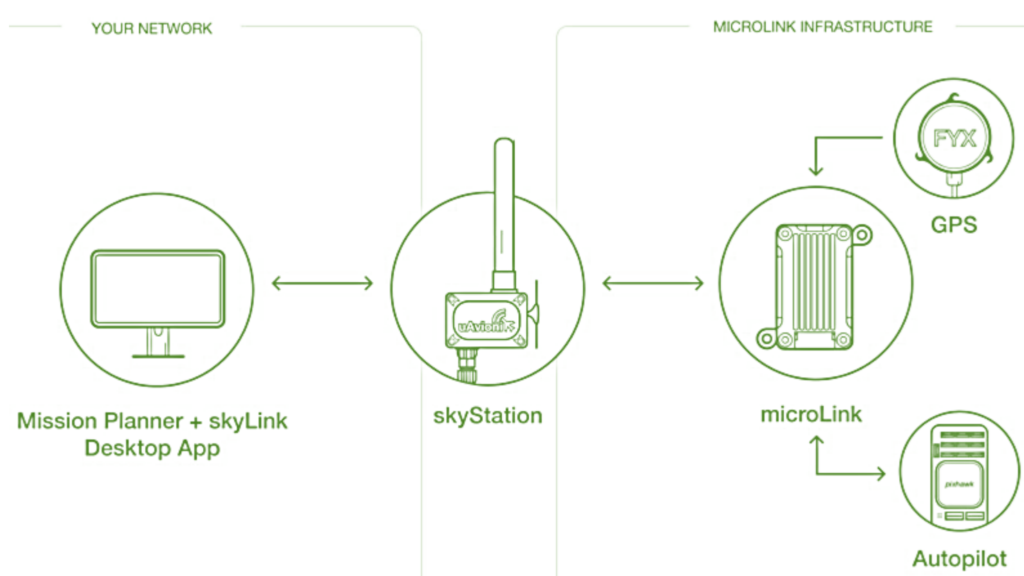
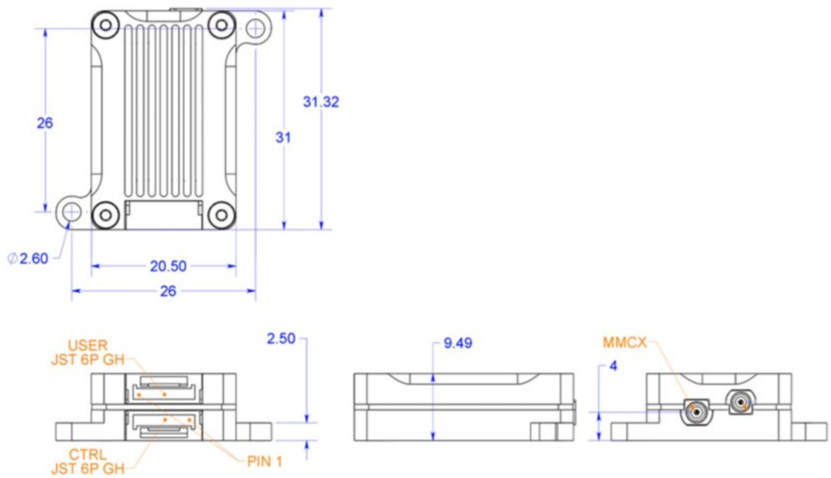


Figure 96: Example of CNPC Implementation

microLink ARS

The microLink ARS is an aviation grade, BVLOS data link specifically designed as a long range, robust UAS CNPC data link. microLink is currently Federal Communications Commission (FCC) licensed for use in the Industrial, Scientific, and Medical (ISM) frequency band of 902-928MHz. The microLink ARS' small size, weight, and power consumption (SWaP) and plug-and-play compatibility with ARDUPILOT/Pixhawk-based autopilots make it an ideal solution for small UAS



(sUAS). Figure **97** illustrates the mechanical specification of the ARS, with measurements provided in millimeters.

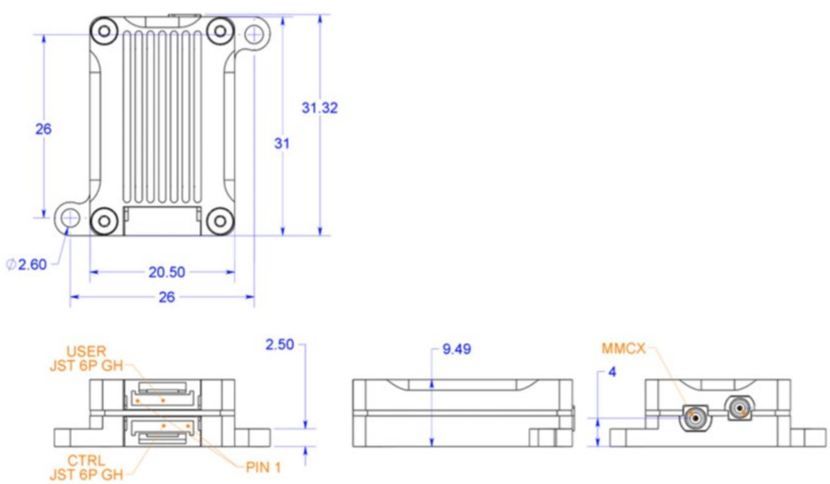


Figure 97: microLink ARS Mechanical Specifications

Figure 98: uAvionix skyStation

The skyStation Ground Radio System (GRS) (Figure 98 above) is a network-capable, Power over Ethernet (PoE), IP67 rated GRS that can serve as a permanent or portable ground component of a CNPC installation. The skyStation contains a microLink radio, dual-antennas, and GPS receiver

for timing and position information. It is recommended to co-locate and install skyStation GRS' at each of the proposed locations overlooking the helipads in both Areas 1-2 and Area 3.
The all-in-one packaging of the GRS allows for easy installation and networking of the GRS to either a local GCS or a centralized Network Operations Center (NOC) capability. Extensive status, health, and integrity monitoring is provided via networked connection from the GRS and contains data for both the ARS and GRS.

C-Band Capability

uAvionix SkyLink as an alternative CNPC solution but operates on the C-Band. Though the use of C-Band has not yet been authorized for use for UAS applications/communications devices, the device is still presented here as a potential means to satisfy the C2 modality, as one of the benefits is the greater range/coverage. The SkyLink is an evolution of the ARS/GRS CNPC solution and is an aviation-protected C-Band (5030-5091 MHz) bi-directional, multiple input & single output (MISO) dual CNPC radio system and is compliant with the RTCA DO-362A standard (Command and Control (C2) Data Link Minimum Operational Performance Standards (MOPS) (Terrestrial)).

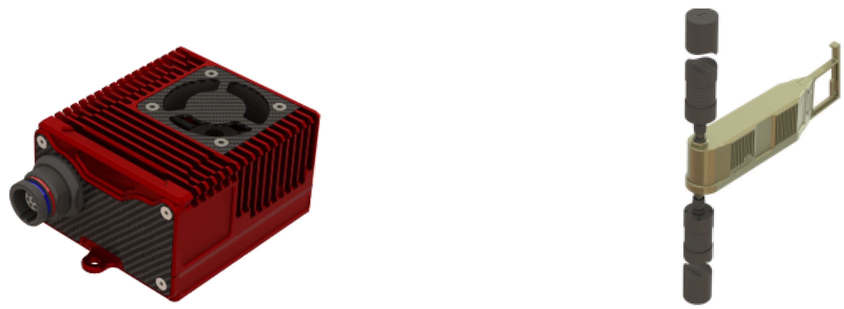


Figure 99: Skylink ARS Radio and SkyLink GRS radio

At the moment, uAvionix is in the process of obtaining authorization of its devices to use the C-Band spectrum.

Ground/Ground (G/G) Communications

Existing Communications Infrastructure

In all three MDOT Areas of interest, an extensive and readily available fiber network is provided by Crown Castle Fiber and its affiliates. Leveraging an existing, commercially available fiber network that can provide connectivity to all remote site locations will not only drive down costs but also time to implement the critical component of the overall connected corridor, which is the Ground-to-Ground communications infrastructure. This infrastructure is the asset that "connects" all the surveillance and C2 systems, UAS infrastructure, and C2 Operations Center capabilities together. All remote sites can be supplied with private/secure fiber network connectivity (Layer 2 Ethernet over private fiber), with throughput performance up to 5-Gbps between Crown Castle to Customer Network Hardware (e.g., remote sites). The current network infrastructure availability and typology, extensibility of the fiber backbone to each remote site, and service aspects are described in turn.

Current Availability/Typology

A fiber network is recommended as the ground-to-ground communications infrastructure (i.e., backhaul network) to connect all remote sites to the C2 Operations Center. The existing network infrastructure is available throughout the State of Michigan, and prevalent throughout the corridors in Areas 1 & 2, as seen in Figure 100, where the magenta line symbolizes the existing Crown Castle network fiber lines, and red triangles symbolizing tower assets with fiber connectivity.

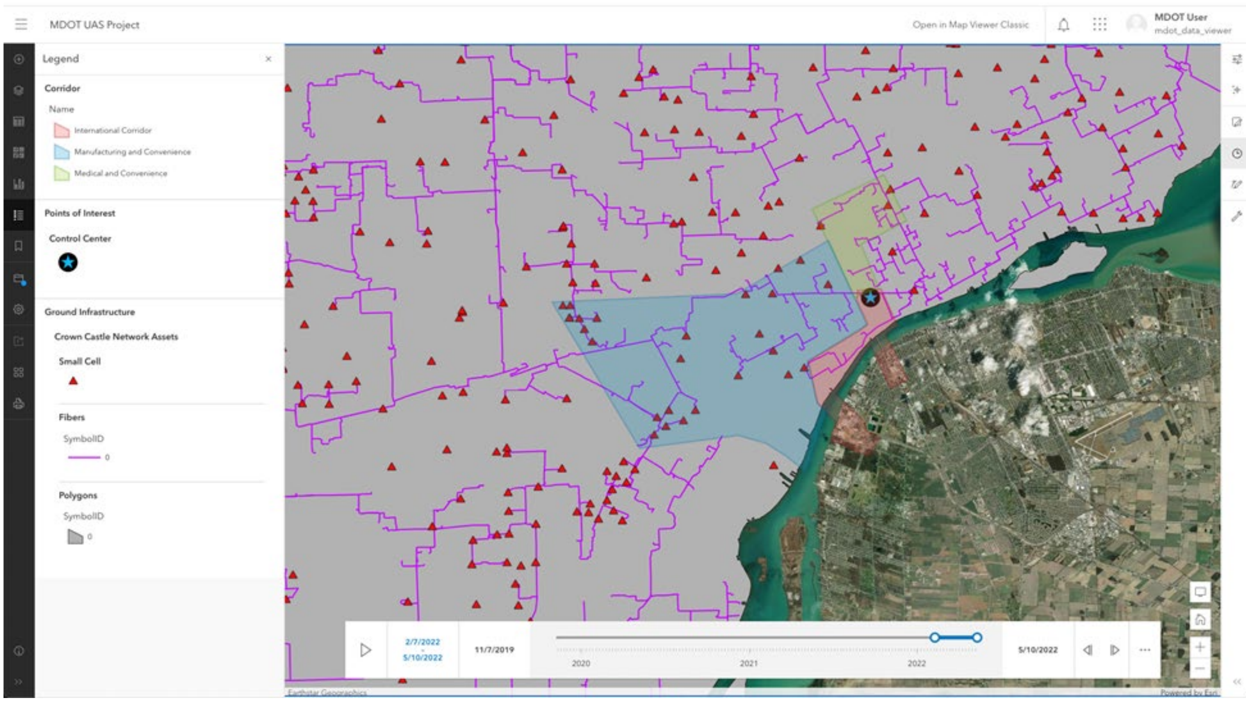


Figure 100: Existing Network Communication Fiber Backbone in Areas 1 and 2 (with Corridor Overlay)

To highlight the availability of the existing fiber lines to the remote site locations identified in the tables above, the following figures illustrate examples of where these existing fiber lines are in relation to the radar site at KDET, Michigan Central Station, and east of the Henry Ford Rouge Complex, respectively.

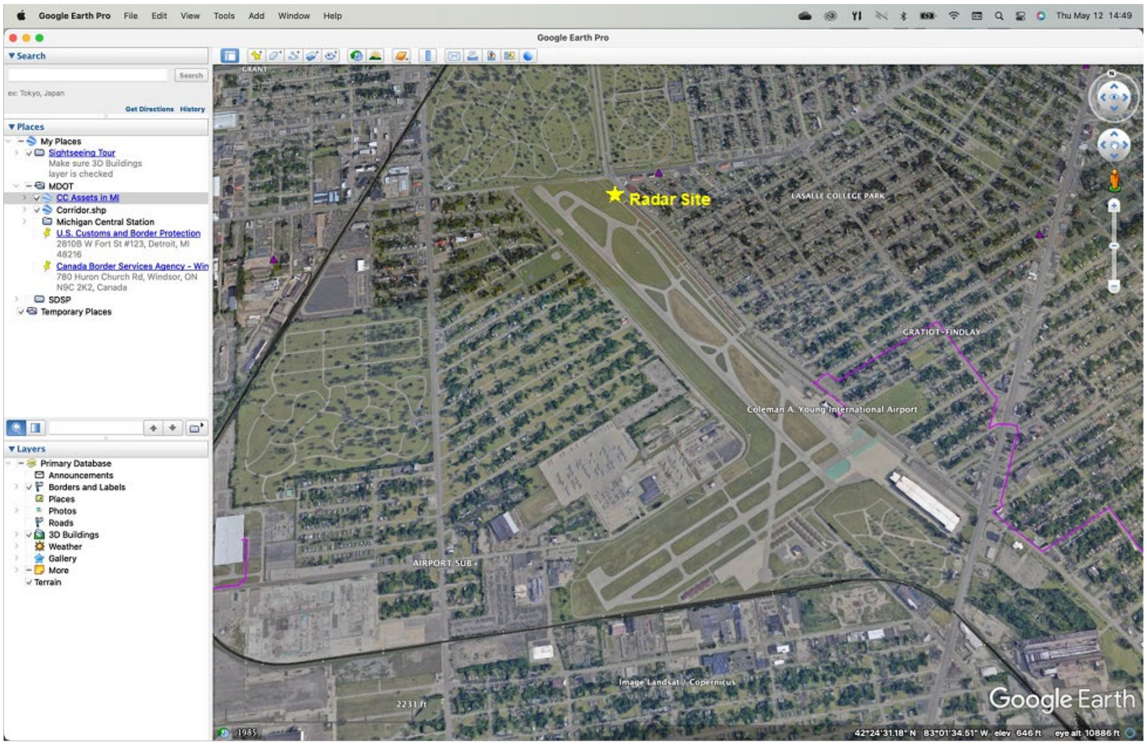


Figure 101: Fiber Network Availability at Michigan Central Station (Proposed C2 Operations Center)

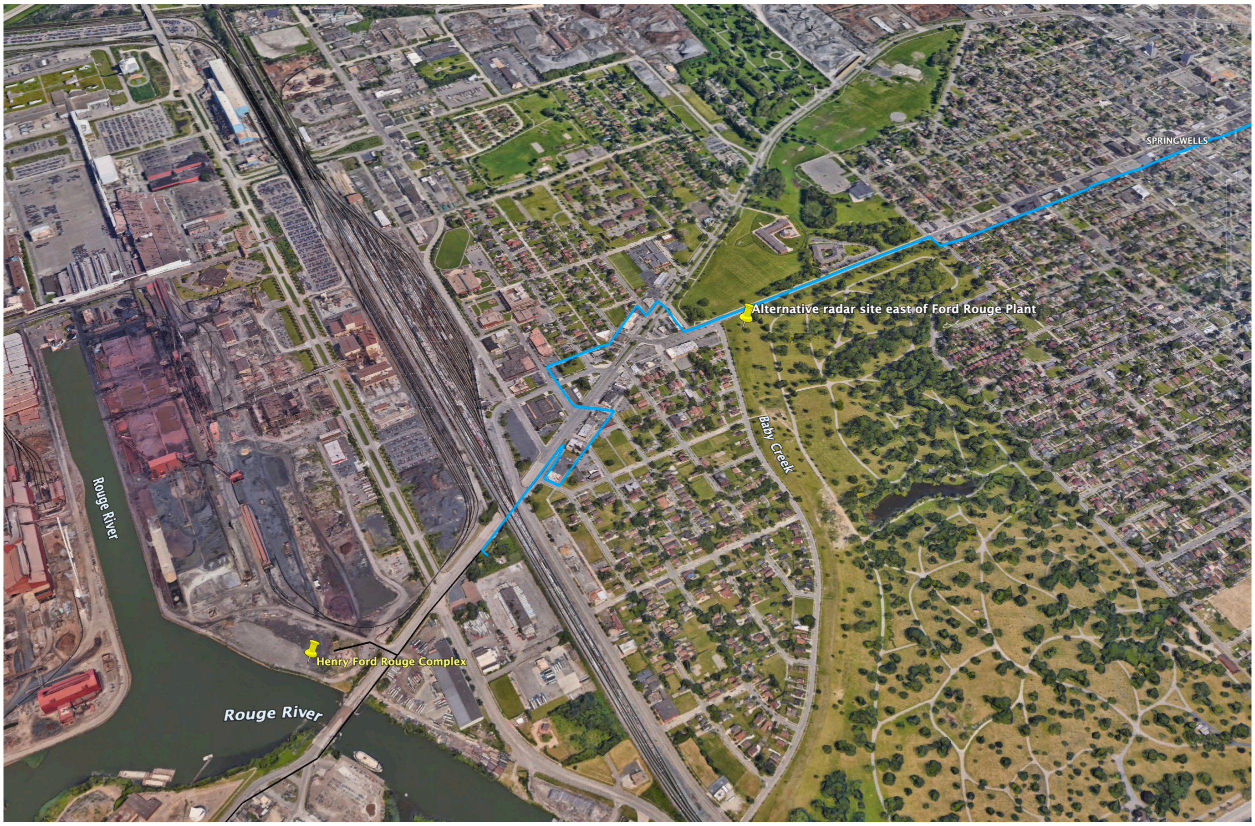


Figure 102: Fiber Network Availability at the East End of Henry Ford Rouge Complex

In Area 3, the fiber connectivity is not as prevalent in the corridor. However, fiber and power at the WICA-FM Transmitter Tower site (Site ID 871964 in Figure 29) does exist. Leveraging this site for emplacement of the HARRIER radar is not only central, but it allows radar coverage for majority of the corridor as seen in the radar coverage analysis in Figure 111.

Site ID	Address	Available Center Lines	Ground Space	Active Meter Available	Fiber
830079	3950 SILVER LAKE ROAD TRAVERSE CITY, MI 49684	30-70, 80-104	6x6	No	Needs field verification
871964	4777 Harris Road TRAVERSE CITY, MI 49684	30-575	Yes	No	ATT, Charter
830223	8500 E. Traverse Hwy Traverse City, MI 49684	452 - 480 ft, 354 - 450 ft, 340 - 346 ft, 267 - 330 ft, 251 - 259 ft, 204 - 241 ft, 184 - 196 ft, 118 - 168 ft, 76 - 112 ft, 30 - 74 ft	Need Verification	Yes	ATT, Charter
830226	11770 U.S. 31 Interlochen, MI 49643	348 ft, 255 - 319 ft, 231 - 247 ft, 213 - 223 ft, 132 - 205 ft, 76 - 128 ft, 30 - 70 ft	Yes	No	Century Link, Verizon, Charter

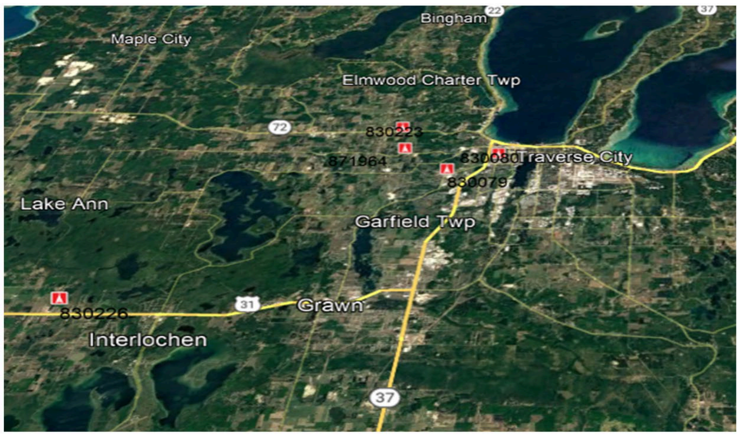


Figure 103: Fiber Network Availability in Area 3

Assessment of Extensibility to Remote Sites and C2 Operations Center

The primary goal was to identify where the existing fiber lines lie in all areas. The secondary goal was to determine if the fiber lines exist at each remote site. If a remote site does not have a fiber line nearby, the team needed to understand if Crown Castle can extend a line from the fiber backbone to reach the remote sites, and the C2 Operations Center. It has been determined that each remote site in all Areas of Interest can be serviced by the fiber network, by means of extension of the existing fiber backbone. As seen in Figure 30, "blue" fiber lines indicate existing Crown Castle layer-1 fiber, and "red" fiber lines indicate new lateral constructions to provide the diversity requirement (i.e., fiber connectivity) into each site/node (i.e., remote sites and to the C2 Operations Center). In total, around 13+ additional miles are the anticipated capital expenditure for the new fiber construction.

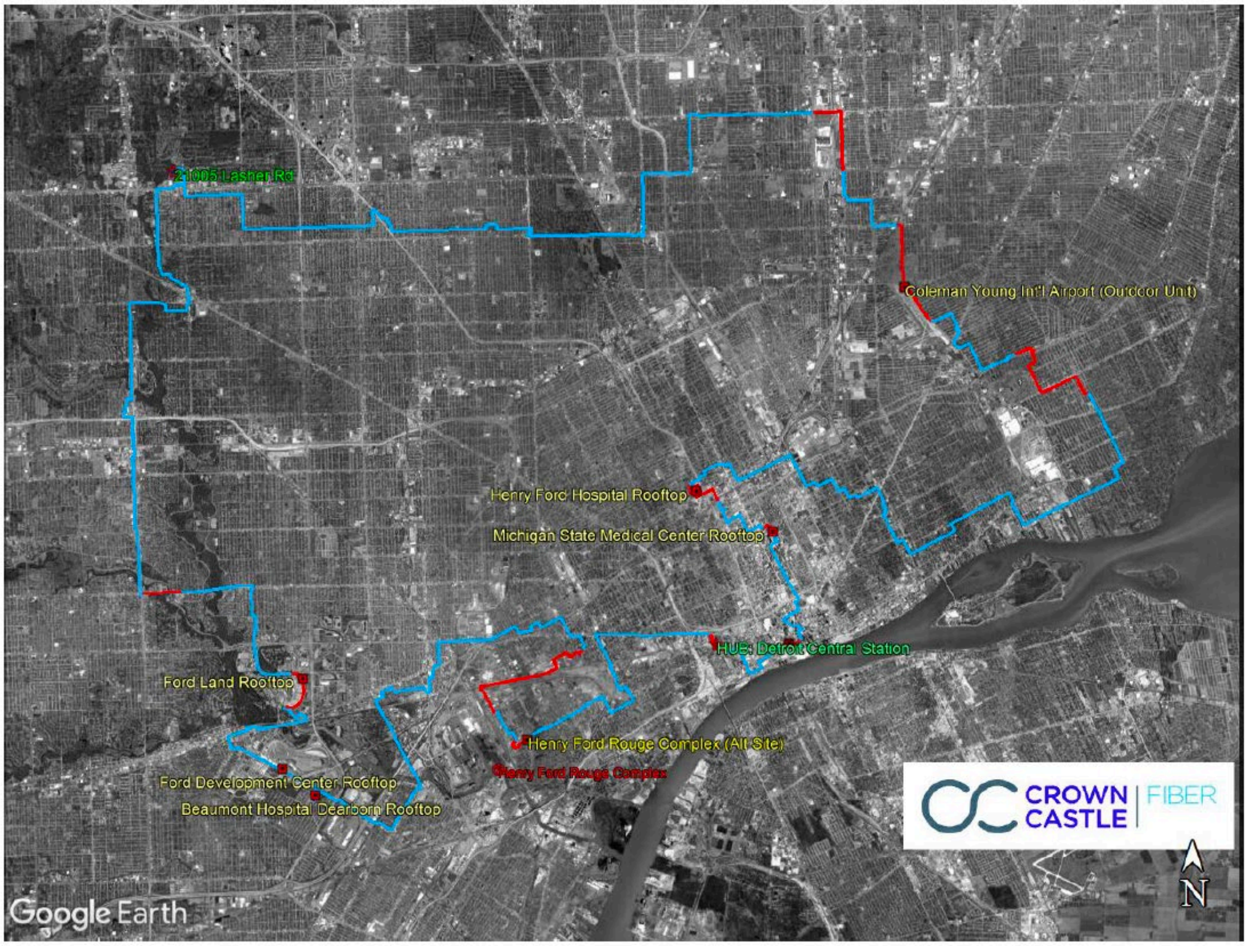


Figure 104: Existing (blue) and Proposed (red) Fiber Network for Areas 1 and 2 (with remote sites labeled)

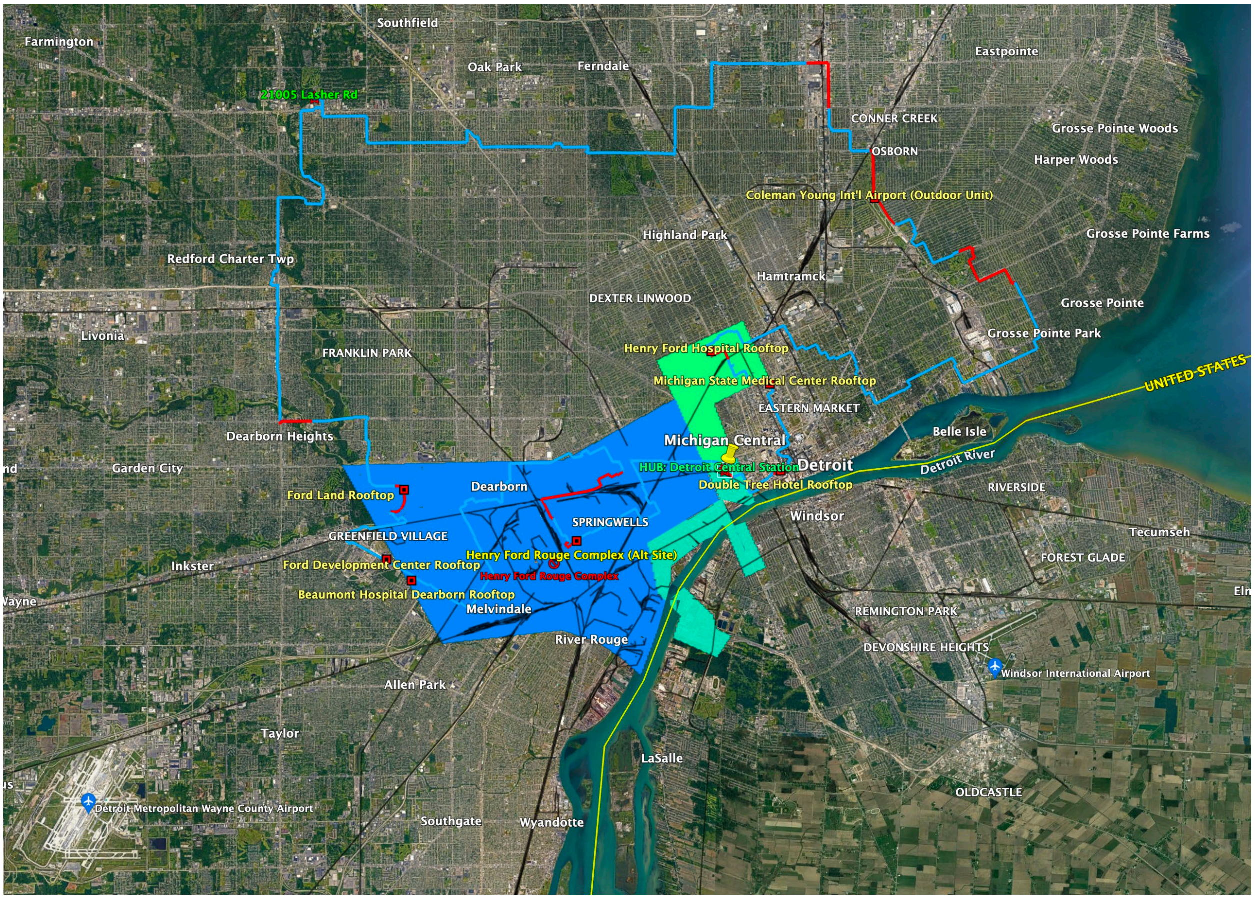


Figure 105: Existing (blue) and Proposed (red) Fiber Network for Areas 1 and 2 (with overlaid corridors)

Ground-to-Ground Communications Service

The service proposed by Crown Castle is representative of a layer-2 lit service built on a 10Gb Metro-E Advanced Private Line (MAPL) Ring, with the C2 Operations Center ("HUB" in the below figure) supplied with 10Gb E-LAN any-to-any access, and each of the remote sites ("spoke nodes") supplied with 5Gb E-LAN any-to-any access. Protection of the network layout is achieved using a fault tolerant "ring" architecture (i.e., Ethernet Ring Protection Switching (ERPS)) designed to the G.8032 Standard. If one node fails, then network traffic can "go around" to continue the data transmission/link.

Remote Site Locations

Leveraging geospatial tools, the following locations are the recommended sites for surveillance and C2 system installations, as well as the location of the C2 Operations Center. The selection of these remote site locations is a result of the sensor coverage analysis, compatibility and geographic aesthetic considerations, and integration plan with the existing network communications fiber backbone.

- Coleman Young International Airport (KDET)

- Henry Ford Rouge Complex (Alternate Site)
- Beaumont Hospital Dearborn Rooftop
- Ford Development Center Rooftop
- Ford Land Rooftop
- Henry Ford Hospital Rooftop
- Michigan State Medical Center Rooftop
- Double Tree Hotel Rooftop

Table 40: Sensor Emplacement by Remote Site Location (Areas 1 and 2)

Sensor	Type	Emplacement (Lat/Long)	Remote Site
DeTect HARRIER ASR (Primary Surveillance RADAR)	Medium Range Air Surveillance Radar	42.4187786, -83.0134351	Coleman Young International Airport
DeTect HARRIER ASR (Primary Surveillance RADAR)	Medium Range Air Surveillance Radar	42.305089, -83.142039	Henry Ford Rouge Complex (Alt Site)
SRC LSTAR (Primary Surveillance RADAR)	Medium Range Surveillance Radar	To be discussed with MDOT	To be discussed with MDOT
Iris Automat–on CAS–A **G – Camera**	Electro-Optical Detection Sensor	42.2909486, -83.2139079	Beaumont Hospital Dearborn Rooftop
Iris Automat–on CAS–A **G – Camera**	Electro-Optical Detection Sensor	42.297601, -83.22509	Ford Development Center Rooftop
Iris Automat–on CAS–A **G – Camera**	Electro-Optical Detection Sensor	42.32031, -83.2181946	Ford Land Rooftop
Iris Automat–on CAS–A **G – Camera**	Electro-Optical Detection Sensor	42.3675432, -83.0843681	Henry Ford Hospital Rooftop
Iris Automat–on CAS–A **G – Camera**	Electro-Optical Detection Sensor	42.3568036, -83.0582923	Michigan State Medical Center Rooftop
Iris Automat–on CAS–A **G – Camera**	Electro-Optical Detection Sensor	42.3289699, -83.0526446	Double Tree Hotel Rooftop
uAvionix ADS-B pingStation	ADS-B Receiver	42.2909486, -83.2139079	Beaumont Hospital Dearborn Rooftop
uAvionix ADS-B pingStation	ADS-B Receiver	42.297601, -83.22509	Ford Development Center Rooftop
uAvionix ADS-B	ADS-B	42.32031, -	Ford Land Rooftop

Sensor	Type	Emplacement (Lat/Long)	Remote Site
pingStation	Receiver	83.2181946	
uAvionix ADS-B pingStation	ADS-B Receiver	42.3675432, -83.0843681	Henry Ford Hospital Rooftop
uAvionix ADS-B pingStation	ADS-B Receiver	42.3568036, -83.0582923	Michigan State Medical Center Rooftop
uAvionix ADS-B pingStation	ADS-B Receiver	42.3289699, -83.0526446	Double Tree Hotel Rooftop
uAvionix Ground Radio System (GRS)	C2 CNPC Radios	42.2909486, -83.2139079	Beaumont Hospital Dearborn Rooftop
uAvionix Ground Radio System (GRS)	C2 CNPC Radios	42.297601, -83.22509	Ford Development Center Rooftop
uAvionix Ground Radio System (GRS)	C2 CNPC Radios	42.32031, -83.2181946	Ford Land Rooftop
uAvionix Ground Radio System (GRS)	C2 CNPC Radios	42.3675432, -83.0843681	Henry Ford Hospital Rooftop
uAvionix Ground Radio System (GRS)	C2 CNPC Radios	42.3568036, -83.0582923	Michigan State Medical Center Rooftop
uAvionix Ground Radio System (GRS)	C2 CNPC Radios	42.3289699, -83.0526446	Double Tree Hotel Rooftop

Table 41: Sensor Emplacement by Remote Site Location (Area 3)

Sensor	Type	Emplacement (Lat/Long)	Remote Site
DeTect HARRIER ASR (Primary Surveillance RADAR)	Medium Range Air Surveillance Radar	44.757798, -85.678692	WICA-FM Transmitter Tower
Iris Automat–on CAS–A G – Camera	Electro-Optical Detection Sensor	44.759592, -85.644146	Munson Medical Center Helipad
Iris Automat–on CAS–A G – Camera	Electro-Optical Detection Sensor	44.749536, -85.583409	TC Helicopter Helipad (at KTVC)
uAvionix ADS-B pingStation	ADS-B Receiver	44.759592, -85.644146	Munson Medical Center Helipad
uAvionix ADS-B pingStation	ADS-B Receiver	44.749536, -85.583409	TC Helicopter Helipad (at KTVC)
uAvionix Ground Radio System (GRS)	C2 CNPC Radios	44.759592, -85.644146	Munson Medical Center Helipad
uAvionix Ground Radio System (GRS)	C2 CNPC Radios	44.749536, -85.583409	TC Helicopter Helipad (at KTVC)

It is recommended that the Casia-G optical system, ADS-B pingStation, and C2 Ground Radio System (GRS) be co-located and installed at each of the rooftop locations identified above for several reasons. First, the rooftops provide an aerial view advantage of the helipads identified in the corridors. Since ADS-B equipped helicopters can take off and land at helipads within the cities, it is critical to ensure ADS-B coverage in those areas. Ideally, the ADS-B receiver would have a direct LOS to the aircraft on the helipads so that once the ADS-B receiver is enabled, the receiver would report the position of the aircraft.

It is not uncommon that helicopters could depart the helipads without turning on their ADS-B transmitters (or are unequipped). Thus, Thales considers the helipads as an area of non-cooperative aircraft activity. Hence, co-locating an IRIS Casia-G camera system with the ADS-B receiver as close as possible to and with direct LOS to the surrounding area. This will provide ADS-B data from the helicopters as soon as their transponder is enabled and other ADS-B aircraft in the area. Also, the Casia-G would provide non-cooperative detection and track data on departing or landing helicopters for roughly 1 nm under normal weather conditions.

The range of the optical system would be limited under adverse weather conditions, but so would drone operations. The optical sensor does have the option to include an infrared (IR) capability. Otherwise, the optical sensor will be limited to daytime operations. In Areas 1 & 2, not only will there be targeted coverage of these critical areas, redundant surveillance coverage from the two DeTect HARRIER radar site locations at Coleman Young Airport and at the Henry Ford Rouge Complex (Alternate Site), or a location to be discussed with MDOT for potential LSTAR emplacements. In Area 3, a single site for radar emplacement is recommended. A single location is proposed given the availability of power and fiber network connectivity, open-area access. Furthermore, co-location of the C2 radio at all the rooftop sites can provide the necessary C2 link for the drones operating inside the corridors without requiring additional sites to be built.

Ground-Based Surveillance Infrastructure

Architecting a robust, high-performance ground-based surveillance infrastructure is perhaps the most important aspect of the MDOT Connected Corridor. Surveillance is the most recognizable and critical component towards gaining the regulatory approvals to enable BVLOS more broadly across the U.S.

The FAA's UAS Safety Risk Management (SRM) Policy Order 8040.6 discusses the essential elements that must be addressed to be granted a waiver for BVLOS operations. The reduction of hazard conditions is clearly linked to the quality of surveillance coverage available to facilitate detect and avoid mitigations and to protect the integrity of the airspace system. Currently, ground-based surveillance is one of the best forms of airspace safety mitigation and the accuracy and reliability of the data will inform the approach the team will take in the completion of the SRM process.

While the FAA data supports general airspace risk identification, additional ground-based infrastructure is required to reduce the airspace risk to regulatory safety standards. This ground-based infrastructure would provide the surveillance, communications, and command and control (C2) resources to provide operators the means to electronically detect and avoid any crewed aircraft within their area of operation. The infrastructure includes:

Medium Range Radar
Augments FAA radar providing coverage and primary detection of aircraft at low altitudes and supports detect and avoid reduced separation event mitigation procedures.

Optical Sensors
Monitors the airspace for at risk aircraft using computer vision and AI technology and reports actionable real time telemetry data to the pilot-in-command.

ADS-B Receivers
Detects cooperative aircraft broadcasting their identity and position to support detect and avoid/ reduced separation event mitigation procedures.

Wireless Communications Receivers
Provides C2 datalink capability to support communications between operator, drone, sensors and C2 center throughout drone operations.

Ground Communication Networks
Provides the ground-to-ground communication network (i.e., backhaul network) to connect all ground-based infrastructure and cloud services.

Drone infrastructure Command and Control Center
Manages drone Infrastructure access, operations and services ensuring proper use and system health.

Existing Surveillance Infrastructure

Use of FAA Surveillance

Thales continues to investigate the possibility of using FAA non-cooperative surveillance data to incorporate into its surveillance services. At the time of this study, the team continues to investigate the availability and security requirements required by the FAA to use this data (including what data restrictions may be applied – filtering, delays, etc.) as an input. Should this be a viable option, the team will review this with MDOT. As an example of existing FAA Surveillance Radars and ADS-B coverages, Figure 18 below depicts coverages of each at 500' AGL around the regions of interest.

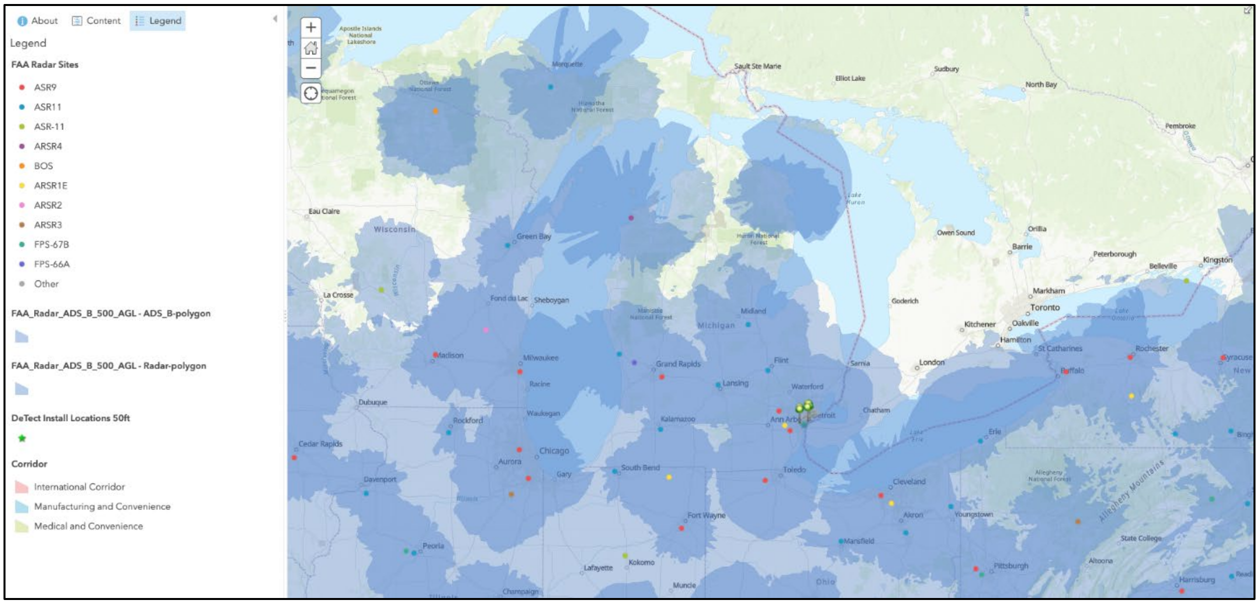


Figure 106: FAA Radar & ADS-B Coverage (500' AGL)

Mature Surveillance Solution Implementation

The surveillance plan will be a multi-layered approach taking full advantage of existing sensors (if available) and supplementing with new sensors, as necessary. The system will be extensible and interoperable with new users and technologies as they emerge over time. The emplacement of new sensors will take advantage of existing infrastructure such as State, county, or municipality owned facilities whenever possible. The plan crafts an approach that uses a disparate set of sensors that are state-of-the-art and very different in performance, update rates, and accuracies. This enables the program to test and integrate a variety of capabilities which is critical for future growth and expansion as new technologies and sensors emerge.

Supplemental Surveillance Infrastructure

ADS-B Receivers

The uAvionix pingStation is a dual band, networkable ADS-B receiver with a Power over Ethernet (POE) interface enclosed in an IP67 rated protective enclosure. The pingStation provides low-altitude ADS-B cooperative surveillance within line of sight of the antenna, with range dependent upon the output power of the transmitting ADS-B transceiver. The pingStations can be installed on poles connected to towers. A single POE cable provides both power and data communications. An integrated GPS provides precision timestamping for messaging. Specifications of the ADS-B pingStation are included in Figure 107.

The Project Team proposes to install uAvionix pingStation ADS-B receivers at each of the proposed locations (Table 40 for Areas 1 & 2, and Table 41 for Area 3, respectively) overlooking the helipads. The pingStation is small, lightweight, power-over-Ethernet, 1090ES/UAT capable, and will significantly enhance coverage of crewed aircraft.

uAvionix pingStation Specs	
Frequency / Band	Dual-Band ADS-B Receiver
Range	100 nm
Clutter Cancellation	N/A
Field of View	360 deg x 90 deg
Update Rate	1 sec
2D / 3D	N/A
Export Control	Non-ITAR

Figure 107: uAvionix Ping Station

Non-Cooperative Surveillance Coverage Considerations for MDOT

Non-cooperative aircraft could be flying in the region and must also be detected. This detection function is achieved with primary radar, from which the overall surveillance system can formulate tracks. Having simultaneous access to cooperative and non-cooperative surveillance data will enable testing, verification, safety case analysis, and validation against emerging standards.

To address the potential safety concerns of the FAA, the surveillance system must have overlapping coverage. This is critical for many reasons, including:

- Redundancy – the system can remain operational during outages, repairs, and upgrades
- Reduction of Line-of-site (LOS) blockages
- Enhances detectability with different aircraft aspect angles
- Increases the target update rate
- Enables enhanced data analysis and system health performance monitoring
- Allows safe and efficient transitions between coverage regions
- Provides additional sensor coverage for ground-based detect and avoid

Given the urban area and desired use cases, the size and type of surveillance sensors may matter when considering the operational environment. For instance, deploying a medium sized or large rotating radar system inside an urban area to provide coverage is not practical for several reasons. These radars would likely be unsightly, harder to install and to find good emplacements, create noise and vibration in the floors below the emplacement, and cause public radiation concerns. Thus, Thales recommends if rotating radars are selected, the emplacements of these types of radars shall be outside of the urban setting. If a non-rotating radar is selected, these types of radar would be suitable for an urban setting. Within the urban setting, short-range systems can also provide more targeted coverage to help airspace detection and monitoring within the “urban canyon”.

Another sensor aspect to consider is whether to use a 2 or 3-dimensional radar. The Vantis (North Dakota) program currently uses the 2-dimensional Terma Scanter 5202 for non-cooperative coverage. When using a 2D radar, the system assumes that if an intruder aircraft is within the small alert region centered on the drone's position, that the aircraft is at the same height as the drone. Based on the surveillance performance and drones used for the Vantis Program, the alert region is approximately 3.43 nm radius centered on the drone's location. A non-cooperative aircraft flying within the alert volume would require the drone pilot to take appropriate mitigation action.

This conservative approach to using 2D radar is acceptable to meeting standards such as RTCA DO-381. Given the different operating environment in an urban setting where there is a higher concentration of traffic, a 3D radar such as the SRC LSTAR could be favorable given its ability to be emplaced within a city setting and provides elevation data. On the other hand, due to the Mode-C veil surrounding KDTW, it is assumed that all crewed aircraft operating within 30nm of the airport are cooperative given the ADS-B Out mandate which requires aircraft to broadcast their position, to include altitude.

Furthermore, non-cooperative sensors represent the largest potential cost for state-wide deployment. Therefore, it is critical to select the most appropriate sensors to facilitate the operational concept. There are several non-cooperative surveillance sensors that MDOT should consider, which are described in turn.

Non-Cooperative Surveillance Sensors				
				
	DeTect Harrier	**Terma Scanter 5202**	**SRC LSTAR**	**IRIS CASIA-G**
Frequency/Band	9.0-9.2 GHz/X-Band	9.0-9.2 GHz/X-Band	1.21-1.39 GHz/L-Band	Optical
Range	15 nm	14 nm	18.6 nm	1.3 nm
Clutter Cancellation	25 dB	35 dB	60dB	N/A
Field of View	360 x 10K ft	360 x 7K ft	360 x 30K ft	360 deg x 40 deg
Update Rate	2.5 sec	2.5 sec	1 sec	0.1 sec
2D/3D	2D	2D	3D	2D
Export Control	ECCN 6A008k	ECCN 6A008k	HW ITAR, Data non-ITAR	Non-ITAR

Short-Range Surveillance

IRIS Automation CASIA-G

The IRIS Casia G is an optical sensor (i.e., camera system) that utilizes five FLIR cameras to provide coverage of 0-360 degrees in azimuth and 0-40 degrees elevation coverage. The system can detect and track aircraft to a range of 1.3nm with a probability of detection of 98%. The Casia G uses five cameras per system and can provide detections at an update rate of 10Hz. It is recommended to deploy an IRIS Automation CASIA-G system at each of the proposed deployed sites/locations overlooking the operational helipads to provide targeted surveillance of these critical areas.

Medium-Range Surveillance Options

In addition to the installation of camera systems at/near the helipad locations Areas 1 and 2, the Project Team proposes to place a different radar type to the northeast, at Coleman Young Airport (KDET), which is approximately 9 statute miles (sm) from the center of the corridors, as well as to the southwest near the Ford Rouge Plant. These are ideal locations for a medium range radar. From these locations, the radars can provide additional, redundant, and overlapping coverage over the corridors. In Area 3, a central emplacement of a single radar in the corridor would provide the best coverage. The team will work with MDOT to determine which radar asset should be chosen, as well as work with MDOT to conduct a proper site assessment to determine where to achieve the best coverage of the radar(s).

DeTect HARRIER Radar

Detection and tracking crewed aircraft by non-cooperative means is achieved with the DeTect X-band radar system that is capable of detecting targets at 15 nm and greater. This medium-range airspace surveillance capability is a 2D rotating antenna open array system that is field-proven and is currently operational at over 20 wind farms sites in North Dakota for several applications, including Aircraft Detection Lighting System (ADLS) and Beyond Line of Sight (BLOS), and in total 60 installation sites in the US, Canada, and Europe.

The HARRIER radar provides zero to 360 in azimuth from the sensor position, zero to 10kft AGL when line of sight (LOS) is available and has a minimum detection range of 50m. The proposed radar system is FCC licensed. More specifically, the DeTect HARRIER radar is 47 CFR Part 87 certified and thus can be used for radio-navigation purposes. The DeTect HARRIER radar can also be deployed as a mobile unit or be installed on radar towers of varying heights. It is recommended that this medium-range radar system be deployed for the corridors in Areas 1-3, installed on 100’ towers at each of the radar sites.

TERMA Scanter Radar

The TERMA Scanter radars are proven commodities and are currently operating at hundreds of locations around the world. The radar is a 2D sensor, as are several operational FAA air traffic control radars, and is capable of providing the accurate target range and information to safely fly BVLOS missions. The radar was originally designed as a coastal surveillance radar and has since been updated to incorporate a solid-state transmitter which provides 35dB of clutter cancellation. The system is provided with an 18’ high gain antenna. The radar operates in the X-Band and is FCC approved. More specifically, the TERMA Scanter radar is 47 CFR Part 87 certified and thus can be used for radio-navigation purposes.

SRC LSTAR Radar

The LSTAR radar is compact (40” x 80”), lightweight (150 lbs.), and low power (1,200 watts) allowing it to be emplaced on towers, rooftops, and other challenging locations making it ideal for emplacement within a city or remote locations. The LSTAR is based on a military counter mortar system and has an exceptional logistics support trail with over 1,000 systems manufactured and deployed. The LSTAR has 60dB of clutter cancellation which enables it to best handle the strong clutter returns from the buildings. The radar has a range of 18.6nm which can cover the entire corridor from either radar site. Furthermore, the radar is a non-rotating 3D radar and operates in the L-Band frequencies governed by Part 87.

Surveillance Coverage Assessment

The surveillance coverage assessment is in ***Ground-Based Surveillance Sites***.

Recommended Ground-Based Surveillance Sensors

The recommended surveillance sensors for the Connected Corridor are as follows:

- DeTect HARRIER ASR or SRC LSTAR as the primary medium-range radars for detecting non-cooperative targets
- uAvionix pingStation as the ADS-B receiver for detecting cooperative targets
- Iris Automation CASIA-G as the optical/camera system for short-range targeted surveillance

Security

Thales system is designed to comply with information security requirements defined by National Institute of Standards and Technology (NIST) FIPS Publication 200, Minimum Security Requirements for Federal Information and Information Systems and in conjunction with the selection and implementation of the appropriate security controls and assurance requirements from NIST Special Publication 800-53, Revision 4, Recommended Security Controls for Federal Information Systems.

Using similarities with NASA UTM and FAA LAANC projects, we assume that the systems and all components interacting with the system API need be secured at the FIPS 199 Moderate Impact Level. As part of the requirement analysis and design phase, the Project Team will prepare the list of applicable NIST 800-53 control to be discussed during PDR.

The following two sections describes the security certification and mechanism available from Microsoft Azure and the Cyber teams, then the recommended approach to NIST security controls.

Azure Cloud Security and Cyber Security Monitoring

Digital product and services are hosted in Azure Cloud. Microsoft cloud services provides an impressive list of certification as shown by Figure 108, and further details on Microsoft Azure Security Compliance Offerings can be found here.

Figure 108: Azure Trusted Cloud Certifications

Azure public cloud offers the following resources and services to secure a workload:

- Public
  - Encryption at-rest and in-transit
  - Virtual Networks
  - Microsoft Intelligent Security Graph: uses advanced analytics to synthesize massive amounts of threat intelligence and security signals obtained across Microsoft products, services, and partners to combat cyberthreats.
  - Security Center: security dashboards, recommendations, alerts, investigation tools and log search
  - Azure Monitor: full observability for your infra, app and network
- Confidential
  - Private Connectivity
  - HSM Based Encryption
  - VNet Integrated Services
  - Azure Lockbox: Azure personnel need customer permission to access resources for maintenance, just-in-time access
  - Azure Key Vault
- Sensitive
  - Confidential Compute: leveraging Intel SGX enclave support
  - Dedicated Hosts/Hardware Isolation

In addition to the above resources and services, the Digital Platform organization implements two dedicated teams who help secure the workloads deployed on the Digital Platform:

- TDP Blue Team: defender view. The blue team operates a Security Information Management System (SIEM) based on Azure (Security Center, Azure Monitor) and other tools. Its mission is to continuously strengthen the digital security infrastructure, detect vulnerabilities and attacks, remediates
- TDP Red Team: attacker view. The red team is focused on penetration testing.

NIST Security Control

FIPS 200 requirements cover seventeen security related areas addressing the protection of confidentiality, integrity and availability of the system and the information processed, stored, and transmitted by those system.

Of those areas the following have direct impact on the system design:

- Access Control **(AC)**
- Identification and Authentication **(IA)**
- System and Communication Protection **(SC)**
- Audit and Accountability **(AU)**
- Incident Response **(IR)**

The Physical and Environmental Protection **(PE)** is applicable to the C2 Operations Center and all the distributed physical infrastructure, and we assume those requirements will be addressed together with MDOT before installation.

The remainder of this section introduces how the Project Team recommends the MDOT BVLOS system addresses these areas.

Access Control

All access to cloud resources, applications, user tools, and services are protected. Access to the Azure Cloud console is protected by Azure Identity and Access Management and restricted to key people within Thales. Access to MDOT BVLOS C2 Operations Center back-end services are protected by Keycloak.

Keycloak COTS is hosted in the US Cloud and secures the access to all web user applications and services using by default a single factor authentication. Access to secure cloud resources is protected using a JSON Web Token (JWT) and access is granted based on user identity and role.

Access to C2 Operations Center web user applications is protected by single factor authentication (username and password). User role-based access policies are enforced to guarantee data access rights. Default role allows only access to resources and services dedicated to pilots and UAS operators.

Specific roles dedicated to authority, traffic flow manager, public safety/govt. users, etc. are manually assigned by Thales during system configuration and maintenance.

Identification and Authentication

All users and client applications are required to register to the MDOT BVLOS C2 Operations Center back-end using the user management web application. User identity and credential are stored by Keycloak. All users and client application are provided with unique credentials.

System and Communication Protection

Both data in transit and at rest are secured using NIST compliant mechanisms:

- Data in transit are encrypted using Transport Layer Security (TLS 1.2) protocol or IPsec.
- Data at rest are encrypted transparently within the storage services for ease of use and performance.

If required encryption keys are managed within Hardware Security Modules (HSM) operated by the cloud provider. These HSM are typically FIPS 140-2 Level 2 validated.

Communications between the MDOT BVLOS Operations Center cloud, the C2 Operations Center front room and backhaul data network are implemented using an IPSec VPN tunnel over the Internet.

The backhaul data network is further protected using a physical firewall located at the C2 Operations Center front room.

Audit and Accountability, Incident Response

In compliance with NIST requirements, system generate and store in the cloud required for audit and accountability purposes:

- System access and account management record
- Security event record

Security audit data are segregated and protected; access is granted only to administrative user. Data retention and rotation policies are implemented. The Blue Team is responsible of managing cyber security incident and responses.

Safety

Support will be required for MDOT's efforts to work with the FAA on maturing the BVLOS Network to accommodate routine BVLOS operations across the State of Michigan. The following sections discuss how the automation of the SORA process maps effectively to the FAA SRM process.

FAA's 8040.4 Order vs SORA

The Project Team understands the FAA's 8040.4 Order requires the MDOT BVLOS Network to provide an Operational Risk Assessment documenting the **severity** and **likelihood** of the hazards, in conjunction with all **mitigations** in place in order for the decision makers within the FAA to verify the **residual risks** are below an acceptable level.

The Project Team proposes to use the JARUS SORA process as a guideline to conduct the Operational Risk Assessment. JARUS WG-6 is recommending a risk assessment methodology to establish a sufficient level of confidence that an operation can be conducted safely. It allows the operation to be evaluated and categorized into six Specific Assurance and Integrity Levels (SAIL) and recommends for each SAIL the operational safety objectives to be met.

The FAA's 8040.4 Order states that the following are the worst **outcome** of a hazard:

1. Collision between UAS and a crewed aircraft in the air (Mid-Air Collision)
2. Collision between UAS (or one of its detached parts) and a person, a moving vehicle on the

ground

3. Collision between UAS (or one of its detached parts) and a critical infrastructure on the ground

Analogously, the SORA framework addresses the following worst **harm** deriving from a **risk:**

1. Fatal injuries to third parties on the air (Air Risk)
2. Fatal injuries to third parties on the ground (Ground Risk)
3. Damage to critical infrastructure (Ground Risk)

Where a **risk** is defined as the combination of the frequency (likelihood/probability) of an occurrence (outcome) and its associated level of severity.

SORA then defines air risk category (**ARC**) and ground risk category (**GRC**) based on the type of operation, the classification of the airspace, the airspace encounter category (**AEC**), and the population type of the area where the operation will be conducted. Figure 109 shows mapping between airspace classes, AEC, and ARC that can be used to determine initial ARC based on the airspace volume the operator is planning to conduct the operation.

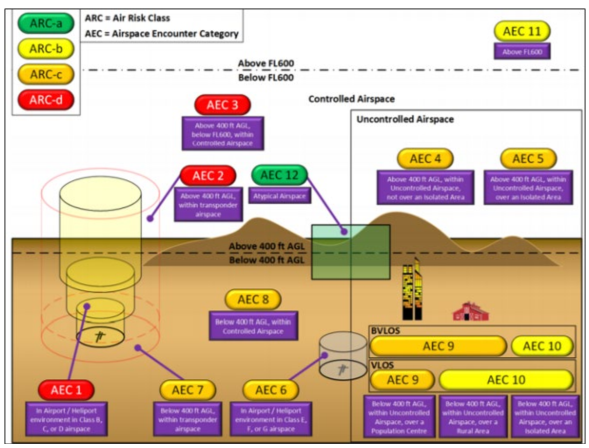


Figure 109: SORA Airspace Risk Classification (ARC)

Full details of the SORA are outside the scope of this plan. However, the Project Team recommends MDOT integrates the maturation of this concept across the State.

The Project Team's experience delivering safety critical Air Traffic Management systems and supporting ANSPs around the world is at the core of what we do. The Project Team is aligned with the JARUS vision and a move towards the standardization of operations along with categorization of operational scenarios, mitigation, and safety objectives are essential towards achieving a repeatable safety process. Publication of guidelines will help UAS operators realize a repeatable process to facilitate routine access to the airspace and accelerate the number of UAS operators that can be onboarded, helping fuel the success of the MDOT BVLOS Network deployment.
The SORA methodology of establishing an initial ARC, GRC, and performing an airspace characterization in order to assess residual air and ground risk is equivalent to the FAA's 8040.4 Order assessment of the Airspace and Operating Environment (FAA's 8040.4 2.b.(2).iii)

The FAA order list factors to be considered pertaining both to the airspace and the ground environment the operations will be conducted.

Airspace volume factors include:

- Class of Airspace
- Traffic density
- Type, speed, and altitude of other aircraft the UA can encounter
- Traffic complexity

Ground factors include:

- Population density
- Terrain and structures

Following the SORA methodology, Thales suggests the execution of the following tasks to advance the MDOT BVLOS Network to achieve the guidance established in FAA's 8040.4 Order assessment of the Airspace and Operating Environment leading towards routine BVLOS operations:

1. Determination of initial GRC and ARC for the MDOT BVLOS corridors and initial use-cases
2. Establishment of MDOT BVLOS Network Ground and Air Risk strategic mitigations guideline
3. Establishment of MDOT BVLOS Network Air Risk tactical mitigation robustness analysis
4. Establishment of a set of MDOT BVLOS Network operation templates derived from initial use cases
5. Establishment of MDOT BVLOS Network UAS Operator processes and procedure guideline (as per SORA Safety Objectives) to address assessment of safety level or robustness of the operator environment

Service as Mitigation

The Project Team will also support the MDOT BVLOS Network safety case by documenting all services of the system that can be used as mitigation and the associated robustness, including but not limited to the following:

- Tracking and Surveillance
- Monitoring and Control (including performance monitoring)
- Authorization & Declaration
- Notification/Flight Advisory
- UAS Monitoring

Risk Modeling

As part of the C2 Operations Center approach, the Project Team recommends the deployment of a risk modelling capability as part of the Monitoring Service. Using the data lake and the geospatial engine that fuses the categorical data into data services and applies them to SORA-based modelling, it's possible to qualify risk and dynamically calculate and publish the likelihood and severity of the risk as system, operations, and environment updates occur. Results can then be used by MDOT to verify SRM assumptions and by UAS operators to optimize mitigation measures such as the introduction or hardening of harm and threat barriers to reduce the consequence of hazards and increase safety.

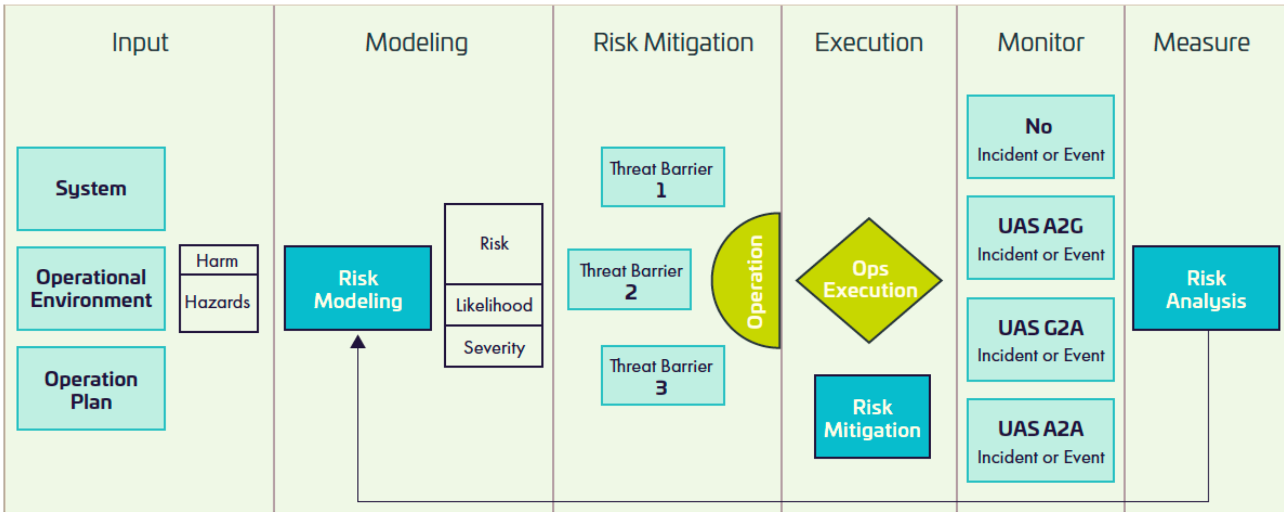


Figure 110: SORA Based Risk Model Diagram

Capital Infrastructure Deployment Strategy

System Implementation

The vision of a Connected Corridor by MDOT informs the team of the overall desire to deploy the right infrastructure to support corridor operations, and the means to approach that vision is described in this document. Each partner supporting the MDOT BVLOS will play a unique role in the establishment of a BVLOS network to support the Connected Corridor and the UAS Operators it intends to service. The actors from the FAA, MDOT, the support team and the user community that will be the beneficiaries of the system, will each have a role to play in the implementation.

The Project Team's approach to system implementation and test will follow a traditional waterfall approach for the deployment, test, and acceptance of remote site infrastructure as well as the physical C2 Operations Center (for the portions of the installation that the team is responsible for), and an agile software development framework for the functions and applications that will reside in the C2 Operations Center, which are foundational to the implementation. Important documents that must be created as part of the holistic implementation process are the customer requirements and the Test and Evaluation Master Plan (TEMP), which entails the system verification & validation activities to ensure the team can demonstrate that all requirements are achieved and the system is fully integrated. A typical scope of a TEMP includes descriptions of:

- Test events, including plans for Development Testing (DT) and Operational Testing (OT)
- Test objectives including mapping to customer requirements

- Test methods
- Test locations
- Required resources
- T&E roles and responsibilities
- Expected durations
- Test entry criteria
- Test exit criteria
- Test outputs and deliverables
- Possible results
- Test waiver/remediation process including criteria for regression testing
- Customer acceptance criteria
- Program Verification Requirements Traceability Matrix (VRTM)

This comprehensive approach ensures the deployment of the infrastructure and system will include development testing, production testing, integration testing, site acceptance testing (SAT), system SAT, and operational testing.

Government Furnished Equipment (GFE)

The following list is assumed to be GFE:

- UAS and Ground Control Software necessary to conduct missions on behalf of MDOT
- Crewed/General Aviation (GA) aircraft necessary for crewed test flights to validate baseline performance of the surveillance assets
- Access to State and/or local government facilities for remote site installations – State shall be responsible for negotiating leases/shared, secure access to remote locations for surveillance and communications equipment
- MDOT will be responsible for providing access to Michigan Central Station in order for the team to contribute to the overall design and layout of the C2 Operations Center capability in cooperation with MDOT
- MDOT will be responsible for the procurement and installation of workstations, furniture, and associated C2 Operations Center specific hardware (server racks, servers, monitors, etc.) per an agreed specification from the team
- MDOT will work with the team to obtain a transmit license from the FAA spectrum office for active surveillance at the remote site locations
- MDOT will be responsible for obtaining GIS data and associated licensing required for C2 Operations Center applications

Site Locations

Sites include locations for the C2 Operations Center, and all proposed remote locations where surveillance and C2 equipment will be installed. MDOT has selected the Michigan Central Station for the C2 Operations Center. The design for the physical layout and locations from which IT equipment will be installed and secured are details that are assumed to be managed by MDOT. The site locations proposed are notional and should be deemed as such until the full site selections process is completed with MDOT as part of the activities to be done prior to a preliminary design review.

Initial sites were selected for the purpose of indicative surveillance and communications coverage based on the compatibility of the sensors, considerations of local geographic and aesthetic requirements, locations of existing fiber networks, and the use cases. Remote sites will be finalized, in full cooperation with MDOT, for the installation and integration of surveillance and associated communication equipment. Sites must be vetted for a number of factors including, but not limited to permissions and regulations, size of access for equipment installation, operator and maintenance worker access, site security for emplaced equipment, power and communications infrastructure, line of sight blockages, RF reflective surfaces and obstructions, weight, stability, and vibration of the mounting point, RF safety radius, allowable noise limits, and others. Approvals for the remote infrastructure will be part of the site survey process.

C2 Operations Center

Though the C2 Operations Center is assumed to be designed by MDOT, along with all leasing and construction including office furniture, facility power, general networking, physical security, conference room furniture, etc., deployment of the cloud services that would enable the installed HW systems at the ops center to display the necessary data (surveillance and C2 system health, surveillance tracks, network status, as examples) will be the responsibility of the Project Team.

Design

The physical Michigan Central Station building is understood to be existing infrastructure. Thus, the responsibility for the physical design lies in the hands of the facility owner, local government authorities, and MDOT.

Construction and Site Preparation

Thales is committed to using local design and construction firms to do site preparation and construction to ensure that MDOT and the team are engaged in the design and flow of the C2 Operations Center. Other activities where local coordination will benefit Michigan businesses will be leveraged to the greatest extent possible. Additional details of the site design process will be provided as part of the site installation activity.

Acceptance

Site acceptance is a formal activity performed by the Project Team and overseen by MDOT to ensure that the site installation, integration, and operational configuration and that all contractual requirements are met at this stage. This will be the milestone that must be achieved to enter the system into operational evaluation or initial operations. Site acceptance will take place first at the subsystem level and then at the full system level testing all end-to-end requirements to be provided by MDOT. A detailed evaluation of the test results will identify items that need to be corrected before the system can enter operation or can enter operation conditionally with the approval of MDOT. This is also a major element of a Test and Evaluation Master Plan (TEMP) and will need to be included as part of that document.

Ground-Based Surveillance Sites

Potential emplacements of the radar systems are included in Table 42 below:

Radar Emplacements

Table 42: Radar Emplacements

Sensor	Type	Emplacement (Lat/Long)	Location	Area
DeTect HARRIER ASR (Primary Surveillance RADAR)	Medium Range Air Surveillance Radar	42.4187786, -83.0134351	Coleman Young International Airport Height: +55ft	1 & 2
DeTect HARRIER ASR (Primary Surveillance RADAR)	Medium Range Air Surveillance Radar	42.305089, -83.142039	Henry Ford Rouge Complex (Alt Site) Height: +55ft	1 & 2
DeTect HARRIER ASR (Primary Surveillance RADAR)	Medium Range Air Surveillance Radar	44.757798, -85.678692	WICA-FM Transmitter Tower Height: +55ft	3
SRC LSTAR (Primary Surveillance RADAR)	Medium Range Surveillance Radar	To be discussed with MDOT	To be discussed with MDOT	1, 2, 3

Table 43: Camera and ADS-B Systems Emplacements

Sensor	Type	Emplacement (Lat/Long)	Location	Area
Iris Automat–on CAS–A G - Camera	Electro-Optical Detection Sensor	42.2909486, -83.2139079	Beaumont Hospital Dearborn Rooftop Height: +25ft	1 & 2
Iris Automat–on CAS–A G - Camera	Electro-Optical Detection Sensor	42.297601, -83.22509	Ford Development Center Rooftop Height: +25ft	1 & 2
Iris Automat–on CAS–A G - Camera	Electro-Optical Detection Sensor	42.32031, -83.2181946	Ford Land Rooftop Height: +25ft	1 & 2
Iris Automat–on CAS–A G - Camera	Electro-Optical Detection Sensor	42.3675432, -83.0843681	Henry Ford Hospital Rooftop Height: +25ft	1 & 2
Iris Automat–on CAS–A G - Camera	Electro-Optical Detection Sensor	42.3568036, -83.0582923	Michigan State Medical	1 & 2

Sensor	Type	Emplacement (Lat/Long)	Location	Area
			Center Rooftop Height: +25ft	
Iris Automat–on CAS–A G - Camera	Electro-Optical Detection Sensor	42.3289699, -83.0526446	Double Tree Hotel Rooftop Height: +25ft	1 & 2
Iris Automat–on CAS–A G - Camera	Electro-Optical Detection Sensor	44.759592, -85.644146	Munson Medical Center Helipad Height: +25ft	3
Iris Automat–on CAS–A G - Camera	Electro-Optical Detection Sensor	44.749536, -85.583409	TC Helicopter Helipad (at KTVC) Height: +25ft	3
uAvionix ADS-B pingStation	ADS-B Receiver	42.2909486, -83.2139079	Beaumont Hospital Dearborn Rooftop Height: +25ft	1 & 2
uAvionix ADS-B pingStation	ADS-B Receiver	42.297601, -83.22509	Ford Development Center Rooftop Height: +25ft	1 & 2
uAvionix ADS-B pingStation	ADS-B Receiver	42.32031, -83.2181946	Ford Land Rooftop Height: +25ft	1 & 2
uAvionix ADS-B pingStation	ADS-B Receiver	42.3675432, -83.0843681	Henry Ford Hospital Rooftop Height: +25ft	1 & 2
uAvionix ADS-B pingStation	ADS-B Receiver	42.3568036, -83.0582923	Michigan State Medical Center Rooftop Height: +25ft	1 & 2
uAvionix ADS-B pingStation	ADS-B Receiver	42.3289699, -83.0526446	Double Tree Hotel Rooftop Height: +25ft	1 & 2
uAvionix ADS-B pingStation	ADS-B Receiver	44.759592, -85.644146	Munson Medical Center Helipad Height: +25ft	3
uAvionix ADS-B pingStation	ADS-B Receiver	44.749536, -85.583409	TC Helicopter Helipad (at KTVC)	3

Sensor	Type	Emplacement (Lat/Long)	Location	Area
			Height: +25ft	

Each of these indicative locations are state, county, municipality or privately owned and are draft recommendations. It is likely that MDOT has more desirable locations for these radars and the performance can be easily recalculated. In addition to the primary and secondary surveillance data, telemetry data from the UAS can be incorporated into the C2 Operations Center, which would provide a more comprehensive and air surveillance picture.

The line-of-sight (LOS) analysis for various heights AGL is shown in the figures below using the DeTect HARRIER ASR as a reference. This analysis portrays overlapping coverage in Areas 1 & 2, and extensive coverage of Area 3 except to the region to the northwest of Traverse City. In Areas 1 & 2, overlapping radar coverage is achieved. Theoretically, if one radar site becomes inoperable, the coverage with a single radar still captures the corridors in totality. Multiple radars provide an opportunity to get to multiple detection opportunities on non-cooperative aircraft and to correlate these detections with secondary surveillance data, if present.

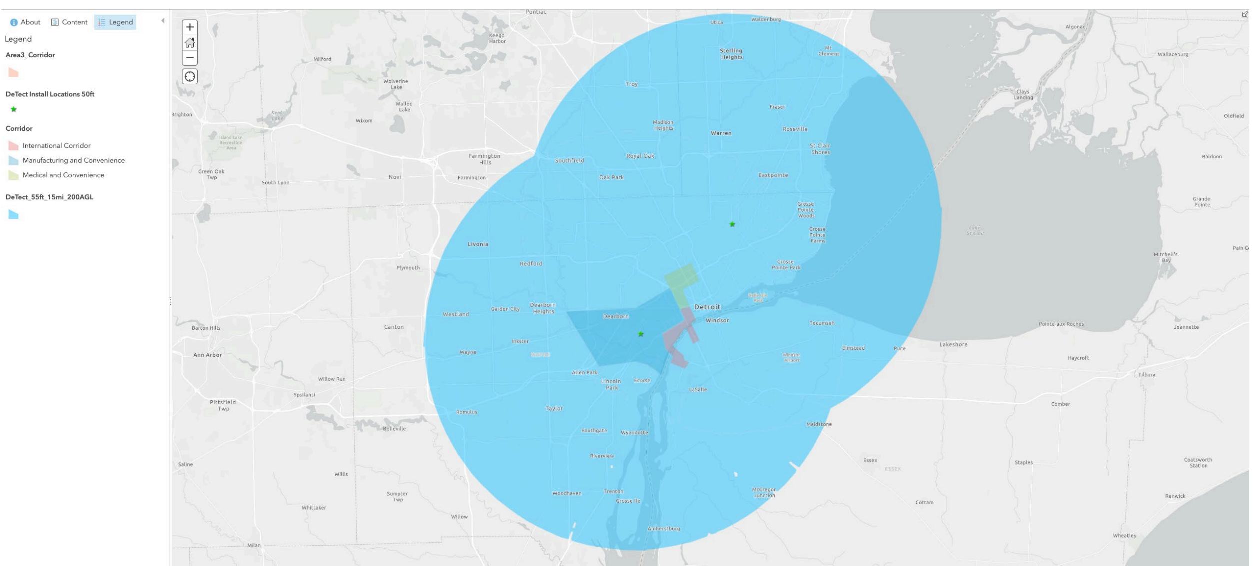


Figure 111: Indicative Primary Radar Surveillance Coverage in Areas 1 and 2 (200ft AGL)

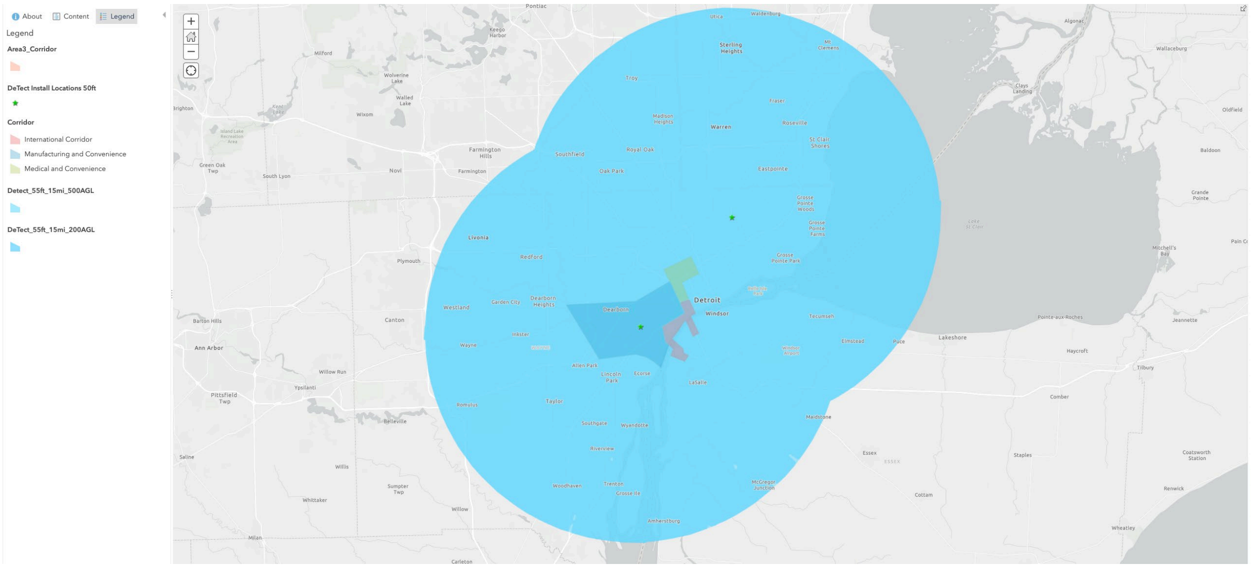


Figure 112: Indicative Primary Radar Surveillance Coverage in Areas 1 and 2 (500ft AGL)

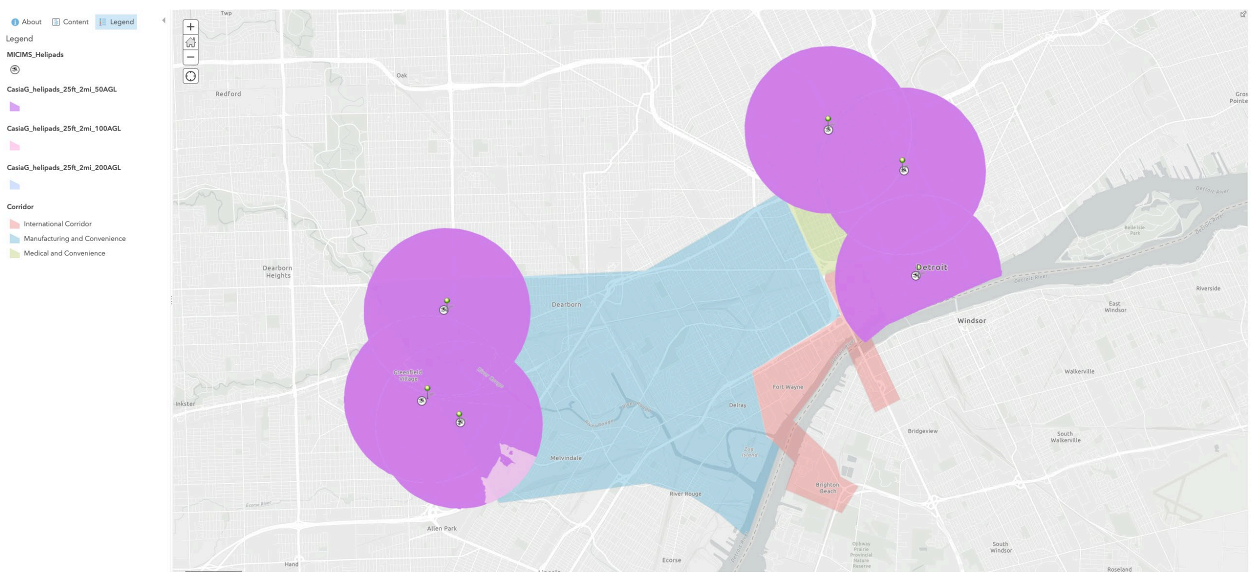


Figure 113: Indicative Optical Surveillance Coverage in Areas 1 and 2 (50ft, 100ft, 200ft AGL)

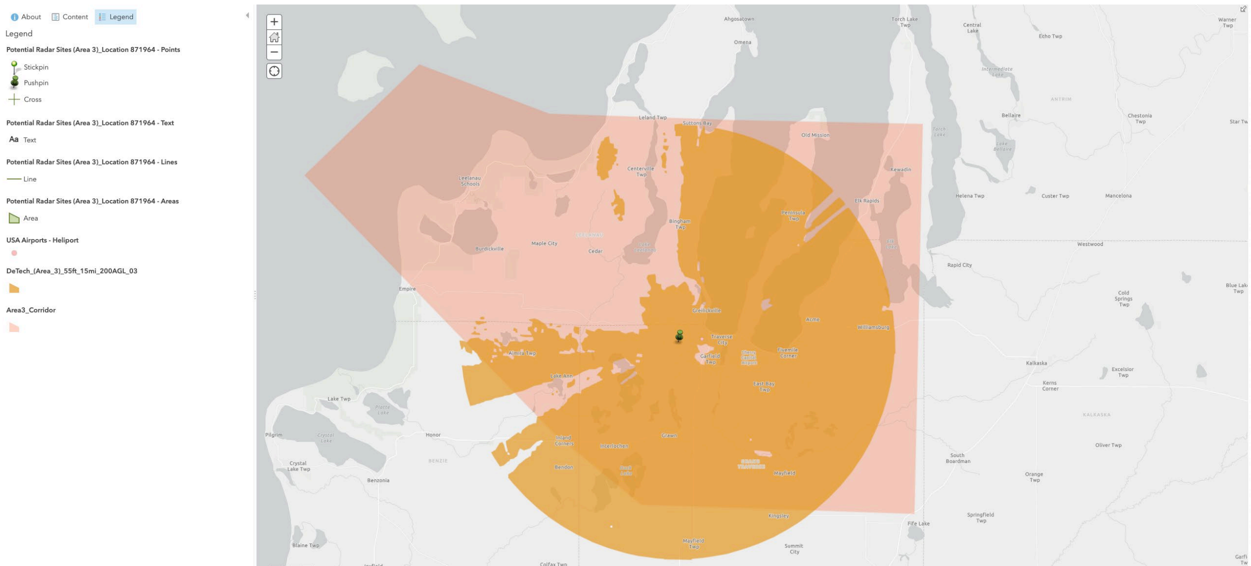


Figure 114: Indicative Radar Surveillance Coverage in Area 3 (200ft AGL)

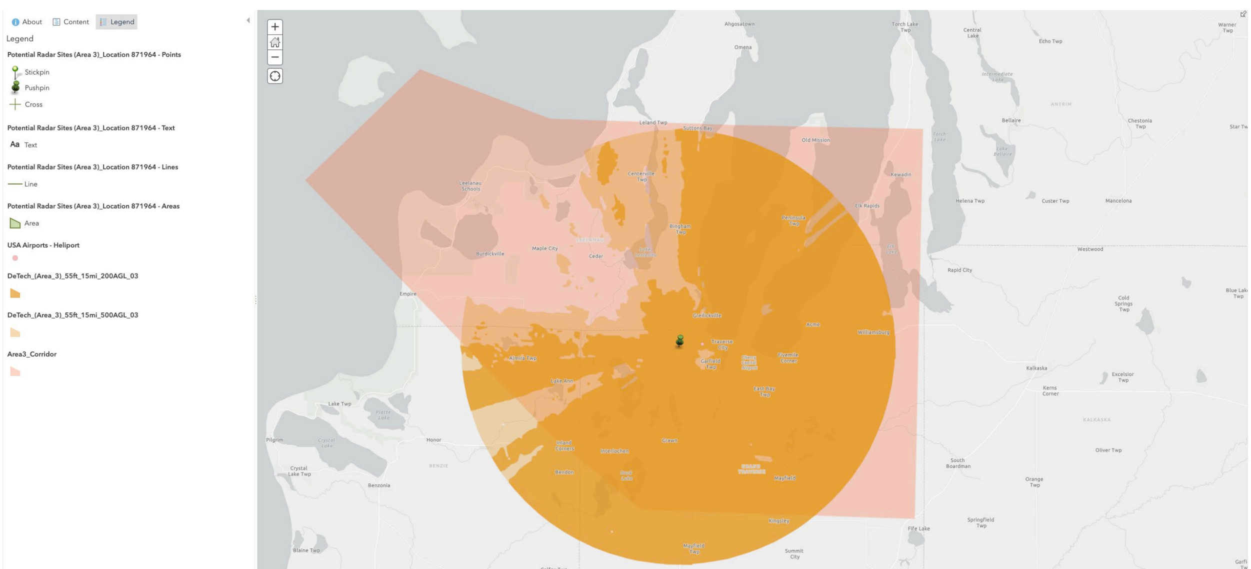


Figure 115: Indicative Radar Surveillance Coverage in Area 3 (500ft AGL)

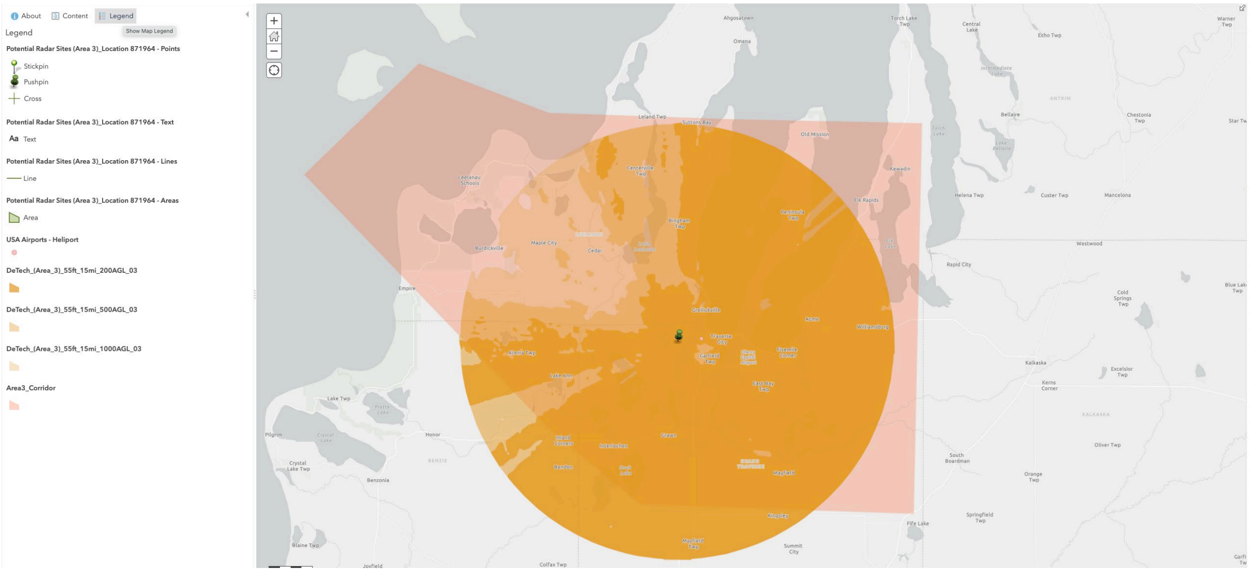


Figure 116: Indicative Radar Surveillance Coverage in Area 3 (1000ft AGL)

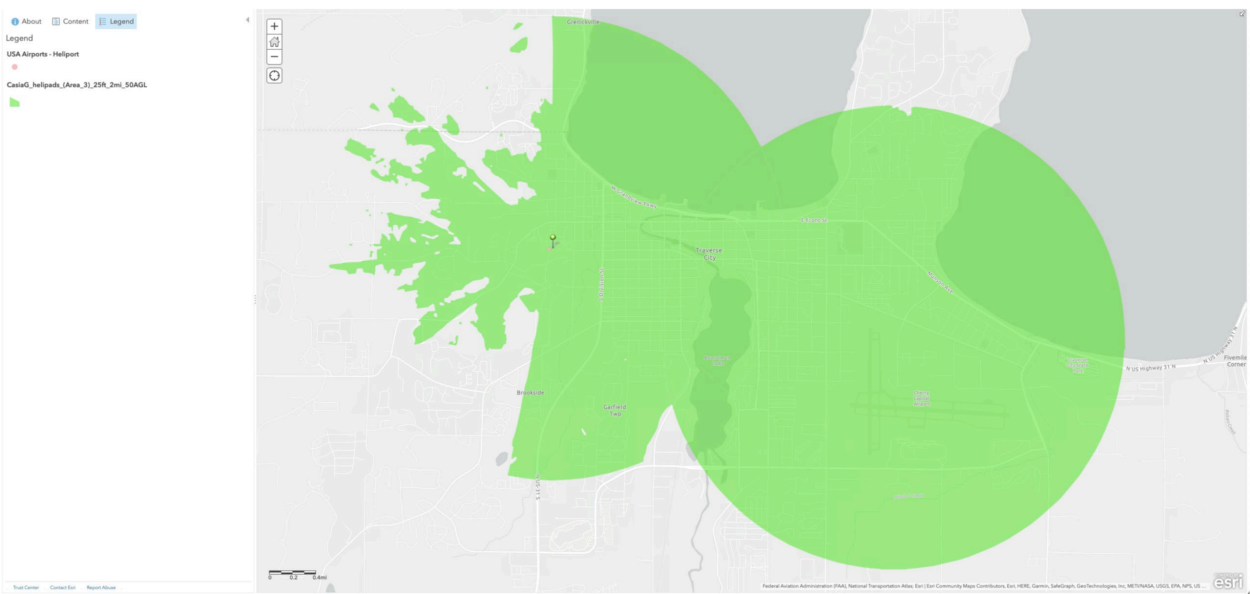


Figure 117: Indicative Optical Surveillance Coverage in Area 3 (50ft AGL)

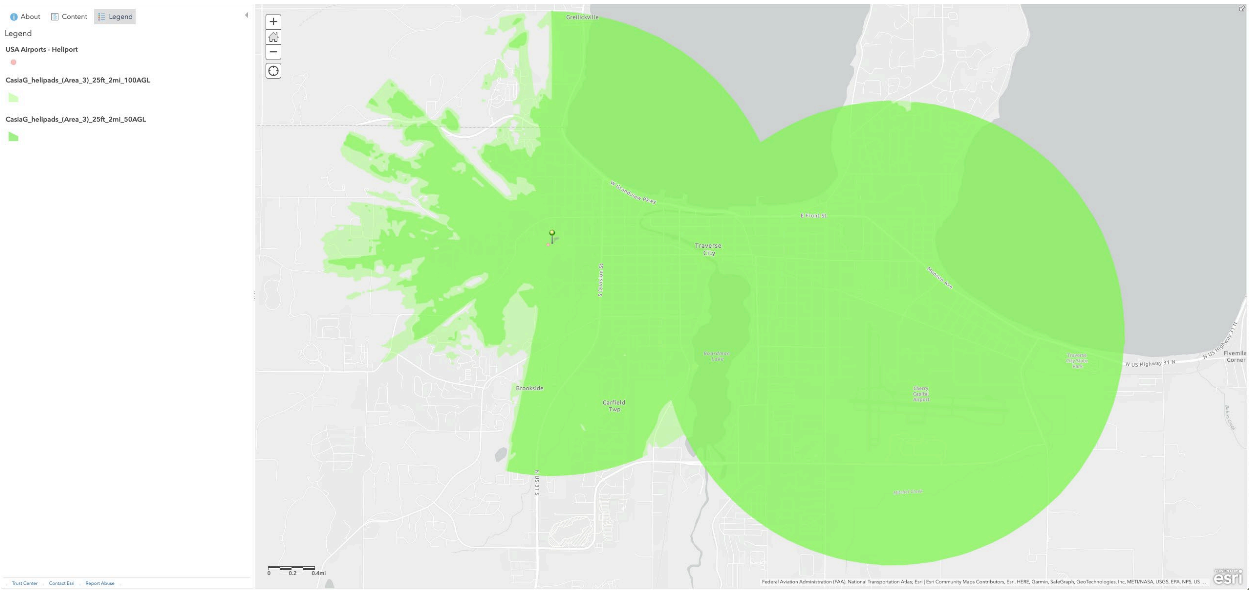


Figure 118: Indicative Optical Surveillance Coverage in Area 3 (100ft AGL)

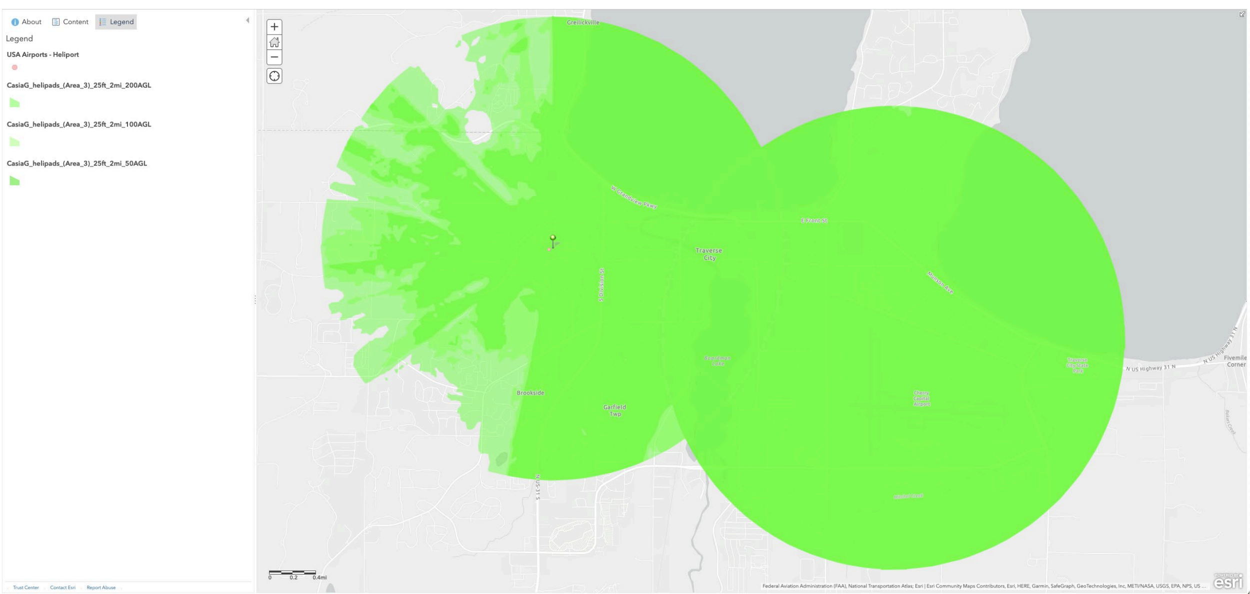


Figure 119: Indicative Optical Surveillance Coverage in Area 3 (200ft AGL)

Pre-Deployment/Site Design & Preparation

All State and local requirements must be adhered to as well as the appropriate FAA orders for the installation of surveillance and communications equipment. The pre-deployment/site preparation phase aims to identify site specific details for material procurement, site acquisition, site specific engineering (including structural and RF analysis), and jurisdictional approvals. Although this phase is dependent on the final design agreement, early site preparation and ordering of long lead procurement items as appropriate will help mitigate schedule risk. Early procurement of the surveillance radar sensors and C2 components is critical to any program schedule.

Each site will be based on a standard design; however, each site will require a site-specific set of drawings that will be used as exhibits for lease agreements, jurisdictional approvals, construction installation, and historical archive as the program matures. MDOT will need to coordinate access and provide lease agreement of State-owned sites and will be used to the greatest extent possible.

Standard Infrastructure Site Design

The economic efficiency of geographic expansion can be improved through the design of modular, standardized infrastructure designs that minimize site non-recurring design costs and speed installation, integration, testing, and commissioning. The Project Team anticipates developing several such designs to support the initial phase and beyond, including packages for airports, installation on existing towers, new tower construction, and transportable applications. The proposed design includes a configuration of redundant radar coverage, plus targeted primary surveillance for detection of non-cooperative aircraft, ADS-B receivers for detection of cooperative aircraft, and C2 Ground Radio Systems (GRSs), where targeted surveillance sensors, ADS-B, and C2 GRSs are all co-located at/overlooking helipad locations. In areas where redundant radar coverage cannot be attained, a single radar configuration may suffice. Additional configurations and variants can be expected as new technologies mature, new suppliers emerge, and field experience allows the models to be refined.

Construction and Site Preparation

It is recommended that local companies for construction and site preparation are leveraged. Local coordination benefits local businesses, and those resources should be used to complete site work. Additional details of the site design process will be provided as part of the site installation activity as part of recurring technical meetings and reviews.

Site Acceptance

Site acceptance is a formal activity that would be performed by the Project Team and overseen by MDOT to ensure that the site installation, integration, operational configuration, and all contractual requirements are met at this stage. This will be the milestone that must be achieved to enter the system into operational evaluation or initial operating capability (IOC). Site acceptance will take place first at the subsystem level and then at the full system level testing all end-to-end requirements within the contract. A detailed evaluation of the test plan will identify items that need to be corrected before the system can enter operation or can enter operation conditionally with the approval of MDOT. Additional activities include:

- Completion of Areas 1-3 system implementation including acceptable site preparation and other pre-deployment activities (e.g., structural and radio frequency (RF) analyses, permitting, and licensing as needed)
- Configuration and shipping of equipment
- Installation at remote sites and the C2 Operations Center
- Validation of Crown Castle access
- Availability of the C2 Operations Center facility

Air-to-Ground Communications Acceptance

It is recommended that MDOT elects to activate the uAvionix skyStation, installation and acceptance of the A/G system will include integration, test, and acceptance of the radio network.

Ground-to-Ground Communications Acceptance

This section briefly describes the activity related to the implementation of the G/G Communication infrastructure (aka Backhaul Data Network or Crown Castle Fiber).

Assumptions

- If MDOT elects to use existing ITS infrastructure, the ITS service provider will contract with MDOT
- ITS is GFE
- Thales will provide MDOT with network connectivity and security requirements for the connected corridor implementation
- ITS or Crown Castle will provide backbone access points at the C2 Operations Center and to all surveillance and C2 remote sites.

G-G Design

During the design phase, the team will work with MDOT to finalize the overall network design covering:

- IP address schema
- Number of VLANs
- ITS or Crown Castle Fiber existing redundancy/resilience mechanisms
- Access point configuration including security controls
- Last mile responsibility and demarcation points between the team and ITS or Crown Castle

ITS is existing communications infrastructure that the team could leverage. When more details of the existing ITS infrastructure is known, the team and MDOT will coordinate network requirements with ITS. Thus, Crown Castle is the proposed ground-to-ground communications provider for the backhaul communications between the remote sites and the C2 Operations Center. The team can coordinate to specify network requirements and work with MDOT on the overall design.

Construction and Site Preparation

As mentioned, Crown Castle has proposed an additional 13+ miles of fiber extensions from its fiber backbone to connect all remote sites in Areas 1 and 2. As this is preliminary work, site preparation will depend on the final design; but based on current assumptions, it will be limited to ensure the network equipment can be properly installed on each site based on Crown Castle requirements.

Acceptance

Acceptance of the network will be performed using networking tools to verify:

- Network access points are configured according to the system requirements

- Each site is visible and reachable using the proper IP address
- Network latency and throughput complies with the system requirements
- No packets are lost/dropped

Testing: Systems of Systems Integration and Validation (SAT)

Acceptance testing includes individual site and system level acceptance testing as agreed upon in the TEMP. Thales will use flight testing to test and validate remote sites and will leverage MDOT as required to assist with the test events. Thales will validate coverage analysis, end-to-end data, system monitoring, safety hazard tracking and specific use cases.
Normal and abnormal operations will be performed; failure mode and system maintenance monitoring per identified system safety case will be tested. It is expected that after SAT(s) (remote sites and C2 Operations Center) are successfully completed, a system-SAT will run for a "burn-in" period of time (e.g., multi-weeks) with the end-to-end system "service" operating and being monitored. Successful completion of the system-SAT will signal initial operational status.

Cloud Services

The deployment of the Cloud will start as soon as possible for the services be ready for test and integration with all system infrastructure as they are installed, tested, and ready for integration.

Deploy Cloud Resources

Thales will prepare the scripts to create and run all cloud resources requires to run applications implementing the necessary back-end services for the C2 Operations Center. New scripts can create two virtual platforms (i.e., operational, and test and validation) for MDOT. After this step, the new platforms security posture is automatically verified to ensure compliance with security policies (e.g., Thales Digital Factory).

Integrate CI/CD Pipeline

Both operational and test platforms will be integrated into the continuous integration and deployment (CI/CD) pipeline making sure all internal virtual networks are properly connected and secured. A deployment policy will be established to document rules and responsibility associated with the deployment of the services into these platforms.

Deploy Services

When the first software baseline passes automatic unit testing, all software quality checks, and initial testing is successfully performed on the internal QA platform, then the software baseline is ready for deployment both on the test and operational platforms.

Testing

All C2 Operations Center system testing procedures are executed at this stage. After this step, the C2 Operations Center back-end services are ready for system integration with the other segments.

Backhaul Data Network

This phase will be finalized after the data network is fully designed to reach all designated remote sites and access policy is established to connect all UAS operator's equipment and applications.

Integrate C2 Operations Center Front Room

Once the C2 Operations Center server room is established and all network equipment has been configured and tested, it is possible to verify the C2 Operations Center front room access (i.e., hardware such as workstations, etc.) to the backhaul data network (Crown Castle Fiber).

Integrate C2 Operations Center Back-end Services (Cloud)

The connection of the C2 Operations Center front end to back-end cloud services will commence with a secure internet connection. From this point, it is possible to test and verify access from the front room positions and server the C2 Operations Center back-end services. At this stage, it is possible to finalize the configuration of displays and all workstations. Because the C2 Operations Center is also the access point to the backhaul data network, the VPN between the C2 Operations Center back-end services and the backhaul data network is established and tested.

Integrate Ground-Based Surveillance Sites

This step requires all ground-based surveillance sites to have been installed and ready for integration. It consists of testing network IP connectivity between sites, the C2 Operations Center front room, and C2 Operations Center back-end services. Verification of sensors and site installs shall consist of three events with corresponding analysis.

1. Individual sensor validation: A flight test shall be conducted to verify the system and its emplacement are producing target state vectors that meet or exceed the system specification.
2. Individual sensor burn-in: Sensor shall be run for 24-72 hours continuously to verify continuous operational capability and establish a baseline on expected output given the operational environment for later comparison.
3. Simultaneous operations validation: All emplaced sensors shall be operated simultaneously including a flight test and burn-in period. Frequency deconfliction shall be conducted as needed and evaluation metrics shall be compared to the system baselines established during individual sensor burn-in.

A/G Communication Infrastructure

This section briefly describes the integration and testing for the A/G communications solutions. In all cases, the establishment of the C2 Operations Center back-end services is a prerequisite for integration.

Integrate uAvionix A/G Communications capability to Cloud

Thales will configure the IAM, appropriate broker, and payload ingestion services, and will confirm successful integration, including successful acquisition of authentication token, connection to the interface, and receipt of payload messages.

Integrate Cloud Data Storage

The A/G communications subsystem will be integrated to the cloud data storage. Once network configuration has been performed, this will be tested by using sample data.

Integrate Monitoring and Control and Cybersecurity

Each A/G communications solution will include health monitoring. These will be integrated to the C2 Operations Center and will be confirmed for successful operation.

Ground-Based Surveillance Infrastructure

The integration between the C2 Operations Center and the ground-based surveillance infrastructure can start after all sites are installed and verified, all sites have been connected to the backhaul data network and the C2 Operations Center back-end services are running. Prior to this step, there are several other incremental integration steps that will be taken.

Integrate Sensors to Cloud

The team's sensor vendors will each provide a sample data output of their respective sensors. This data will be played back into the Cloud and be used to verify the sensor's Interface Control Document (ICD), or equivalent, and to verify the data format and proper decoding. Connectivity of each sensor to the C2 Operations Center back-end service is verified.
The team will verify the correct reception and processing of all sensor output by the Tracking and Surveillance service.

Integrate GCS Telemetry to Cloud

Using the tools and applications provided by the chosen vendor/supplier of the C2 system, or a participating UAS operator, Thales will verify the Tracking and Surveillance Service correctly receives and processes UAV telemetry.

Configuring and Tuning the Tracking and Surveillance Service

Once all MDOT and the FAA sensors are properly connected and enough UAV telemetry data is available, the team will finalize the setup and tuning of the entire Tracking and Surveillance Service. A mix of traffic of opportunity (TOO) and crewed/uncrewed ad-hoc flights will be used to verify the final system coverage. Performance of the primary surveillance sensor will be compared with truthed data to determine and correct any errors. Thales will support the data collection and analysis of dedicated customer flight tests.
A preliminary report of sensor and system surveillance performance will be created to establish an initial baseline and verify initial assumptions and estimates.

Integrate Cloud Data Storage

Thales will verify that all sensor data are continuously received and stored via the C2 Operations Center/Data Storage Service.

Integrate Built-In-Test (BIT)

The Project Team will verify that all sensor BITs and health data are received and correctly processed by the Monitoring and Control Service. The Project Team will verify that the available and accessible remote maintenance actions can be successfully performed. The Project Team will verify that all available sensor remote control actions can be successfully performed. The correctness of computation of surveillance performance metrics (KPIs) is verified as an offline activity. The Project Team will conduct testing to verify that metrics respond accordingly when sensor input is degraded and that appropriate contingencies are triggered.

MDOT Connected Corridor Testing and Validation

Once all system components are integrated and the SATs entry criteria as described in the TEMP are met, the system is ready for testing and validation.
SAT goals are to demonstrate that the system meets the requirements and is ready for operational evaluation.
At this stage all system requirements presented during the preliminary design review are verified using written procedures (e.g., System Test Procedure Book). The system acceptance procedures will be written around MDOT use cases.
The team will execute a dry run of the acceptance test at least once before SAT (pre-SAT) in order to make sure all blocking issues (the TEMP will contain the final acceptance criteria to enter and exit the SAT) are resolved.
A test readiness review (TRR) will be conducted to brief the SAT team, composed by Thales, sensor vendors, partners, and MDOT representatives, about the following topics:

- Demonstrate system readiness
- Walk-through maintenance tickets that were closed during pre-SAT activities
- Walk-through maintenance tickets that are still open but not affecting SAT results
- Presentation of final SAT schedule (SAT are usually multi-day events)
- Presentation of SAT flights and acceptance procedure and criteria
- Final agreement on alternate schedule if testing cannot be conducted due to weather or other adverse environmental conditions

The SAT is executed by Thales and optionally witnessed by MDOT representative(s). UAS operations, as described by the system test procedure book, will be planned and executed by a member/partner of the Project Team.
Results, formal acceptance, and formal comments needing to be addressed at a later stage will be formally recorded in the SAT procedure book results.
If required, a daily SAT kick-off and recap meetings are held to prepare the day, discuss potential observations, and record notes from the conduct of that days SAT.

Initial Operations

The initial operations capability (IOC) phase will prove the system meets the MDOT Connected Corridor ConOps approved by the FAA as a result of the SRM process, and as such, can be used to support participating UAS operators.
The duration and scope of the IOC phase is defined by MDOT and conducted under the MDOT leadership. The Project Team will support IOC, as required. Once the system is fully operational, designated Thales team members will staff the C2 Operations Center working positions and the maintenance service desk will be open to all authorized MDOT Connected Corridor users.

During IOC, Thales will support OT and perform required maintenance as prescribed by the final Contract and Service Agreement with MDOT.

Appendix A

Terminology

Acronym/Term	Definition
AAM	Advanced Air Mobility
ADA	Air Domain Awareness
ADIZ	Air Defense Identification Zone
ADS-B	Automatic Dependent Surveillance - Broadcast
AGL	Above Ground Level
Air Traffic Organization (ATO) Safety Management System Manual	A collection of principles, policies, processes, procedures, and programs used to identify, analyze, assess, manage, and monitor safety risk
AMOC	Air and Marine Operations Center
ARC	UAS Beyond Visual Line-of-Sight Operations Aviation Rulemaking Committee
ASPM	Aviation System Performance Metrics
ASPM Airport	Airports participating in the Aviation System Performance Metrics program
ATC	Air Traffic Control
ATM/UTM	Air Traffic Management/UAS Traffic Management
BVLOS	Beyond Visual Line of Sight
C2	Command & Control
CBP	US Customs and Border Protection
CBSA	Canada's Border Security Agency
Class A Airspace	FAA Controlled Airspace starting at 18000ft MSL
Class B Airspace	FAA Controlled Airspace around the busiest USA commercial airports
Class C Airspace	FAA Controlled Airspace around regional commercial airports
Class D Airspace	FAA Controlled Airspace around towered local General Aviation and light commercial airports
Class E Airspace	FAA Controlled Airspace around regional untowered and other controlled airspace where ATC services are available
Class G Airspace	Uncontrolled Airspace
CMAA	Customs Mutual Assistance Agreement
ConOps	Concept of Operations document
CONR	Combined Air Operations Center
DAA	Detect and Avoid
DHS	Department of Homeland Security
EADS	Eastern Air Defense Sector
eVTOL	Electric Vertical Takeoff and Landing vehicle
FAA	Federal Aviation Administration
FCC	Federal Communications Commission
HSPD 16	Homeland Security Presidential Directive 16 details a strategic vision for aviation security while recognizing ongoing efforts, and directs the production of a National Strategy for Aviation Security and supporting plans.

ISED	Innovation Science and Economic Development Canada
JARUS	Joint Authorities for Rulemaking on Unmanned Systems Joint Authorities for Rulemaking on Unmanned Systems
MDOT AERO	Michigan Department of Transportation Aeronautics
MDOT PMO	Michigan Department of Transportation Program Management Office
MITRE	Not-for-profit corporation committed to the public interest, operating federally funded R&D centers on behalf of U.S. government sponsors
MDOT 2045 Mobility Plan	25-year plan for transforming Michigan's transportation system.
MDOT Aviation System Plan	Documents the planning process that identifies the aviation role of public-use airports in Michigan through the year 2035.
MOU	Memorandums of Understanding
Multi-Modal	Characterized by several different modes of activity or occurrence
NAS	National Airspace System
NASA	National Air & Space Administration
NORAD	North American Aerospace Defense Command
NPUASTS	Northern Plains UAS Test Site
OEP 35	Operational Evaluation Partnership (OEP) 35 airports are commercial US airports with significant activity
Part 107 VLOS	Flying a drone under the FAA 14 CFR Part 107 regulations while the drone is in visual line of sight (VLOS) of the operator
POE	Ports of Entry
PSP	Partnership for Safety Program
RTCA	Radio Technical Commission for Aeronautics
Safety Management System (SMS) Policy	Establishes SMS policy and requirements and emphasizes Safety Risk Management (SRM) and Safety Assurance (SA) processes
Safety Risk Management (SRM) Policy	Establishes requirements to conduct SRM
SDO	Standards Development Organization
SFOC-RPAS	Special Flight Operations Certificate for a Remotely Piloted Aircraft System (TC)
SORA	Specific Operation Risk Assessment
TAF	Terminal Area Forecast
TSA	Transportation Security Agency
UAS	Uncrewed Aircraft Systems
UAS Safety Risk Management Policy	Establishes a methodology for conducting SRM specifically for drone operations
UASRMs	Static Air Risk Maps
UAV/RPAS	Uncrewed Aircraft Vehicle/Remotely Piloted Aircraft System
UTM	acronym for Universal Transverse Mercator, a plane coordinate grid system named for the map projection on which it is based (Transverse Mercator).
VMTs	Vehicle Miles Traveled

Appendix B

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Appendix C

Project Team

The key personnel supporting this project are listed in the Table below.

KEY PERSONNEL			
Name and Title	**Roles & Responsibilities**	**Direct/Subcontract/ Contract**	**Location**
Name: Colby Free Title: Program Manager and VP, Geospatial Data Science Team	Program Management and Data Science/Analysis Team Lead	Direct	San Antonio, TX
Name: Corey Whittington Title: Sales Director	Secondary Business Development and Customer Relationship Management	Direct	Alexandria, VA
Name: Tyler Dicks Title: Sr. UAS Solutions Architect	UAS Solutions Design and Architecture	Direct	Atlanta, GA
Name: Mary Siedell Title: Senior Solutions Engineer	UAS Data and Solutions Engineering Support	Direct	Seattle, WA
Name: Jeff Beyer Title: Project Design Authority	Technical Management	Subcontract: Thales	Detroit, MI
Name: Jeffrey Richards Title: ATM Operations Expert	Airspace/ATC Consulting	Subcontract: Thales	Chicago, IL
Name: Adrian Solomon Title: UAS UTM Engineer	UAS UTM System Architecture Design and Engineering	Subcontract: Thales	Washington, DC
Name: Craig Spence Title: Founder & CEO	International Aviation Consulting	Subcontract: Aviation Innovations	Wirtz, VA
Name: Trevor Woods Title: Executive Director, Northern Plains UAS Test Site	Executive oversight for Safety Case development and approach with regulators. Manages staff which includes Aviation Safety experts.	Subcontract: Northern Plains UAS Test Site	Grand Forks, ND
Name: Jeremy Amundson Title: Project Manager	Project planning and management	Subcontract: Northern Plains UAS Test Site	Grand Forks, ND
Name: Danielle Miller Title: Director of Safety	UAS Regulatory and Safety Expert	Subcontract: Northern Plains UAS Test Site	Grand Forks, ND
Name: Matt Henry Title: UAS Safety Lead	UAS Regulatory and Safety Expert	Subcontract: Northern Plains UAS Test Site	Grand Forks, ND
Name: Gabe Klien Title: Executive Advisor Mobility	Mobility Advisor	Subcontract: Cityfi	Los Angeles, CA
Name: Chelsea Lawson Title: Director of Analytics	Advising on data, approach and assisting with analysis for community, environment, economic, transportation network impacts.	Subcontract: Cityfi	Los Angeles, CA
Name: Karla Peralta Title: Senior Associate, Cityfi	Conducting impact analysis with a focus on the economy	Subcontract: Cityfi	Los Angeles, CA
Name: Tom Swoyer Title: Aerospace Economic Development	UAS Economic Development Advisor	Subcontract: Infinity Development Partners	New Braunfels, TX

Appendix D

Impact Scoring Summary

Table 44: Consolidated Summary of Impact Scoring

Social Impact	Primary Category	Secondary Categories	Impact Score: Areas 1 & 2	Impact Score: Area 3	Rationale	Sources/Further Reading
Increase productivity	Economy		4	2	Delivery drones can reduce costs and friction for businesses to conduct logistics. We expect this productivity increase to come primarily from the transfer of cargo from freight to drone, rather than an increase of shipping demand or volume. Using this conservative method of analysis, we find a market potential of $7M annually that can leverage drone delivery for the defined corridor use cases.	(Lyon-Hill et al, 2020)
Benefit consumers	Economy		6	4	Through cargo and freight delivery within the manufacturing and medical use cases, we anticipate the Connected Corridor to enable faster deliveries and service to under-served areas. Our analysis finds a market potential of $7M annually that can leverage drone delivery for the defined corridor use cases. This impact would be significantly increased with the addition of retail deliveries in the longer term.	(USDOT, 2022)
Create skilled jobs	Economy	Community	7	4	While the shift in deliveries from vehicles to UAS would presumably remove some driving jobs from the Michigan economy, we also expect new and existing industries to create high-paying jobs in aviation, engineering, and finance. More generally, contrary to economic forecasts of the past, real-life data has repeatedly shown a relationship between automation and greater employment at both a macro-economic and firm level. Greater diversity of industries is a particular boon for the Detroit area which has struggled to compete with peer cities due to a concentration of skilled jobs in the auto industry.	(Dyment & Leeby, 2021) (Aghion et al., 2022)
Reduce emissions	Environment	Community, Economy	2	1	Reducing emissions helps to mitigate climate change- related risks in Michigan and beyond. Our analysis finds an estimated emissions reduction of about 1-2K tons of CO_2 annually from the pilot project depending on the area and level of adoption.	(Victoria Transport Policy Institute, 2016) (Environmental Protection Agency, 2018)

Noise and visual pollution	Environment	Community	-2	-1	Noise has a negative impact on the environment, economy, and community well-being as it can interfere with sleep, work, or recreation, and is shown to lower residential property value. Newer research even shows that plants do not grow as well when exposed to urban noise. Existing delivery conditions, including highway traffic and last-mile delivery, present a significant amount of noise, which the UAS corridor project has an opportunity to reduce. However, some studies suggest that even if noise volume decreases, the novelty of the sound of drones may cause an increase in the perception of noise pollution. We recommend conducting public outreach activities to better understand the impact of drones on the environment and community from an auditory and visual perspective.	(U.S. Department of Transportation Federal Highway Administration, 2006) (Economist, 2022) (Christian & Cabell, 2017)
Improve accessibility to pharmacy services	Community	Health & Safety, Equity	3	9	The use cases for the Connected Corridor pilot are focused on manufacturing, pharmaceutical, and medical deliveries. The latter two can have a major impact on the health of the community and lives of individuals as populations previously lacking medical access can get medications more easily.	(Lyon-Hill et al, 2020)
Increase general competitiveness	Community		8	3	As operation of the corridor brings new demand for and, in time, supply of skilled labor, we anticipate an increase in Michigan's competitiveness in attracting talent and businesses. Outside of directly impacted jobs, we anticipate spillover effects on job and wage growth in industries like hospitality and business services. Both proposed geographic areas have seen population declines in the past two decades, so a renewed vitality represents a significant if somewhat intangible impact.	(US Census Bureau, 2020) (Fikri, 2015)
Improve mobility	Community	Economy	1	4	Reduced congestion improves mobility access for road users. This benefits the economy and quality of life through reduced commute times and increased productivity. Longer term, use cases may also expand to an air transportation system that moves people between places previously not served or underserved by aviation. We also consider the distribution of this social benefit and how it can especially serve populations that are mobility challenged.	

Healthcare savings	Community	Health & Safety	2	1	Emissions reduction is not only good for the sake of the environment and mitigating climate change, it also has impacts on health and quality of life. Improvements in air quality result in healthcare savings via a reduction in asthma and other respiratory related illnesses. Studies of the shift to electric vehicles find substantial savings in avoided asthma attacks, death from lung disease, and workdays lost to pollution-triggered events. Since the VMT reduction from our use cases is relatively small and we are only estimating savings on a 5-year time horizon, we model this impact as a 2 out of 10, but we see potential for it to grow with time.	(Shindell, 2015) (Monteith, 2022) (Holmes-Gen & Barrett, 2016)
Decrease traffic accidents	Community	Health & Safety	2	1	In 2020, there were 1,084 traffic fatalities in the state of Michigan, equating to a rate of 1.25 deaths per 100 million vehicle miles traveled. Since the VMT reduction in the connected corridor given our use cases is relatively small and we are only estimating savings on a 5-year time horizon, we model this impact as a 2 out of 10, but we see potential for it to grow in time and think it is still important to recognize the directional impact from finding safer alternatives to vehicle transport.	(IIHS, 2022)
Concerns over safety and privacy	Community		-2	-2	Impacts related to community concerns are highly influenced by the implementation of the project. Similar to autonomous vehicles, any early mishaps can create a lasting perception of danger even if drones are safer than the vehicles they are replacing. When it comes to privacy, if people feel that their local government proactively sought community input, positive feelings of trust that privacy is being protected and balanced against economic benefits may even amount to a benefit. We represent this impact as cost in the visualization and recommend targeted public outreach over the course of implementation to mitigate it.	(Stanley, 2022)
Generate revenue	Fiscal	Economy, Community	4	2	The proposed business model for the UAS corridor is a public-private partnership in which fees are collected on a per-trip basis. Our analysis finds annual expected revenue generation of \$165-495K for Areas 1 and 2 and \$45-135K for Area 3 based on fees alone. We also expect increased productivity and new business growth to drive an increase in overall tax	

					generation, despite loss of fuel tax revenue from VMT reduction. MDOT has the opportunity to further enhance this benefit by reinvesting the money into projects that benefit the community.	
Operation and maintenance	Fiscal		-3	-3	As with any infrastructure project, the UAS connected corridor will have costs associated with its ongoing operation. These may include MDOT staff resources and drone hardware and software. Detailed estimates are outside the scope of this analysis. However, compared to alternative infrastructure for delivery transport (namely, roads), this cost is less as there is not the same real maintenance for resurfacing and utilities. The project also leverages existing assets to gain efficiencies, such as through using the airport as a hub for multi-modal connections and logistics.	(Strong Towns, 2020)

Appendix E

Methodology and Findings of Increased Accessibility to Pharmacy Services

A community impact that was crucial to study was how the use of drones could impact the accessibility of pharmacy services to disadvantageous communities. To assess this in both areas of study, the density of population by square mile, the lack of accessibility to public transportation, the vehicle accessibility by household, and the distance to the nearest pharmacy were calculated.

Table 45: Total households and Population Density

Measure Name	Location 1 & 2	Location 3
Total Population 2021	204,218	146,104
Population Density (Pop per Square Mile) 2021	3,218	75
Total Households 2021	74,979	61,654

To determine which percentage of the population had a low accessibility to pharmacy services it was assumed that the pharmacy should be no further than half a mile from the household and the household had limited accessibility to public transportation and private vehicles. The results on Table (Population with Low Accessibility to Pharmacies) show that 25 percent of the total population in Corridor Areas 1 & 2 could benefit from the drone services, and 59 percent of the total population of area 3.

Table 46: Population with Low Accessibility to Pharmacies

Measure Name	Areas 1 & 2	Percentage of total population in Areas 1 & 2	Area 3	Percentage of total population in Area 3
Total Population 2021	204,218	100%	146,104	100%
Population 0-0.49 mi to closest pharmacy	134,181	65.70%	58,868	40.29%
Population 0.49-0.98 mi to closest pharmacy	21,871	10.71%	7,265	4.97%
Population 0.98-1.47 mi to closest pharmacy	5,065	2.48%	9,788	6.70%
Population 1.47-1.96 mi to closest pharmacy	3,992	1.95%	16,808	11.50%
Population 1.96-2.45 mi to closest pharmacy	2,326	1.14%	5,929	4.06%
Population 2.45-8.47 mi to closest pharmacy	0	0.00%	47,446	32.47%

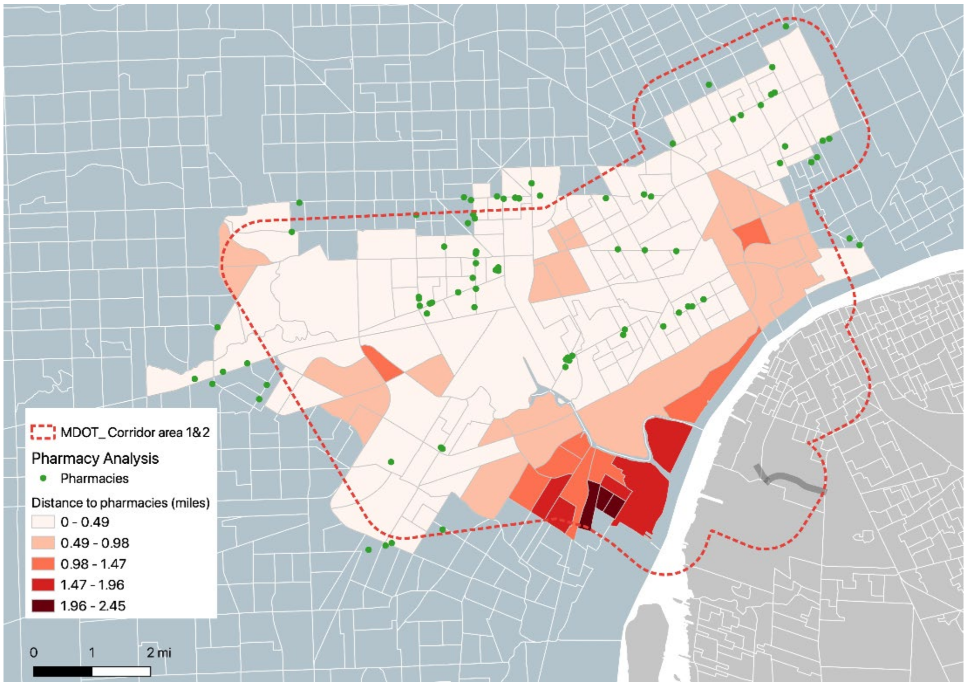

Figure 120: Identification of Blocks with Less Accessibility to Pharmacies for Corridor Areas 1 and 2

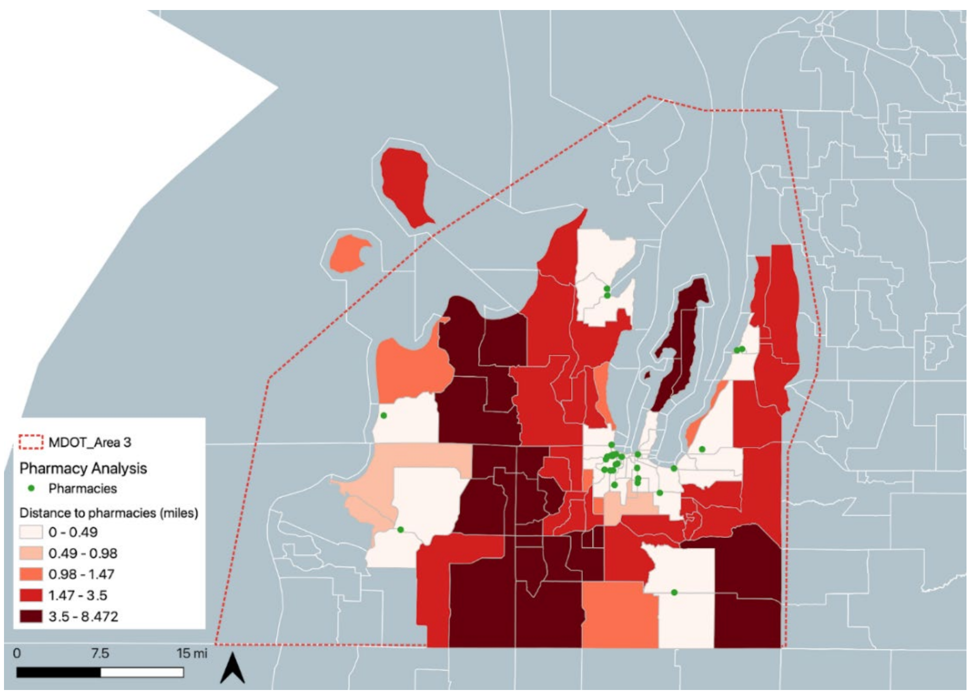

Figure 121: Identification of Blocks with Less Accessibility to Pharmacies for Area 3

Appendix F

Methodology and Findings of Estimated Vehicle Miles Traveled (VMT) and Emissions Reduction

The estimate for VMT reduction began by calculating existing VMT within each area. Open data from MDOT and Ontario Ministry of Transportation (MTO) of annual daily traffic volumes along major highways were used to triangulate these values. By calculating the distance of the various highway networks within each geographic area, total VMT and commercial VMT were calculated for each area.

Existing VMT Per Geographic Area

Formula: VMT = Avg traffic volume of roadway segment x length of the segment

Table 47: Summary of Vehicle Miles Traveled in Areas 1-3

Measure Name	Areas 1 and 2 - All VMT	Areas 1 and 2 - Commercial VMT	Area 3 - All VMT	Area 3 - Commercial VMT
Annual Daily Traffic Flow - Michigan	11,050,899	616,368	2,769,420	137,733
Annual Daily Traffic Flow - Canada	14,700	2,809	NA	NA
Highway distance (Miles) - Michigan	259	259	953	953
Highway distance (Miles) - Canada	0.0149	0.0149	NA	NA
Total existing VMT across major arterials	2,861,826,890	159,619,488	2,640,392,722	131,316,020

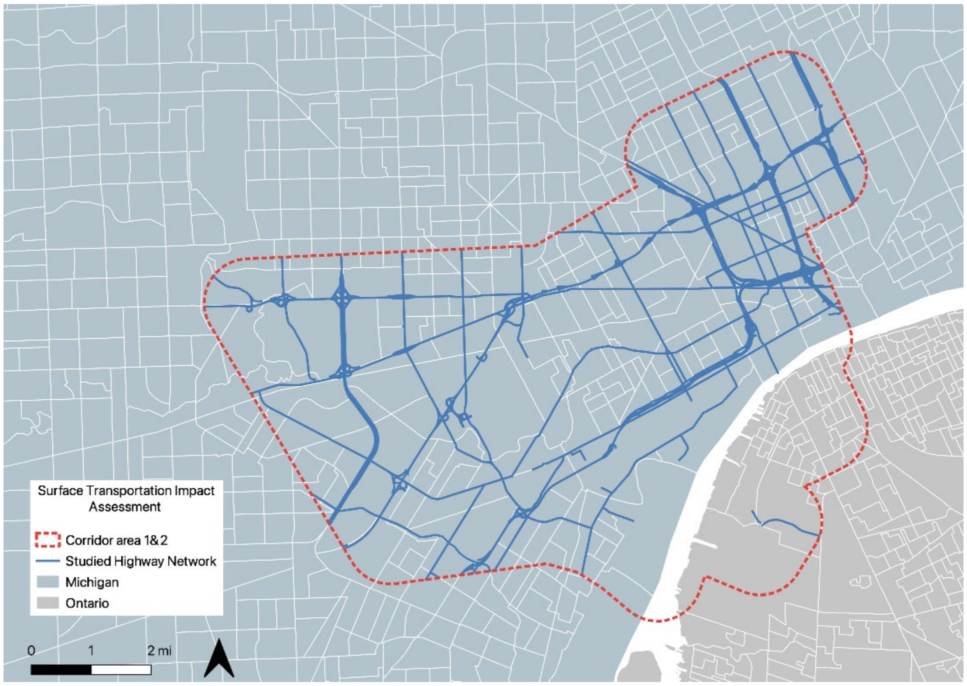

Figure 122: Studied Highway Network for Areas 1 and 2

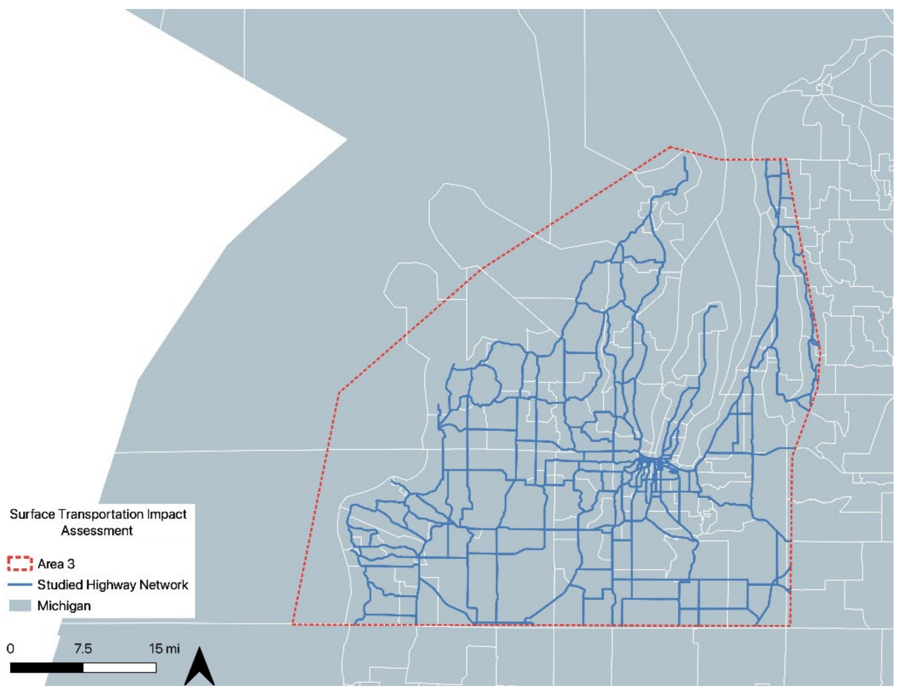

Figure 123: Studied Highway Network for Area 3

To understand how integration of UAS operations in the defined use case areas may impact traditional surface transportation networks, order-of-magnitude estimates were used for the assumed percentage of total vehicle miles traveled and commercial vehicle miles traveled that make up the use cases. Finally, two potential scenarios we modeled, or levels of UAS adoption across each geographic area, and multiplied these adoption scenario percentages with our assumptions to develop a range of expected VMT reduction for each area.

For instance, it was estimated that manufacturing, pharmaceutical, and medical material deliveries make up 1% of total VMT in both geographic areas, and 10% of commercial VMT. Given those assumptions and defined adoption scenarios of 10% conversion from vehicles to drones versus 30% conversion, then values for estimated VMT reduction were able to be calculated.

Findings: Forecasted Surface Transportation Impact for Each Region and Scenario

Table 48 shows the estimated VMT reduction for each scenario and in each area.

Assumptions made in creating this estimate are:
Values are calculated over a five-year time horizon
Low adoption scenario means 10% conversion from vehicles to drones
High adoption scenario means 30% conversion from vehicles to drones

Table 48: Surface Transportation Impact Assessment for UAS Connected Corridor

Measure Name	Areas 1 and 2 - All VMT	Areas 1 and 2 - Commercial VMT	Area 3 - All VMT	Area 3 - Commercial VMT
Defined use cases	Manufacturing, pharmaceutical, and medical material	Manufacturing, pharmaceutical, and medical material	Manufacturing, pharmaceutical, and retail	Manufacturing, pharmaceutical, and retail
Assumed percentage of existing VMT	1%	10%	1%	10%
VMT reduction - low adoption scenario	2,861,827	1,596,195	2,640,393	1,313,160
VMT reduction - high adoption scenario	8,585,481	4,788,585	7,921,178	3,939,481

Using the VMT calculations, we then estimated emissions reduction using the formula:
Emissions reduction = VMT reduction x (emissions per vehicle mile (grams CO_2) - emissions per drone mile)

The emissions per vehicle mile that we used was a rounded estimate for a passenger vehicle (400 grams CO2), given the lightweight nature of the cargo for our delivery use cases (Environmental Protection Agency, 2018). For emissions per drone mile, while there will be some emissions when considering the lifecycle advanced air mobility such as battery charging and the extraction of parts, we assume these emissions to be negligible when realistically compared with vehicle emissions. This is especially true given our assumption of passenger delivery vehicles, since the true makeup of the vehicles is likely some combination of cars and trucks. Our analysis of emissions per vehicle mile also only considers carbon dioxide and not nitrogen oxides (NOx) or particulate matter, two vehicle exhaust emissions that are particularly bad for air quality. As such, we believe this simplified comparison evens out to be conservative.

Appendix G

UAS Operator Registry; please see table below.

Table 49: UAS Operator Registry

Company	Industry Role	Regulatory Certifications	HQ Country	Market Focus	Use Case(s)	Vehicle Name/ ID	Website
3D Robotics	OEM	*sUAS Process	USA	Imaging	Security & Imaging	3DR H520-G	https://www.3dr.com/
Aerialloop	OEM + Operator			Package Delivery			https://www.aerialoop.com/
Aerial Robotics	OEM						https://airialrobotics.com/
AeroVironment, Inc.	OEM		USA	Cargo/Freight	Tactical Missions, surveillance	*Various*	https://www.avinc.com/uas
AgEagle	OEM	Flight Testing	USA	Imaging/Photogrammetry	Aerial Imagery for Agriculture		https://ageagle.com/
Airbus	OEM + Operator	pilot on board	Netherlands	Passenger/Air Taxi	Passenger transport		Not listed
Alpha Unmanned Systems	OEM + Operator		Spain	Cargo	Tactical Missions, surveillance		https://alphaunmannedsystems.com/
Amazon	Operator - Part 135	Part 135 Standard Cert	USA	Cargo	Package/ Cargo Delivery		Amazon.com: Prime Air
Aquiline Drones	OEM + Operator + Production + Cloud	Flight Testing	USA	Cargo	Surveillance; Public Safety; Agriculture		https://www.aquilinedrones.com/
Archer	OEM	pilot on board	USA	Passenger	Commercial Passenger Transport	Maker	https://www.archer.com/news/archer-unveils-evtol-aircraft
Bell Flight	OEM + Operator	Flight Testing	Canada	Passenger	Passenger transport		https://www.bellflight.com/products/bell-apt
Beta Technologies	OEM	pilot on board	USA	Cargo	Large Cargo Delivery	ALIA-250c (1)	https://www.beta.team/aircraft/

Company	Industry Role	Regulatory Certifications	HQ Country	Market Focus	Use Case(s)	Vehicle Name/ ID	Website
Beta Technologies	OEM	pilot on board	USA	Passenger	Passenger transport	ALIA-250c (2)	https://dronedj.com/2021/04/08/ups-flight-forward-to-use-drones-from-beta-technologies/
Blade Urban Air Mobility	Air Charter Broker, Indirect Air Carrier	Type Certified, Crewed Aircraft	USA	Passenger	Medimobility, healthcare, charter	Sikorsky S-76	https://www.blade.com/UAM-eva
Blade Urban Air Mobility	Air Charter Broker, Indirect Air Carrier	Type Certified, Crewed Aircraft	USA	Passenger	Medimobility, healthcare, charter	Bell 407	https://www.blade.com/UAM-eva
Boeing/Wisk/Aurora	OEM + Operator	Flight Testing	USA	Passenger	Passenger transport		https://wisk.aero/
Causey Aviation	Operator - Part 135	Part 135 Standard Cert	USA	Cargo	Charter Flights; Food Delivery		https://www.causeyaviation.com/
Deuce Drone	OEM + Operator	Flight Testing	USA				https://deucedrone.com
Dragonfly Innovations Inc.	OEM	Flight Testing	USA	Cargo	Surveillance; Public Safety; Agriculture		www.draganfly.com
Drone Aviation Corp.	OEM	Flight Testing	USA	Cargo	Tactical Missions, surveillance	WATT 200	https://droneaviationcorp.com/
Drone Aviation Corp.	OEM	Flight Testing	USA	Cargo	Foul Weather, multi-missions	WATT 300	https://droneaviationcorp.com/
Drone Delivery Canada Corp	OEM	Transport Canada Certified	Canada	Cargo	Package/ Cargo Delivery - Healthcare/First Aid	Sparrow	https://dronedeliverycanada.com/

Company	Industry Role	Regulatory Certifications	HQ Country	Market Focus	Use Case(s)	Vehicle Name/ ID	Website
DroneUP	OEM + Operator	None	USA	Cargo	Contract Drone Pilots - Multi Missions	DJI	https://www.droneup.com/
Ehang Holdings Inc.	OEM + Operator		China	Passenger	Passenger transport		https://www.ehang.com/ehangaav/
Elroy Air	OEM + Operator	TC In Process	USA	Cargo	Commercial; Humanitarian Aid; Military		http://elroyair.com/
Fixar UAS	OEM		Latvia	Cargo	Package/ Cargo Delivery		www.fixar.pro
Flirtey	OEM + Operator	TC In Process	USA	Cargo	Package/ Cargo Delivery - Healthcare		https://www.flirtey.com/
BluFlight (FlugAuto)	OEM + Operator		UAE	Cargo	Food & Beverage Delivery		https://www.flug-auto.com/
Flytrex	OEM + Operator	TC In Process	Israel	Cargo	Food & Beverage Delivery		https://www.flytrex.com/
HiRo	OEM		USA	Imaging	Telemedicine		https://www.youtube.com/embed/VwXJnr4s6Ps
HopFlyt	OEM		USA	Cargo	Passenger transport	Venturi	Home - New | HopFlyt
Hyundai	OEM + Operator	pilot on board	USA	Passenger	Passenger transport	S-A1	https://www.hyundai.com/worldwide/en/company/newsroom/-0000016369
Jaunt	OEM	Pilot on board	USA				https://jauntairmobility.com/
Joby Aviation	OEM	pilot on board	USA	Passenger	Passenger transport		https://www.jobyaviation.com/
JumpAero	OEM + Operator		USA	Cargo + First Responder	Package/ Cargo Delivery - First Responders		https://www.jumpaero.com/
Kitty Hawk	OEM		USA	Passenger	Recreational	Heaviside	https://kittyhawk.aero/

Company	Industry Role	Regulatory Certifications	HQ Country	Market Focus	Use Case(s)	Vehicle Name/ ID	Website
Kitty Hawk	OEM		USA	Passenger	Passenger transport	Cora	https://kittyhawk.aero/
Lilium	OEM	pilot on board	Germany	Passenger	Passenger transport		https://lilium.com/
Manna Drone Delivery	OEM + Operator		USA				https://www.manna.aero/
Matternet	OEM	TC Approved - Sept 2022	USA	Cargo	Package/ Cargo Delivery - Healthcare/Pharmaceuticals	M2 Drone	UPS Flight Forward Adds New Aircraft
Mighty Fly	OEM + Operator	TC in process	USA	Cargo	Large Cargo Delivery		https://mightyflying.com/
MissionGO	OEM + Operator	TC in process	USA	Cargo	Package/ Cargo Delivery - Healthcare, Utilities Inspections	MG Velos 100	https://www.missiongo.io/
Moog Aircraft Group	OEM	pilot on board	USA	Cargo	Large Cargo Delivery		https://www.moog.com/Innovation.html
Overair	OEM	Pilot on board	USA	Passenger	Passenger transport		overair.com
Percepto	OEM	TC in Process	Israel	Imaging	Inspections, Imaging		percepto.co
Pipistrel	OEM		USA				https://www.pipistrel-aircraft.com/
Robodub	OEM	None	USA	Cargo	Package/ Cargo Delivery - last mile	Volaire 55	https://robodub.com/
Sabrewing	OEM		USA				https://www.sabrewingaircraft.com/
SenseFly	OEM		France	Imaging	Aerial Imagery for Agriculture		https://www.sensefly.com/
Skycart	OEM		USA				https://www.skycart.net/
Skydio	OEM		USA				https://www.skydio.com/

Company	Industry Role	Regulatory Certifications	HQ Country	Market Focus	Use Case(s)	Vehicle Name/ ID	Website
Speedbird Aero	OEM + Operator		USA				https://www.speedbird.aero/
Sunflower Labs	OEM						https://sunflower-labs.com/
SwoopAero	OEM + Operator		Australia	Cargo	Package/ Cargo Delivery - Healthcare		https://swoop.aero/our-solutions
Telegrid (Drone Express)	OEM + Operator	TC In Process	USA	Cargo	Small Cargo Delivery - Grocery & Healthcare		https://droneexpress.ai/intelligent-uav-technology/
Terrafugia	OEM		China	Passenger	Passenger transport		https://terrafugia.com/
UAVOS	OEM		USA			*various*	https://www.uavos.com/products
UPS Flight Forward	Operator - Part 135	Part 135 Standard Cert	USA	Cargo	Small Cargo Delivery	various	https://www.ups.com/us/en/services/shipping-services/flight-forward-drones.page
Urban Aeronautics	OEM		USA				https://www.urbanaero.com/
Vayu Aerospace	OEM	Flight Testing	USA				https://vayuaerospace.com/
Vertical Aerospace	OEM	Pilot on board	USA				https://vertical-aerospace.com/
Volatus Aerospace	Operator - Canadian & American	Transport Canada Certified	Canada				https://volatusaerospace.com/
Volansi	OEM + Operator	TC In Process	USA	Cargo	Small Cargo Delivery - Healthcare		https://volansi.com/
Volocopter	OEM	pilot on board	Germany	Passenger	Passenger transport	Volocopter 2X	https://www.volocopter.com/
Volocopter	OEM		Germany	Cargo	Cargo Transport	Volodrone	https://www.volocopter.com/

Company	Industry Role	Regulatory Certifications	HQ Country	Market Focus	Use Case(s)	Vehicle Name/ ID	Website
Watts	OEM	Flight Testing					https://wattsinnovations.com/
Wing	OEM + Operator	Part 135 Standard Cert	USA	Cargo	Passenger transport		https://wing.com/
Wingcopter	OEM	TC In Process	Germany	Cargo	Package/ Cargo Delivery	W198	https://wingcopter.com/
Wingcopter	OEM	TC In Process	Germany	Cargo	Package/ Cargo Delivery	W178	https://wingcopter.com/
Workhorse Group, Inc.	OEM + Operator	TC in process	USA	Cargo	Package/ Cargo Delivery	HorseFly	https://workhorse.com/
Zing Drone Delivery	Operator		USA				https://www.zingdrones.com/
ZipLine	OEM + Operator	TC In Process	USA	Cargo	Package/ Cargo Delivery - Healthcare/Blood Units (rural)		https://flyzipline.com/

Appendix H

Please see below the criteria used to score the use cases that would jump-start drone operations and provide immediate and long-term benefits to the communities in Areas 1,2, and 3. The last row represents a theoretical use case, as an example to showcase the scoring methodology.
Due to the length of the table, we have divided into four sub-tables, for the ease of presentation only.

	Use Case Scoring				MDOT 2045 Mobility
DEFINITION	MDOT Region	Use Case	Use Case Score	Total Regional Score	Operations within a **Strategic Multimodal Corridors (SMC)**
	Criteria Definition ----> Source documents include the MDOT 2045 Mobility Plan, MDOT Aviation Systems Plan, the State of Michigan Feasibility Analysis - Unmanned Aerial System Connected Corridor, and Stakeholder feedback received in its execution.				Does the use case exist within or service an SMC (defined as integrated, multimodal system serving the movement of people, services, and goods that are vital to the economy)
	Evaluation Rubric			High (3)	Exists within an SMC and impacts a multimodal asset/service
				Moderate (2)	Exists within an SMC
				Low (1)	Does not exist within an SMC
Example	Bay	Cargo Movement (eVTOL)	35	35	3

Table 50: Use Case Scoring MDOT 2045 Mobility

	Use Case Scoring				MDOT Aviation Systems Plan Criteria					
	MDOT Region	**Use Case**	**Use Case Score**	**Total Regional Score**	Serves Population Center	Serves Business Center	Serves Tourism Center	Provides Access to General Population	Serves Isolated (including seasonally) Areas	Enables All Weather Access
DEFINITION	**Criteria Definition --->** Source documents include the MDOT 2045 Mobility Plan, MDOT Aviation Systems Plan, the State of Michigan Feasibility Analysis - Unmanned Aerial System Connected Corridor, and Stakeholder feedback received in its execution.				Does the use case serve the most densely populated areas of the state (defined by 250 ppl per sq. mile)	Does the use case serve or positively impact businesses in areas of the state with increased business activity (defined employment projections of at least 3,000 by year 2040)	Does the use case serve or exist in reasonable distance to tourist locations within Michigan (defined by counties with $75 million or more in visitor spending)	Does the use case serve non-business, non-recreational use within Michigan (i.e., law enforcement, healthcare organizations, educational institutions, etc.).	Does the use case serve islands that have year-round residents (Beaver, Bois Blanc, Drummond, Harsens, and Mackinaw Islands)	Does the use case enhance or positively impact all weather operations and access?
	Evaluation Rubric			High (3)	Exists within a population center and serves constituents	Exists within a business center and serves businesses	Exists within a tourist center and impacts tourism industry	Provides non-business, non-tourism aviation access of critical importance	Serves seasonally isolated populated islands, enables year-round access	Significantly enhances or impacts all weather access
				Moderate (2)	Exists within a population center	Exists within a business center	Exists within a tourism center	Provides non-business, non-tourism aviation access	Serves seasonally isolated populated islands	Enhances or impacts all weather access
				Low (1)	Does not exist within a population center	Does not exist within a business center	Does not exist within a tourism center	Does not provide non-business, non-tourism aviation access	Does not serve seasonally isolated populated islands	Does not enhance or impact all weather access
Ex.	Bay	Cargo Movement (eVTOL)	35	35	2	3	1	2	2	2

Table 51: Use Case Scoring MDOT Aviation Systems Plan

DEFINITION	**Use Case Scoring**				**Strategic Impact Criteria**						
	MDOT Region	**Use Case**	**Use Case Score**	**Total Regional Score**	Leverages **Existing P3 /**	Leverages **Existing Transportatio**	Proximity to **Corporate HQs**	Proximity to **Industry Clusters**	Operators: Path to Commercial	Operators: Transferability	Economic, Community and
	Criteria Definition ----> Source documents include the MDOT 2045 Mobility Plan, MDOT Aviation Systems Plan, the State of Michigan Feasibility Analysis - Unmanned Aerial System Connected Corridor, and Stakeholder feedback received in its execution.				Is the use case of benefit or interest to existing private, public partnerships or related associations	Is the use case able to leverage funding, expertise, momentum or other capital of existing transportation initiatives	Is the use case located in proximity to corporate HQs that are of particular significance to Michigan, or a relatively high quantity of corporate HQs	Does the location of the use case have the potential to impact a known industry sector cluster, i.e., high tech manufacturing	Does the use case provide a clear path to commercialization for the operator	Can the Operator easily transfer assets, experience or qualifications to new use cases/locations	What are the economic effects of implementation & adoption of UAS activity across selected locations. What are the positive environmental impacts?
	Evaluation Rubric			High (3)	Championed by existing P3 or associations	Leverages significant capital from existing transportation initiatives	In close proximity *and of interest* to significant corporate stakeholder or a large quantity of corporate HQs	In close proximity *and of interest* to industry clusters	Provides a clear path to commercialization	Easily transferable assets, experience or qualifications to known opportunities	Significant Economic, Community and Environment Impacts
				Moderate (2)	Is of interest to existing P3 or association	Is connected or has shared goals to existing transportation initiatives	In close proximity to significant corporate stakeholder or a large quantity of corporate HQs	In close proximity to industry clusters	Potentially provides a path to commercialization	Potential transferability	Moderate Economic, Community and Environment Impacts
				Low (1)	Is not of interest to existing P3 or association	Has no connection or shared goals to existing transportation initiatives	Not in close proximity or in interest of corporate HQs	Not in close proximity or in interest of industry clusters	Does not provide a path to commercialization	Unlikely to be transferable	Low Economic, Community and Environment Impacts
Ex.	Bay	Cargo Movement (eVTOL)	35	35	1	2	1	1	2	2	2

	Use Case Scoring				Operational Criteria				
	MDOT Region	**Use Case**	**Use Case Score**	**Total Regional Score**	Existing Air Traffic Infrastructure	Airspace Characteristics and Risk	Ground Infrastructure	Ground Risks	Community Network Coverage and Quality
DEFINITION	**Criteria Definition ---->** Source documents include the MDOT 2045 Mobility Plan, MDOT Aviation Systems Plan, the State of Michigan Feasibility Analysis - Unmanned Aerial System Connected Corridor, and Stakeholder feedback received in its execution.				Does the use case leverage existing communications, surveillance infrastructure or sensor networks	Does the use case interfere with existing manned/unmanned flight paths, aeronautical imaginary surfaces related to airports, and/or applicable State of Michigan approach plans	Are there MDOT-owned rights-of-way and existing/planned multi-modal facilities and state-owned airports that may serve as nodes for the use case.	What is the cumulative risk profile for the use case based on authoritative GIS datasets maintained through direct connections with government agencies	Is the use case able to leverage existing/planned infrastructure for connected autonomous vehicles (CAV)
	Evaluation Rubric			High (3)	Leverages all needed existing infrastructure, no new infrastructure required	Does not interfere with existing airspace use	Leverages all needed ground infrastructure, no new infrastructure required	Low ground risk profile	Accesses existing/planned CAV infrastructure for all of its requirements
				Moderate (2)	Leverages some existing infrastructure, some new infrastructure required	Limited potential to interfere with existing airspace use	Leverages some existing ground infrastructure, some new infrastructure required	Moderate ground risk profile	Accesses existing/planned CAV infrastructure for some of its requirements
				Low (1)	All new infrastructure required	Known, significant potential to interfere with existing airspace use	All new infrastructure required	High ground risk profile	Does not access existing/planned CAV infrastructure
Example	Bay	Cargo Movement (eVTOL)	35	35	2	3	2	3	2

Table 52 & 53: Use Case Scoring Strategic Impact Criteria & Operational Criteria