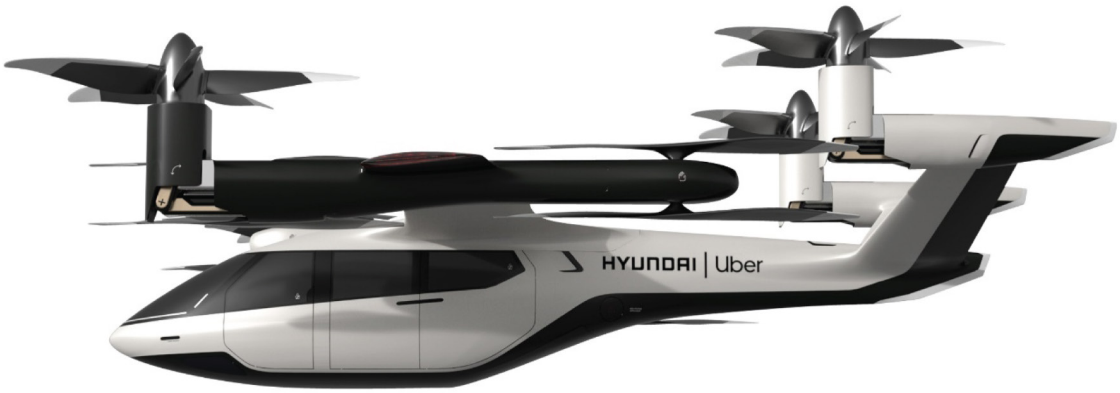


# Advanced Air Mobility Comes to Vancouver

***Exciting New Mobility Options for Residents, Businesses, Indigenous Peoples, and Public Responders***

CAAM Canadian Advanced Air Mobility Consortium

NEXA Advisors
A NEXA Capital Company

CCI
CROWN CONSULTING, INC.


**White Paper**
**September 15, 2020**

# Canadian Advanced Air Mobility Consortium Members and Observers

## Greater Vancouver Region

### Industry

CAAM Canadian Advanced Air Mobility Consortium

ISKWEWAIR

HeliJet

CCI Crown Consulting, Inc.

YVR Vancouver International Airport — Beyond, Every Day.

INDRO Robotics and Remote Sensing

DRONE Delivery Canada.com

M1 Composites Technology

hmmh

APMA Lead. Reach. Connect.

GeoSim

wisk

UAM Geomatics, Inc. A NEXA Capital Company

NEXA Advisors A NEXA Capital Company

5α

Vertical Flight Society

### Federal, Provincial and Municipal Government

Canada NRC·CNRC

Transport Canada

British Columbia

Vancouver Economic Commission

TransLink Greater Vancouver Transportation Authority

NAV CANADA

Innovation, Science and Economic Development Canada / Innovation, Sciences et Développement économique Canada

Western Economic Diversification Canada / Diversification de l'économie de l'Ouest Canada

### Infrastructure and Project Finance

KingSett Capital

NEXA Capital Partners, LLC

Canadian Air Mobility

### Academia

BCIT British Columbia Institute of Technology

UBC The University of British Columbia

University of Victoria

SFU Simon Fraser University

### Vision of Canadian Advanced Air Mobility (CAAM)

CAAM intends to facilitate development of airspace above Canada's cities and exurban areas, delivering advanced mobility options and benefits to society, especially residents, businesses, disadvantaged communities, Indigenous peoples, and emergency responders. The VISION for Advanced Air Mobility will be to deliver equitable, inclusive, resilient, intermodal, and accessible elements with Zero Emission Aircraft. A centralized strategy is planned, nationally and regionally, with the inclusion of stakeholders across government, industry, academia, and the investment community.

### About This Paper

This paper is about new mobility options available to metropolitan areas of the world, making use of the underutilized airspace above cities, and their expected societal and economic benefits. It is also an exploration of how Vancouver may become North America's first Advanced Air Mobility (AAM) city, with the opportunities and challenges involved in being first. Our question is: How should Vancouver go about building an enhanced, sustainable, and safe transportation economy, with the goal of increasing accessibility and quality of life for all communities?

Audiences are municipal and government agencies, transportation and social policy experts, the aviation and tech industries, research organizations, the media, universities, community leaders and, most significantly, residents of the Metro Vancouver region.

Several companies and individuals are responsible for the research and preparation of this document. Researched and prepared by NEXA Advisors LLC, the team included transportation economists and experts in aerospace transportation systems, extensively supported by Crown Consulting Inc.  Thanks go to authors Eleanor Herman, Phillip Dyment, Chase Leeby, Benjamin Merran and Thomas Edwards.

### Sponsors

This paper was sponsored by the Canadian Advanced Air Mobility (CAAM) Consortium, a non-profit effort bringing together partners across government, academia, industry, and local communities, to lay the foundation for advanced air mobility in Canada, seeking to maximize public benefits for all.

### Further Deep Appreciation

We express our deep appreciation to the more than sixty individuals and organizations, most in Vancouver, contributing their time and perspectives to the preparation of this paper.

### Acknowledgement of Ancestral Territories

We respectfully acknowledge that this work is taking place on the unceded and traditional ancestral territories of the Coast Salish Peoples of the Skwxwú7mesh (Squamish), xʷəəθkwəəy̓əəm (Musqueam), kwikwəəƛ̓əəm (Kikwetlem), q̓ic̓əəy̓ (Katzie), Kwantlen and Semyome (Semiahmoo) Nations.

### Note on Currencies

All currency amounts in this paper are expressed in Canadian dollars.

### On the Cover

Hyundai S-A1 Electric Powered Four-Passenger Air Taxi eVTOL (Compliments of Hyundai Corp.)
https://youtu.be/oFTRdDauX7I

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# Executive Summary

Advanced Air Mobility (AAM) is a new form of aviation utilizing airspace above congested cities to better serve the public, businesses, disadvantaged communities, and emergency responders. Exciting new technologies—from lithium ion batteries to light-weight electric motors, advanced composites, aircraft automation processes, and safety systems—enable safe, green, affordable flight, greatly expanding the mobility of people and goods.

This paper explains what AAM is, the obstacles currently standing in its way, and its numerous uses. Social benefits will be numerous. We see this new technology providing more convenient transportation and delivery of goods, as well as jobs to Indigenous and remote communities. We see it energizing businesses, universities, and students in technical fields. We envision this technology saving lives by transporting critically ill patients, as well as organs, blood, plasma, vaccines, PPE, and cancer-treating isotopes. We see missions deploying unmanned aircraft systems (UAS), often referred to as drones, to help track wildlife, fight fires, prevent illegal fishing, and study coastal erosion. We note the importance of AAM being accessible to all, initially focusing on public safety and emergency response.

AAM is not simply an extension of today's aviation industries – it will be enabled by entirely new products and services that will rely on investment and development (Figure 1.) This paper explores the four supply chains required to make AAM a reality and the anticipated GDP growth and long-term job creation. We also examine how the region could finance the purchase of aircraft, build the required infrastructure, and ensure safe flight operations.

AAM is not intended to replace existing means of transportation but to enhance them, to become part of a sophisticated, seamless, multi-modal transportation system. We discuss how this could take place.

Many cities are planning to introduce AAM in the next few years, including Singapore, Munich, Paris, Dubai, and Dallas. Vancouver, however, is a special case; its unique characteristics such as numerous waterways and several helicopter operators position it to become a world leader in this new transportation endeavor and the first AAM city in North America. It is important to point out that if the city fails to seize this new opportunity, it will lose talent and capital to those cities that do.

The Canadian Advanced Air Mobility Consortium has tapped the expertise and perspectives of more than 60 luminaries and stakeholders to prepare this paper and will seek continued feedback in the months ahead.

*Figure 1 - Bell Nexus Hybrid Electric Prototype at Consumer Electronics Show 2020.*

## Introduction

The Greater Vancouver region stands poised to embrace revolutionary new aviation technologies that will reduce greenhouse gas emissions, improve transportation system efficiency, promote public health and safety, create jobs and revenue, and improve equitable access to opportunities for all residents throughout the region—particularly low income groups, seniors, youth, people with disabilities, and other vulnerable population groups.

> ***"We are a built-out city. It's very challenging to add additional capacity in our streets."***
>
> *Sherwood Plant, Senior Traffic Engineer, City of Vancouver*

Aerospace manufacturers are developing small, exceptionally quiet electric vertical takeoff and landing (eVTOL) aircraft that can hover, take off, and land vertically (Figure 2)—with the intent to use the underutilized airspace above cities. The aircraft will be powered by batteries or a combination of batteries and fuel (hybrid) for longer-range trips. At some point further in the future, hydrogen fuel cells will be an alternative. Known as Urban Air Mobility (UAM) and Advanced Air Mobility, this capability will become visible in heavily congested metropolitan areas of the world in just a few years' time. Market analysis performed by companies such as Morgan Stanley[1] and NEXA Advisors/UAM Geomatics[2] forecast a $1.9 trillion opportunity, with much of this business flowing into the metropolitan areas eager to adopt this service.

*Figure 2 – Airbus four-seat "CityAirbus" highly automated eVTOL during flight testing in July 2020.*

What is behind the development of AAM? The steady growth in global population, and the strong desire of people in rural areas to migrate to cities for improved economic outcomes, are important factors. In turn, cities are becoming more densely populated, their streets congested, with local economies adversely impacted. At the same time, advances in vertical-lift aircraft design, electric propulsion, higher energy-density batteries, and hydrogen fuel cells, as well as flight automation, are converging to solve technical challenges and will enable new uses to emerge. eVTOL promises to address the primary limitations of today's turbine-powered helicopters, namely: cost, safety, noise, and carbon emissions.

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[1] https://irei.com/news/morgan-stanley-flying-care-preparing-takeoff/
[2] Urban Air Mobility: Economics and Global Markets 2020-2040. www.nexa-uam.com

Globally, AAM sector momentum is high:

- In July 2020, the Vertical Flight Society added the 300th eVTOL aircraft development program to its World eVTOL Aircraft Directory.[3]
- Over 43 companies or projects are at the large-scale eVTOL demonstrator phase.
- The top 10 eVTOL aircraft developers, including Joby Aviation, Lilium, Bell, and Volocopter, have secured over $5 billion in development funding, and have a timeline for aircraft certification before 2024.
- Aerospace giants such as Airbus, Boeing, and Embraer are currently investing their own capital to compete in the AAM space.
- About a dozen developers have flown engineering or certification prototypes including Joby Aviation, Kitty Hawk, Lilium, Volocopter, eHang, LIFT Aircraft, and the Boeing Cargo Air Vehicle. Of these, three aircraft have gone into low volume batch production.
- Regulators including Transport Canada, the European Union Aviation Safety Agency and the U.S. Federal Aviation Administration are developing regulations to certify and ready eVTOLs for passenger operations.
- Existing helicopter operators such as Helijet (Figure 3), Blade, and MicroFlight are gearing up to become the first operators of eVTOLs, once they are available for purchase or lease.
- Over 4,300 heliports (public and private) are available today in and around the world's largest cities. Greater Vancouver has 54 (see map on page 18), public and private, with some operated for the public good by private entities.

*Figure 3 – Helijet's Sikorsky S76 operates over Vancouver Harbour and Canada Place. Today Helijet is a leader in Vancouver's Air Mobility industry.*

A dozen cities including Seoul, Singapore, Los Angeles, Dallas, Paris, and Munich are in the pre-planning phase, eager to bring AAM to their airspace. Dubai and Shanghai are already permitting limited air taxi operations in trials.

> ***"When people see eVTOL aircraft in action and serving the public interest, performing missions that positively impact lives, the cultural acclimation to eVTOL aircraft will accelerate."***
>
> *NASA 2020 Transformative Flight White Paper*

Based on the limited information we have so far, it is likely that the cost to fly on an eVTOL will be surprisingly affordable. An emerging view of the next 20 years is that automation of flight, including aircraft specifically designed to operate without pilots, will be necessary to improve the reliability and thus the safety of this new market sector. Automation will augment pilot capabilities while enhancing safety, enforce sense-and-avoid rules, and safely separate all aircraft, including eVTOLs and drones. Automation will reduce the cost of operations and

[3] Go to www.evtol.news/aircraft to access the World eVTOL Aircraft Directory

permit greater aircraft access to city centers. This is the “Inflection Point” where the cost structure of the entire industry will be dramatically reduced in synchronization with the expansion of aircraft and airspace capacity.

Safe, efficient, convenient transportation of both people and goods is critical to urban viability and the quality of life for residents. This paper is about AAM and its potential impact on Vancouver and British Columbia now and in the months and years ahead. Although AAM is not completely without challenges, we present a blueprint, including costs and benefits, giving readers an idea about what lies in the City’s future.

## What is Advanced Air Mobility and Why is it Important?

*Figure 4 - An image of a German-developed Volocopter 2X eVTOL aircraft in flight over San Francisco, CA.*

Advanced Air Mobility is a new concept of air transportation that moves people and cargo between places not conveniently served by surface transportation, or underserved by aviation—local, regional, intraregional, urban—using revolutionary new aircraft that are only just now becoming possible (Figure 4). AAM uses eVTOL aircraft, both those that carry passengers and small unmanned aircraft systems (sUAS), also known as drones. The passenger aircraft will be powered by hybrid electric systems, batteries or, at some point further down the road, hydrogen fuel cells. While batteries currently limit flight times and require long charging times in between flights, fuel cells—such as those that will be used in aircraft developed by Alakai Skai in Massachusetts and ZeroAvia in California—should offer long-range flight capabilities as well as fast refueling. Their only local emissions are water, and there are ways to develop these aircraft in a green and sustainable fashion.

> ***"AAM could allow lower-income groups and/or physically distanced groups such as Indigenous communities easier access to centers of economic activity and healthcare."***
>
> ***Martin Richardson, Jaunt Mobility***

Until quite recently, this new aviation technology was referred to as Urban Air Mobility, a name that reflected its intended uses in a congested urban environment. However, it is becoming apparent that its benefits will not be limited to cities. These aircraft may range far and wide, bringing accessibility to geographically distant, underserved communities. This is especially so for British Columbia. That is why we use the term Advanced Air Mobility in this paper.

### Metropolitan Areas Have a Vision for AAM

Stakeholders have varying visions for AAM and its mobility value consequences. Some view AAM as a version of highways in the sky that mirror ground vehicle traffic. These visions come in the form of manned air taxis and connected commuter aircraft picking up passengers on request or on a schedule as part of an on-demand urban network. Passengers will be able to book flights using mobile app technologies, have the nearest on-grid aircraft sent directly to a convenient pickup location, and be fully integrated with other mobility modes such as airports or train stations. An important early use will be first-responder transport of injured victims to local emergency centers. Smaller and possibly safer than helicopters, eVTOLs could provide transport to improve survivability as much as 85%[4] by getting the injured to emergency facilities within the "golden hour" after an accident. All predicted models boast significant societal benefits in environmental impact, new services for underserved and vulnerable communities, economic productivity, and job creation.

For all its future promise, there are barriers to acceptance and implementation that must be overcome so that AAM can live up to its full potential:

- Regulatory development and interoperability standards are needed to facilitate and reduce time to market for aircraft manufacturers, fleet operators, and infrastructure/facilities managers, while at the same time imposing extremely high levels of safety for passengers and the communities of operation.
- Adequate capital and venture investment are required for development and commercialization of electric, hybrid or hydrogen cell-powered aircraft, control systems, and operational models. While venture/corporate/institutional funds are closely watching, investment can only be forthcoming if supported by city-by-city business cases with reasonable cash-on-cash returns flowing within sensible timelines.
- Infrastructure investment is necessary to fund Unmanned (Air) Traffic Management (UTM or UATM) systems that integrate eVTOLs with drones into the existing airspace, and vertiports (new landing and takeoff facilities) (Figure 5) to facilitate cost efficient and convenient passenger access. Again, the business cases are what matter.
- Sufficient market demand must be present, including commercial, industrial, and consumer customers, where value delivered may significantly exceed cost.
- Public acceptance of these new systems and services is imperative, driven by positive perceptions of safety, mobility value, cost effectiveness, and affordability.
- Privacy, environmental impacts such as noise and, in some cases, property rights will weigh in this dimension, often at the local level.

*Figure 5 - Urban multiport concept under study by Uber Elevate.*

---

[4] American College of Surgeons (2008). Atlas, Advanced Trauma Life Support Program for Doctors.

> ***" The simplification of the technology, combined with the sophistication that can be pushed into the software, has completely changed the landscape of what you can do with these flying vehicles."***
>
> *Eric Allison, Uber Elevate*

These elements and their associated risks are equally critical. The upfront infrastructure investments for AAM heliports, vertiports (heliports with charging stations), multiports (vertiports servicing multiple aircraft at once) and airport landing sites, including passenger services and security, and UTM, will require capital. To ensure that the new market opportunities succeed, investment funding is the most essential, and will be needed across several industry fronts, and always first in line. These factors pose significant risks that investment capital will recognize and must find acceptable ways to mitigate.

The next decade (2020-2030) will be critical to the design, launch and acceptance of the AAM Industry. During this decade, standards for safety, security, interoperability, UTM architecture, and noise will become crucial. Public perception will be formed and will become the litmus test for the future of the industry as automation takes hold, providing the scale needed to drive the sector to its full potential and profitability.

In the meantime, nascent markets will appear city by city, and current players such as helicopter charter operators, emergency service organizations, and corporate flight departments will be able to demonstrate many of the advantages of AAM thus far unachievable with their current mobility choices. For the most part, air traffic control operations provided by existing Air Navigation Service Providers (ANSPs, e.g. NAV CANADA) can be tapped while UTM services take hold incrementally in coordination with the ANSP and under the oversight of the regulatory body, Transport Canada. This decade will provide a proving ground for aircraft manufacturers to refine and certify an array of eVTOLs including all-battery, hybrid electric, and hydrogen fuel cell-based designs.

## What are the Central Social Benefits?

A wide range of social benefits are derived from the implementation of AAM which include the following:

**For the environment:**

- Decarbonizing, over time, transportation with zero emission aviation using clean electric and hydrogen fuel cell technology.
- Monitoring wildfires, marine life, forests, and coastal health.
- Improvement in agriculture and minimizing fertilizer and pesticide use through prescriptive farming techniques.
- Delivering retail goods to residences, thereby reducing the number of trucks—including their noise and polluting exhaust—from neighborhoods.
- Eliminating other pollutants such as volatile organic compounds, particulate matter, sulphur dioxide, nitrous oxides, and unburned fuel.

**For public health and safety:**

> ***"Isotope delivery, organ transplant delivery, and Medevac are good use cases to start developing public acceptance."***
>
> *Jim Sherman, Vertical Flight Society Director of Strategic Development*

- Taking injured and critically ill patients to hospitals more efficiently and quietly than Medevac helicopters. Based on currently available information, eVTOLs should be easier to maneuver and more capable of landing close to an accident site.
- Allowing lower-income groups and/or physically distanced groups, such as Indigenous communities, easier access to centers of economic activity and healthcare, such as obstetrics or dentistry.
- Providing crucial supplies, medicine, and transportation to underserved Indigenous communities in the north of the province that are difficult to serve with fixed-wing aircraft.
- Delivering medical supplies, blood, organs, and plasma quickly to and between hospitals.
- Assisting fire fighters and law enforcement personnel by providing no-risk early assessments of potentially dangerous situations.
- Inspecting bridges, high-rise buildings, and horizontal infrastructure (power/water/gas supply lines) safely and efficiently.

**For the region's residents and workforce:**

- Setting aside up to 15 percent of AAM capacity and flights to guarantee low- or no-cost access for the region's most vulnerable residents. These costs would be cross-subsidized through multi-tier pricing regimes developed in agreement, and in full transparency, between operators and local and provincial transportation authorities.
- Opening up opportunities to those who live too far from the city center to have a feasible commute. Easier, more rapid, and inexpensive transportation would provide greater access to better-paying jobs.
- Providing regional transportation of passengers and delivery of goods between city pairs such as downtown Vancouver to Greater Seattle (Kent, Renton, etc.), Whistler, Kamloops, Abbotsford, Osoyoos, and Kelowna.
- Complementing and diversifying public transportation operations. For example, providing metropolitan transportation options for commuters between heavily populated suburban communities, such as Surrey, the Gulf Islands, the North Shore of Vancouver, and the lower Mainland, to the outermost Skytrain stations.
- Tourism in clean, green, quiet aircraft to British Columbia's breathtaking natural wonders and the world's most diverse assembly of living Indigenous communities.

## What are the Business and Economic Benefits?

*Figure 6 - Joby has secured $1 billion to place its aircraft in manufacture by 2022.*

A recent 75 city study on AAM performed by /NEXA Advisors/UAM Geomatics Inc.[5] estimated that, over a 20-year period, the Greater Vancouver area would cumulatively serve about 4.2 million passengers using eVTOL aircraft, limited to five service types: airport shuttle, on-demand air taxi, regional air mobility, business and corporate campus services, and Medevac. This would produce about $2.1 billion in new business activity over that same period. The estimate includes $181 million in ground infrastructure, $78 million for UTM systems and infrastructure, and finally, $250 million in eVTOL aircraft acquisitions (Figure 6). The investment required to complete the new facilities can be arranged through formation of public-private partnerships, largely or exclusively funded by the private sector.

This is also “greenfield”, incremental revenue for Vancouver, and drives an economically beneficial development phase that at the same time brings environmental, social, commercial and even increased trade benefits. An economic impact assessment is being undertaken to estimate direct, indirect, induced, and catalytic benefits for the community from AAM. The approach will impart a solid understanding of the economic opportunities and various benefits that these services can deliver.

> ***"By 2040, we envision a city with a smart and efficient transportation system that supports a thriving economy while increasing affordability; healthy citizens who are mobile in a safe, accessible, and vibrant city; and an enhanced natural environment that ensures a healthy future for people and the planet."***
>
> *Greater Vancouver Transportation 2040 Vision.*

Any transportation system, either new or an expansion of existing facilities, must be expected to produce a wide range of economic benefits, and for greater Vancouver, AAM will generate:

- GDP growth measured in the billions of dollars.
- New direct and indirect job creation, much of it in highly skilled disciplines.
- Clean, green tourism with quiet aircraft bringing tourists to British Columbia’s breathtaking natural wonders and culturally rich, extremely ancient, Indigenous communities.
- Tax revenues for local and provincial governments.
- Catalytic effects from increased trade and commerce, in particular along the Cascadia Corridor. (Cascadia is the region also known as the Pacific Northwest and generally refers to the area that encompasses the drainages of the Columbia and Fraser Rivers. This vast landscape of half a million square miles of

[5] Urban Air Mobility – Economics and Global Markets, June 2020, www.nexa-uam.com

mountains, rivers, farmland, rain forests, and cities is home to some 16 million people in British Columbia, Washington State, and Oregon.)

## Who Will Pay for AAM Infrastructure?

Today, heliport infrastructure in Vancouver and many places in the Pacific Northwest is financed and managed privately or, from time to time, in partnership with regional transportation agencies. The greater Vancouver region has 54 heliports (Figure 7.)[6] To expand infrastructure access with an array of newly constructed vertiports throughout the Vancouver region, it is likely that a Public-Private Partnership or P3 (Figure 8) will be formed to fund the needed AAM infrastructure, using a consortium that includes metropolitan authorities, private financial institutions, commercial and government users and operators, and other stakeholders. The most important member is the project sponsor, which could be the city of Vancouver and its economic development organization, in granting a concession for construction of the vertiports and UTM systems to proceed.

*Figure 7 - Vancouver Harbour Heliport, a floating superstructure, can accommodate up to four parking positions and one FATO (final approach and takeoff) position for all category size helicopters. Shown is a Sikorsky S-76 parked. Main Passenger Terminal and Cargo Terminal are situated on the shoreline. Scheduled service operations to Victoria and other destinations can be booked daily from this public heliport facility.*

[6] Urban Air Mobility: Economics and Global Markets 2020-2040. www.nexa-uam.com

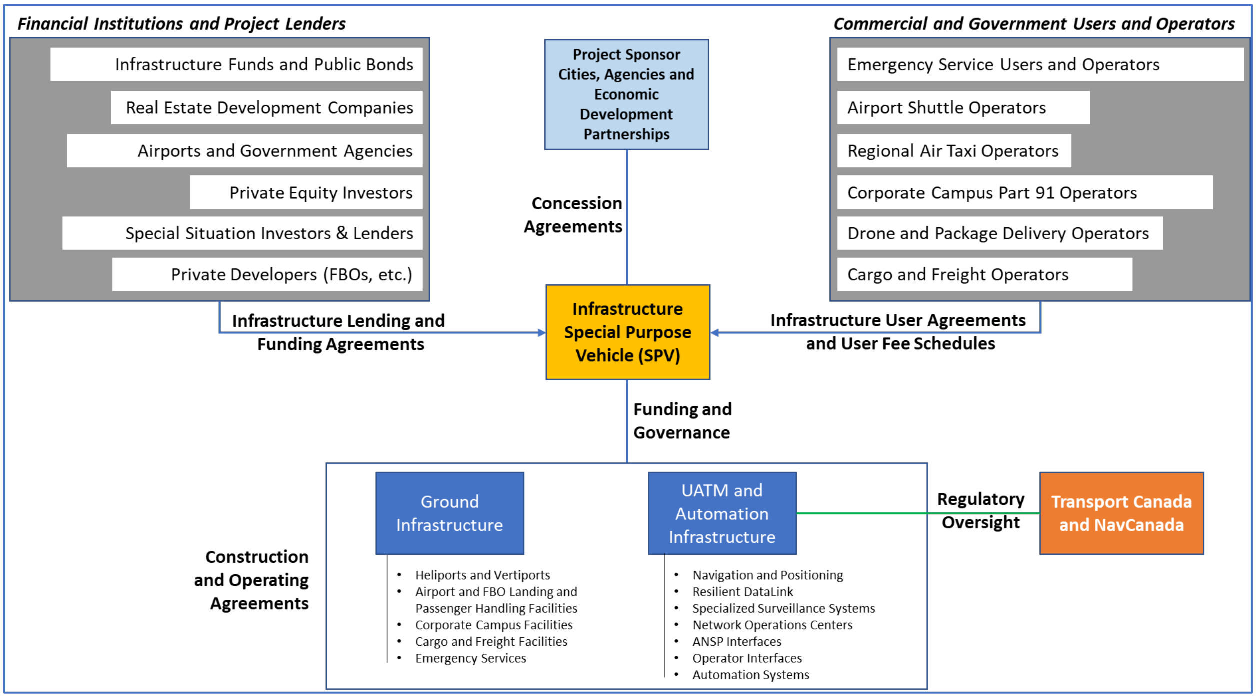


*Figure 8 - Consortium approach to funding and operating AAM infrastructure.*

Although not without their challenges, P3s deliver three key advantages: risk transfer, bundling project delivery components, and expanded capital access.

**Risk Transfer.** A major advantage of P3s is the transferring of financial risk from taxpayers to investors. Under traditional procurement, a project's risks are entirely shouldered by the taxpayer. If the project experiences cost overruns, change orders, delays, or anything else that increases costs, the public sector—which means taxpayers—foot the bill. The private sector is typically better equipped and more motivated to assume these financial risks since they affect the private partner's bottom line.[7]

**Bundling.** In a well-structured P3, the private sector partner is responsible for designing, building, financing, operating, and maintaining the project. The private firms that compose the consortium will work together over the duration of the project's life, so there is a shared interest in ensuring a synergistic approach to the project's delivery.

**Expanded Capital Opportunities**. P3s are financed using a blend of equity and debt. Financing infrastructure projects exclusively through government revenue may limit the ability to raise the appropriate amount of capital required since the entity issuing the debt may not have enough bonding capacity to sufficiently finance the project.

The ratio R/I stands for forecasted revenue divided by infrastructure capital expenditures. Any R/I above a factor of three signals that private capital can be attracted to a capital infrastructure project. Figure 8 points to a range of government and private financial institutions as potential sources of capital for AAM infrastructure, and because Vancouver has a strong ratio of (R/I) in the range of four, private capital, equity and debt, should be tapped exclusively.

[7] Reason Foundation, August 2019

# Vancouver May Choose to Be the First AAM City in North America

> ***" The entrepreneurial culture in British Columbia will get AAM moving."***
>
> *Dave Frank, Executive Director, B.C. Aviation Council.*

We are at a unique juncture in time and opportunity where Vancouver is ideally positioned to become a world leader in AAM, thereby securing multiple first-mover advantages such as availability of talent and capital.

Vancouver is a coastal, seaport city on the mainland of British Columbia. Located on the western half of the Burrard Peninsula, Vancouver is bounded to the north by English Bay and the Burrard Inlet and to the south by the Fraser River. The City of Burnaby lies to the east and the Strait of Georgia to the west. Vancouver Island, across the Strait of Georgia, shields Vancouver from the Pacific Ocean. The U.S border is only 35 km away from downtown Vancouver. Overlooking Vancouver are the majestic North Shore Mountains, 28 km away. This distinctive combination of factors—many bodies of water, mountains, and the capital of British Columbia, Victoria, on a nearby island—presents challenges to convenient mobility and positions the city to become an excellent early user of AAM.

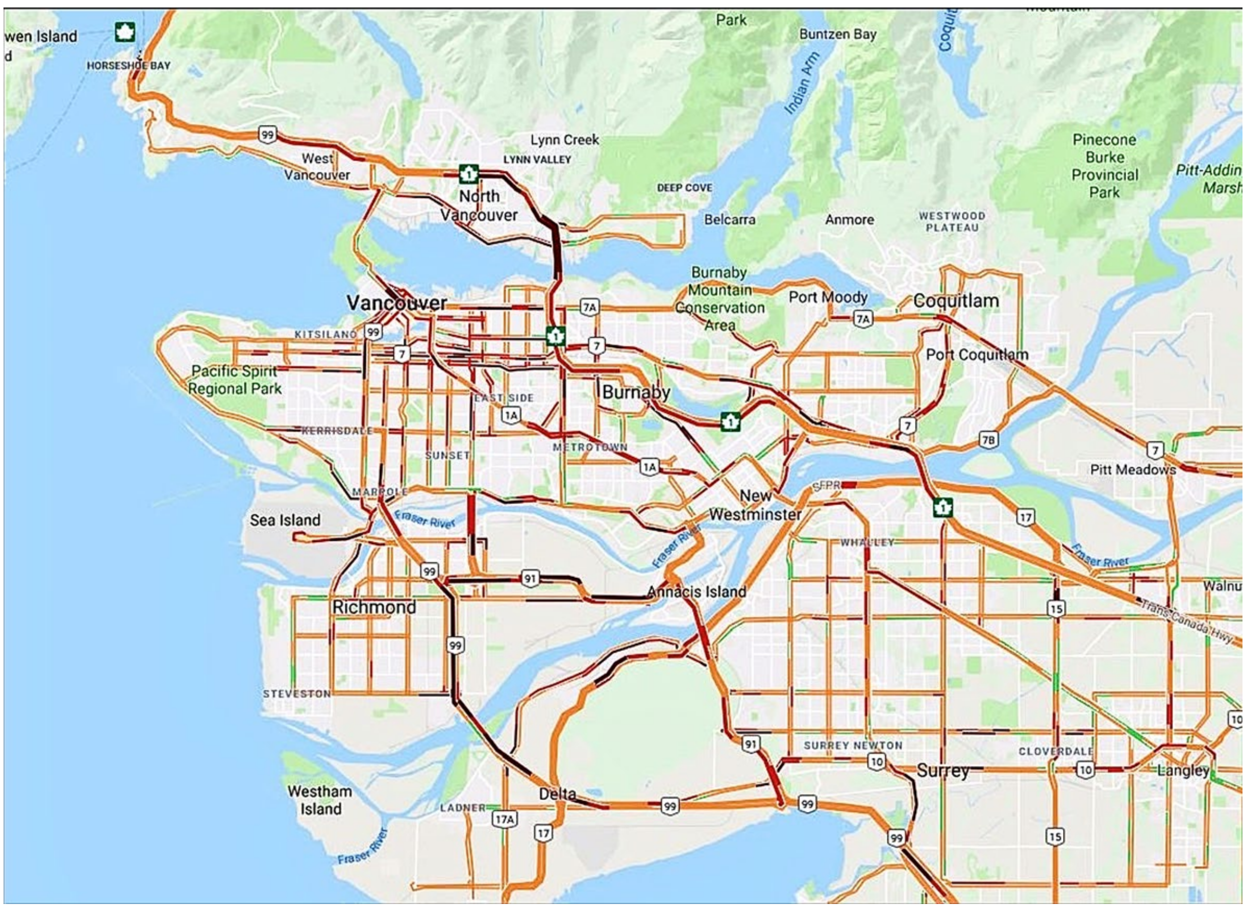


*Figure 9 – Rush-hour congestion in Greater Vancouver is Canada's worst (dark red).*

AAM is a significant economic opportunity globally, and a noble race is already underway among cities to be first to develop and showcase these new mobility options. Is there an advantage to being first?

Vancouver sees this challenge and is primed to become the first AAM user in North America because the benefits are tantalizing.

> *"While less than 30% of the population lives within 30 minutes of a major hub airport, more than 90% lives within 30 minutes of a small community airport. This illustrates the practicality of using AAM to support user demand between community airports in addition to hub airports, allowing impressive access to commerce, commercial airline travel, and urban centers."*
>
> *Community Air Mobility Initiative, January 2020*

## Factors Pointing to Rapid AAM Deployment for Vancouver

Vancouver can list several factors that cry out for AAM:

- Diversified, green, knowledge economy: Several sectors are attracting global talent, corporations, and investment to Vancouver, while fast becoming the new foundation of the knowledge economy. For example, the city is the third greenest in the world[8], and has long recognized the economic opportunity and global imperative of driving green. Also, Vancouver's economic diversity ranges from leadership in traditional resource industries to social enterprise, technology, aerospace, and digital entertainment.
- Increasing congestion: Vancouver-area commuters face the worst congestion in Canada and 40th worst in the world, with rush-hour driving some 40% longer than non-rush hour (Figure 9). A 2015 study estimates the cost of lost efficiency and productivity due to congestion in the Metro Vancouver area at between $500 million to $1.2 billion annually.[9]
- Growing population: From a 2016 base population of 2,570,000, Metro Vancouver's population is forecast to increase by about one million people to 3,600,000 by the year 2050 (Figure 10).[10] This growth will accelerate population density and will require that the transportation network be improved by any means possible.
- Strong government commitment on the local, provincial, and national levels to encourage green technology and reduce carbon emissions. Vancouver has initiated the Greenest City Action Plan to

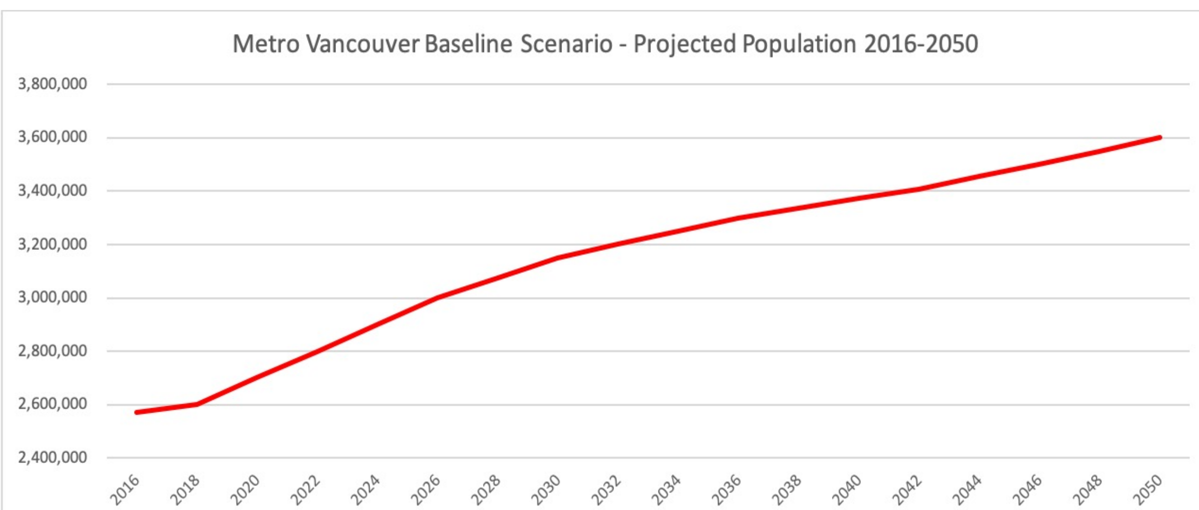


*Figure 10 – Forecasted population growth will require improved forms of transportation throughout the Vancouver region.*

[8] According to the 2016 Global Green Economy Index, behind only Copenhagen and Stockholm.
[9] Tackling Traffic: The Economic Cost of Congestion in Metro Vancouver, 2019, C.D. Howe Institute.
[10] http://www.metrovancouver.org/services/regional-planning/PlanningPublications/OverviewofMetroVancouversMethodsinProjectingRegionalGrowth.pdf

achieve zero waste, zero carbon, and healthy ecosystems, in order to make Vancouver "the greenest city in the world."[11] Translink, Metro Vancouver's transportation network, has followed up with Transportation 2040, a long-term strategic vision for efficiently moving people and goods. The British Columbia Climate Change Accountability Act (CCAA) requires greenhouse gas emissions to be reduced by 40 percent below 2007 levels by 2030, 60 percent by 2040, and 80 percent by 2050. And the national government has announced a plan to achieve net-zero emissions by 2050.

- Long experience with and public acceptance of helicopters and sea planes. The active Air Operators maintain licenced AOCs (Air Operator Certificates) and ferry several hundred thousand passengers annually. They have the experience, infrastructure, and regulatory licenses to easily transition to eVTOL aircraft using their current offshore flight corridors—channeling noise and visual disturbances away from populated areas.
- 54 existing helipads. These could be remediated at reasonable cost as vertiports with battery recharging stations and passenger amenities (Figure 11).

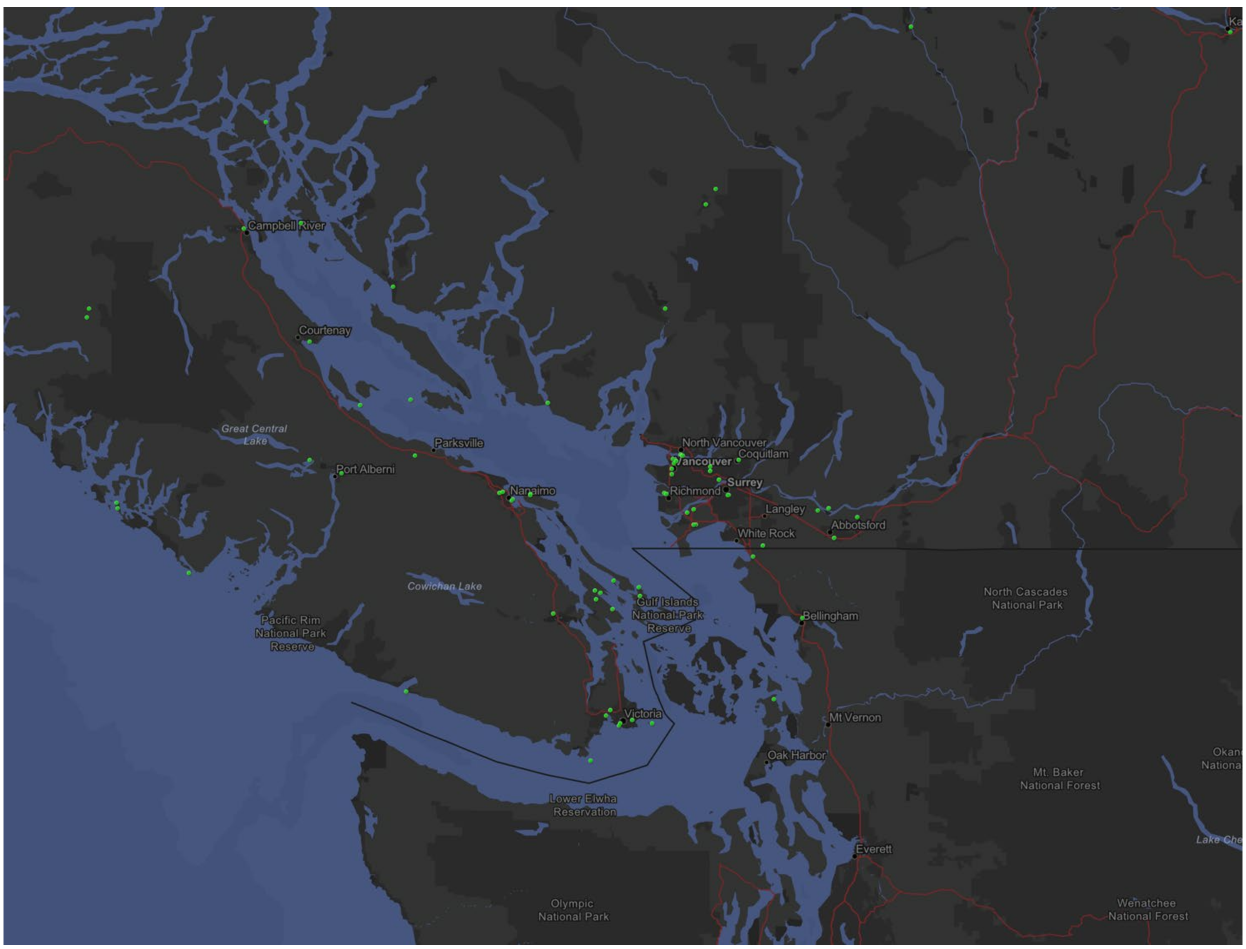


*Figure 11 - Greater Vancouver with heliports, airports, hospitals and other AAM-centric features (www.NEXA-UAM.com).*

- 15 hospital centers. Seven are equipped with helipads. These would benefit from drone delivery of supplies and eVTOL Medevac rescue operations.
- A strong in situ base of scientific and technical know-how. Vancouver has a network of educational institutions that provide a deep pool of highly skilled talent. For instance, the University of British

[11] www.vancouver.ca/green-vancouver/greenest-city-action-plan.aspx

Columbia is a global center for research and is consistently ranked as one of the top 20 public universities in the world.

- Vancouver's innovation economy. The city has been voted the number one Job-Creating Economy in Canada; the Most Diverse Economy in Canada[12]; the number one Startup Ecosystem in Canada[13]; and the "Number One Cleantech Cluster" in Canada[14].
- Vancouver has a vibrant aerospace sector, globally recognized for its excellence in delivering highly specialized products and services. With close proximity to Boeing's final assembly lines in the Seattle area, British Columbia bridges space and culture between Asia Pacific, the Pacific Northwest and Canada's growing aerospace industry. British Columbia's aerospace sector is the third largest in Canada, with more than 200 companies, generating $2.4 billion in revenue annually, and directly employs nearly 9,000 people.[15] Vancouver is the location of more than a dozen AAM projects involving large aerospace companies, universities, and both the federal and provincial governments.


*Figure 12 - Congestion in Vancouver is among Canada's and the world's worst.*

## Vancouver's Transportation Planning Challenges

A convenient, accessible transportation system that allows the easy movement of goods and services is the heart of a healthy economy. It takes people to work, shopping, recreation, and other places that also support the economy and improve their quality of life. Moreover, the system allows for the rapid response of emergency relief services to help people in urgent need. Clogged streets make for dangerous emergency service response (Figure 12), among other problems.

Unlike many large cities, Vancouver has no freeways into or through the downtown area. Hemmed in by water and mountains, the area is almost completely built-out with few opportunities for new roads.

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[12] By the Conference Board of Canada.
[13] By Startup Genome.
[14] By the Global Cleantech Cluster Association.
[15] https://www.britishcolumbia.ca/TradeBCPortal/media/Marketing/bc-aerospace-mit.pdf

Widening roads and freeway corridors and building more bridges is not only cost-prohibitive but flies in the face of Vancouver's Transportation 2040 plan, which aims for the majority of trips on foot, bike, and transit, eliminating dependence on fossil fuels, and offering its citizens and visitors the cleanest air of any major city in the world.

> *" Both price elastic [price sensitive] and inelastic segments are identified in Vancouver. For example, business travel is price insensitive for certain executives. Emergency medical services are inelastic as well. General consumer travel is highly elastic."*
>
> *UAM Geomatics Report, 2020*

According to a 2015 report, the hidden costs of congestion—lost productivity and more car accidents—were about $500 million, forecast to rise to $1 billion a year by 2045 for the Metro Vancouver area.[16] However, taking into account additional, broader economic losses, the current figure could already be $1.2 billion. This larger figure considers the fact that because of congestion many workers forego jobs that would bring in higher salaries and greater satisfaction. Companies, too, lose out when the best qualified workers don't bother to apply. Businesses lose customers.

Without new roads and bridges, somehow the Vancouver region must continue to provide convenient transportation to the 3.5 million people expected to live in the region by 2050. Fortunately, today Vancouver has a flexible, multi-modal transportation system that can be enhanced by Advanced Air Mobility. The SkyTrain is a highly reliable, light rapid transit system with 80 miles of track and 53 stations on three lines.

The Vancouver bus system has a vast network of buses, trolleys, and community shuttles linking to various hubs, exchanges, and SkyTrain stations throughout the metro area. The region also has a robust network of ferries. Vancouver is one of the best biking cities in North America with 449 km of bike lanes. The number of people biking to work has nearly doubled in the past five years and now stands at 12 percent.

Advanced Air Mobility will not replace current transportation modes but will complement them, especially where expansion of the Skytrain, ferry line, or bus service is simply not economical or feasible. eVTOL aircraft stationed at the end of the SkyTrain lines may take commuters into further-out communities where housing is more affordable, opening up more areas for development and alleviating the real estate crunch closer to downtown.

For instance, the area south of the Fraser River, some 34 km from downtown Vancouver, is one of the fastest growing in the region. By 2050, the City of Surrey, City of Langley, and Township of Langley are forecast to have 420,000 new residents and 147,000 new jobs.[17] Surrey alone added more than 16,000 new residents in 2019[18] and is projected to surpass Vancouver in population in the next thirty years.

## Translink Expansion

Translink is the statutory authority responsible for the regional transportation network of Metro Vancouver, including public transport, major roads, and bridges. Translink must meet the demand for transit as the population in Vancouver's suburbs continues to grow. A plan to extend a Skytrain route 16

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[16] C.D. Howe Institute, Tackling Traffic: The Economic Cost of Congestion in Metro Vancouver.
[17] https://www.translink.ca/Plans-and-Projects/Rapid-Transit-Projects/Surrey-Langley-Line.aspx
[18] https://www.westerninvestor.com/how-to-invest/decade-of-demand-begins-with-land-1.24129257

km to Surrey/Langley with eight new stations is in the works for an estimated $3.1 billion (or about $194 million per kilometer) though only half of that funding is currently identified, and so the project is likely to be undertaken in phases and require several years to complete.

Similarly, Translink is preparing to extend the SkyTrain to the University of British Columbia, which has the busiest bus service in all of North America. On weekdays, more than 1,000 buses flow through the UBC bus exchange, most of them overcrowded. Some 80,000 people use transit to and from UBC every weekday. The underground 5.7 km route would cost $3.8 billion, or more than $600 million per kilometer.

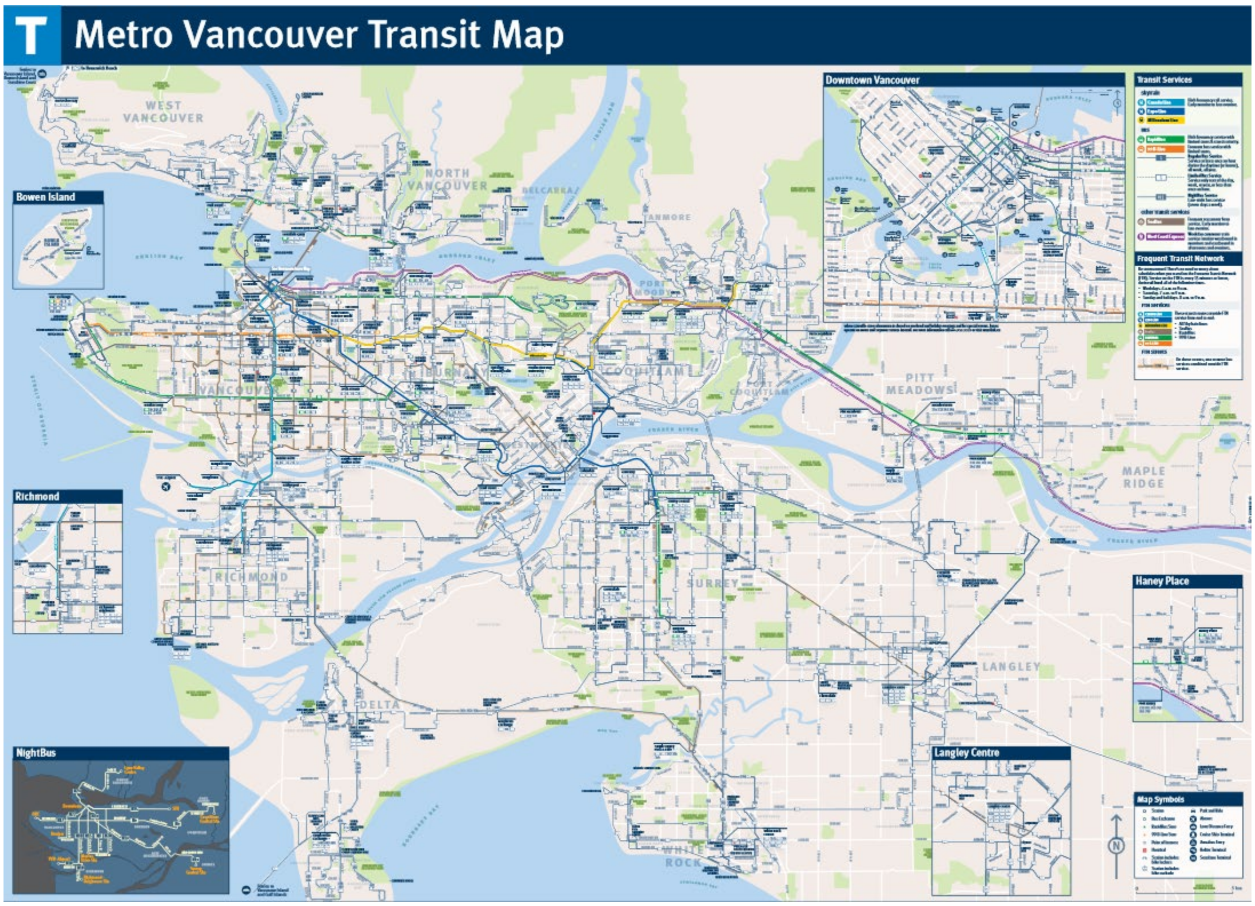


*Figure 13 – Vancouver's Translink system-wide map covers hundreds of-square kilometers.*

Translink is also studying a rapid transit link to North Vancouver, which would require the construction of a tunnel or bridge. No estimates for those costs have been given. eVTOL aircraft could transport passengers from vertiport stations in these communities to the outermost SkyTrain station, reducing congestion and carbon emissions, and saving time. According to the study prepared by NEXA Advisors/UAM Geomatics, ***"Urban Air Mobility – Economics and Global Markets, 2020-2040,"*** by 2040 the Vancouver region will serve some 683,000 eVTOL passengers a year. This will alleviate some congestion as AAM fares are expected to be competitive by then.

## The Effects of COVID-19 on Transportation in Metro Vancouver

> ***"The global pandemic has given us an opportunity to redefine systems in a way that is in service to humanity. Let's rebuild systems together in the service of all."***
>
> *Teara Fraser, Founder, Iskwew Air, servicing Indigenous communities.*

The state of emergency declared in mid-March 2020 due to the coronavirus dramatically changed transportation in Vancouver as it did for much of the world. The overall demand for mobility—public as well as personal transportation—decreased immediately by nearly 70 percent. Public transportation alone has seen a 47% reduction.

A recent survey by movmi (movmi.net) found that in June and early July 2020, while the city cautiously reopened, almost 72% of participants were still reducing the number of trips, while 17% had stopped traveling altogether. Over 75% of the movmi survey respondents indicated that they were working from home full-time, while only 13% of them had worked from home before the shutdown. Translink is losing about $2 million a day in revenue, despite reducing service.

How will transportation change as virus cases are reduced? Will everything go back to the way it was once an effective vaccine is available? It is safe to say that transportation, commuting habits, and public perception have, in at least some respects, been altered for the time being (Figure 14). Many companies have found the same productivity from employees working at home as when they were working from the office. Others have found increased productivity: workers arrive at their computers earlier in the morning and unstressed by a frustrating commute. There are also financial benefits to companies that rent less office space, and environmental benefits to the public at large. It is likely that the post-COVID world will see a mix of work from home and at the office. However, face to face meetings are the most effective in building trust between parties–-an essential business outcome. Whatever the eventual outcome, a more efficient system of mobility will be needed, with AAM a part of the solution set.

Normally, increased numbers of those working from home would result in an overall reduction in transportation demand, and less of a crush in the morning and evening peak hours. But another factor is working against reduced congestion: health is the new mobility decision factor. Sharing space in a bus or train is seen as high risk. A survey conducted by the Mustel Group indicated that 36% of Vancouver participants planned to increase their car use, while the movmi survey found that 14% of car-free households in Vancouver are considering buying a new car. Translated into the Metro Vancouver population, if that 14% figure is representative, it could mean an additional 122,500 cars on the roads.

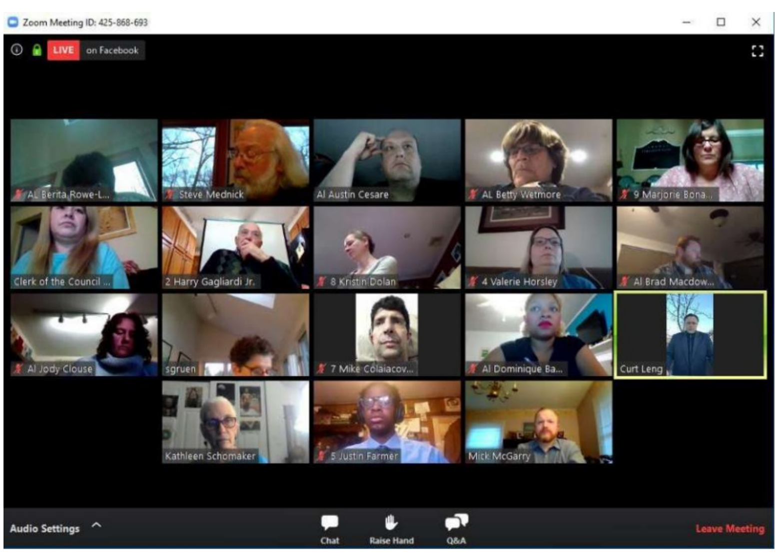


*Figure 14 – Internet-based meetings will slowly go back to in-person meetings when an effective COVID-19 vaccine becomes available and widely distributed.*

Movmi survey respondents indicated strong public support for policies that reduce vehicles on the road: continued support for public transportation, more support for shared mobility, and more road space dedicated to biking. As the pandemic abates, Vancouver's balanced, sophisticated multi-modal transportation system will be well-suited to introduce Advanced Air Mobility into the mix.

eVTOL passenger aircraft and drones will, as we have mentioned, play an important role in promoting public health by transporting patients, blood, organs, and medical supplies. With regards to COVID-19, these aircraft could be used to transport PPE, ventilators, and medications quickly and efficiently to hospitals in need, especially in underserved, remote Indigenous communities.

For instance, the Beausoleil First Nation community on Christian Island in Ontario uses a ferry during summer months to transport supplies. But in June 2020, Drone Delivery Canada announced a commercial agreement with GlobalMedic, a humanitarian aid organization, to deliver PPE, hygiene kits, test swabs, and other COVID-related medical equipment to limit person-to-person contact on the ferry. In August 2020, Drone Delivery Canada (Figure 15) also announced an agreement to deliver the supplies to the Georgina Island First Nation, where ferry deliveries could take as long as a week due to bad weather. Now supplies can reach both First Nations on an hourly basis. The use of drones not only speeds up deliveries, but limits person-to-person contact.

The Canadian government recently ordered 177 million needles and syringes to deliver the coronavirus vaccine when it eventually becomes available. Drones could provide an important service in transporting the syringes, swabs, vaccines, and other medical material across the nation—especially to hard-to-reach northern communities—to combat the virus.


*Figure 151 - sUAS by Drone Delivery Canada in Northern Ontario*

Use cases for drone delivery in British Columbia begin on page 46. Within the next few years, drone use may become ubiquitous in and around the Vancouver region.

# The Advanced Air Mobility Industry

## It Takes Four Supply Chains to Build a Commercially Viable AAM Ecosystem

Advanced Air Mobility will require the effort of several different supply chains to assemble and operate this new transportation system. Shown in Figure 16, these begin with AAM ground infrastructure needed to provision landing facilities. The world is actually well populated with heliports; however, fewer than half are in locations convenient for AAM applications. Ground infrastructure will require expansion into network configurations, with each node or vertiport, carefully located and built to ensure passenger convenience and value. Vancouver has 54 heliports throughout the region, including at most airports, but may need an additional 10-15 to fully optimize operations, thus delivering the highest convenience to passengers.

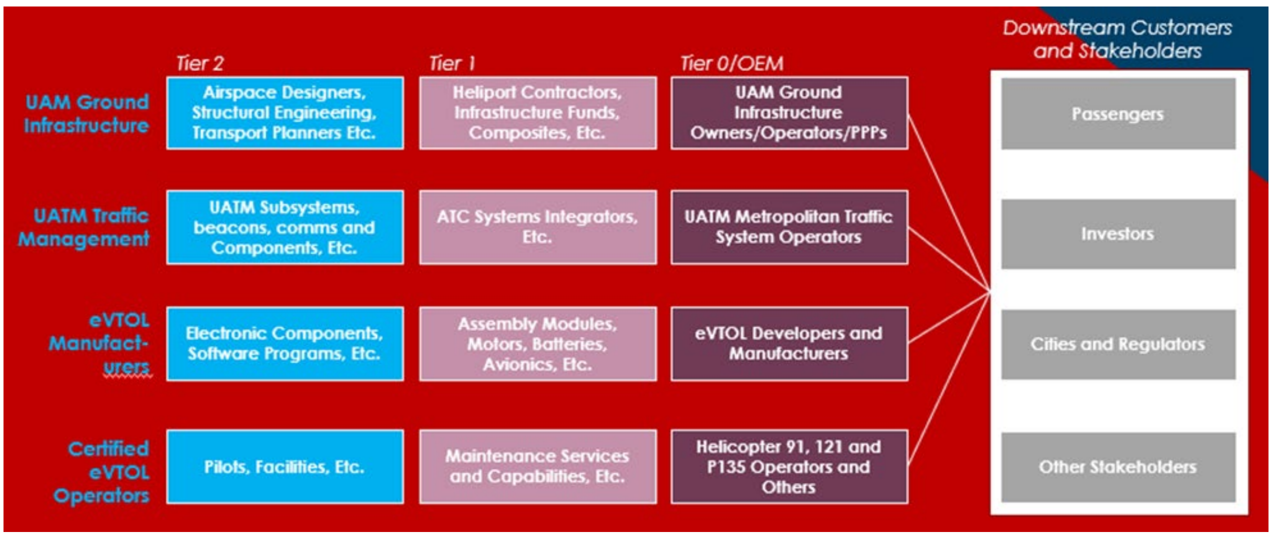


*Figure 26 - The four supply chains necessary for the AAM ecosystem to achieve commercial and economic viability.*

Next is traffic management capability, known as UTM or UATM. The AAM industry has the potential to deliver solutions that benefit communities, generating revenues, jobs, and economic activities, with new streams of tax revenue that cities need. Realizing these benefits, however, requires workable solutions that ensure safe airspace coexistence for commercial and general aviation, drones, and AAM aircraft. Technological advancements will push eVTOLs closer to full autonomation beyond the "Inflection Point" described earlier. Finding the right UTM solutions on a city-by-city basis will be necessary to unlock full market potential and requires increased collaboration and planning among all stakeholders. For Vancouver, NAV CANADA is responsible for managing its airspace, and as a member of the Canadian Advanced Air Mobility Consortium, has committed to developing the air traffic management portion of the AAM ecosystem.

> ***"As Canada's air navigation service provider, NAV CANADA has an essential role to play in developing an operating environment that supports the innovative potential of the drone industry and ensures safety across Canadian airspace."***
>
> *Mark Cooper, SVP, NAV CANADA*

The remaining two supply chains—eVTOL aircraft manufacturing and the aircraft operators that will fly them—will be fully discussed in sections below. An important conclusion one can draw from this is that the ecosystem needs to provide great services to passengers at affordable prices and where the sector itself finds an equilibrium, thereby becoming and remaining profitable.

AAM has important benefits that will flow to Vancouver's communities and regions. We can view these in environmental, economic, social, and business terms.

## Supply Chain 1 - Developing eVTOL Aircraft

Several eVTOL prototypes around the world are either in or nearing advanced stages of development and operational trials of one kind or another. Designs vary widely in terms of numbers of passengers, number of rotors, and distance traveled before recharging.

Even those developers furthest along have not released certain details about their aircraft, but we believe they will be lighter, quieter (Figure 17), and more flexible than helicopters. Medevac eVTOLs, for instance, will be able to land safely in a smaller area, a great bonus when emergency rescue personnel need to reach a critically injured person on a congested road.

Nearly all eVTOL aircraft currently in development are designed to be piloted, at least initially. The next two decades will see increasing use of automation and autonomy performing many functions traditionally performed by humans. Automation and autonomy offer the opportunity to reduce workload and enhance safety for critical aviation functions.

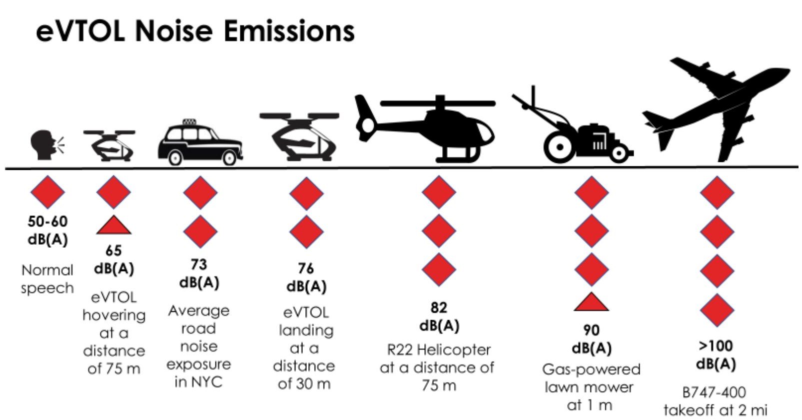


*Figure 3 - eVTOL noise is expected to be acceptable with noise mitigation practices developed for individual cities.*

Aircraft noise is a key determinant defining success and acceptance of eVTOLs that will operate in areas of higher population density at low altitudes. Smaller eVTOL aircraft are expected to fall well within current noise guidelines, and noise-reducing technologies hold promise for larger aircraft to be good neighbors as well. The next two pages provide details on eight aircraft well along in their development.

- **Joby S4**
- Santa Cruz, CA, USA – www.JobyAviation.com
- 1+4 passenger eVTOL with 6 tilting propellers
- Safety features – Distributed Electric Propulsion
- Total funding – $720 million announced in 2019
- Investors – Toyota Motor Group, Capricorn Investment Group, Intel Capital, JetBlue Technology Ventures, and Toyota AI Ventures
- Range – 150 miles
- Speed – 200 mph

- **Hyundai S-A1**
- Seoul, South Korea – www.Hyundai.com
- 1+4 passenger eVTOL with 4 tilting propellers and 6 lifting propellers
- Safety features – Distributed Electric Propulsion
- Total funding – $1.5 billion into UAM over next 5 years announced in Jan 2020
- Joint partnership with Uber Elevate
- Range – 60 miles
- Speed – 180 mph


- **CityAirbus**
- Marignane, France – www.AirbusHelicopters.com
- 4 passenger autonomous eVTOL with 4 pairs of co-axial propellers
- Safety features – Single failure tolerant architecture
- Total funding – Undisclosed
- Internal Airbus development
- Average range – Undisclosed
- Average speed – 110 mph


- **Wisk Cora**
- Mountain View, CA, USA – www.Cora.aero
- 2 passenger autonomous eVTOL with 12 lifting propellers and 1 pusher propeller
- Safety features – Distributed Electric Propulsion and Triple Redundant Flight-Computer
- Total funding – Undisclosed
- Joint project with Boeing and Kitty Hawk
- Average range – 62 miles
- Average speed – 110 mph

- **XTI Aircraft TriFan 600**
- Englewood, CO, USA – www.XTIaircraft.com
- 1+5 passenger hybrid electric VTOL/CTOL aircraft with 3 ducted fans
- Safety features – Computerized controls for takeoff and landing
- Total funding – $22.5M
- Investors – Meyer Equity, StartEngine, Primary Capital
- Average range – VTOL: 770 miles, CTOL: 1,380 miles
- Average speed – 344 mph

- **Volocopter VoloCity**
- Bruschal, Germany – www.Volocopter.com
- 1+1 passenger eVTOL with 18 fixed-pitch propellers
- Safety features – multi-redundant propellers, batteries, motors, electronics, and displays, can function on 12 propellers
- Total funding – $132 million
- Investors – Daimler, Mitsui Sumitomo Insurance, MS&AD, TransLink Capital, Lukasz Gadowski and others
- Range – 22 miles
- Speed – 62 mph

- **Lilium Jet**
- Wessling, Germany – www.Lilium.com
- 5 passenger autonomous eVTOL with 36 ducted fans
- Safety features – redundancy with 36 independent engines
- Total funding - $340M
- Investors – Tencent, Freigest Capital, Automico, LGT Capital Partners
- Range – 186 miles
- Speed – 186 mph

- **VEA Aircraft Inc. (Piasecki) PA890**
- Essington, PA, USA – www.Piasecki.com
- All-electric Slowed-rotor Winged Compound Helicopter with a three-bladed main rotor, a variable incidence wing, and swiveling tail rotor
- Safety features – highly redundant and reliable propulsion system
- Total Funding – Undisclosed
- Investors – Undisclosed
- Range – 280 miles
- Speed – 140 mph cruise speed

- **Alaka'i Skai**
- Hopkinton, MA, USA – www.Skai.co
- 1+4 passenger e/hVTOL with 6 propellers
- Hydrogen fuel cell hybrid-electric aircraft
- Safety features – Distributed Electric Propulsion
- Total funding - Undisclosed
- Investors - Undisclosed
- Average range – 400 miles
- Average speed – 118 mph


- **Jaunt Aircraft**
- Glassboro, NJ, USA – www.JauntAirMobility.com
- 1+4 passenger eVTOL with 1 lifting rotor and 2 cruise propeller
- Safety features – Dual redundant electric systems
- Total funding – Undisclosed
- Joint partnership with Uber Elevate
- Average range – 60 miles
- Average speed – 175 mph

## Supply Chain 2 - Building Vertiports and Multiports

The easiest way to create vertiports is to remodel existing heliports. The basic elements of a heliport are clear approach/departure paths, a clear area for ground maneuvers, final approach and takeoff area (FATO), touchdown and liftoff area (TLOF), safety area, and a wind cone. This existing infrastructure can be updated for eVTOL aircraft by adding battery recharging stations and fuel stations for hybrid aircraft, as well as perimeter security, shelters, and other amenities. The region's power grid becomes an essential factor in determining vertiport locations.

> ***"We believe the regional transportation ecosystem is ripe for disruption ,and startups like Joby Aviation will revolutionize how people move across urban areas."***
>
> *Bonny Simi, President, JetBlue Technology Ventures*

Metro Vancouver has 54 heliports. Of Vancouver's 15 hospital centers, seven have heliports. In addition, most of the area's 12 airports have one or more helicopter landing facilities.

Globally, many cities have heliports that are rarely or no longer used. Helicopters are often seen as a nuisance by local communities due to their noise. Given the lower noise signature of eVTOLs, it is likely that some of the unused or underutilized heliports—particularly those near hospitals—may be renovated to receive the new aircraft.

At some point in the future, eVTOL aircraft will land and take off from multiports (Figure 18). These large, specially designed transportation hubs will be able to service several aircraft at once and may offer passenger amenities such as food, restrooms, and shopping.


*Figure 4 - Uber Elevate multiport concept for high volume traffic.*

Integrating an eVTOL aviation network with the existing system of public transportation modes requires detailed planning and analysis. With objectives of implementing the greenest, most cost-effective, and commuter-friendly transit system possible, planners must consider the needs of all users when locating vertiports to enable practical end-to-end solutions for passengers. The UAM Geomatics Urban Air Mobility Study projected that by 2040 Greater Vancouver would need twelve new vertiports and possibly one multiport, strategically placed throughout the Metro region, in addition to those presently at airports and hospitals.

While the technology is available to upgrade heliports to vertiports, Transport Canada has not yet finalized standards. These regulations may be dependent on the types of aircraft selected, their footprint, weight, and electric or hydrogen charging requirements.

While certain aspects of vertiports remain to be determined, it is safe to say that the development of infrastructure to support an eVTOL network has significant cost advantages over heavy-infrastructure approaches such as roads, light rail lines, bridges, and tunnels. Compared to the billions of dollars required to extend lines, for instance, the estimate for the 12 new vertiports projected to operate in Greater Vancouver by 2040 (a mix of remediating existing heliports and building new ones) is in the range of $70 million total.

## Supply Chain 3 - Managing the Air Traffic Flow

An air traffic management system ensures the safe and efficient movement of aircraft. Airplanes and helicopters are guided through the airspace by air traffic controllers. Drones and eVTOL passenger aircraft must also be safely and efficiently managed. It is likely that the first passenger use cases will rely on NAV CANADA's existing system of air traffic controllers: those eVTOL aircraft replacing and/or complementing existing aircraft operations.

Some Medevac operators, for instance, will transition from helicopters to eVTOLs; others will add eVTOLs to the mix for greater flexibility. The same is true for Vancouver's helicopter operators. eVTOLs, which will probably be less expensive to buy and maintain and will certainly offer a much lower carbon footprint, will be mixed into the existing fleet. Medevac and helicopter operators have the permits, the pilots, the experience, and the routes. Transitioning from one kind of aircraft to another will not be difficult nor will it greatly increase the load on Canada's air traffic controllers.

> ***"We believe that in the next decades eVTOL will have the potential to become an essential tool to Public Service agencies around the world in applications such as firefighting, public safety, search and rescue, disaster relief and law enforcement."***
>
> *NASA Transformational Vertical Flight White Paper, 2020*

It is unlikely, however, that the many new uses and new routes of eVTOLs—both passenger aircraft and drones—will rely on the traditional system of air traffic controllers for traffic management when volumes become challenging. NAV CANADA's 1,900 air traffic controllers[19] already manage 12 million aircraft movements a year for 40,000 operators in over 18 million square kilometers,[20] making it the world's second-largest air navigation service provider (ANSP) by traffic volume. The addition of hundreds more aircraft movements a day in Vancouver alone will put too great a strain on the system.

Advanced Air Mobility will need its own air traffic management system working in conjunction with the current system. Human controllers in a UTM facility may become airspace managers, focused on

[19] NAV CANADA at a Glance: Who We Are.

[20] Meet NAV CANADA.

supervising automated systems and aircraft oversight, safety, and security. At such a facility, a single controller could control many more aircraft movements than working in an airport ATC tower. (Figure 19 is a photograph of NAV CANADA's downtown Vancouver air traffic control tower overlooking Vancouver Harbour.)

> ***"In the future, 'mobility hubs' will integrate different modes of transportation together."***
>
> *Nik Kviselius, Manager, New Mobility, Translink*

There are various concepts of how the airspace could be managed. One is having a single authority for managing the urban airspace on a daily basis, with the UTM entity opening and closing routes, granting flight authorizations, and executing a single, integrated flow management plan. It would collect, analyze, and exchange airspace and flight information to support safe operations. When an emergency or off-nominal situation arises during flight, the UTM entity would have human operators communicate with pilots and fleet operators to guide aircraft to safety. Other concepts allow for the coexistence of multiple UTMs that collaborate under a set of prescribed requirements.

A mix of beacon (cooperative surveillance) and radar sensor (noncooperative surveillance) systems will monitor traffic and the location of aircraft in areas of the UTM entity airspace most likely to exhibit high traffic volumes. These surveillance systems will also interact with counter-UAS (C-UAS) systems to detect any unauthorized flights that may pose a threat to traffic.

*Figure 19 - View of Vancouver Harbour ATC Center operated by NAV CANADA safely managing airspace for helicopters and seaplanes.*

UTM equipment will include automation platforms capable of eVTOL air traffic management, resilient wireless communications systems, detect-and-avoid systems, augmentation of GPS through navigation beacons, and weather-related sensors.

The airspace of a given jurisdiction will be divided up horizontally, like the layers of a cake (Figure 20). The highest level is where commercial aircraft currently fly without interference from drones and eVTOL. The middle level is where eVTOL passenger aircraft will fly. And the lowest level will be utilized by drones. The most challenging operations will be managing traffic as it transitions up or down through airspaces as well as merging traffic. Transport Canada, the department responsible for determining regulations and policies, has not yet defined the standards, and it is likely that it will take two more years for such standards to emerge and become generally accepted.

According to the NEXA Advisors/UAM Geomatics study[21], the estimated cumulative cost for Metro Vancouver Advanced Air Mobility Air Traffic Management systems and operations will be in the range of

[21] Urban Air Mobility: Economics and Global Markets 2020-2040. www.nexa-uam.com.

$80 million. This amount includes the need for a fully manned Network Operations Center or NOC, within the city's boundary. The NOC would be overseen by NAV CANADA.

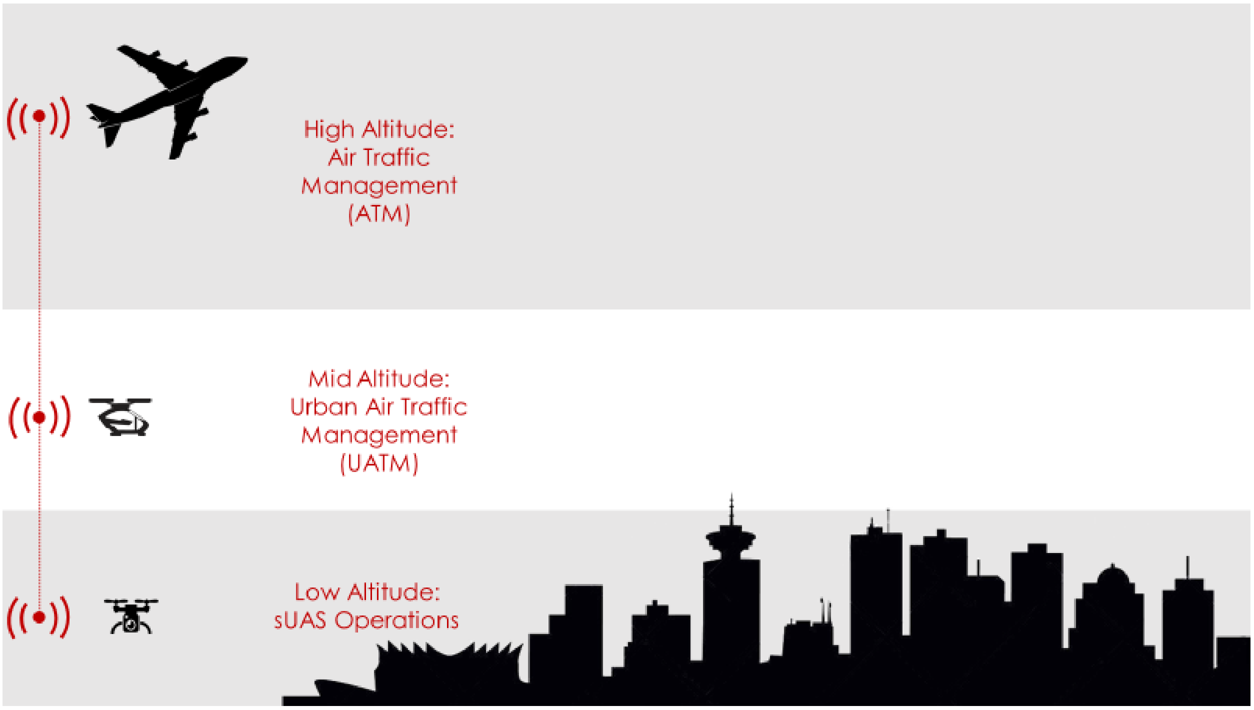


*Figure 20 - Airspace allocations for drones, eVTOLs and commercial air transport are under development.*

Advanced Air Mobility must, within a few years, become economically viable to pay off investors as well as to pay recurring costs such as equipment maintenance and upgrades, and employee salaries, and maintain public safety and convenience.

## Supply Chain 4 - Operators of eVTOLs and Drones

Current operators of helicopters are today's vanguard for eVTOL services. Charter helicopter companies in Vancouver, the most familiar being Helijet, have excellent longstanding safety records, trained pilots, weather dispatching expertise and systems, quality and safety programs. They are also familiar with the regulations, terrain and locations of the 54 heliports and airports in the region. As an industry, their current services are scheduled operations (e.g. Vancouver Harbour to Victoria), and more, including medical/emergency services, airport shuttle services, regional transport, cargo delivery, tourism, and heli-skiing.

Drone operators can be independent individuals, small companies, and large players such as Amazon, FedEx, and DHL. Their missions are diversified, and range from healthcare (isotope delivery, vaccine delivery, COVID test kits, blood transport) to package delivery, agricultural purposes, bridge inspection, and other useful applications.

# What We Heard from Vancouver Stakeholders

We sought out and collected perspectives from Vancouver stakeholders for this paper. We interviewed a wide variety of experts, policy makers, and luminaries across the Vancouver region to gather insights about the introduction of eVTOL and drone aircraft into the City's transportation system. Participants in this process included government agencies at the local, provincial, and federal level, university research groups, eVTOL aircraft developers, helicopter and fixed-wing operators, Air Traffic Management providers, healthcare workers, economists, transportation planners, and regulatory bodies.

> ***" Urban Air Mobility is coming because it has to… We have no more room on the ground to move cars around."***
>
> *Robin Lineberger, Leader, Deloitte A&D Industry Practice*

## Priorities

*In terms of utilizing Advanced Air Mobility in the Vancouver region, our respondents' main priorities are:*

- Inclusion, equity, and accessibility to all, especially lower-income and Indigenous people.
- Positive social impact.
- Clean energy. British Columbia will not approve anything that increases Vancouver's carbon footprint.
- Affordability. AAM should not be just for the wealthy.
- Safety. eVTOLs must be extremely safe to gain public and governmental support.
- Multi-modality. AAM cannot be a standalone product; it must serve as one part of a larger, multi-modal, technologically integrated transportation system.
- Persuasive first use cases. Most likely, emergency medical uses and Indigenous community assistance will receive the most public and governmental support.

## Questions

*Respondents posited important and relevant questions that need further research and dialog:*

- How would AAM integrate with transit and other transportation modes to allow for multi-modal connections?
- What are the potential key destination connections?
- What are the potential pilot demonstration project proposals, business models, and partnerships?
- How can AAM advance equity and access for everyone?
- How would AAM impact or mitigate congestion and promote health and safety?
- What is the role of AAM for goods movement and deliveries, forest fire monitoring, critical infrastructure surveying, first responder, time sensitive medical emergency services, and equitable passenger movement across Metro Vancouver?
- What type of infrastructure is needed (e.g. remote operation centers, high bandwidth fiber optic cables, 5G Wifi for communications, etc.)?
- What would be needed to create a business licensing framework that ensures the support of regional goals and regulatory processes (e.g. data sharing, insurance and liability, compatibility

and consistency of technology and operations with multiple vendors and stakeholders, cost sharing, maintenance, oversight and enforcement)?
- What are the job transition strategies as automation is introduced, and what are the new jobs resulting from this emerging market?

## Impediments to Introduction

*Our respondents felt that the impediments standing in the way of near-term AAM introduction are:*

- Quantifiable data collection as it relates to measuring community acceptance of an AAM industry.
- Clear roadmap for solicitation of federal and provincial funding to support CAAM non-profit business initiatives.
- Regulation/Certification. There must be new government-approved standards, aircraft and air traffic management certifications, airspace regulations, infrastructure permitting, route planning, and other aspects of AAM. It will take time for the government to set up these new standards, certifications, regulations, and approvals.
- Public acceptance. The public is concerned with safety, noise, privacy, emissions, visual annoyance, etc.
- Energy infrastructure. Vertiports must be on the power grid to charge eVTOL batteries. Building out the power grid is extremely expensive.

> ***"This innovation is for everybody. It is not only a playground for the rich. It creates connections for families, creates jobs for communities, and brings people together safely."***
>
> *Gaia Borgias, Director of Mobility Innovation Center, University of Washington Seattle*

## Concerns

*Their concerns about eVTOL and drone operations and flights are:*

- Excessive noise
- Visual Annoyance such as many aircraft overhead
- Privacy and property rights
- Safety of operations, air and ground
- Integration with other modes of transportation
- Affordability
- Accessibility
- Airspace congestion and restrictions due to multifaceted aviation community

## Excitement

*Respondents stated that they are excited about:*

- The potential benefits for Indigenous communities.
- The efficient delivery of medicine and supplies, as well as numerous benefits to the healthcare sector.
- Potential alleviation of traffic congestion and public transportation crowding.
- Potential economic benefits for British Columbia: jobs, revenues, research, new companies, boosting local businesses.

- Adapting university curriculum to reflect ongoing technological developments and preparing students for jobs in the emerging industries.
- A wide variety of cost savings in terms of:
  - expanding the transportation system. Establishing an eVTOL system will be remarkably less expensive than digging tunnels, building bridges, and constructing train lines.
  - flight operations. Electric engines are estimated to save $1-2 million dollars per 10,000 flight hours.
  - infrastructure inspection.
  - environmental inspection.
  - less spoiled perishable goods transported to remote communities.
  - less spoiled blood products for hospitals.

> ***" … Five or six years ago, it was hard to imagine a world where you'd rent out your house or apartment, so once people get the idea that this is the future, I see no reason why this won't be prevalent in the next few years."***
>
> *Carter Reum, Co-Founder M13 Investment Company*

*They also want to know:*

- What is the roadmap from today to the future?
- How will AAM become a viable business?
- And who will pay for it?

# AAM Missions and Services for Greater Vancouver

In this section, we discuss "Use Cases," or specific services performed for passengers and for cargo or package delivery. First are five use cases for eVTOL moving people, followed by drone use cases for medical supplies, package delivery, and other missions.

## Missions and Services Moving People

### Regional Air Mobility Including Trans-Border Services

Many regional B.C. city pairs are at an awkward distance: not far apart enough to justify a commercial flight, yet distant enough for a time-consuming drive: Vancouver to Seattle, for instance. Some manufacturers of eVTOLs are investing in hybrid aircraft that have the ability to gain altitude from a vertiport under electric power, and transition to vertical flight using lift from fixed wings.[22] Powering and recharging batteries using small jet turbine generators while at altitude, these aircraft have the range (400 KM) and capability to fly point-to-point from one city to another, but using the new UAM infrastructure available at over 200 heliports located throughout B.C. A strong preference for short inter-regional travel, such as Nanaimo to Langley or Victoria to Port Hardy, finds new demand that airlines cannot serve. Vancouver has long, thin routes such as downtown Vancouver heliport to Kent or Renton, as well as Abbotsford, Osoyoos, and Chilliwack.

*Figure 21 - A NEXUS kiosk will smooth travel between U.S. and Canadian vertiports.*

British Columbia has 13 drivable border crossings along its 687-kilometer border with Washington State. The busiest crossings are the four that serve the Seattle /Vancouver area. Before the COVID-19 epidemic reduced traffic in the spring of 2020, some 32,000 vehicles crossed through the Peace Arch, Blaine, Lynden, or Sumas ports with wait times of between two and four hours during peak travel times.

One key aspect of eVTOL travel will involve using biometrics to ensure travelers are "trusted", thus Figure 21 shows a familiar NEXUS kiosk that would need to be utilized before a traveler embarks on a non-stop flight. Airlines themselves see the potential of this form of travel. Regional air transport using eVTOLs is also potentially disruptive to today's commercial air transport model.

The map below estimates travel time from downtown Vancouver directly to Kent, Washington. eVTOL aircraft will travel *over* the congestion in minutes. Figure 22 illustrates one-way travel time between a

[22] Go to www.xtiaircraft.com

residence in downtown Vancouver to Everett, Washington, and applying modes of travel: car, commercial flight (YVR to SEA), and eVTOL from Vancouver Harbour Heliport. Driving will take more than three hours, while an eVTOL flight will be a third of that in total.

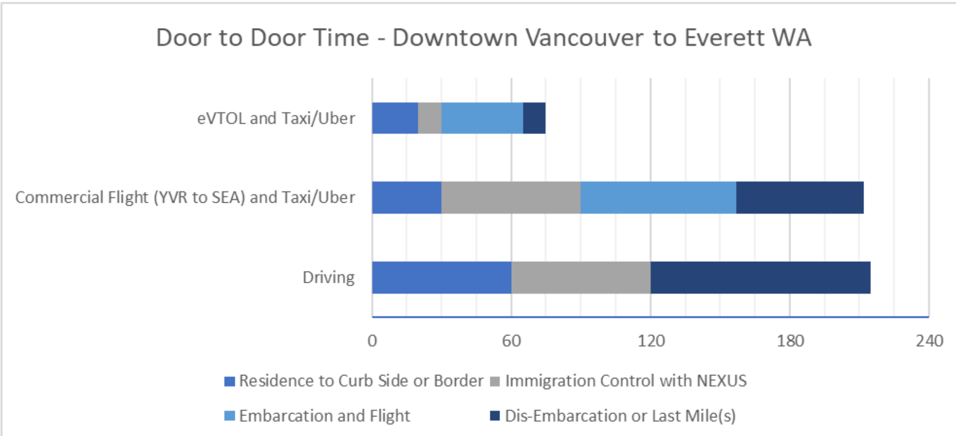


*Figure 22 – Door-to-door travel comparisons along the Cascadia Corridor.*

Imagine finding a means with which to shrink the distance between Vancouver and Seattle by 50 miles and the positive effect of this on trade. The eVTOL travel option has the potential to boost trade and cooperation along the Cascadia Innovation Corridor. Vancouver, Seattle and Portland have much in common: proximity to Asia and market-leading capabilities in key economic sectors. By more closely and conveniently linking these cities through new AAM transportation options, enhanced mobility should guarantee greater trade opportunities. The Corridor will create incremental new prospects beyond what could be achieved with the status quo.

Regional Air Mobility can also serve communities across British Columbia. Tying air mobility services into the Translink stations within Greater Vancouver can offer options and create new economics for businesses and residents.

## Emergency Services, Including Medevac and Critical Supply or Equipment Delivery

Emergency services include medical evacuation using eVTOL and the delivery of critical supplies and equipment, all in life threatening and time-critical situations. In British Columbia, the Province funds and maintains a service to provide such capabilities through existing charter operators of fixed-wing and helicopter aircraft. eVTOLs will likely complement these fleets in the near future.

> ***"“We believe the regional transportation ecosystem is ripe for disruption and startups like Joby Aviation will revolutionize how people move across urban areas.”***
>
> *Bonny Simi, President, JetBlue Technology Ventures, an Investor in Joby Aviation*

### Medevac

eVTOL aircraft will likely see their first uses in helping save lives as Medevac aircraft. Conventional Medevac helicopters take 10-13 minutes to prepare for lift-off,[23] while eVTOL aircraft will take only about one minute, depending on the final designs. In the case of a critically ill or injured person, every minute lost before help arrives means there is a greater chance of death, brain damage, and other serious complications. With regards to cardiac arrest, for every minute

[23] https://www.airmedicaljournal.com/article/S1067-991X(18)30236-0/abstract

the victim waits to receive defibrillation, his or her odds of survival decrease by about 10 percent.

Moreover, in the case of traffic accidents, a helicopter needs 100 square feet of space to safely land. Sometimes, on a gridlocked road, such a space is difficult to find. Police must first clear out a space, or the helicopter must land further away and its team travel toward the victim with a stretcher, again wasting time. eVTOLs, however, will need much less square footage to land safely (Figure 23).

*Figure 23 - Astro Highly Automated Medevac pod concept – patient plus EMT nurse.*

Many hospital centers in densely populated areas do not use Medevacs as the helicopter noise is a nuisance to the surrounding community. But given the potentially much lower noise signatures of eVTOLs, more hospitals may opt for life-saving Medevac eVTOLs. Another benefit of eVTOL Medevacs will be the cost. B.C. Emergency Health Services (BCEHS) transports about 7,000 patients each year. About 90 percent of the flights transfer critically ill patients from one hospital to another. Airplanes are used in 70 percent of the air ambulance calls, helicopters in 30 percent.[24] These flights comprise a large part of an urban area's daily helicopter operations and are responsible for the majority of objectionable noise.

The average air ambulance flight in Canada today costs between $25,000 and $30,000 per mission. Insurance covers most of that for patients, but leaves hospitals, insurance companies, and government healthcare providers with a large bill. With eVTOL aircraft still in development, it is difficult to say exactly how much the average Medevac flight would cost, but it will likely to be much less than the current price tag for helicopters. An eVTOL alternative would save financially strained hospitals and healthcare systems millions of dollars a year.

[24] http://www.bcehs.ca/about-site/Documents/factsheets/Fact%20Sheet%20AIR%20AMBULANCE.pdf

**Transportation of Time-Critical Supplies: Radioisotopes**

Radioisotopes play an important role in treating cancer, and B.C. Cancer-Victoria treats its patients with a particular type produced by a cyclotron at B.C. Cancer-Vancouver, 1.5 blocks away from Vancouver General Hospital. Unfortunately, it has a half-life of only 110 minutes, which means that within two hours it will decay to less than half its original amount (Figure 24). Delivery from B.C. Cancer-Vancouver to B.C. Cancer-Victoria, located at the Royal Jubilee Hospital, is currently by means of truck and ferry (light blue). Depending on traffic and weather, a good portion of the material and its effectiveness can deteriorate by the time it arrives. A more rapid transfer would mean more of the material is available to treat patients, translating into better patient outcomes, a reduction in cost and waste, and a reduced production burden on the radioisotope facility at B.C. Cancer-Vancouver.

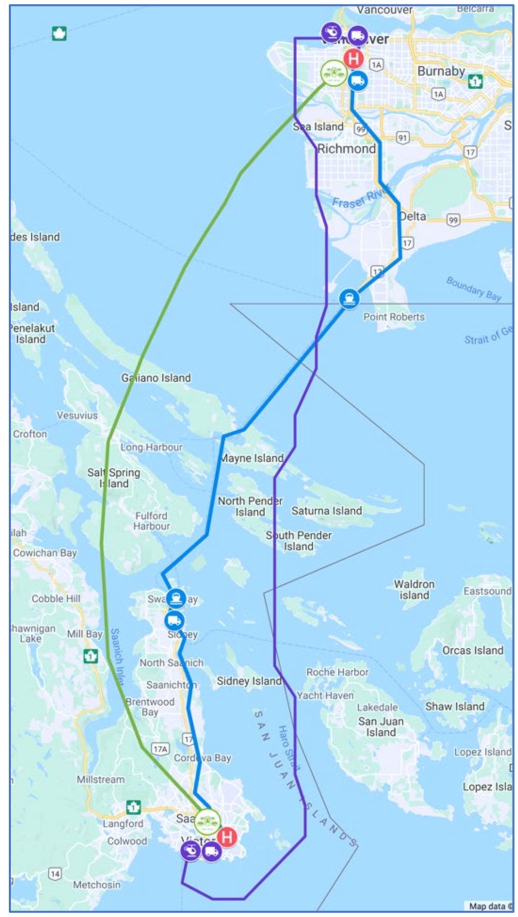

*Figure 25 - Isotope delivery options*

To provide the most efficient access to radioisotopes, a new partnership has been formed between B.C. Cancer (part of the Provincial Health Services Authority) (Figure 24), Helijet International, and TForce Logistics. The partnership is examining the use of helicopters and eVTOL aircraft to transport the material sealed in a fifty-pound lead container. In Figure 25, the most likely transportation routes are represented by different colored lines.

The first pathway (shown in blue)—conventional ground transport—represents the transportation of cancer isotopes from Vancouver via conventional vehicles (historically, Ford Ranger and Toyota Prius) to the Tsawwassen ferry terminal, ferried across the Georgia Strait to Swartz Bay ferry terminal from where it is trucked over to RJH. This 35 km journey usually takes about three hours.

The second pathway (shown in purple)—helicopter transport—represents the transportation of the cancer isotopes from Vancouver General Hospital via conventional vehicles to a helipad in Vancouver Harbour, flown via a Helijet Sikorsky S76 across the Georgia Strait to Ogden Point's helipad in Victoria Harbour, from where it's transported over to Royal Jubilee Hospital via conventional vehicles. The helicopter will cruise at a speed of around 248 km/hour, at an altitude of approximately 8,000 feet above ground level in Class 'C' airspace following Visual Flight Rules (VFR) and ATC clearance. The aircraft can hold up to 12 passengers, two crew and the respective cargo. The estimated time for this route is about one hour.


*Figure 24 – A team of B.C. scientists have engineered a breakthrough in isotope production. Cancer isotopes have a half-life of two hours.*

The third option, using eVTOL aircraft (shown in green), represents the transportation of the cancer isotopes via a representative eVTOL directly from a helipad on the rooftop of Vancouver General Hospital to a helipad on the rooftop of Royal Jubilee Hospital. The eVTOL will hold one passenger and the cargo. This pathway presumes that the eVTOL obtains certification and communication for Class 'C' Airspace Access & Operation. The estimated time for this journey is 30 minutes.

There are wide-ranging benefits wrapped around this use case. Efficient eVTOL transportation effectively extends the reach of major medical facilities, thereby reducing the need to situate expensive equipment, test laboratories, and perishable inventory in forward-operating locations. For example, one cyclotron in Vancouver could serve the needs of most of B.C., whereas without eVTOLS the province may need several of them. This saves a tremendous amount of money and at the same time makes the highest quality healthcare accessible to a greater portion of the population.

## eVTOL Services for Underserved Northern Communities

Well before the advent of COVID-19, Canada's Indigenous communities suffered from substandard housing and healthcare, and a lack of accessible transportation opportunities for both people and supplies. There are 637 First Nations on what is now known as Canada—some 203 of them in British Columbia—as well as two culturally distinct Indigenous groups, the Inuit and the Métis. Many of these communities are located in remote, northern areas that are difficult and even impossible to reach with trucks or rail. Some can only be accessed by aircraft or ferries. Others must wait for good weather for deliveries and mobility of any kind.

The arrival of COVID-19 has multiplied the challenges of these communities which, because of systemic inequities and discrimination, could suffer disproportionately from the virus. Federal and provincial governments have encouraged handwashing, for instance, as a method to keep the virus at bay, but many Indigenous communities lack access to clean water. Social distancing is another important health measure, but many Indigenous people live in severely overcrowded homes. Many, too, suffer from underlying health conditions known to greatly increase COVID-19 mortality rates—diabetes and tuberculosis, for instance—resulting from poverty and lack of access to a healthful diet.

*Figure 26-Teara Fraser, owner and Lead Executive Officer of Iskwew Air, serving Central British Columbia.*

Medical treatment in these communities is often far below the standards of city hospitals. Many nursing centers are underfunded and understaffed, lacking equipment, PPE, and medications.

Transporting critically ill patients and medical supplies is challenging, expensive, and time-consuming.

In October 2019, Teara Fraser (Figure 26) started Iskwew Air (Iskwew means "woman" in the Cree language, a name she chose as a reclamation of matriarchal leadership) to provide Indigenous tourism, the fastest-growing kind of tourism in Canada. Five months later, COVID-19 struck, and tourism was one of its first victims. Since then, Fraser, operating out of Vancouver International Airport, has been crowdfunding deliveries of urgent supplies in her twin-engine Piper Navajo Chieftain to Indigenous communities in British Columbia: Namgis and Whe-la-la-u Area Council in Alert Bay; the Tseshaht First Nation in Port Alberni, and the Tahltan First Nation in Dease Lake, Telegraph Creek, and Iskut.

On July 31, 2020, she flew five hours one way to Dease Lake and the Alberni Valley, transporting essential supplies and cargo to Indigenous, remote communities, including PPE, hand sanitizer, fresh fruit and vegetables, blueberry bushes, portable toilets, garden seeds, feminine hygiene products, and baby supplies. Dease Lake had been on lockdown due to the death of a young woman and an Elder from COVID-19.

***"The world is broken open. We have an opportunity to recreate [air services] in a way that has never existed before. Let's rebuild systems together in service of all."***

*Teara Fraser, Owner and Lead Executive Officer of Iskwew Air*

As important as her cargo is, Fraser worries about person-to-person contact in the age of COVID-19 in such high-risk communities. She is also concerned about the carbon footprint of her aircraft. "How do I balance that existing need with the footprint that I leave?" she asks. "I am carbon-offsetting and doing everything that I can. But I have to be a meaningful contributor to how to do it differently in the future so we can walk more gently on the earth."

Fraser sees the advent of green, clean eVTOL aircraft as the answer. In the age of COVID-19, large drones could fly supplies from major airports to the communities. Once the virus has abated, eVTOL aircraft with room for passengers and more space for cargo could complement the drones. Fraser's aircraft has a range of 700nm and can carry a total payload of 1,600 lbs. The new eVTOL technology, supported by future charging infrastructure, could be applied to the more than 1,000 remote communities across Canada, especially in Arctic regions.

*Figure 5 - Kingcome Inlet (Gwayi) in Central Western British Columbia.*

In a time of global health and financial crises, inequities often widen. But this is also time of new possibilities. As a Métis, Fraser's heritage is both Indigenous and non-indigenous, and she has always seen herself as a bridge builder between cultures. Now, however, she is beginning to see herself as building bridges between two different types of aviation—traditional aircraft and eVTOLs to reach the communities Iskwew Air serves.

Duncan Kennedy, co-founder and managing director of Indigenext, a firm that supports Indigenous entrepreneurship and opportunities for youth, sees eVTOL aircraft as a source of jobs, tourism revenue, and meeting basic transportation needs of people and supplies. "Many Coastal Indigenous communities in B.C. rely entirely on water transportation," he explained, "on floatplanes, and helicopters. A one-way trip by water-taxi for a 4-10 passenger boat is often more than $1000, for a 2+ hour trip of 50-100 miles. Flying by helicopter is more than twice the price and is the only option during winter months when the outflow of the river valleys makes boat and seaplane transportation dangerous."

Kennedy pointed out that many of the communities, such as Kingcome Inlet (Gwayi) (Figure 27) and Gilford (Gywasdums) which have been continuously inhabited for more than 10,000 years, have difficulty in creating jobs and keeping youth in their communities. As a result, some communities suffer from unemployment rates of over 50%.

Kennedy believes that eVTOL aircraft, at a price-point that competes with water transportation, would offer profound opportunities for coastal Indigenous communities. While urgent medical transportation is already available, regular medical transportation—residents wanting to visit a dentist or see a doctor for a check-up—is expensive and time-consuming. The same transportation difficulties face residents who want to visit family and friends in different communities. In addition to providing accessible transportation, eVTOL aircraft would also boost ecotourism which, until COVID-19, had been growing at more than 20% per year.

> ***"The goal is to create this world-class hub ecosystem related to UAM that will touch on transport of people, transport of goods, medical capabilities, and UAS services."***
>
> *Eric Lefebvre, National Research Council of Canada*

While these remote areas offer no electric power grid to charge aircraft, Kennedy believes that mindfully placed vertiports could take advantage of small micro hydro powered facilities utilizing the countless rivers in the area. "A private/public investment of $50-100 million," he said, "coupled with an investment in micro-hydro—we could build a 100MW hydro facility for under $2 million—could result in several small scale vertiports and 100 or more clean energy transportation and tourism jobs for the most vulnerable sector we have in this country."

## Airport Shuttle Services


*Figure 28 - YVR received the "Accessibility Gold Rating" Award from the Rick Hansen Foundation in 2018.*

Greater Vancouver, including southern Vancouver Island, has 12 airports, including several that handle airline traffic, the largest being Vancouver International, Victoria International, and Abbotsford International. Smaller airports such as Nanaimo and Tofino are used principally by private aircraft and small commercial turboprop planes. These airports provide a valuable mobility platform for British Columbia as the mountains make surface travel very difficult.

Vancouver International (YVR), the region's largest airport, managed over 26.4 million passengers in

2019, and has averaged 5.6 percent year-over-year growth since 2011. International travel accounted for 28 percent of this in the most recent full year for which data is available. As Canada's second busiest airport, 56 airlines serve YVR, connecting people and businesses to more than 125 non-stop destinations worldwide. In 2019, YVR was voted Best Airport in North America for the tenth consecutive year in the Skytrax World Airport Awards. In keeping with the region's social values, the airport also received the "Accessibility Certified Gold" rating under the Rick Hansen Foundation Accessibility Certification™ (RHFAC) program (Figure 28). YVR is the first airport to receive the rating and is the highest rated building in the national program.

Tying downtown city locations (like UBC, North Vancouver, etc.) and regional centers (like Surrey, Abbotsford, etc.) to YVR will become a high-value application of AAM. A well-run airport will look towards capitalizing AAM to maximize the utility and convenience of its facilities. Airports are the logical point of ingress for eVTOLs into an urban transportation network. Early on, airports will be the only locations with UTM systems required for low volume flights. However, as AAM becomes more prevalent, airports will be required to build out vertiport facilities, battery charging stations, hydrogen cell refueling, and people moving systems, as well as isolating the AAM activity from and integrating passenger flow with conventional airport operations. Vancouver has an incredible public transportation service to YVR with emphasis on light rail, taxis, bus service, and even float planes as options. In future, however, passengers originating in far-flung locations such as Nanaimo, Tofino, Port Hardy, or Chilliwack could find greater utility from a direct connection. In addition, we anticipate airport-to-airport shuttles; for instance, from YVR to Abbotsford, as well as airport-to-ferry terminals, such as Tsawassen and Horseshoe Bay. AAM costs will likely be affordable and competitive and should have the potential to reduce surface traffic congestion as the eVTOLs will be operating within the airport perimeter.


*Figure 29 - Possible airport shuttle routes between VYR and bedroom communities, through Vancouver Harbour Heliport. (Compliments of Helijet).*

One of the most impactful social benefits of AAM will be transferring wheelchair-bound passengers directly from point of origin to YVR. Another will be expediting emergency supplies from local warehouses or facilities to destinations only served by fixed-wing aircraft due to their distance or remoteness. A possible route structure serving YVR is shown in Figure 29. Note that time savings will be significant. As YVR averages 70,000 passenger arrivals and departures each day, the market for such services is promising.

## Air Metro Services

The Air Metro Concept of AAM resembles current public transit options such as subways and buses, with pre-determined routes, regular schedules, and set stops in high traffic areas throughout each city.

Aircraft are highly automated and can accommodate two to five passengers at a time, with an average load of three passengers per trip. Larger aircraft capacities are possible (Figure 30).

*Figure 30 - AeroG aG-4 twelve-passenger air metro eVTOL.*

The geography of the Vancouver region—water and mountains—means that traditional methods of metro expansion carry prohibitive costs for tunneling, constructing bridges over large bodies of water, and purchasing ever rarer and more expensive tracts of land. The Greater Vancouver region will be able to plan for and eventually incorporate larger aircraft carrying 10-50 people as well as goods between major Skytrain stations in the city center and those on the periphery of the public transportation system. For example, White Rock, home to many commuters, is only 50 km away from downtown Vancouver, but a car trip is often an hour or more, and a bus ride ninety minutes. Translink could build a vertiport in White Rock and have a 10- to 50-passenger aircraft fly either directly to the downtown core or to the nearest train station. Rather than littering the sky with multiple small aircraft, Air Metro would have fewer, larger ones, and operate similar to a bus system in the sky.

## Other eVTOL Use Cases

### On Demand Air Taxi

On-demand air taxi services have the potential to radically improve urban mobility. The time lost in daily commutes, or getting from one location to another, is substantial. Vancouver faces significant commuter delays, among the highest in Canada. According to Uber Elevate, just as skyscrapers allowed cities to use limited land more efficiently, urban air transportation will use three-dimensional airspace to alleviate transportation congestion on the ground. A network of small, electric aircraft that take off and land vertically should enable rapid, reliable transportation between suburbs and cities and, ultimately, within cities.

Uber Elevate, a strong proponent of on-demand air taxi and ride sharing, is working toward transforming cities through aerial ridesharing at scale. Uber is developing shared air transportation—planned for 2023—between suburbs and cities, and ultimately within cities. It is currently working with its growing list of Elevate Network partners to launch fleets of eVTOL aircraft in Dallas, Los Angeles, and Melbourne, Australia (Figure 31).

*Figure 31 - Uber Elevate intends to advance its vision of ubiquitous air taxis for major cities including Vancouver.*

**Corporate and Business Aviation**

Business aviation is a global industry, and business aircraft are tools that strengthen or leverage the impact of a company's intangible assets, including key employee talent. Companies everywhere have long benefitted from business aviation, as demonstrated by a host of studies, surveys and other types of analysis. For example, a 2017 study from NEXA Advisors measured the effects of business aviation on shareholder value creation of the S&P 500, for which over 450 companies operate aircraft. The report found that business aircraft make a substantial difference in how a company performs its mission, in many cases generating significant gains in shareholder value. Increased mobility was at the core of these gains—satisfying management's need for greater organizational agility, knowledge integration and transaction speed.

> ***"The development of eVTOL aircraft holds significant promise for a wide variety of business aviation applications, and the potential to transform on-demand aerial transportation."***
>
> *Ed Bolen, President and CEO, NBAA*

Existing heliport infrastructure, particularly outside of commercial and general aviation airports, provides eVTOL business aviation users with access to highly convenient urban destinations. Many current heliports have the operating certificates and access to airspace to begin stationing eVTOL aircraft immediately, though, depending on as-yet-to-be-determined regulations, some heliports will need to undergo modification to offer recharging stations, hybrid aircraft refueling, passenger shelters, and other amenities. We estimate the cost to retrofit a simple landing pad into an eVTOL vertiport to be between $1-2 million.

**Tourism and Sight Seeing**

Vancouver offers tourists not only the sophistication of a world-class city, but British Columbia also offers primeval rain forests, snow-capped volcanoes, towering mountain ranges, pristine national parks, sweeping glaciated valleys, and a rich network of rivers and lakes. In 2018—the last year for which statistics are available—the B.C. tourism industry generated $20.5 billion in revenue—an 4.9% increase over 2017, and a 53.3% increase from 2008. Ecotourism, particularly, was on the rise before the interruption of COVID-19. This new kind of tourism caters to tourists without damaging the natural environment or disturbing habitats. The destinations are fragile, relatively undisturbed natural areas, which most visitors rarely get to see. Ecotourism is a low-impact and often small-scale alternative to standard commercial mass tourism. It means responsible travel to natural areas, conserving the environment, and improving the economic opportunities of the local people.

The use of quiet, environmentally clean eVTOL aircraft to bring visitors to these areas would fit in well with ecotourism intentions. Visitors would learn about these fragile habitats; remote communities would benefit from income and jobs; and the environment would not be disrupted by the carbon emissions or irritating noise of traditional aircraft. Flight paths would be mindfully designed—as much as possible over water, for instance—to further minimize noise and disruption to wildlife, backpackers, hunters, and others enjoying the pristine wilderness experience.

**Personal Transportation**

North America has had a strong general aviation community for almost a century. General aviation is particularly popular, with over 6,300 airports available for public use by pilots of general aviation aircraft (around 5,200 airports in the U.S. and over 1,000 in Canada). In comparison, scheduled flights operate from around 560 airports in the U.S. Over 200,000 small single-engine general aviation aircraft are registered in North America, with an average age of 40 years. It is expected that eVTOL aircraft catering to recreational and weekend pilots will become increasingly popular when prices become affordable. Licensed GA pilots will easily qualify, with some additional training, to operate these new aircraft.

Innovation is also found globally. As shown in Figure 32, Japanese entrant teTra Aviation, winner of the $100,000 Pratt & Whitney Disruptor Award, appearing at Boeing's GoFly personal flight contest in February 2020, has recently partnered with Yoshimasu Seisakusho in a capital and business partnership that will have Yoshimasu investing 50 million yen ($630,000) in the University of Tokyo aviation startup.


*Figure 32 – Team Tetra award-winning eVTOL design for personal transport using lithium ion battery power*

# Missions and Services Using Drones

## Wildlife Tracking and Monitoring

Tracking and monitoring of endangered species is an important part of wildlife protection and conservation. Tracking and monitoring systems use photo traps, mobile phones, conventional cameras, and other methods to capture wildlife imagery. Although these methods are well integrated into the wildlife monitoring processes, there remains a desire for faster and more efficient image collection. Aviation, in the form of small aircraft flying at very low altitudes, has long been used to capture quality imagery for monitoring wildlife. However, this method is often dangerous to the wildlife, and it has caused dozens of deaths of wildlife biologists in air crashes. Small unmanned aerial systems (UAS), also called drones, which can capture the same quality imagery as traditional aviation, but with greatly reduced risk for wildlife biologists, are playing a growing role in radio-tracking of tagged animals, poaching prevention, terrain mapping, multispectral vegetation analysis, and oceanic detection services.

> ***"These are some of the most exciting innovations and developments in aerospace since the Wright Brothers, and it's all taken place over the course of a few short years."***
>
> *Dan Elwell,*
> *Acting Administrator,*
> *U.S. Federal Aviation Administration*

British Columbia is home to more than 1,138 species of vertebrates, which includes 368 saltwater species. The Southern Resident killer whale (Orca), a native of British Columbia waters (Figure 33), is an endangered species of great interest to researchers. Conventional methods of tracking them are limited to observations from a boat; however, UAS technology allows observations of Orca at the surface to as much as 10 m deep. This allows scientists to analyze the species searching for food, in coordinated travel, socializing, and other behavioral patterns.

UAS can be deployed noninvasively from ad hoc locations with minimal infrastructure, and they can transmit live video and other sensor data while in flight. UAS-derived imagery has demonstrated far better quality, timeliness, and cost than traditional terrestrial collection methods. In British Columbia, sophisticated UAS offer highly automated flight and data capture options that enable more streamlined flight operations and post-flight data processing using onboard or ground station computers. For example, one supplier has developed an artificial intelligence solution using a UAS to detect sharks along beaches while in flight. Another has developed an image processing system to count penguin nests in the Southern Hemisphere. Generating terrain maps and vegetation maps is another capability of UAS that can generate unique insight about the wilderness environment, particularly in difficult-to-reach areas.

*Figure 33 - Drones can monitor wildlife without invasive disturbance (InDro Robotics).*

Small UAS are controlled by an operator who can either fly the mission manually or program preplanned trajectories. Considering the remote nature of wildlife locations, regulatory issues are minor for this class of missions. Operations currently consist of low-altitude flights within visual line-of-sight (VLOS), but introduction of communications and airspace control capabilities will enable flights beyond visual line of sight (BVLOS). Operators can satisfy regulatory requirements through basic certification, although additional requirements will have to be satisfied for operations over people or in controlled airspace.

Primary drivers for adoption by industry and researchers will be the ability to access difficult-to-reach areas; the need for accurate, timely, and reliable data; and savings in time and cost. Technology advances in battery efficiency and low-noise aircraft will address the challenges of potential disruption of wildlife from low altitude operations and the limited range and endurance capabilities of current small UAS.

The table below summarizes the characteristics of wildlife tracking and monitoring operations.

| *Characteristic* | Characteristic Details |
| --- | --- |
| ***Use Case*** | • Wildlife tracking and monitoring |
| ***Payload*** | • Weight: 1-3 kg |
| ***Infrastructure*** | • Ground stations |
| ***Scheduling*** | • Regular scheduled inspections, with on-demand capability |
| ***Locations of Flight*** | • Low altitude<br>• Predetermined routes<br>• Rural forestry or coastal locations |
| ***Range*** | • ~20 km radius |
| ***Density of Operations*** | • ~1-5 aircraft per wildlife area<br>• ~1-2 aircraft flying simultaneously |
| ***Diversity of Aircraft Types and Procedures*** | • Low to moderate diversity<br>• Approximately 10-50 aircraft types<br>• Candidate for highly automated operations |

## Coastline Monitoring and Conservation

Coastline erosion is a vivid example of the impact of climate change on the environment. In British Columbia, as elsewhere, the average sea level has risen along most of the coast and is projected to continue to rise. The British Columbia coastline extends for over 25,000 km, which makes monitoring the coastline both challenging and expensive using conventional monitoring. Additionally, Vancouver sea levels are projected to rise between 60 to 70 cm by 2100 with British Columbia cities averaging approximately 30 to 50 cm.


*Figure 34 - Complex bio-regions of British Columbia require drone inspection missions tailored to coastal challenges.*

Continuous monitoring is thus essential to assess and mitigate the effects of coastal erosion on agricultural, commercial, residential, and public use of land surrounding the coastline (Figure 34). UAS in this role can quickly be deployed to cover long distances in a single flight and capture highly detailed imagery data along the coastline. UAS can be particularly valuable by enabling safe and rapid assessment of areas with deteriorating or unstable conditions.

Conventional coastline monitoring methods include aircraft-obtained aerial imagery, satellite imagery, and in-person inspection. All of these methods require extensive resources and time to deliver quality data. In contrast, UAS flying beyond visual line-of-sight can cover large distances in a short time at relatively low cost. UAS will be deployed with an operator and support crew to cover a designated coastal area. Flights will be controlled either manually or automatically, depending on the UAS capabilities, data collection requirements, and flight regulations. For detailed imagery of a specific region, the operator will manually control the UAS, adjusting the trajectory according to real-time analysis of data or requests from the survey crew. For map generation, the operator will program automated missions considering the data required, sensor capabilities, and vehicle performance. The UAS will fly at low altitudes to achieve the required accuracy for mapping data. Most operations will use a fixed-wing UAS to conduct inspections and mapping across long spans, while easily deployed small UAS capable of hovering and low-speed flight may be used for detailed evaluation of a local area. Small UAS can also conduct geological rock and cliff surveys, monitor water color and temperature, evaluate the impact of flooding, inspect breakwaters, and monitor aquatic wildlife.

> ***"It's important to protect the environment while offering young indigenous people good jobs in their communities."***
>
> *Duncan Kennedy, Indigenext*

UAS operations will take place largely along rural coastlines. Regulations in rural regions are less stringent than in urban areas, therefore operational limitations will not be a significant barrier except in fringe cases such as densely developed housing areas or sensitive coastal nature preserves. The greatest regulatory hurdle will be posed by operation BVLOS, which requires operators to hold a Special Flight Operations Certification as well as advanced operations certification. To simplify operations, Transport Canada has recently proposed an amendment which eases BVLOS restrictions in rural areas. Restrictions can be further mitigated for small UAS by limiting flights to VLOS.

Adoption of small UAS for this mission will continue to grow as sensors, aircraft, and analysis software become more capable and affordable and the impact of climate change on coastal areas becomes more severe. Ultimate growth will be limited by the fixed amount of coastline.

The table below summarizes the characteristics of coastline monitoring and conservation operations.

| *Characteristic* | Characteristic Details |
|---|---|
| ***Use Case*** | • Coastline Monitoring and Conservation |
| ***Payload*** | • Weight: 1-3 kg |
| ***Infrastructure*** | • Ground stations |
| ***Scheduling*** | • Regular scheduled inspections |
| ***Locations of Flight*** | • Low altitude<br>• Predetermined routes<br>• Rural coastal locations |
| ***Range*** | • ~20-50 km radius |
| ***Density of Operations*** | • ~1-5 aircraft per rural area<br>• ~1-2 aircraft flying simultaneously |

| | |
|---|---|
| ***Diversity of Aircraft Types and Procedures*** | • Low to moderate diversity<br>• Approximately 10-50 aircraft types<br>• Candidate for highly automated operations |

## Fishery Monitoring and Compliance

Illegal, unreported, and unregulated (IUU) fishing is a major concern for coastal areas around the world. This activity not only reduces existing aquatic populations, but it also can—and does— cause permanent damage by its impact on future stocks. For British Columbia, the Exclusive Economic Zone (EEZ) of sovereign rights spans more than 470,000 km2. It is estimated that each year in this zone between 1950 to 1980, 10,000 to 20,000 tons of salmon and groundfish were IUU – 18% of the total catch. That number was reduced to approximately 8,000 tons per year by 2005, demonstrating the potential of tighter enforcement.

> ***"Canadians know that climate change is among the greatest challenges of our time, and they also recognize the opportunity it brings."***
>
> ***Catherine McKenna, as Canadian Environment Minister***

UAS can serve as a major multiplier for the impact of human activity combating illegal fishing. Small UAS equipped with high-resolution cameras and sensors can transmit real-time surveillance data to control stations on the ground or aboard vessels. The speed of small UAS will provide large area coverage, and their small size and relatively low noise will minimize advanced warning to offenders. UAS can be used not only to detect IUU activity, but their presence can also deter further illegal activity. Small fixed-wing UAS are currently performing such operations in Belize to monitor the Turneffe Marine Protected Area and in Alaska to monitor the northern fur seal population. Other measures in use include loudspeakers mounted on UAS to warn fishers that they are fishing illegally and use of artificial intelligence to autonomously detect illegal activity.

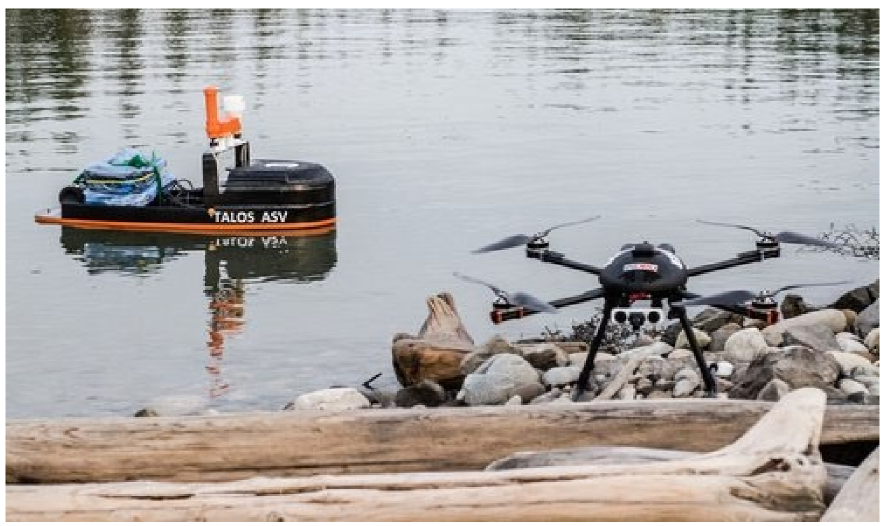


*Figure 35 - Talos ASV drone equipped with multiple sensors (InDro Robotics).*

Small vertical takeoff and landing (VTOL) UAS (Figure 35) could be deployed ashore or onboard patrol vessels to conduct VLOS flights. The UAS may fly at low altitudes to avoid detection and gather detailed data, or they may operate at higher altitudes and descend to collect more granular data. Payloads may range from conventional high-definition imagery to thermal or multispectral sensors, depending on time of day, visibility conditions, and nature of the mission.

UAS operating from land or ships may also conduct long-range, long-endurance flights for broad area coverage beyond VLOS (BVLOS). These UAS could operate as part of a network of platforms, control stations, and data-gathering resources monitoring area-wide activity.

Operations will take place within Canadian airspace, so there should be no significant regulatory barriers to operating short-range small UAS. Deployment of these systems will generally require little regulatory oversight for operations at low altitude and within VLOS. Longer-BVLOS operations will require an approved aircraft and a Special Flight Operations Certification (SFOC).

Use of UAS for monitoring IUU activities is currently in its early stages. This application is expected to grow as current uses demonstrate significant benefits. Relaxed requirements for BVLOS flight over open waters could facilitate adoption of small UAS to gain significant savings in cost and timeliness. Technologies that will lead to further growth of this concept include improved sensors and machine intelligence, aircraft performance and controls that enable landings and takeoffs in high winds and higher sea states, and counter-UAS methods to mitigate threats to assets in flight.

The table below summarizes the characteristics of fishery compliance operations.

| *Characteristic* | Characteristic Details |
|---|---|
| ***Use Case*** | • Fishery Compliance |
| ***Payload*** | • Weight: 1-3 kg |
| ***Infrastructure*** | • Launch and recovery equipment (sea- and land-based), command and control center, ground stations |
| ***Scheduling*** | • Regular scheduled patrols, with on-demand capability |
| ***Locations of Flight*** | • Low to medium altitudes<br>• Over-water flights<br>• Preplanned patrols |
| ***Range*** | • ~20 km radius |
| ***Density of Operations*** | • ~1-10 aircraft per coastal area<br>• ~1-5 aircraft flying simultaneously |
| ***Diversity of Aircraft Types and Procedures*** | • Low to moderate diversity<br>• Approximately 10-50 aircraft types<br>• Candidate for highly automated operations |

### Rapid-Fire Dispatch

Response time is critical for emergency responders to prevent or contain damage, treat injuries, and save lives. In 2018, Vancouver Fire Rescue Services (VFRS) responded to 60,000 incidents, 70% of which were medical—twice as many incidents as the Canada average. The key first step is to assess the situation and determine the capabilities that need to be deployed to address the situation at hand. Fire departments respond to fires, events involving hazardous material, medical emergencies, maritime emergencies, motor vehicle accidents and fires, rescue calls, and other situations for which time is of the essence. Thus, the ability of drones or UAS to provide a bird's-eye view and avoid the congestion and delays of surface traffic is a major new benefit for a growing number of cities' fire departments.

For instance, drones built by InDro Robotics played a significant role in helping fight the May 6, 2019 fire that destroyed Victoria's Plaza Hotel. The drones directed firefighters to the hot spots with real-time visuals and helped them save historic structures nearby.

Initially, designated firefighters will be trained as UAS operators, and small UAS with appropriate sensors will be launched at the scene of a fire or other emergency to operate within visual line of sight. In the future, with appropriate communications and control of airspace, small UAS may be operated BVLOS and from facilities such as fire stations or emergency control centers, or they may be positioned at locations, such as atop buildings, that are more advantageous for aircraft. Due to payload limitations, small UAS equipped with different sensors may operate in teams selected for the situation, or they may be equipped with interchangeable payload packages than can be configured for the mission. Night operations will require special equipment, such as lighting.

Eventually, highly automated small UAS systems may be deployed across community networks at nodes located to provide the best coverage for the area (Figure 36). Visual, infrared, thermal, and other sensors will rapidly collect data and disseminate it to firefighters at the scene and to command and control centers, while data processing and intelligent machine systems will help to determine the best response strategy to the situation and the capabilities to be dispatched. Continuously updated data will enable swift and accurate responses to changes at the scene.

> ***"To our knowledge, this is the first full-time, in-service UAS program in the ... division, which led to our work with InDro Robotics out of British Columbia."***
>
> *Scott Wilkinson, Winnipeg Fire Paramedic Service*

*Figure 36 - Illustration of a fire extinguisher drone being directed by a spotter drone.*

Human operators will control the UAS within the existing regulatory framework. Initial operations will be limited to VLOS and altitudes well below conventional aviation. Future operations BVLOS will require regulatory permission, advanced pilot training, and approval from air traffic control (ATC) to fly in controlled airspace. Operators may be accompanied by visual observers in some scenarios to reduce risk and improve situational awareness. Fleet size will start small, with units in the single digits in a metropolitan area growing to double digits within a few years of operations.

Highly automated UAS will require an effective traffic management system, capability to avoid other traffic, and means to prevent or counter unauthorized flights in designated airspace. Flight altitudes will generally be lower than conventional aviation operations. Highly automated operations will likely start in rural areas, where risk to persons on the ground is lowest, and gradually move to residential and urban areas. Certification may be required on the complete UAS and support hardware to verify consistent performance and adequate safety in case of system degradation. Continued innovation in automation, communication systems, and UAS range and endurance capabilities will further open the market and better support the business case for installation and deployment.

The table below summarizes the characteristics of rapid-fire dispatch operations.

| *Characteristic* | Characteristic Details |
|---|---|
| ***Use Case*** | • Rapid-fire dispatch |
| ***Payload*** | • Weight: 1-3 kg |
| ***Infrastructure*** | • Human Operator<br>• Storage facility<br>• Highly Automated System<br>• Docking/charging stations, command and control center |
| ***Scheduling*** | • On-demand capability |
| ***Locations of Flight*** | • Low altitude<br>• Urban and remote locations<br>• Variable routes |
| ***Range*** | • Human operator: VLOS; highly automated system: ~20 km radius |
| ***Density of Operations*** | • ~5-20 aircraft per metro area<br>• ~1-5 aircraft flying simultaneously |
| ***Diversity of Aircraft Types and Procedures*** | • Low to moderate diversity<br>• Approximately 10-50 aircraft types<br>• Candidate for highly automated operations |

## Wildfire Response

Wildfires have a major impact on the environment and society around the world (Figure 37). As of August 26th, 2020, British Columbia had experienced 569 wildfires this year. Because of their rapid and often unpredictable spread, fighting wildfires requires proper planning, rapid response, and flexible management of firefighting response efforts. To meet these needs, small UAS are gaining acceptance for use in enhancing response to wildfire events quickly and with enhanced strategies and allocation of resources.

*Figure 37 - Forest fires force closure of roads and endanger the public and fire fighters.*

While satellite and aerial imagery play a major role in the assessing the magnitude and extent of a wildfire, small UAS equipped with high-definition sensors can provide more precise and accurate data to better understand the nature of a wildfire. When a fire crew is deployed, the crew will include a trained and qualified operator and one or more visual observers to operate the UAS for surveillance of the fire. Because endurance and range capabilities of small UAS limit how far the aircraft can travel, UAS will often complement conventional aviation or larger long-endurance UAS. Small UAS can be used to launch a controlled fire to prevent wildfires from spreading across large areas by carrying pods that can be remotely triggered to deploy a fire starter, and they can also be used for support missions such as surveys, assessment of fire hazards, protecting and re-deploying ground crews, and replanting land or forest that was burned in a fire.

Since most wildfires tend to occur in rural locations, regulatory concerns with airspace or operations over people will be limited. Night operations will require special equipment, such as lighting. Traffic management is not of great concern within the current regulatory environment and considering the small size of the operational fleet. Operations in government-restricted areas or flight in controlled airspace may require special permission. In some cases, airspace over a fire may be blocked to any air operations other than those supporting the firefighting effort. Operations will initially take place within VLOS of the operator or a visual observer, with special procedures required for operations obscured by smoke or tall trees. Introduction of sensor technologies and UAS traffic control will enable extended ranges of operation beyond visual line of sight. Most, if not all, operations will take place below 400 ft above ground level, separating small UAS operations from conventional aviation.

Weather and fire-induced winds or updrafts will pose challenges for small UAS, requiring wind- and weather-resilient aircraft and procedures. In the future, sophisticated sensors, machine learning, and artificial intelligence applied to capturing and assessing the data collected from flight operations will be pivotal in the acceptance and growth of small-UAS applications.

The table below summarizes the characteristics of wildfire response operations.

| *Characteristic* | Characteristic Details |
|---|---|
| ***Use Case*** | • Wildfire response |
| ***Payload*** | • Weight: 1-3 kg |
| ***Infrastructure*** | • UAS fleet storage, ground stations |
| ***Scheduling*** | • On-demand capability (surveillance and mitigation), with regular scheduled deliveries (inspection, reforestation) |
| ***Locations of Flight*** | • Low altitude<br>• Rural fire locations |
| ***Range*** | • ~20 km radius |
| ***Density of Operations*** | • ~1-15 aircraft per rural area<br>• ~1-5 aircraft flying simultaneously |
| ***Diversity of Aircraft Types and Procedures*** | • Low to moderate diversity<br>• Approximately 10-50 aircraft types<br>• Candidate for automated operations |

## Retail Goods and Food Delivery

Short-range package delivery is a major potential mission for UAS weighing up to 25 kilograms carrying packages of up to five kilograms. Due to aircraft payload limitations, it is expected that most flights will perform a single delivery before returning to their base of operation, but there may be cases in which the delivery comprises more than one package and multiple destinations within the nominal 20-kilometer mission radius capability of the UAS.

Customers and businesses will determine the best use of these aircraft (Figure 38). Last-mile package delivery could be accomplished by transporting packages from distribution facilities to receiving vessels, such as Amazon lockers, or directly to a final destination, such as a residential backyard. Delivery sites for these operations may be purpose-built or adaptations of existing facilities, such as shopping malls. The sites will include landing pads and facilities such as package drop chutes or lockers, and they may be designed such that the delivery aircraft can place the payload from a hover without landing on the ground. Launch sites will generally be fixed, but in some cases, UAS may deliver packages from a warehouse to a truck situated close to the final destination, or in other cases it may be advantageous to launch UAS from a truck to make the final delivery. Facilities for passenger-carrying operations may also house designated delivery stations, or they may be collocated with package distribution facilities.

Operator and vehicle certification regulations will support safe operations and enable growth and integration of the UAS industry with the rest of aviation. A UTM system will enable safe separation between flights. The UAS will fly at low altitudes and avoid interference with manned flight operations, but they may fly higher than 400 feet above ground level in areas devoid of manned traffic, including urban canyons or the rooftops of tall buildings. Package delivery operations will employ machine intelligence, automation, and sensor technology to safely operate BVLOS between the operator and the vehicle, and increasing levels of automation will enable a single operator to manage multiple aircraft at a time. Flights are expected to operate in clear weather conditions until implementation of a traffic management system, the associated infrastructure, and aircraft designs that enable navigation in inclement weather and poor visibility. The diversity of aircraft types that support package delivery is expected to grow as various types of new delivery services are approved and implemented.


*Figure 38 - Amazon package delivery drone. The retailer received FAA Part 135 approvals in August 2020 for U.S. delivery service commencement.*

To pose the least risk and facilitate public acceptance, package delivery operations in the metro Vancouver area will initially be conducted within selected locations, using predetermined routes, such as over roadways or railways, or operating over less-populated areas. As improvements in electric propulsion, aircraft reliability, and automation enable increased range and density of operations and enhance market acceptance by reducing operating costs, the package delivery fleet population in the area is expected to eventually grow to number in the thousands, with hundreds of flights operating at any time. This volume of traffic may dictate a new class of low-altitude airspace replacing uncontrolled airspace, as well as reallocation of low-altitude airspace over urban areas.

The table below summarizes the characteristics of small-package delivery operations.

| *Characteristic* | Characteristic Details |
|---|---|
| ***Use Case*** | • Last-mile package delivery |
| ***Payload*** | • Weight: approximately 5 kilograms |
| ***Infrastructure*** | • Delivery sites, receiving vessels, distribution hubs, docking/charging stations |
| ***Scheduling*** | • Regular scheduled deliveries, with on-demand capability |
| ***Locations of Flight*** | • Low altitude<br>• Limited flight in urban canyons<br>• Predetermined routes |
| ***Range*** | • ~20 kilometers radius |
| ***Density of Operations*** | • ~1,000-2,000 aircraft per metro area<br>• ~500-1,000 aircraft flying simultaneously |
| ***Diversity of Aircraft Types and Procedures*** | • Low to moderate diversity<br>• Approximately 10-50 aircraft types<br>• Candidate for highly automated operations |

## Other Applications for Drones

We can name a host of other applications for drones and leave detailing of these for future work of the CAAM Consortium:

- **Delivery of Medications and Emergency Equipment:** In August 2019, Canadian drone manufacturer InDro Robotics conducted tests delivering medications to individuals living in remote areas without nearby pharmacies. InDro developed a tamper-proof case with a dial-in code and software to control the temperature of the drugs. That same year, the company tested whether ambulances or drones were the faster delivery method for automated external defibrillators. They found that the drones arrived between 7 and 30 minutes before the ambulances on every occasion. For every minute that passes, a heart attack victim's chance of survival goes down 10 percent.
- **Infrastructure Inspection:** Inspecting bridges, high-rise buildings, residential roof-tops (Figure 39) and critical power/water/gas supply lines can be done safely and efficiently.

*Figure 39 - Residential roof top inspections can reduce injury and more accurately assess conditions of shingles.*

Drones are in use daily, providing this capability in the Vancouver region.

- **Agricultural and Prescription Farming:** An agricultural drone is a UAS used to help optimize agriculture operations, increase crop production, and monitor crop growth. Sensors and digital imaging capabilities can give farmers a richer picture of their fields. This bird's-eye view can reveal many issues such as irrigation problems, soil variation, and pest and fungal infestations. Multispectral images show a near-infrared view as well as a visual spectrum view. The combination shows the farmer the differences between healthy and unhealthy plants, a difference not always clearly visible to the naked eye. Thus, these views can assist in assessing crop growth and production.

# Next Steps

The CAAM Consortium will further explore the many findings in this White Paper over the coming months. This section suggests next steps in six directions:

**Benefit Analysis and Benefit Realization**

The significant array of public benefits discussed in this White Paper should be further validated:

- Complete the AAM economic impact analysis currently underway by NEXA Advisors, with special focus on direct, indirect, and induced job creation.
- Investigate and identify local catalytic economic impacts of AAM: 1) Increased trade between West Coast communities along the Cascadia Corridor; 2) Improvements in economic conditions for Indigenous communities; 3) Economic impact of increased investment in science and technology; and 4) An increased role for Vancouver's hydrogen programs and results benefiting the AAM sector.
- Evaluate in greater depth the immediate as well as long-term public benefits of drone and eVTOL use in medicine, public health, emergency medical services, and COVID-19 amelioration.
- In partnership with Indigenous Services Canada and those B.C. Indigenous communities most interested, develop pathfinder drone and AAM programs to improve public health outcomes, reduce Indigenous community isolation, spur youth involvement, and create long-term jobs.
- Prepare and widely circulate a "Public Interest Survey", possibly through BCIT, UBC or UV, to develop a baseline of public perceptions about AAM and its importance to the greater Vancouver area. Such a survey can be updated annually to track changes in public perceptions.
- Engage the B.C. and federal ministries, using this White Paper to show public benefits.

**Maximize Environmental Benefits of AAM**

AAM has the enviable potential to eliminate dependency upon hydrocarbon fuels for propulsion, at the same time reducing noise pollution and increasing public acceptance. Next steps should be:

- Develop environmental targets and goals for AAM to eliminate net greenhouse gases through electric aircraft and limit greenhouse gases to water vapour for hydrogen-based aircraft.
- Encourage companies with hydrogen fuel cell-based eVTOLs (hVTOLs) under development to come to the region with well-designed incentives. Deployment of hydrogen in British Columbia will be required for the Province to meet 2030 and 2050 decarbonization goals and emissions reduction commitments.
- Undertake noise and noise abatement studies to support AAM deployment for the good of residents and better understand public perceptions of these new transportation systems and technologies.

**Advanced Air Transportation Policy Development**

Public policy is considered strong when it solves problems efficiently and effectively, serves and supports governmental institutions and policies, and encourages active citizenship. In this category, next steps should include:

- Develop AAM transportation policies that will encourage multi-modality, provide alternative means to optimize public funding of expensive public transit, and offer preferred or priority access to disadvantaged communities.
- Develop policies and procedures for the location, construction, and operation of more extensive vertiport networks within city limits, capable of better serving the mobility needs of the public.
- Examine the full range of P3s that can be utilized to attract private capital to fund AAM ground infrastructure and needed UTM facilities and services.
- Consider policies that take advantage of the Vancouver region as a "cradle of hydrogen" together with the U.S. West Coast.

**Analytics for Greater Vancouver Airspace Development**

To move the City of Vancouver forward on its path to utilizing AAM, it will be vital to enter into an intensive analytical phase for future airspace design. This will need to take into consideration the public perception of AAM and its risks to demonstrate that mitigation has been considered. These next steps include:

- Develop an analytical framework and program to design and validate Vancouver airspace for safe operation of drones, eVTOLs, and conventional aircraft.
- Facilitate completion of the Canadian Aviation Regulations to accommodate all practical AAM use cases by drafting detailed Concept of Operations documents and supporting the development of new regulations.
- Bring together multi-dimensional visualization tools (Figure 40) to design and simulate airspace configurations for safe and efficient operation, integration with other airspace users, noise abatement (see comments on noise in the educational segment below), and improved network benefits.

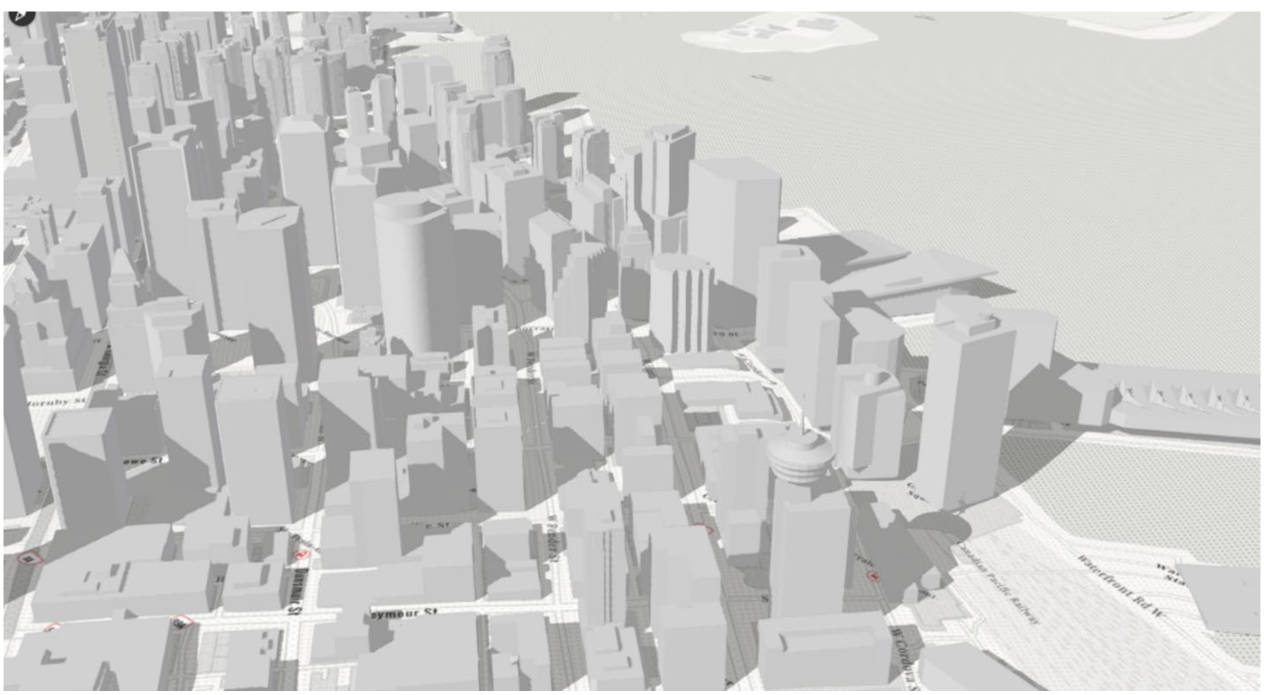

*Figure 40 – Three-dimensional, high resolution digital maps of Vancouver will speed airspace design analysis (ESRI, 2020)*

- Plan and execute drone and AAM demonstration flight testing within the Vancouver Harbour and greater region, with partners to include the CAAM stakeholders, aircraft developers, and regulators. Analyze the performance and extract information to support benefits and economic assessments and to validate regulatory needs.
- Consider developing cooperative programs with the Seattle Region and its emerging AAM consortium to ensure that cross-border considerations are made early.

**Educational, Scientific, and Technical Promotion**

Educating the broader community on the safety, benefits, and societal value of AAM will be critical for public acceptance of AAM. To achieve this, steps include:

- Consider building an innovation hub for Small to Medium Enterprises (SMEs) to begin to leverage newfound CAAM network/collaboration momentum, thus allowing low Technology Readiness Levels (TRLs) to move to commercialization, a key strategy toward this ecosystem's successful maturity.
- Call for an AAM "STEM Summit" to promote the new AAM ecosystem to colleges, universities, and high schools, and identify skills needing further development in Vancouver and the rest of Canada.
- Emphasize the importance of public understanding of the science behind noise and the actual impact of eVTOLs on their daily exposure. Urban design disciplines will become essential.
- Ensure that drones and eVTOLs offer important educational opportunities to Indigenous communities.
- Seek federal funding for university and college-based research across all STEM disciplines.
- Place vertiports and drone-ports at participating campuses.

**Communications Strategy**

An effective short-term communications strategy will be developed by CAAM to:

- Articulate a message that UAM/AAM and drone missions will deliver tremendous long-term benefits for the region and its stakeholders.
- Point to other cities currently in the advance planning stages (Singapore, Seoul, Dallas, Munich, etc.)
- Emphasize that a single eVTOL can perform multiple missions and uses.
- Provide early emphasis on use cases such as Medevac, emergency services, first responder needs, COVID-19 response, isotope delivery, and related services for disadvantaged communities.
- Stress affordability and accessibility over time, with a focus on Air Metro aircraft and services, and the fact that AAM will not be a premium service.
- Ensure and include benchmarks and an evaluation process to measure commitments delivered and success along the way.
- Provide stakeholders with additional value in form of high-quality content. As a practical matter, develop a series of white papers that are researched, referenceable, and articulate on the most critical topics by today's vision: Safety, environmental benefits, noise abatement, public perception, and public benefit delivery.