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Flight Research – Aerospace Research

Canadian Airspace and Aircraft Equipment Requirements

LTR-FRL-2023-0053

16 June 2023

Author/Auteur: **Daniel Nelson[1], Teresa Krings[1], Josh Chang[1], Aman Basawanal[1], Sam Kingma[1], Brendan Ooi[1], Iryna Borshchova[2], and Jeremy Laliberte[1]**

1 – Carleton University, 2 – National Research Council of Canada

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Canada

FLIGHT RESEARCH LABORATORY

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1.0 EXECUTIVE SUMMARY

This report provides an overview of the sensor equipment requirements for crewed aviation aircraft operating in the various types of airspaces in Canada. It outlines the equipment requirements based on the operational airspace of the aircraft, as well as the minimum performance and design standards mandated for the equipment systems themselves. Specifically, the requirements are elaborated for 12 selected Canadian airports that align with the statistical airspace models previously developed by the research team for the same 12 airports [1].

The objective of this report is to provide a comprehensive understanding of the current equipment requirements for crewed aviation aircraft. This information serves as a crucial context for analyzing and informing the development of future Detect-And-Avoid (DAA) equipment requirements for Remotely Piloted Aircraft Systems (RPAS).

Funding for this project was provided by Transport Canada (TC) and the Natural Sciences and Engineering Research Council of Canada (NSERC) Collaborative Research and Training Experience (CREATE) Uninhabited Aircraft Systems Training, Innovation, and Leadership Initiative (UTILI) Program. The analysis presented in this report is based on the National Research Council of Canada (NRC)-developed airspace datafile, utilizing NAV CANADA’s 2021 airspace data.

2.0 ACKNOWLEDGEMENTS

The research team would like to thank both TC and the NSERC CREATE UTILI Program for the financial contributions made to enable the completion of this project.

Additionally, we thank Kris Ellis for sharing airspace datafiles, as well as for his support and advocacy for the importance of this project to support TC's data-driven approach to RPAS regulations.

3.0 INTRODUCTION

Canada represents a nation with unique airspaces, as the large ground area of the country, coupled with many airports of varying operational sizes spread out across the country. This results in a mixture of many different combinations of airspace classes that are in close proximity to each other, particularly around the larger commercial airports across Canada (Figure 1). As TC is seeking to take a stepped approach to the development of regulations to enable the safe incorporation of RPAS into the Canadian airspaces, the research team (National Research Council of Canada and Carleton University) identified the need to assess the current sensor equipment requirements of crewed aviation aircraft that operate in the various airspace classes across Canada. This assessment was completed to provide an informed overview of the different types of available sensor technologies that are equipped on crewed aviation. The findings of this assessment will be utilized for future work aimed at validating Air Risk Classes (ARCs) in Canada. Additionally, the content of this assessment can provide valuable insights to facilitate the development of guidelines for Detect-And-Avoid (DAA) equipment requirements for RPAS, specifically tailored to the intended operational areas within Canada. This information will contribute to enhancing the safety and effectiveness of RPAS operations in the country.

It is worth noting that all figures and analyses conducted by the research team were performed using an NRC-developed airspace dataset containing information extracted from the Designated Airspace Handbook that was in effect in June 2021 [2], which was modified and adapted for the research purposes. This dataset not only facilitated accurate plotting of airspace configurations but also provided the researchers with more insightful analysis capabilities. The utilization of this dataset enhances the reliability of the findings, further supporting the research team's efforts in assessing sensor equipment requirements and contributing to the safe integration of RPAS into Canadian airspaces.

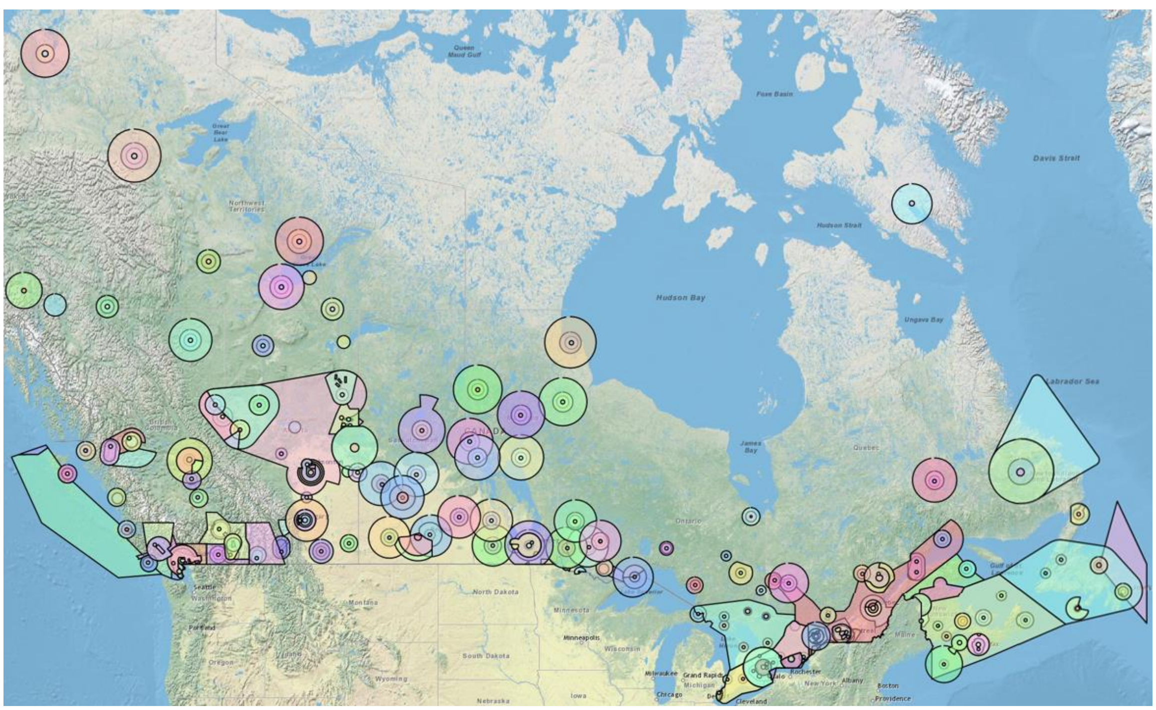

Figure 1: Controlled airspace in Canada (excluding low level airways and special use airspace)

4.0 CANADIAN SENSOR EQUIPAGE ANALYSIS

4.1 Canadian Airspace Classes Overview

Canada's airspace is divided into 7 classes: Class A through G [2], each of which has defining regulations and requirements that aircraft must comply with in order to operate within. These regulations are largely based around flight tracking and communication with other aircraft and Air Traffic Control (ATC). Typically, specifying if a transponder (mode C), a two-way radio, and/or ATC clearance are required to enter. Table 1 summarises these requirements for each airspace class. It should be noted that Canada has plans to implement ADS-B throughout its airspaces in the near future, and thus transponders capable of ADS-B out will be required in stages in the next few years. The dates released for these additional requirements coming into effect can also be found in Table 1.

Table 1: Summary of Canadian airspace class requirements [3]

Airspace Class	A	B	C	D	E	F	G
Transponder (Mode C) Required	Yes	Yes	Yes	Yes, in designated areas	Yes, in designated areas	As specified	No
Two Way Radio Required	Yes	Yes	Yes	Yes	Mandatory if under Instrument Flight Rules (IFR)	As specified	No
ATC Clearance Required Prior to Entry	Yes	Yes	Yes	Establish radio contact	Mandatory if IFR	As specified	No
Transponder with ADS-B Out Capability Required	Starting August 10, 2023	Starting May 16, 2024	After 2026	After 2026	After 2026	As specified	No

<u>Class A</u>: This airspace is between 18,000 ft to 60,000 ft Above Sea Level (ASL). Only flights operating under IFR are permitted and require ATC clearance prior to entry. ATC provides separation to all aircraft. Mode C transponders and two-way radios are required. [3]

Class B: This airspace is between 12,501 ft and 17,999 ft ASL. Flights operating under IFR, and Visual Flight Rules (VFR) are permitted and require ATC clearance prior to entry. ATC provides separation to all aircraft. Mode C transponders and two-way radios are required. Flight operating under VFR must be always no closer than 1 Statute Mile (SM) horizontally and 500 ft vertically from clouds and fly with 3 SM of visibility. Special VFR is permitted. Special VFR is defined under General Airspace Restrictions below [3]. Figure 2 illustrates the geographic distribution and boundaries of this specific airspace type in Canada.

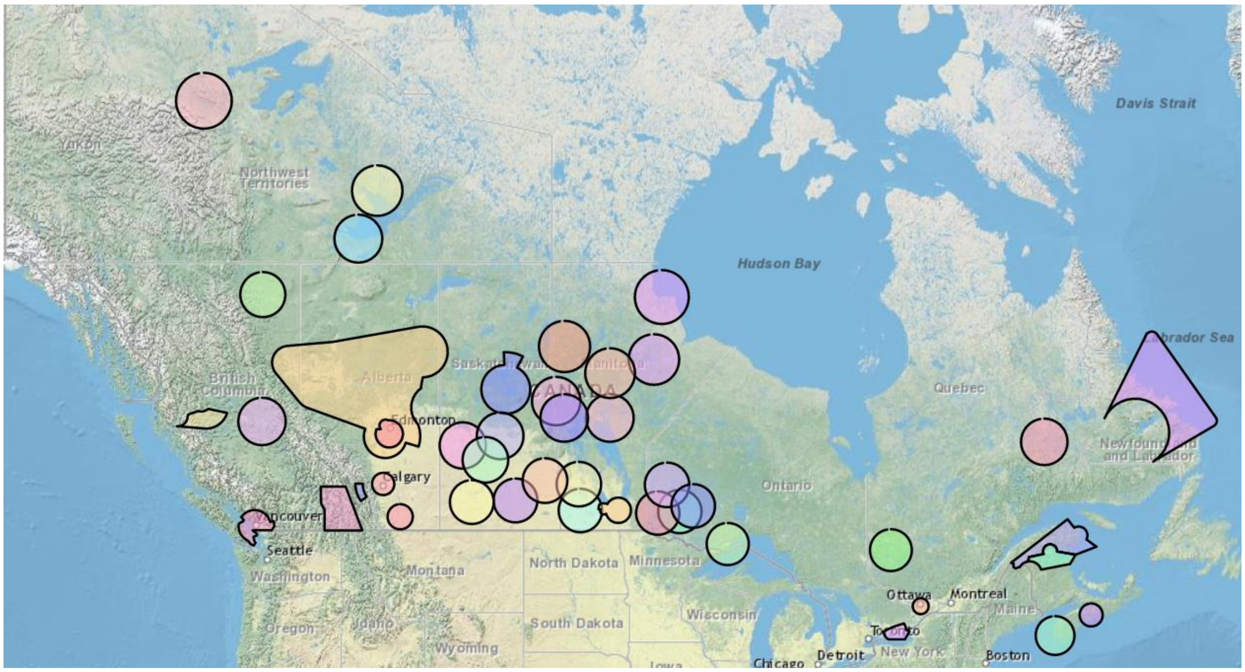

Figure 2: Class B airspaces in Canada

Class C: This airspace is typically the control zone and terminal control area for busy airports; therefore, they usually are 10 NM radius with a height of 12,000 ft Above Aerodrome Elevation (AAE). Flights operating under IFR and VFR are permitted and require ATC clearance prior to entry. ATC provides separation between IFR aircraft, and conflict resolution between IFR and VFR aircraft. Mode C transponders are required. Aircraft not equipped with two-way radiocommunication equipment may enter Class C airspace if authorization is granted to the aircraft before entering the airspace, when operating during daylight in Visual Meteorological Conditions (VMC) as defined under General Airspace Restrictions below. Special VFR is permitted. When ATC is not in operation, class C airspace becomes class E [3]. Figure 3 illustrates the geographic distribution and boundaries of this specific airspace type in Canada.

Class D: This airspace is typically the control zone and terminal control area for moderately busy airports. Flights operating under IFR require ATC clearance prior to entry and VFR must establish radio contact with ATC. Aircraft not equipped with two-way radiocommunication equipment may enter Class C airspace if authorization is granted to the aircraft before entering the airspace, when operating during daylight in VMC. Mode C transponders are required in designated areas. ATC provides separation between IFR aircraft, and conflict resolution between IFR and VFR aircraft, equipment and workload permitting. Special VFR is permitted. When ATC is not in operation, class D airspace becomes class E [3]. Figure 4 illustrates the geographic distribution and boundaries of this specific airspace type in Canada.Figure 4: Class D airspaces in Canada

Figure 3: Class C airspaces in Canada

Figure 4: Class D airspaces in Canada

Class E: This airspace is typically the control zone for airports without towers and in low level airways. Only flights operating under IFR require ATC clearance prior to entry. ATC provides separation between IFR aircraft. Two-way radios are required for IFR flights, and mode C transponders are required in designated areas. Special VFR is permitted [3]. In Canada, Figure 5 depicts the geographic distribution and boundaries of control zones and transition areas specific to this airspace type, while Figure 6 illustrates the low-level airways.

Class F: This airspace is special use airspace. There are three categories: restricted (CYR), advisory (CYA) and danger (CYD). Aircraft are not permitted to enter a CYR or a CYD without the approval of the user or controlling agency. For CYA, non-participating traffic should avoid flight within. When class F airspaces are not active, the rules of the surrounding airspace apply [3]. Figure 7 illustrates the geographic distribution and boundaries of this specific airspace type in Canada.

Class G: This airspace is uncontrolled. Pilots are responsible for separating themselves from other aircraft. There are no requirements on radio or transponder use. [3]

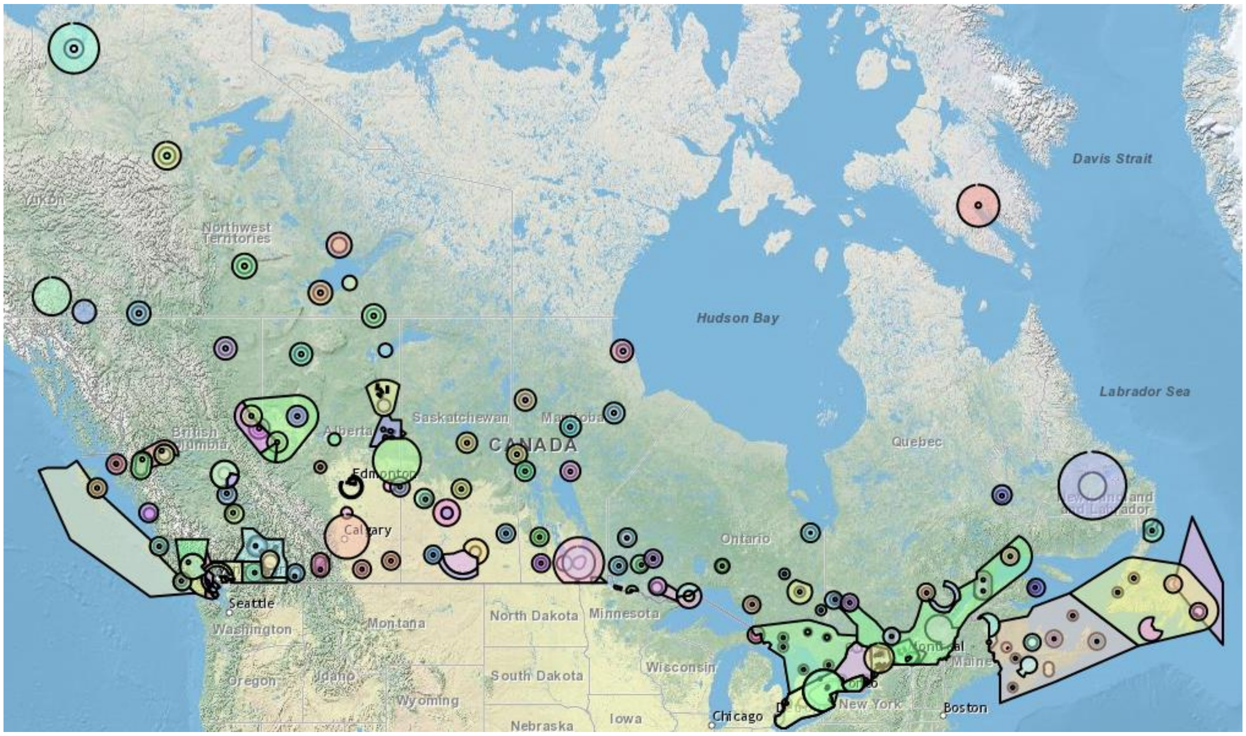

Figure 5: Class E airspaces in Canada

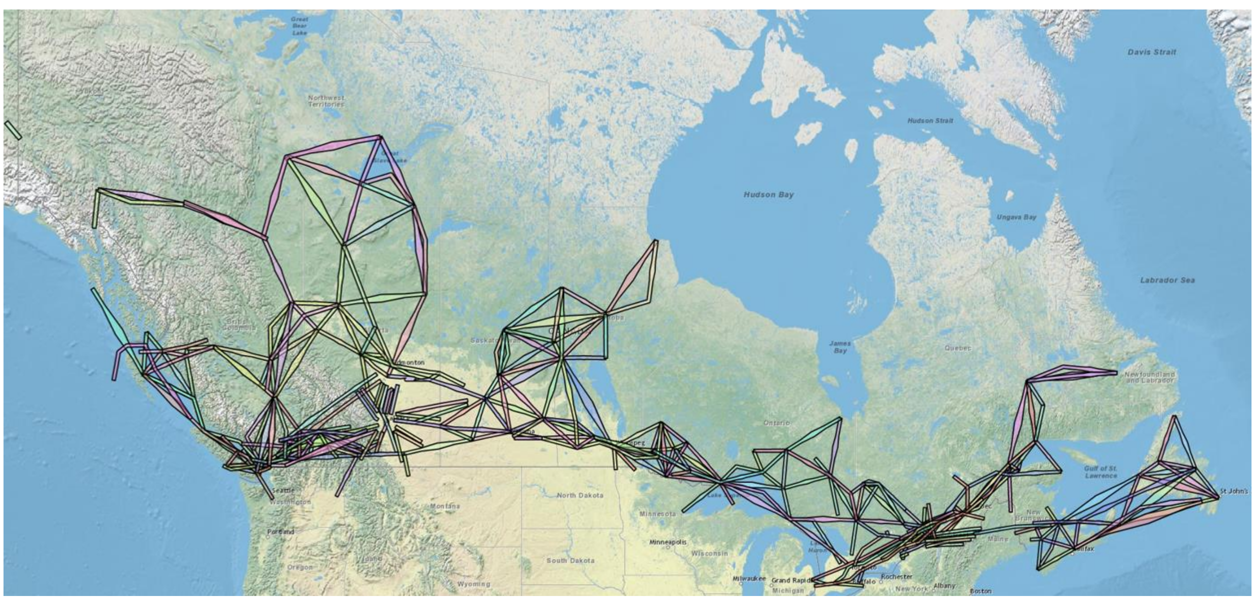

Figure 6: Low level airways in Canada

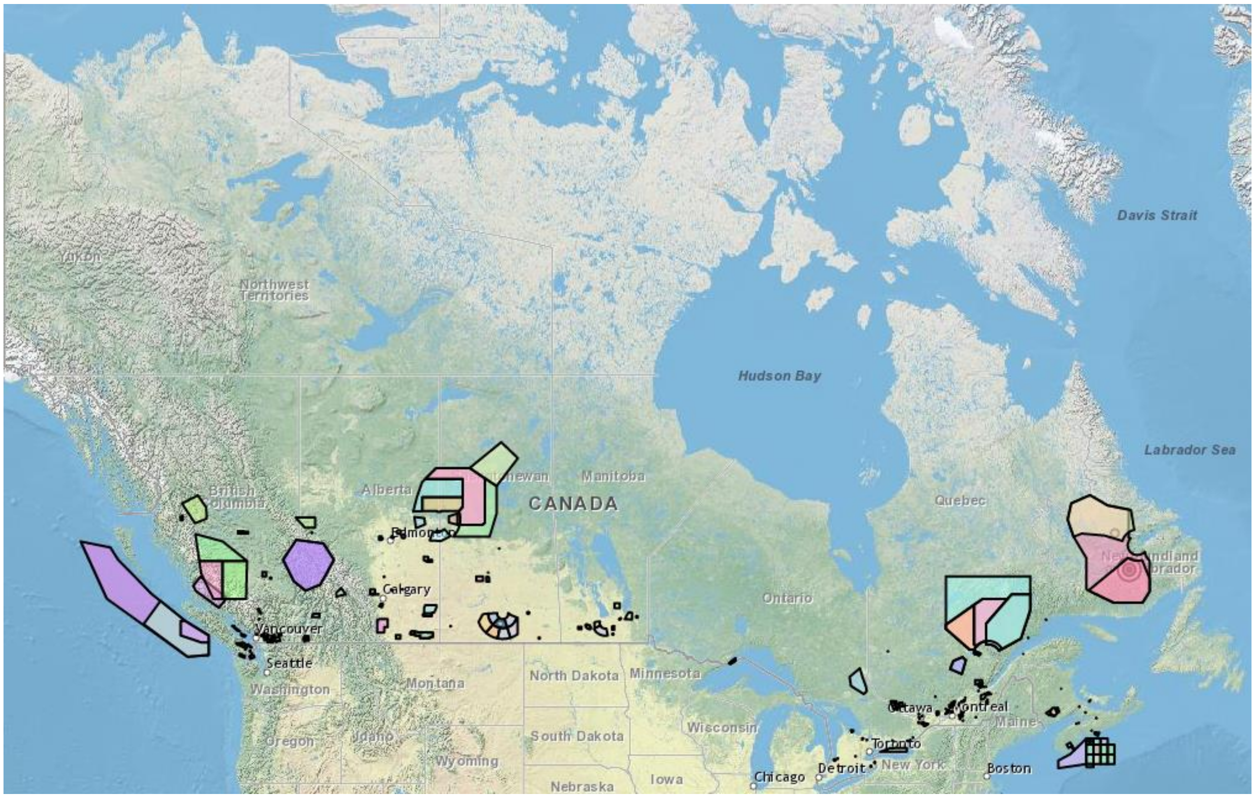

Figure 7: Class F airspaces in Canada

<u>General Airspace Restrictions</u>:

In airspace B, C, D, E, and G, below 10,000 ft ASL, aircraft must fly slower than 250 kts, and below 3000 ft AGL within 10 NM of controlled airports, speeds must be below 200 kts. [3]

Aircraft under VFR must always operate under the following VMC conditions, unless operating as VFR Over - The - Top (OTT) or special VFR. [3]

In controlled airspaces (Class B, C, D, E), flights operating under VFR must be no closer than 1 SM horizontally and 500 ft vertically from clouds and always fly with at least 3 SM of flight visibility. When operating in a control zone, the ground visibility must be at least 3 SM and the aircraft must remain at least 500 feet from the surface unless taking off and landing. [3]

In uncontrolled airspaces (Class G) at or above 1000 feet AGL, the flight visibility must be at least 1 SM during the day, and 3 SM during the night. Aircraft must operate no closer than 2,000 ft horizontally and 500 ft vertically from clouds. The aircraft must be operated with visual reference to the surface. [3]

In uncontrolled airspaces (Class G) under 1000 feet AGL, the flight visibility must be at least 2 SM during the day, and 3 SM during the night. and aircraft must remain clear of clouds. The aircraft must be operated with visual reference to the surface. [3]

VFR OTT is an exception to the regulation that aircraft must be operated with visual reference to the surface. An aircraft may operate under VFR OTT flight during the cruise portions of a flight during the day. VFR OTT permits an aircraft to operate between two cloud layers as long as the vertical distance between the layers is at least 5000 feet, the aircraft remains at least 1000 feet vertically from clouds, the flight visibility at the cruising altitude is at least 5 SM, and the weather at the destination aerodrome is forecast to have no broken, overcast, or obscured layers lower than 3000 feet above the planned flight altitude with a visibility of at least 5 SM. [3]

Special VFR is an exception to the visibility and distance from clouds regulations within controlled airspace. Special VFR allows aircraft to operate with a visibility not less than 1 SM non-helicopter aircraft, and ½ SM for helicopters, and clear of cloud with a visual reference to the surface at all times. Authorization must be requested and obtained from ATC. [3]

4.2 Canadian Airspace Distribution Analysis

Table 2 Percentage of Controlled Airspace by Altitude Range in Canada

Altitude (ASL)	Overall (%)	Local (%)
0-3000	1.76	10.53
0-5000	3.91	14.09
0-10000	9.09	16.36
0-18000	18.86	18.86
3000-5000	2.16	19.44
5000-10000	5.17	18.63
10000-18000	9.77	21.99

Table 2 illustrates the distribution of controlled airspace in Canada based on different altitude ranges. The overall percentage represents the proportion of airspace controlled within the given altitude range in relation to the entire airspace from 0 to 18000 feet. The local percentage indicates the proportion of airspace controlled within the specified altitude range in relation to the total airspace contained within that range.

At altitudes between 0 and 3000 feet, 1.76% of the total airspace in Canada is controlled, while at the same altitude range, 10.53% of the local airspace is under control. Moving to higher altitude ranges, the trend in controlled airspace increases, indicating a greater extent of control over the airspace volume. Between 0 and 5000 feet, the overall controlled airspace percentage rises to 3.91%, whereas the local percentage increases to 14.09%. This suggests that a significant portion of the airspace within this range is under control in specific areas, reflecting a denser concentration of controlled airspace.

Considering altitudes up to 10000 feet, the overall controlled airspace expands to 9.09%, while the local percentage grows to 16.36%. This demonstrates a further increase in airspace control throughout the altitude range, highlighting the importance of regulation and coordination in these areas. The highest overall controlled airspace percentage is observed between 0 and 18000 feet, reaching 18.86%. This indicates that a considerable portion of the total airspace in Canada falls within this range and is subject to control.

Additionally, the table includes information about controlled airspace in specific altitude sub-ranges. For example, between 3000 and 5000 feet, 2.16% of the total airspace volume is controlled, while 19.44% of the local airspace within this range is regulated. Similarly, within the 5000-10000 feet altitude range, 5.17% of the total airspace volume is controlled, with 18.63% of the local airspace falling within this range being regulated. Moving higher, in the 10000-18000 feet altitude range, 9.77% of the total airspace volume is controlled, and 21.99% of the local airspace within this range is subject to regulation. These percentages provide further insight into specific areas where increased control measures are implemented, potentially due to factors such as high air traffic density or strategic importance.

It is important to note that the percentages provided are not entirely precise due to some factors. Firstly, altitudes presented as Above Ground Level (AGL) were not compensated for, and thus, the overall distribution may not fully account for this minority. Additionally, conversions were made for volume calculations, which could potentially introduce some error into the results. Despite these limitations, the table and analysis offer valuable insights into the controlled airspace distribution in Canada. These findings can aid in understanding the allocation of airspace resources and contribute to improved airspace management and planning in the region.

4.3 Sensor Requirements – Transponders

Canadian Aviation Regulation 605.35 [3] requires aircraft operating in transponder airspace, excluding balloons and gliders, to have a transponder and automatic pressure-altitude reporting equipment, with exceptions outlined in subsections 2, 3, and 4. Subsection 2 allows operation without this equipment if a Minister-approved minimum equipment list is followed or if the aircraft proceeds to the next intended aerodrome and adheres to air traffic control clearance. Subsection 3 exempts aircraft meeting specific conditions within defined airspace, receiving air traffic control service, and posing no safety risk. Subsection 4 provides an exception for aircraft involved in special aviation events, operating under air traffic control supervision within Class A, B, C, D, or E airspace.

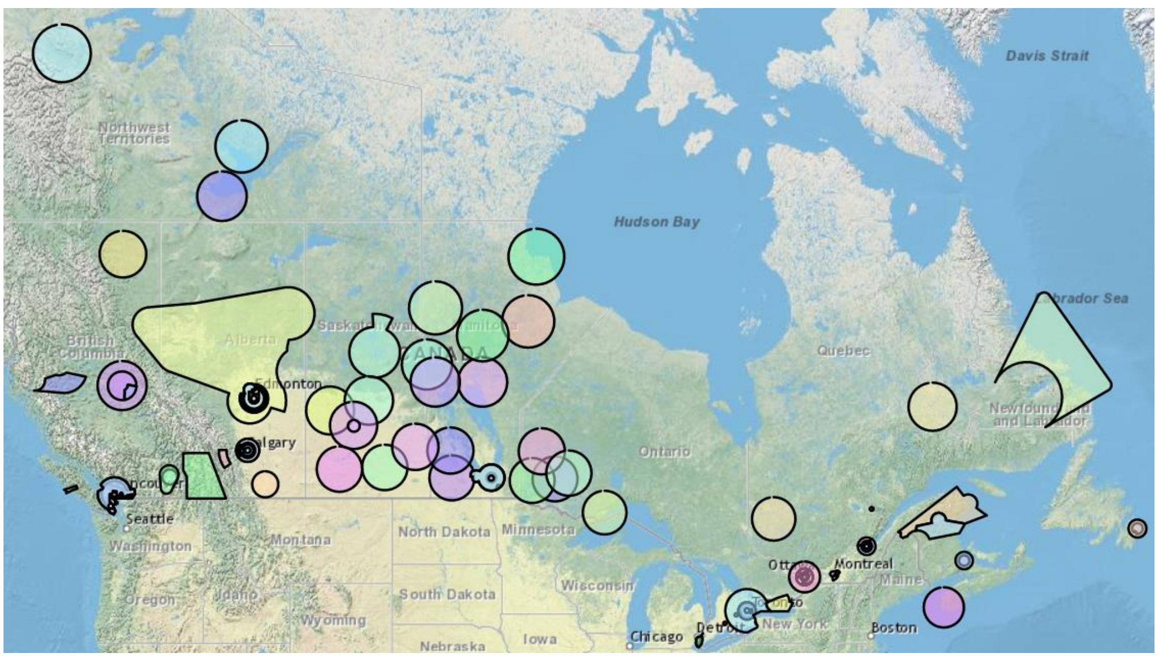

Figure 8: Areas in Canada where transponders are required.

In the realm of transponders, various types can be identified, such as:

Mode C: The following are several noteworthy minimum performance and design standards imposed on mode C transponders such that they perform as required. More details on the design and performance standards can be found in TSO-C74c [4] and AC 23-8C [5].

Signal Strength – When the aircraft is flown in straight and level flight, the return signal to an interrogating radar signal shall be strong and stable up to a radius of 160 Nautical Miles (NM) of the radar station from radio line of sight up to 90% of the certified maximum altitude of the aircraft. If the aircraft is not to exceed 18000 feet ASL, the radius requirement becomes 80 NM. [5]

Receiver Operating Frequency and Bandwidth – The receiver nominal centre frequency must be 1030 MHz [4].

Reply Transmission Frequency – The centre frequency of the reply transmission must be 1090 ± 3 MHz [4].

Transmitter Power Output – For aircraft that operate at altitudes not exceeding 15,000 ft ASL, the peak pulse power available at the antenna end of the transmission line must be at least 18.5 dB, and no greater than 27 dB above 1 watt at any reply rate up to 1200 per second for a 15-pulse coded reply. [4]

Mode S: Mode S transponder requirements supersede those of mode C when the aircraft in question requires a mode S transponder. This is the case when the aircraft is being operated by an air operator in accordance with Traffic Collision Avoidance System Requirements (TCAS) outlined in Transport Canada, Civil Aviation (TCCA) AC 700-004 [6] [3]. An air operator is the holder of an air operator certificate, which authorizes the holder to operate a commercial air service [3]. Identical minimum design and performance standards are in place for mode S transponders as for mode C in terms of signal range and receiving and transmitting frequencies. Further details on the minimum design and performance standards for mode S transponders can be found in TSO-C112f [7], AC 20-131A [8], and AC 20-151C [9].

Figure 8 illustrates the various airspace classifications in Canada that require transponders at different altitudes.

4.4 Sensor Requirements – Radio

The details for when a two-way radiocommunication system is required was outlined in section 4.1. The following are several key specifications required from these systems.

Operating Frequency – Radiocommunication systems must be adequate to permit two-way communication on the appropriate frequency of the area that the aircraft is operating within. Specific frequency bands for various radionavigation and radiocommunication utilities can be found at [10]. Furthermore, a two-way radio onboard an aircraft must be capable of providing communication on the emergency radio frequency 121.5 MHz [3].

Power Output – Except for government of Canada operations, the peak envelope power output of the radio is 30 watts [10].

4.5 Sensor Requirements – ADS-B

To meet the ADS-B performance mandate that is to come into effect as outlined in table 1, aircraft must:

a) Be equipped with a transponder with ADS-B out capabilities, which meets the performance standards outlined in Radio Technical Commission for Aeronautics (RTCA) DO-260B [11] [12].
b) Have antenna capability for broadcast toward space-based ADS-B receiver emitting 1090 MHz extended squitter [12].

Further information can be found in AIC 24/22 [12].

5.0 SUMMARY OF SELECTED AIRPORTS AND SURROUNDING AIRSPACES

The 12 selected airports and surrounding airspaces include many of Canada's large international airports, as well as some smaller regional airports. These airports provide a diverse set of locations to study and were selected to match the 12 airports that were analyzed in the Canadian Airspace Modelling project [1], where the airspace statistical models for these same airports were developed based on data collected from May 2017 to May 2018 by NAV CANADA's sensors. For more detailed information, please refer to the report [1].

For each airport, the following information is summarized:

- Airspace composition, which presents the percentages of the highest proportions of aircraft types based on their predominant wake turbulence category (WTC). Please note that the total percentages may not add up to 100%, as the remaining percentage represents other categories or aircraft that could not be classified due to insufficient information.
- Aircraft sensor equipage requirements.
- Control zone airspace classification and their estimated geometry, including latitude, longitude, and altitude.

In the tables that highlight the estimated control zone geometry for each airport (Tables 3 – 14), the surface level information is **bolded** to highlight the key information, as it would be most applicable to RPAS operators. Typical RPAS operations would take place at or below 400 ft AGL, as per the current Canadian Aviation Regulations (CARs) Part IX, that covers regulations for Visual Line of Sight (VLOS) operations. [3]

5.1 Billy Bishop Toronto City Airport (CYTZ)

CYTZ is a regional airport located in Toronto, Ontario. As a regional airport with relatively short runways, it primarily accommodates smaller aircraft, which can be classified into medium and small categories based on their WTC. According to [1], approximately 73% of the total air traffic at the airport consists of medium-sized aircraft, while small aircraft account for around 13%. It is positioned about 20 km away from the much larger Lester B. Pearson International Airport (CYYZ), so the surrounding airspace is primarily within the class C terminal control area (TCA) of CYYZ. Due to this there are typically many heavy class aircraft airborne within close proximity of CYTZ. CYTZ has its own class C control zone surrounding the airport extending from the ground to 2500 ft ASL [2]. Being class C airspace, traffic traveling within are required to have a mode C transponder, a two-way radio, and ATC clearance prior to entry [3]. Figure 9 illustrates the layout of the airspaces surrounding CYTZ with the CYTZ control zone in the image on the right. Table 3 provides a general description of the horizontal and vertical boundaries of each airspace.

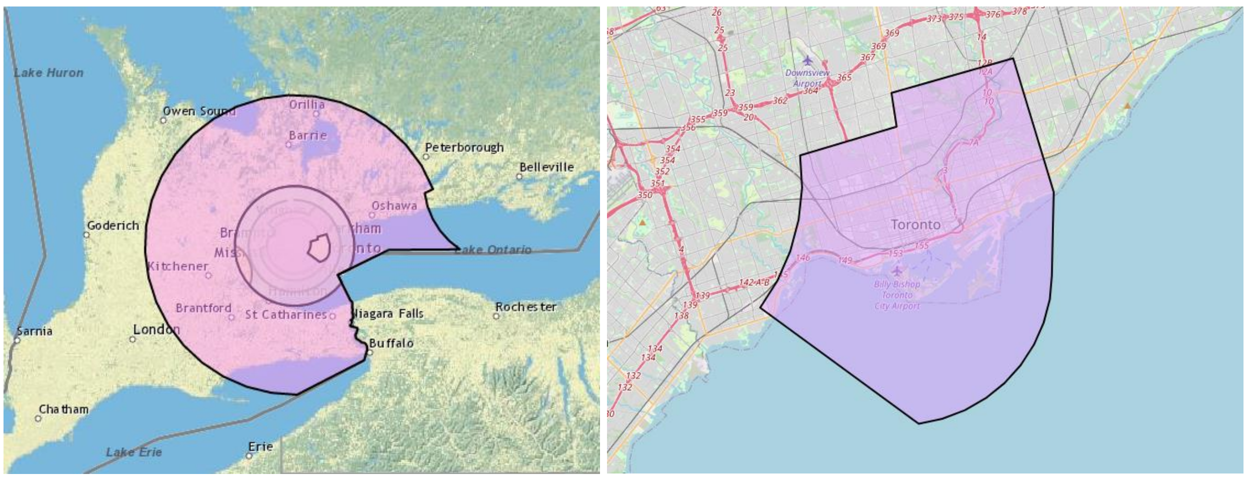

Figure 9: Airspace surrounding Billy Bishop Toronto City Airport (CYTZ)

Table 3: General vertical and horizontal boundaries of airspaces surrounding Billy Bishop Toronto City Airport (CYTZ) [2]

Airspace Class	Min Latitude	Max Latitude	Min Longitude	Max Longitude	Min Altitude (feet ASL)	Max Altitude (feet ASL)
C	N43°27'29.88"	N43°51'27.58"	W79°54'28.15"	W79°23'50.24"	1700	2000
C	N43°24'30.53"	N43°56'37.36"	W79°58'29.86"	W79°14'39.55"	2000	2500
C	N43°19'30.14"	N43°59'27.85"	W80°05'31.06"	W79°10'16.93"	2500	3500
C	N43°13'32.56"	N44°05'25.69"	W80°13'42.82"	W79°02'03.66"	3500	4500
C	N43°13'32.74"	N44°05'23.82"	W80°13'40.26"	W79°02'02.51"	4500	12500
C	**N43°32'41.35"**	**N43°44'38.29"**	**W79°30'03.78"**	**W79°16'48.00"**	**Surface**	**2500**
E	N42°34'29.82"	N44°44'22.06"	W81°07'34.07"	W77°58'39.36"	6500	18000

5.2 Toronto-Lester B. Pearson International Airport (CYYZ)

CYYZ is a large international airport located in Toronto, Ontario. Being an international airport, it sees a larger volume of aircraft, typically of medium (71%), light (10%) and heavy (8%) categories [1]. It has a large class C TCA surrounding the airport, with multiple tiers as outlined in Table 3. Its control zone extends from the ground to 2500 ft ASL [2]. Traffic traveling within the class C airspace are required to have a mode C transponder, a two-way radio, and ATC clearance prior to entry [3]. Figure 10 illustrates the layout of the airspaces surrounding CYYZ with the CYYZ control zone in the image on the right. Table 4 provides a general description of the horizontal and vertical boundaries of each airspace.

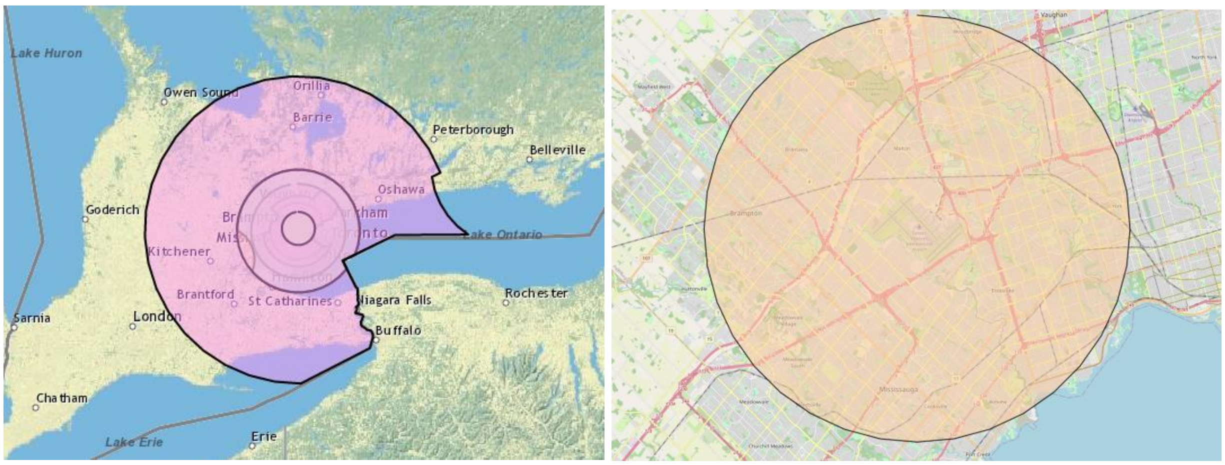

Figure 10: Airspace surrounding Toronto - Lester B. Pearson International Airport (CYYZ)

Table 4: General vertical and horizontal boundaries of airspaces surrounding Toronto - Lester B. Pearson International Airport (CYYZ) [2]

Airspace Class	Min Latitude	Max Latitude	Min Longitude	Max Longitude	Min Altitude (feet ASL)	Max Altitude (feet ASL)
C	N43°27'29.88"	N43°51'27.58"	W79°54'28.15"	W79°23'50.24"	1700	2000
C	N43°24'30.53"	N43°56'37.36"	W79°58'29.86"	W79°14'39.55"	2000	2500
C	N43°19'30.14"	N43°59'27.85"	W80°05'31.06"	W79°10'16.93"	2500	3500
C	N43°13'32.56"	N44°05'25.69"	W80°13'42.82"	W79°02'03.66"	3500	4500
C	N43°13'32.74"	N44°05'23.82"	W80°13'40.26"	W79°02'02.51"	4500	12500
C	**N43°33'38.38"**	**N43°47'37.57"**	**W79°47'30.16"**	**W79°28'09.80"**	**Surface**	**2500**
E	N42°34'29.82"	N44°44'22.06"	W81°07'34.07"	W77°58'39.36"	6500	18000

5.3 Ottawa Macdonald-Cartier International Airport (CYOW)

CYOW is an international airport located in Ottawa, Ontario. Being an international airport, it sees a larger volume of aircraft, typically of light (41%), and medium (32%) categories [1]. It has a class C TCA surrounding the airport with a control zone extends from the ground to 3000 ft ASL [2]. Traffic traveling within the class C airspace are required to have a mode C transponder, a two-way radio, and ATC clearance prior to entry [3]. Figure 11 illustrates the layout of the airspaces surrounding CYOW with the CYOW control zone in the image on the right, and Table 5 provides a general description of the horizontal and vertical boundaries of each airspace.

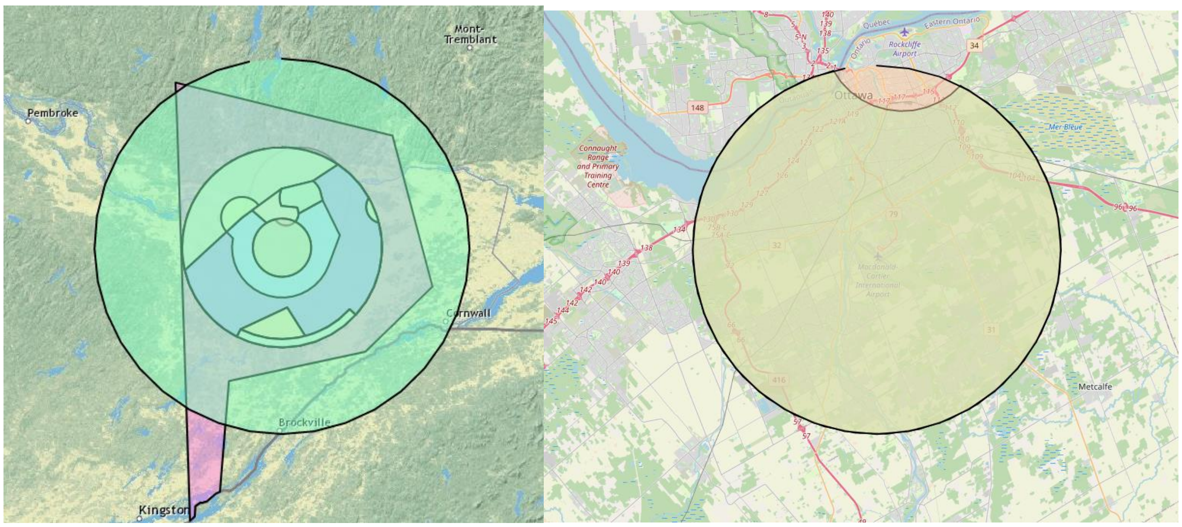

Figure 11: Airspace surrounding Ottawa Macdonald-Cartier International Airport (CYOW)

Table 5: General vertical and horizontal boundaries of airspaces surrounding Ottawa Macdonald-Cartier International Airport (CYOW) [2]

Airspace Class	Min Latitude	Max Latitude	Min Longitude	Max Longitude	Min Altitude (feet ASL)	Max Altitude (feet ASL)
E	N45°22'18.98"	N45°43'16.28"	W75°53'48.98"	W75°16'44.94"	1500	18000
E	N44°13'17.08"	N45°58'40.98"	W76°16'25.97"	W74°48'49.97"	2500	18000
B	N44°55'22.37"	N45°43'19.60"	W76°14'15.00"	W75°06'02.95"	12500	18000
C	N44°55'22.37"	N45°43'19.60"	W76°14'15.00"	W75°06'02.95"	5000	12500
C	N44°57'22.46"	N45°43'15.42"	W76°14'09.06"	W75°06'06.19"	4000	5000
C	N44°57'58.10"	N45°39'13.97"	W76°13'16.00"	W75°06'09.79"	3000	4000
C	N44°57'58.10"	N45°39'13.97"	W76°13'16.00"	W75°06'09.79"	2500	3000
C	N45°27'28.62"	N45°35'18.10"	W75°40'57.97"	W75°26'15.97"	2500	3000
C	N45°07'22.91"	N45°30'38.99"	W75°59'03.48"	W75°20'25.98"	1500	2500
C	**N45°12'22.07"**	**N45°26'09.13"**	**W75°50'04.60"**	**W75°30'13.03"**	**Surface**	**2000**
C	N45°12'21.38"	N45°26'20.58"	W75°50'05.75"	W75°30'12.20"	2000	3000
E	N45°23'07.84"	N45°31'28.67"	W76°00'55.44"	W75°48'04.72"	2500	4000
E	N44°57'22.97"	N45°04'58.98"	W75°54'16.42"	W75°32'10.79"	2500	4000
E	N44°55'22.58"	N45°04'33.74"	W75°55'32.63"	W75°15'01.84"	2500	5000
E	N45°25'17.26"	N45°33'27.04"	W75°50'21.05"	W75°34'30.61"	2500	3000
E	N44°34'23.56"	N46°04'18.41"	W76°44'05.14"	W74°36'12.82"	6500	12500

5.4 Montréal – Pierre Elliott Trudeau International Airport (CYUL)

CYUL is a large international airport located in Montréal, Quebec. Being an international airport, it sees a larger volume of aircraft, typically of medium (60%), and light (24%) categories [1]. It has a large class C TCA surrounding the airport. Its control zone extends from the ground to 3000 ft ASL [2]. Traffic traveling within the class C airspace are required to have a mode C transponder, a two-way radio, and ATC clearance prior to entry [3]. Figure 12 below illustrates the layout of the airspaces surrounding CYUL with the control zone in the image on the right. Table 6 provides a general description of the horizontal and vertical boundaries of each airspace.

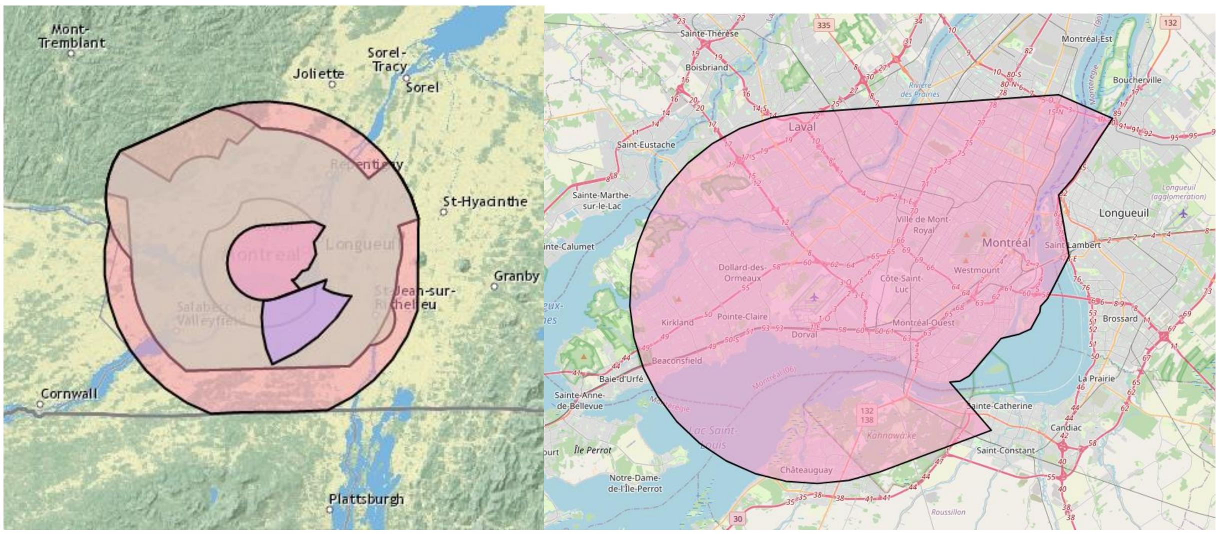

Figure 12: Airspace surrounding Montréal – Pierre Elliott Trudeau International Airport (CYUL)

Table 6: General vertical and horizontal boundaries of airspaces surrounding Montréal – Pierre Elliott Trudeau International Airport (CYUL) [2]

Airspace Class	Min Latitude	Max Latitude	Min Longitude	Max Longitude	Min Altitude (feet ASL, unless stated otherwise)	Max Altitude (feet ASL)
C	N45°16'07.28"	N45°40'03.22"	W74°01'34.64"	W73°30'26.60"	1500	2000
C	N45°07'54.19"	N45°53'43.87"	W74°26'42.86"	W73°03'32.76"	2000	3000
C	N45°07'54.19"	N45°56'47.36"	W74°26'45.78"	W73°03'32.76"	3000	5000
C	N44°59'50.60"	N45°58'02.89"	W74°27'04.75"	W73°03'32.76"	5000	12500
C	**N45°21'05.44"**	**N45°35'44.84"**	**W73°54'26.71"**	**W73°28'28.38"**	**Surface**	**3000**
E	N45°09'06.41"	N45°24'55.94"	W73°45'15.98"	W73°21'24.73"	700 AGL	18000

5.5 Montréal–Mirabel International Airport (CYMX)

CYMX is a second international airport located in Montréal, Quebec. It too sees a larger volume of aircraft, typically of medium (47%), light (26%), and helicopter (11%) categories [1]. It lies within the class C TCA of CYUL with its own class C control zone extends from the ground to 2000 ft ASL [2]. It also has a class E transition area between 1300 ft ASL and 1500 ft ASL on the northeast and southwest sides of the control zone as seen in Figure 9 [2]. Traffic traveling within the class C airspace are required to have a mode C transponder, a two-way radio, and ATC clearance prior to entry [3]. The class E transition area is a designated transponder airspace, meaning mode C transponders are also required there [2]. Figure 13 below illustrates the layout of the airspaces surrounding CYMX with the control zone and transition area in the image on the right. Table 7 provides a general description of the horizontal and vertical boundaries of each airspace.

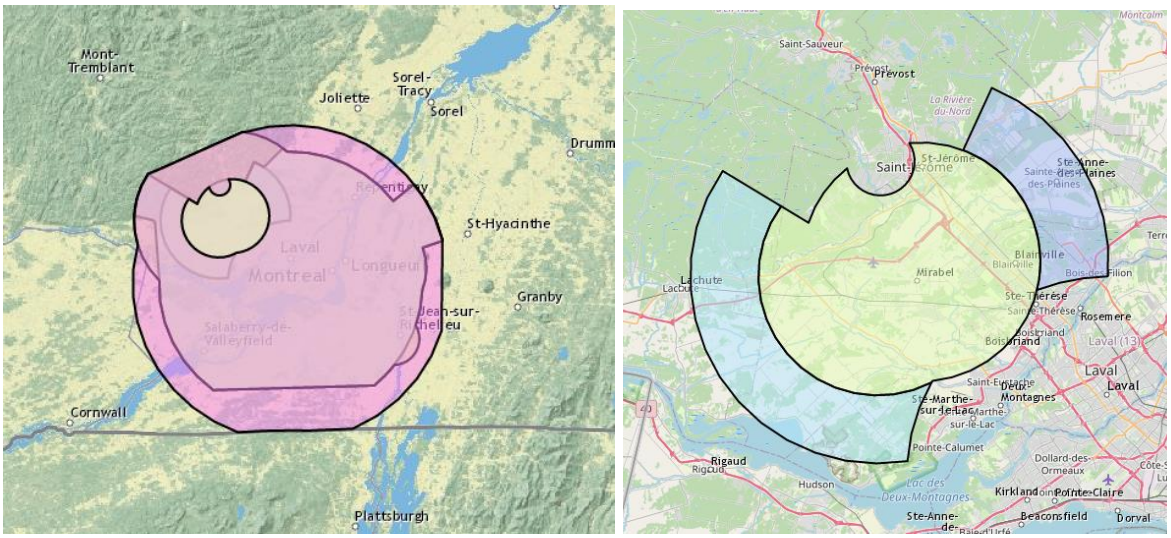

Figure 13: Airspace surrounding Montréal – Mirabel International Airport (CYMX)

Table 7: General vertical and horizontal boundaries of airspaces surrounding Montréal – Mirabel International Airport (CYMX) [2]

Airspace Class	Min Latitude	Max Latitude	Min Longitude	Max Longitude	Min Altitude (feet ASL)	Max Altitude (feet ASL)
E	N45°29'06.47"	N45°46'14.99"	W74°19'37.45"	W73°59'25.80"	1300	1500
E	N45°39'16.88"	N45°51'06.12"	W73°56'47.00"	W73°44'37.75"	1300	1500
C	N45°16'07.28"	N45°40'03.22"	W74°01'34.64"	W73°30'26.60"	1500	2000
C	N45°29'06.47"	N45°46'14.99"	W74°19'37.45"	W73°59'25.80"	1500	2000
C	N45°39'16.88"	N45°51'06.12"	W73°56'47.00"	W73°44'37.75"	1500	2000
C	N45°07'54.19"	N45°53'43.87"	W74°26'42.86"	W73°03'32.76"	2000	3000
C	N45°07'54.19"	N45°56'47.36"	W74°26'45.78"	W73°03'32.76"	3000	5000
C	N44°59'50.60"	N45°58'02.89"	W74°27'04.75"	W73°03'32.76"	5000	12500
C	**N45°33'06.44"**	**N45°47'53.84"**	**W74°13'56.17"**	**W73°50'18.02"**	**Surface**	**2000**

5.6 Timmins Victor M. Power Airport (CYTS)

CYTS is a regional airport located in Timmins, Ontario. Being a regional airport, it typically sees aircraft of the light (50%), and medium (34%) categories [1]. CYTS is surrounded by a class E control zone extending from the ground to 3000 ft AAE [2]. It is not a designated transponder area, so mode C transponders are not required, though recommended [3]. Figure 14 below illustrates the layout of the airspaces surrounding, and Table 8 provides a general description of the horizontal and vertical boundaries of each airspace.

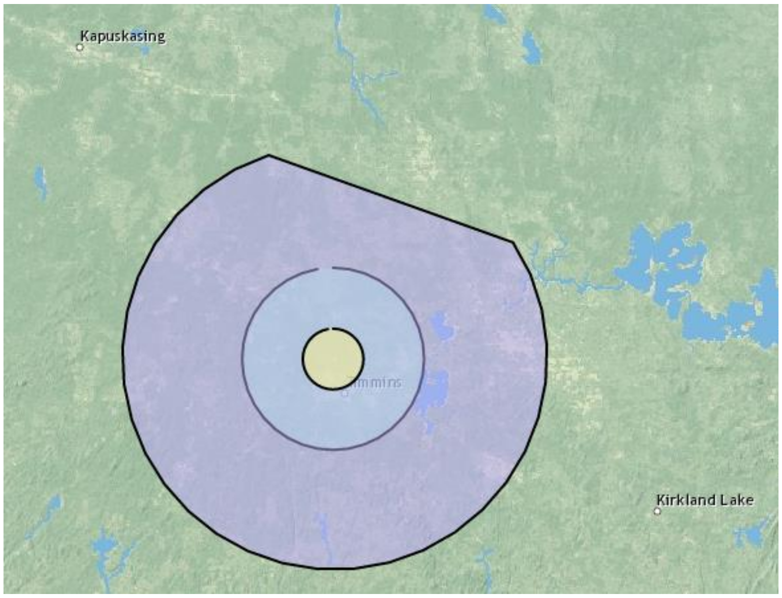

Figure 14: Airspace surrounding Timmins Victor M. Power Airport (CYTS)

Table 8: General vertical and horizontal boundaries of airspaces surrounding Timmins Victor M. Power Airport (CYTS) [2]

Airspace Class	Min Latitude	Max Latitude	Min Longitude	Max Longitude	Min Altitude (feet ASL)	Max Altitude (feet ASL)
E	N48°19'11.86"	N48°49'10.13"	W81°45'14.80"	W80°59'57.19"	700	18000
E	N47°59'27.74"	N49°07'31.98"	W82°14'59.68"	W80°29'25.87"	2200	18000
E	**N48°29'11.26"**	**N48°39'10.69"**	**W81°30'08.93"**	**W81°15'03.06"**	**Surface**	**3000**

5.7 Victoria International Airport (CYYJ)

CYYJ is an international airport located in Victoria, British Columbia. It sees a larger volume of aircraft, typically of light (65%), medium (16%) and helicopter (11%) categories [1]. Its control zone is class C and extends from the ground to 2500 ft ASL [2]. Traffic traveling within the class C airspace are required to have a mode C transponder, a two-way radio, and ATC clearance prior to entry [3]. It also has several class F airspaces south of it. Figure 15 illustrates the layout of the airspaces surrounding CYYJ with the control zone in the image on the right. Table 9 provides a general description of the horizontal and vertical boundaries of each airspace.

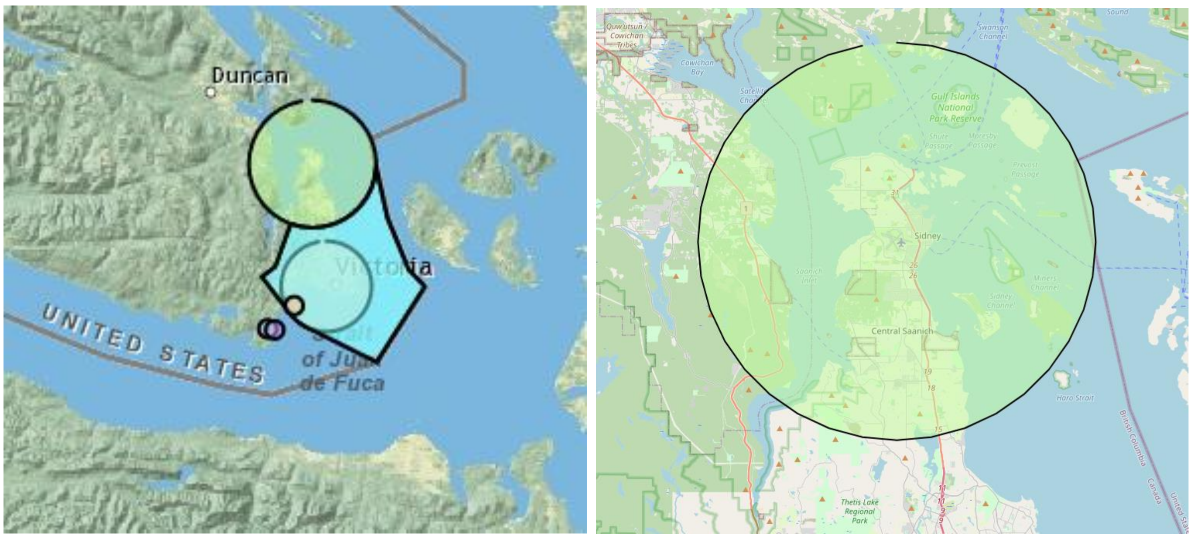

Figure 15: Airspace surrounding Victoria International Airport (CYYJ)

Table 9: General vertical and horizontal boundaries of airspaces surrounding Victoria International Airport (CYYJ) [2]

Airspace Class	Min Latitude	Max Latitude	Min Longitude	Max Longitude	Min Altitude (feet AGL)	Max Altitude (feet ASL)
E	N48°17'02.47"	N48°38'28.32"	W123°33'56.16"	W123°06'54.47"	700	18000
C	**N48°31'49.69"**	**N48°45'48.89"**	**W123°36'07.88"**	**W123°14'57.70"**	**Surface**	**2500**
E	N48°20'22.27"	N48°30'21.71"	W123°30'46.62"	W123°15'43.34"	Surface	2500
E	N48°17'02.47"	N48°38'28.32"	W123°33'56.16"	W123°06'54.47"	700	18000
F	N48°19'42.02"	N48°21'41.94"	W123°34'30.18"	W123°31'29.78"	Surface	3000
F	N48°19'35.04"	N48°21'34.92"	W123°33'20.16"	W123°30'19.80"	Surface	1000
F	N48°22'15.02"	N48°24'14.94"	W123°30'06.23"	W123°27'05.72"	Surface	3000

5.8 Vancouver International Airport (CYVR)

CYVR is a large international airport located in Vancouver, British Columbia. Being a major international airport, it sees a larger volume of aircraft, typically of light (46%), and medium (38%) categories [1]. It has a large class C TCA surrounding the airport with several portions being class D. Its control zone extends from the ground to 2500 ft ASL [2]. Traffic traveling within the class C and D airspace are required to have a mode C transponder, a two-way radio, and ATC clearance prior to entry [3]. Figure 16 illustrates the layout of the airspaces surrounding CYVR with the control zone in the image on the right. Table 10 provides a general description of the horizontal and vertical boundaries of each airspace.

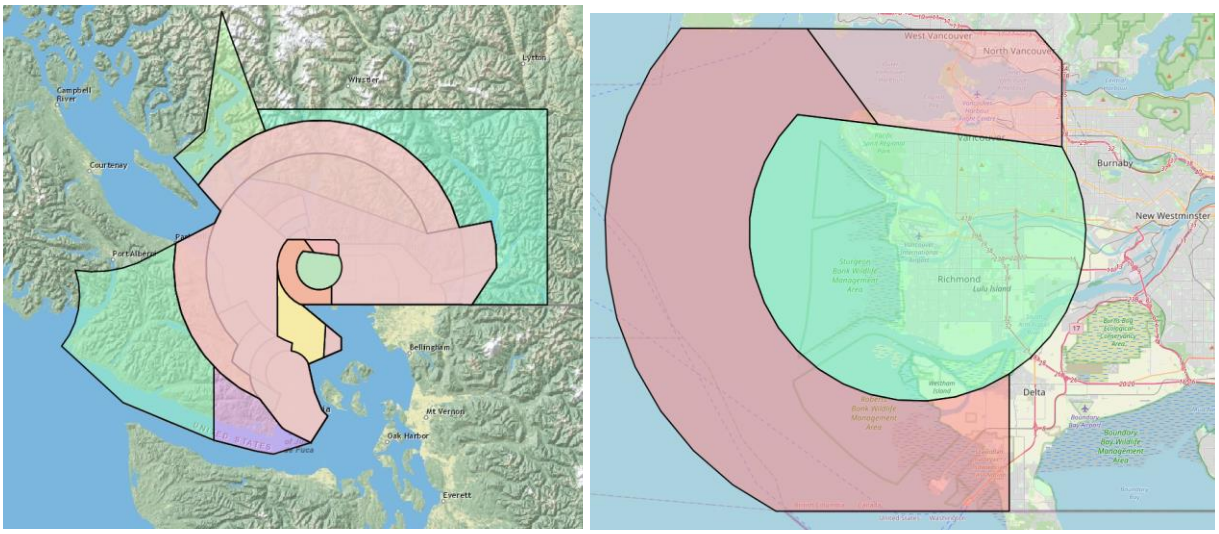

Figure 16: Airspace surrounding Vancouver International Airport (CYVR)

Table 10:General vertical and horizontal boundaries of airspaces surrounding Vancouver International Airport (CYVR) [2]

Airspace Class	Min Latitude	Max Latitude	Min Longitude	Max Longitude	Min Altitude (feet ASL, unless stated otherwise)	Max Altitude (feet ASL)
E	N49°21'58.64"	N49°56'32.35"	W124°08'03.59"	W122°04'45.66"	700AGL	18000
E	N48°38'02.00"	N48°54'35.82"	W123°52'10.06"	W123°30'36.04"	700AGL	18000
E	N48°47'32.39"	N49°01'15.10"	W123°59'13.74"	W123°38'35.92"	700AGL	18000
E	N48°26'24.50"	N48°38'02.00"	W123°43'36.05"	W123°29'08.92"	700AGL	18000
E	N48°30'44.96"	N49°25'17.04"	W124°19'42.78"	W123°38'59.14"	700AGL	18000
E	N49°00'00.97"	N50°00'00.00"	W123°40'05.20"	W121°23'04.99"	9000	12500
E	N49°36'47.74"	N50°29'32.75"	W124°19'31.98"	W123°36'25.81"	2200AGL	18000
E	N48°17'47.98"	N49°19'04.26"	W125°12'39.10"	W124°00'43.38"	1600AGL	12500
E	N48°13'28.38"	N48°40'58.37"	W124°00'43.38"	W123°14'54.38"	700AGL	18000
D	N48°41'41.14"	N49°11'40.42"	W123°30'44.14"	W123°07'53.47"	1200	2500
D	N49°00'07.49"	N49°01'56.06"	W122°45'36.97"	W122°33'17.10"	1500	2500
C	N49°07'14.38"	N49°15'16.92"	W123°02'42.11"	W122°53'19.25"	1200	2500
C	N48°17'02.47"	N49°34'27.19"	W124°03'22.43"	W122°33'17.10"	2500	4500
C	N48°17'02.47"	N49°34'27.19"	W124°04'21.61"	W122°10'58.44"	4500	6500
C	N48°32'53.56"	N48°50'20.22"	W123°43'36.05"	W123°23'38.11"	700AGL	6500
C	N48°26'24.50"	N48°38'02.00"	W123°43'36.05"	W123°29'08.92"	3000	6500
C	N48°38'02.00"	N48°54'35.82"	W123°52'10.06"	W123°30'36.04"	3500	6500
C	N48°47'32.39"	N49°01'15.10"	W123°59'13.74"	W123°38'35.92"	5500	6500
C	N49°20'10.72"	N49°28'14.34"	W123°30'34.74"	W123°15'23.51"	3200	6500
C	N49°22'46.85"	N49°34'04.48"	W123°37'33.20"	W123°16'46.56"	5000	6500
C	N49°00'02.59"	N49°11'29.72"	W122°14'10.64"	W121°47'06.54"	5500	6500
C	N48°17'02.47"	N49°38'57.70"	W124°04'20.17"	W121°47'06.54"	6500	8500
C	N48°17'02.47"	N49°46'35.22"	W124°04'14.09"	W121°47'06.54"	8500	9500
C	N48°17'02.47"	N49°56'32.35"	W124°19'42.78"	W121°47'06.54"	9500	12500
B	N48°17'02.47"	N49°56'32.35"	W124°19'42.78"	W121°47'06.54"	12500	18000
C	**N49°04'42.96"**	**N49°16'35.98"**	**W123°21'34.92"**	**W123°00'13.03"**	**Surface**	**2500**
C	**N49°15'16.31"**	**N49°20'09.74"**	**W123°17'55.72"**	**W123°01'44.08"**	**Surface**	**2500**
C	N49°00'07.49"	N49°20'10.97"	W123°30'45.94"	W123°05'04.96"	800	2500
D	**N49°00'07.49"**	**N49°20'10.97"**	**W123°30'45.94"**	**W123°05'04.96"**	**Surface**	**800**
D	N48°41'41.14"	N49°11'40.42"	W123°30'44.14"	W123°07'53.47"	1200	2500
E	N48°41'41.14"	N49°11'40.42"	W123°30'44.14"	W123°07'53.47"	1200	18000

5.9 Winnipeg James Armstrong Richardson International Airport (CYWG)

CYWG is an international airport located in Winnipeg, Manitoba. It sees a large volume of aircraft, typically of medium (50%), and light (34%) categories [1]. The airfield is shared with military operations, under the name of Canadian Air Force Base Winnipeg. It has a class C TCA surrounding the airport with a control zone extends from the ground to 3000 ft ASL [2]. Traffic traveling within the class C airspace are required to have a mode C transponder, a two-way radio, and ATC clearance prior to entry [3]. Figure 17 illustrates the layout of the airspaces surrounding CYWG with the control zone in the image on the right. Table 11 provides a general description of the horizontal and vertical boundaries of each airspace.

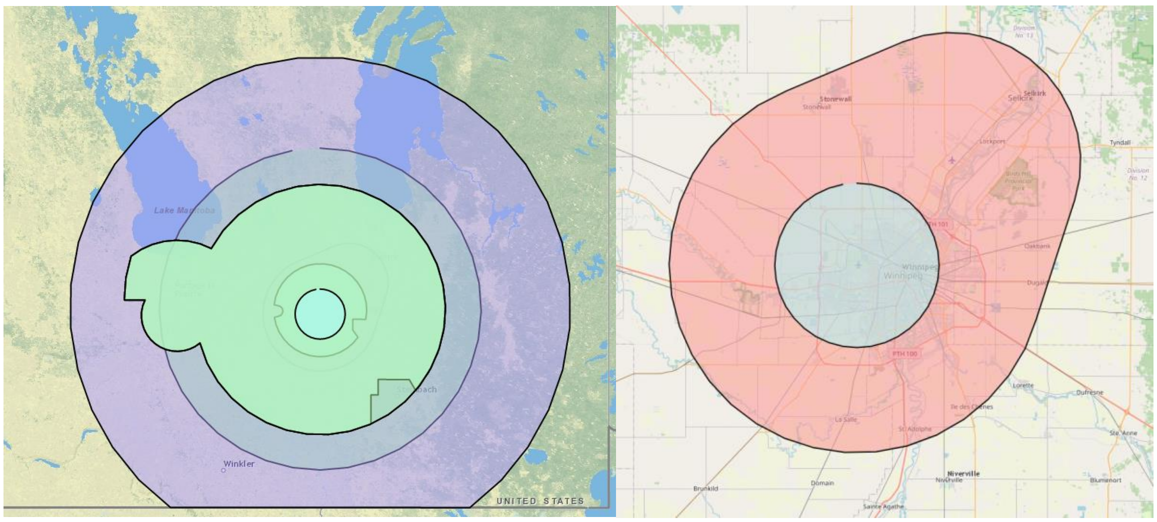

Figure 17: Airspace surrounding Winnipeg James Armstrong Richardson International Airport (CYWG)

Table 11: General vertical and horizontal boundaries of airspaces surrounding Winnipeg James Armstrong Richardson International Airport (CYWG) [2]

Airspace Class	Min Latitude	Max Latitude	Min Longitude	Max Longitude	Min Altitude (feet ASL, unless stated otherwise)	Max Altitude (feet ASL)
E	**N49°38'38.98"**	**N50°14'21.34"**	**W97°39'13.61"**	**W96°44'51.50"**	**700AGL**	**18000**
E	N49°10'42.31"	N50°40'37.16"	W98°24'11.27"	W96°04'31.69"	6500	18000
E	N48°59'59.96"	N51°05'20.00"	W99°02'38.36"	W95°26'04.78"	7000	18000
B	N49°20'46.03"	N50°30'37.40"	W98°39'21.35"	W96°20'03.77"	12500	18000
C	N49°42'42.16"	N50°08'36.96"	W97°34'19.88"	W96°54'11.48"	2000	3000
C	N49°20'47.72"	N50°30'37.73"	W98°39'21.35"	W96°20'02.51"	3000	4000
C	N49°20'46.03"	N50°30'37.40"	W98°39'21.35"	W96°20'03.77"	4000	12500
C	**N49°47'36.42"**	**N50°01'35.62"**	**W97°25'15.89"**	**W97°03'32.76"**	**Surface**	**3000**

5.10 Canadian Forces Base Goose Bay (CYYR)

CYYR is an air force base operated by the Royal Canadian Air Force located in Goose Bay, Newfoundland. The airfield is also used for civilian operations, under the name of Goose Bay Airport. CYYR has a class D control zone surrounding the airport extending from the ground to 4000 ft ASL and has a class E around that airport [2]. Traffic traveling within the class D airspace are required to have a mode C transponder, a two-way radio, and ATC clearance prior to entry [3]. The class E TCA It is not a designated transponder area, so mode C transponders are not required here, though recommended [2]. Figure 18 illustrates the layout of the airspaces surrounding, and Table 12 provides a general description of the horizontal and vertical boundaries of each airspace.

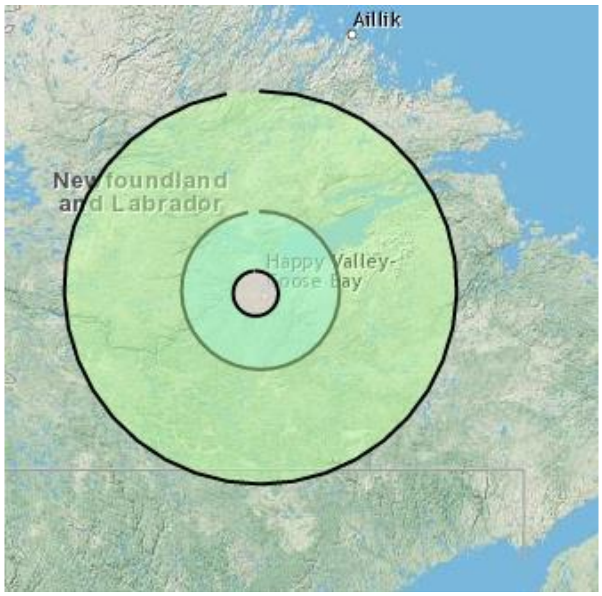

Figure 18: Airspace surrounding Canadian Forces Base Goose Bay (CYYR)

Table 12: General vertical and horizontal boundaries of airspaces surrounding Canadian Forces Base Goose Bay (CYYR) [2]

Airspace Class	Min Latitude	Max Latitude	Min Longitude	Max Longitude	Min Altitude (feet AGL)	Max Altitude (feet ASL)
E	N52°45'18.00"	N53°55'13.98"	W61°20'30.41"	W59°23'23.53"	700	18000
E	N51°53'20.98"	N54°47'11.00"	W62°47'27.56"	W57°56'26.38"	2200	28000
D	**N53°09'09.54"**	**N53°29'08.41"**	**W60°42'16.45"**	**W60°08'49.52"**	**Surface**	**4000**

5.11 Yellowknife Airport (CYZF)

CYZF is a smaller airport located in Yellowknife, Northwest Territories. It typically sees aircraft of medium (48%) categories, though a large amount (42%) of additional aircraft appears as an "unknown" category [1]. It has a class E TCA surrounding the airport with a class D control zone extends from the ground to 3000 ft AAE [2]. The class E TCA and class D control zone are not designated transponder areas, so mode C transponders are not required, though recommended [3]. Figure 19 illustrates the layout of the airspaces surrounding CYZF, and Table 13 provides a general description of the horizontal and vertical boundaries of each airspace.

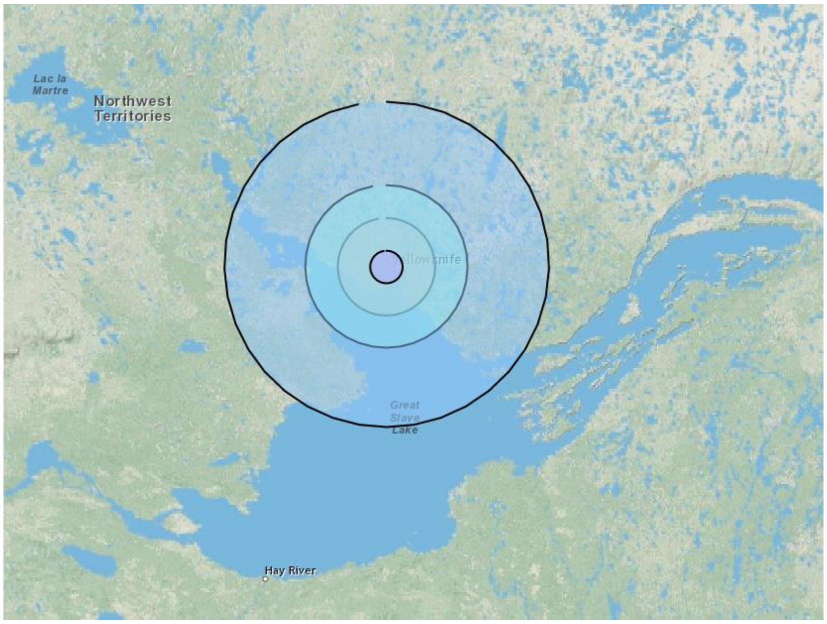

Figure 19: Airspace surrounding Yellowknife Airport (CYZF)

Table 13: General vertical and horizontal boundaries of airspaces surrounding Yellowknife Airport (CYZF) [2]

Airspace Class	Min Latitude	Max Latitude	Min Longitude	Max Longitude	Min Altitude (Feet ASL)	Max Altitude (Feet ASL, unless stated otherwise)
E	N62°12'46.84"	N62°42'45.11"	W114°58'49.76"	W113°54'00.22"	700	18000
E	N62°02'47.40"	N62°52'44.54"	W115°20'26.16"	W113°32'23.82"	2200	18000
B	N61°37'54.84"	N63°17'49.13"	W116°14'13.42"	W112°38'10.57"	12500	18000
D	**N62°22'46.27"**	**N62°32'45.71"**	**W114°37'13.26"**	**W114°15'36.72"**	**Surface**	**3000 AAE**

5.12 Iqaluit International Airport (CYFB)

CYFB is a small international airport located in Iqaluit, Nunavut. It typically sees aircraft of medium (58%), and light (14%) categories, though like CYZF, a large amount (23%) of additional aircraft appears as an "unknown" category [1]. It has a class E Transition surrounding the airport with a class E transponder area extending from the ground to 3000 ft AAE [2]. In the class E transponder area mode C transponders are required [3]. Figure 20 below illustrates the layout of the airspaces surrounding CYFB, and Table 14 provides a general description of the horizontal and vertical boundaries of each airspace.

Figure 20: Airspace surrounding Iqaluit International Airport (CYFB)

Table 14: General vertical and horizontal boundaries of airspaces surrounding Iqaluit International Airport (CYFB) [2]

Airspace Class	Min Latitude	Max Latitude	Min Longitude	Max Longitude	Min Altitude (feet AGL)	Max Altitude (feet ASL, unless stated otherwise)
E	N63°04'02.28"	N64°23'57.70"	W70°03'09.90"	W67°02'36.06"	700	18000
E	**N63°40'23.27"**	**N63°50'22.70"**	**W68°44'38.76"**	**W68°22'03.18"**	**Surface**	**3000 AAE**

6.0 CONCLUSION AND FUTURE WORK

This report offers a concise summary of the sensor equipment requirements across the various airspace classes in Canada, along with the corresponding minimum design and performance standards for sensor equipment employed in conventional crewed aircraft. In Section 4.0, the overview of airspaces reveals that a significant portion of Canadian airspace falls under Class G (uncontrolled) airspace, which does not mandate specific equipment requirements. However, Classes A-F are predominantly situated in urban environments, warranting the necessity for additional specialized sensor equipment. These urban areas experience higher air traffic density, thereby posing increased conflict risks between RPAS operations and other air traffic. As a result, the proper utilization of sensor equipment becomes crucial in such contexts to ensure safety and mitigate potential conflicts.

Upon careful analysis of the airspace distribution, it has been determined that approximately 18.8% of Canadian airspace, spanning from the surface up to 18,000 feet Above Sea Level (ASL), falls under the classification of controlled airspace. Pilots should exercise caution to ensure compliance with the corresponding requirements in these areas. Conversely, 81.2% of the airspace is categorized as uncontrolled. The analysis also revealed that only 5.46% of the total airspace requires a transponder, which corresponds to approximately 28.94% of the controlled airspace.

The findings from this work not only provide valuable insights into sensor equipment requirements but also serve as a foundation for future research and decision-making. By contributing to the validation of existing Air Risk Classes (ARCs) in Canada and aiding in the development of guidelines for Detect and Avoid sensor requirements, the report supports the ongoing efforts to ensure the safe and effective integration of RPAS into Canadian airspaces.

As part of ongoing discussions with TC for future projects, the research team has several recommendations as outlined in sections 6.1 and 6.2.

6.1 Air Traffic Density and Airspace Class Correlation

The correlation between airspace class, air traffic density, and sensor equipment requirements can further be used by TC to perform validation of the existing ARCs in Canada as per RPAS Specific Operations Risk Assessment (SORA) [13] [14] process for approving RPAS operations that currently fall outside the scope of the CARs Part IX [3].

6.2 RPAS Detect-and-Avoid (DAA) Requirements Assessment

By identifying the trends in aircraft behavior within certain classes of airspace and equipage requirements, it may also be possible to determine what types of DAA sensors (as well as its operational characteristics – range, accuracy etc.) should be required to ensure safe operations in the specific airspace.

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