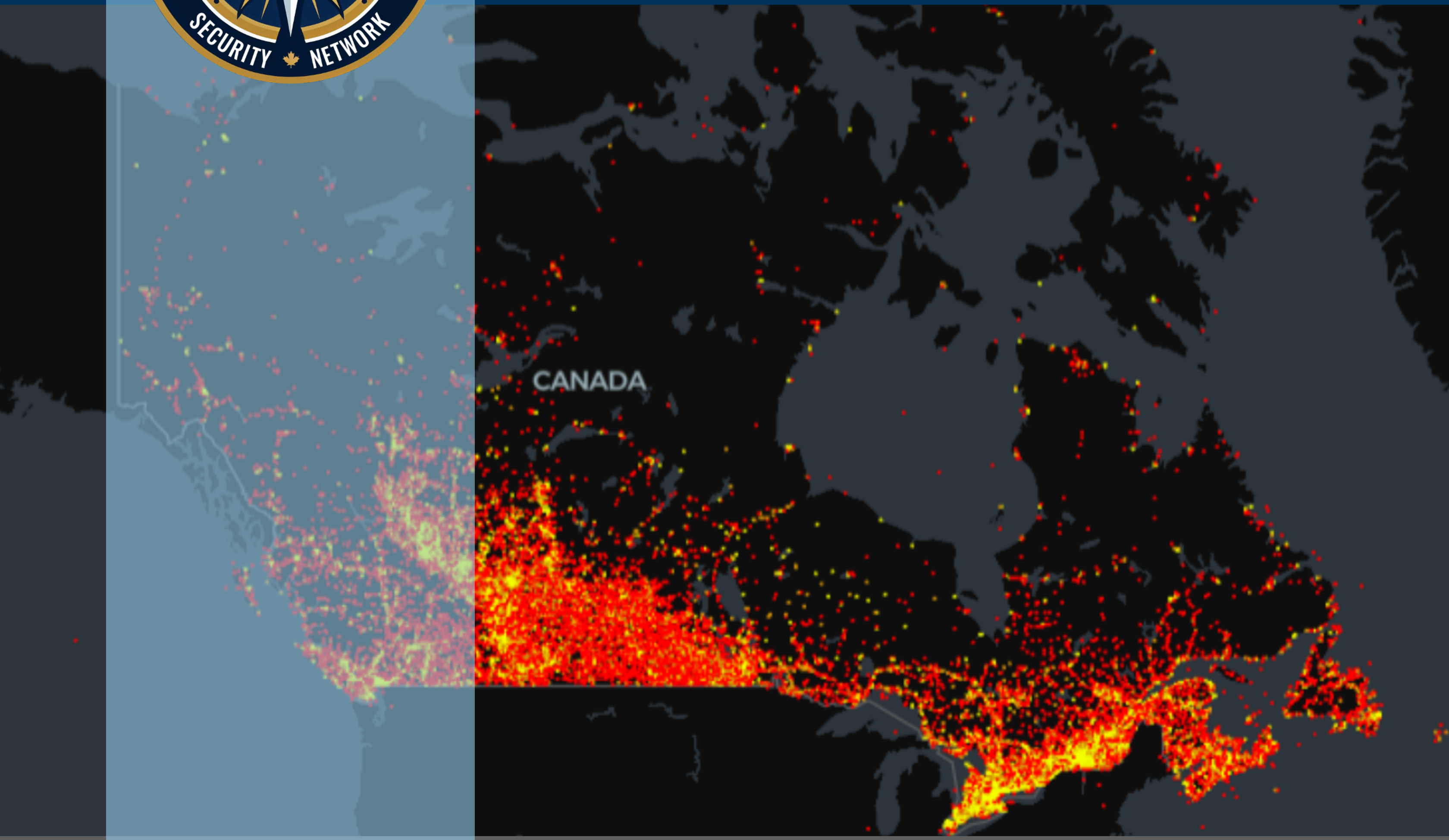
Michael Cabral



CONTESTED, CONGESTED, AND CONSTRAINED

Control of the Mid-Band and its Implications for Canadian National Security

February 2026

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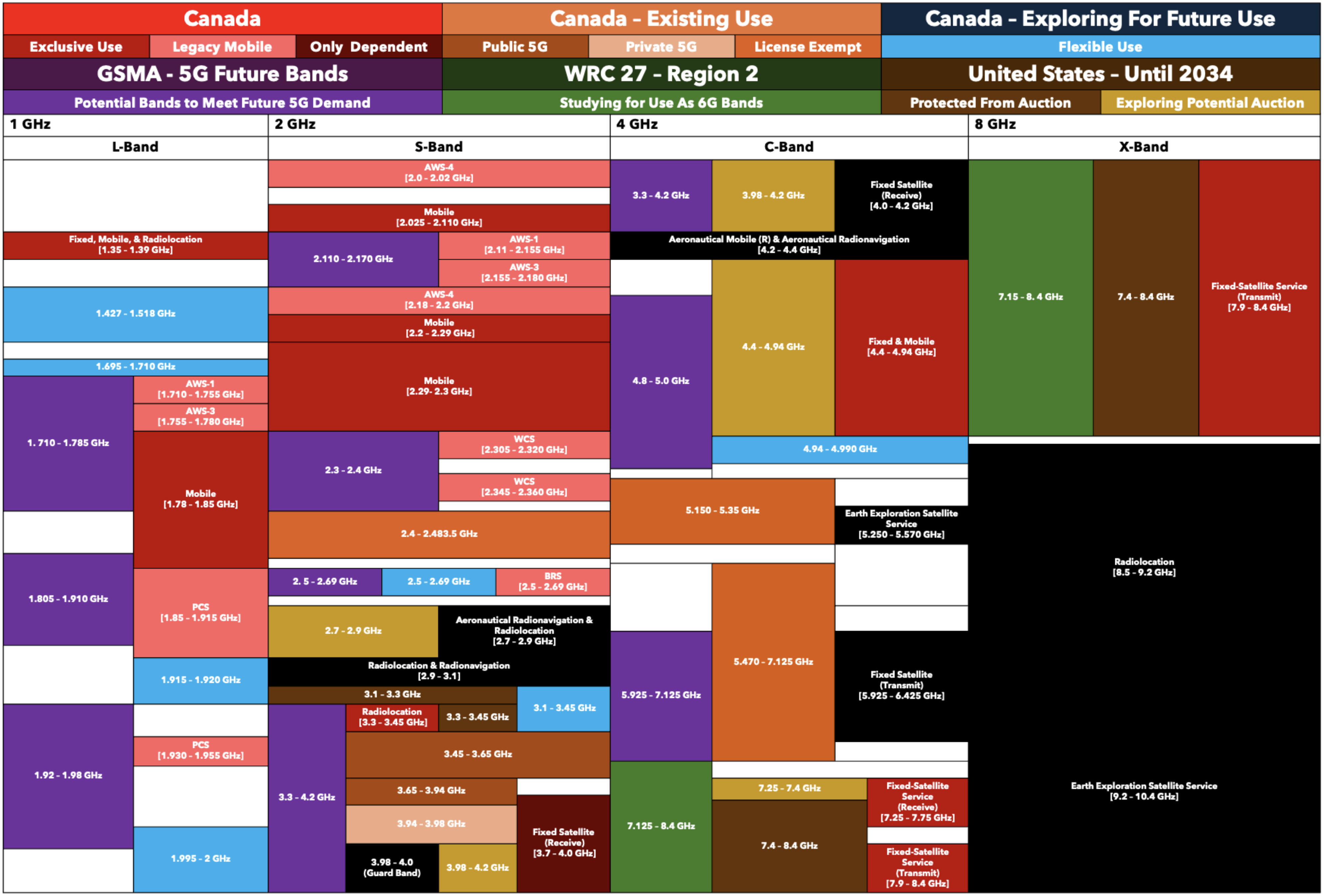
Figure 1: Future Mid-Band Congestion



Source: Author's Summary of Various Sources

* White Space Does Not Indicate No Service Assignments *

** The Space Allocated to the Services in the Spectrum Segments Shown Is Not Proportional to the Actual Amount of Spectrum Occupied **

Table of Contents

"The [Electromagnetic Operating Environment] is a maneuver space, a battlespace, a place where competition and warfare, as well as commerce and other non-military activities, are conducted. The [Electromagnetic Spectrum] is not a separate domain of military operations because the [Electromagnetic Spectrum] is inseparable from the domains established in joint doctrine. In modern warfare, the [Electromagnetic Spectrum] is a leading indicator and fundamental component of achieving superiority in air, land, sea, space, or cyberspace."

United States Department of Defense,
Electromagnetic Spectrum Superiority Strategy, 2020

About This Report

This report was produced by the Canadian Maritime Security Network (CMSN), a collaborative research network dedicated to providing timely policy advice on maritime security to the Government of Canada (GoC). CMSN is supported by the Mobilizing Insights in Defence and Security program of the Department of National Defence (DND). CMSN's research focuses on pressing defence issues with respect to strategic competition, global issues, continental defence, and domains and technologies.

This report assesses Canada's current and future use of mid-band radio frequency (RF) spectrum and provides an overview of the use of these critical bands by the private sector, GoC departments, and the Canadian Armed Forces (CAF). Furthermore, it identifies a growing trend: increasing digitization and demand for connectivity and speed are driving congestion in the mid-band. This congestion creates the conditions for a spectrum standoff, with different stakeholders lobbying for greater access to this crucial slice of the RF spectrum. The technologies that would enable spectrum sharing have yet to mature, meaning the GoC will be forced to make difficult decisions as to who gets what spectrum, where, and under what conditions. These decisions will have significant consequences for Canada's national security objectives, in particular its economic security, air and missile defence, and Arctic sovereignty priorities.

Despite the growing body of literature in allied and competitor countries, information in Canada on the topic of mid-band congestion remains scarce or classified. Therefore, this report is designed as a policy primer to equip decision-makers with the essential information needed to make informed choices on the reallocation of mid-band spectrum. Additionally, this report emphasizes that if any side 'wins' the spectrum standoff, Canada loses.

This report relies on open-source information and uses data gathered from Canada's Spectrum Management System (SMS). Importantly, the GoC does not warrant the accuracy of the information provided by the SMS; therefore, the data presented throughout this report is meant to be illustrative rather than authoritative. It is intended to give the reader an idea of the types of services offered, their locations, as well as the scale of spectrum management. Moreover, while all information used in this report was obtained from open sources, it may not be in the public interest to make them readily available. Therefore, the full report, including the figures and Excel data, can be made available upon request to CMSN. Finally, given the scope of the topic, some information was omitted for the sake of clarity and brevity. Any errors or omissions remain the responsibility of the author.

Executive Memo

Background

The Electromagnetic Spectrum

- In modern warfare, nearly every weapon system depends on the electromagnetic spectrum (EMS) to function.
- The mid-band, a small slice of the EMS, is vital for radars, next-generation telecommunications networks, and satellite imaging and communications.
- Commercial demand for increased network capacity is driving the private sector further into the mid-band, laying the foundations for a standoff with the CAF.

Physics, Interference, and Trade-Offs for All Electromagnetic-Reliant Systems

- As frequency increases, communication systems have greater capacity and radars have greater resolution, but both sacrifice range and reliability.
- The mid-band is coveted for commercial and military systems due to the range striking the ideal balance between capacity, range, reliability, and resolution.
- As congestion increases in the mid-band, interference – the disruption of electronic systems – will increase, degrading the performance of future systems.

Spectrum Management

- Internationally, spectrum management is overseen by the International Telecommunication Union, which convenes the World Radiocommunication Conferences every three or four years to update radio frequency policies.
- Domestically, spectrum is the responsibility of Innovation, Science and Economic Development Canada and the Minister, with the Department of National Defence, advocating for the spectrum needs of the Armed Forces.
- To date, Canada has reallocated 530 megahertz (MHz) of mid-band spectrum for next-generation telecommunications networks.

Key Considerations

The Role of the Mid-Band in Canadian National Security

- Mid-band spectrum will help ensure Canadian economic security by providing the network capacity necessary to harness the full potential of emerging technologies like artificial intelligence and edge computing.
- Mid-band radars are indispensable for air and missile defence, serving as the primary sensors that guide interceptors engaging incoming threats.
- Domain awareness aircraft, naval vessels, and satellites all require mid-band frequencies to operate, making these ranges vital for Arctic sovereignty.

Future Bands for 5G and 6G

- 2 gigahertz (GHz) of additional spectrum may be required for fifth-generation communications networks (5G), with industry-led reallocation efforts focused on the 3.3–4.2, 4.8–5.0, and 5.925-7.125 GHz ranges.
- The International Telecommunication Union is expected to explore the 7.125–8.4 GHz band for potential reallocation to support the deployment of sixth-generation communications networks (6G).
- With future bands in conflict with bands vital for the CAF, the GoC will have to make difficult decisions on the allocation of spectrum, often trading off economic security for military effectiveness, or vice versa.

Allied Responses

- Australia's 2025 *Spectrum Outlook* specifically references the government's need for spectrum and emphasizes that the new defence acquisition program will involve spectrum-dependent technologies that require spectrum access.
- The United Kingdom's *Public Sector Spectrum Framework* now requires all government departments to maintain and present an up-to-date overview of their current and expected future spectrum use every three or four years.
- The United States has planned to release an additional 800 MHz for 5G/6G, while excluding the 3.1–3.45 and 7.4–8.4 GHz bands from reallocation.

Policy Recommendations

Remove the 3.1–3.45 GHz Range from Consideration for Flexible Use

- CAF access to this frequency band is essential to both Canadian security and to ensuring the stability of the international security environment. Any interference or bandwidth reduction within this range would entail unacceptable risk; therefore, the band should be removed from consideration for flexible use.

Require Government Departments to List Projected Spectrum Needs

- To ensure Canadian needs are met domestically and internationally, the GoC should follow the United Kingdom's lead and require all government departments to maintain a database of current and projected spectrum needs.

Update Canada's Spectrum Policy to Align with Modern National Security Needs

- The Government should revisit Canada's *Spectrum Policy Framework*. Two areas should be identified for discussion: first, whether to include explicit national security language in the objective of spectrum management; and second, identifying whether the use of set-asides continues to serve the national interest.

Introduction

The RF spectrum will play an essential role in Canada's future, serving as both a vehicle for ensuring Canada's economic security and a critical enabler of the CAF's military effectiveness. Effective control of the RF spectrum and its efficient allocation to meet commercial, government, and defence needs will determine the degree to which the GoC can manage the deteriorating international security environment. That said, the RF spectrum is a finite resource, and this scarcity lays the foundation for a spectrum standoff between commercial, government, and military stakeholders. The advanced technologies needed to enable spectrum sharing across the RF spectrum have yet to mature, forcing the GoC to make difficult decisions over the next decade on who gets what spectrum, where, and under what conditions. These decisions will have direct consequences for key national security priorities, including economic security, air and missile defence, and Arctic operations.

The main policy challenge for the GoC is that the spectrum required for 5G and 6G networks overlaps with the spectrum the CAF will increasingly rely on to detect, deter, and defend against the escalating threats to Canada. This range, commonly known as the mid-band, will require the GoC to trade off economic security and military effectiveness, or vice versa. Given the current and emerging threats to Canada, deciding on the allocation of mid-band spectrum will be one of the most important policy challenges the GoC will face over the next decade.

Despite the growing body of literature on this topic from key allies and competitors alike, current discussions of RF spectrum policy in Canada are almost entirely focused on commercial or social benefits, with spectrum needs for the defence of Canada being underdiscussed. This report aims to fill this gap by providing an overview of the importance of the mid-band to Canada's future. To that end, this report argues that Canada's future depends on the GoC's ability to effectively balance the mid-band spectrum needs of both the private sector and the CAF. Importantly, this report is not intended to be a comprehensive overview of all aspects of the mid-band; rather, it is designed as a policy primer to provide Canadian decision-makers with the information needed to make informed decisions regarding the future reallocation of mid-band spectrum.

To support this argument, this report is structured into six sections. The first offers an overview of the RF spectrum, describing its role in modern strategic competition and explaining how physics informs the importance of the mid-band for communications and radar systems. The second section discusses the division of labour for spectrum management, detailing how RF spectrum is managed internationally, domestically, and within DND. The third section examines the vital role of the mid-band in key GoC priorities – namely, economic security, air and missile defence, and Arctic sovereignty. The fourth section highlights Canada's response to growing commercial mid-band spectrum demand, identifies the future mid-band bandwidths that are likely to be targeted for lobbying by commercial actors, and reviews how Australia, the United Kingdom (UK), and the United States (US) have responded. The fifth section reviews the mid-band frequencies most likely to be reallocated and discusses their current and projected use by the GoC and the CAF, as well as the risks of losing access to these bands. The final section presents three policy recommendations to enhance Canada's spectrum policy and ensure that commercial, government, and military stakeholders have access to the spectrum they need to keep Canada safe, secure, and prosperous.

Electromagnetic Warfare and the Mid-Band

When electric or magnetic fields change, they induce effects in one another; these effects generate electromagnetic waves that travel at the speed of light. Unlike mechanical waves, electromagnetic waves do not require a medium to propagate and can even exist in the vacuum of space.[1] The utilization of electromagnetic waves in weapon systems has provided significant advantages to militaries that employ them effectively. For allied forces, electromagnetic warfare has been crucial to success: high-frequency direction finding helped sink German U-boats and ensure victory in the Battle of the Atlantic; satellite-based systems facilitated communications, navigation, and weapons guidance in the first Gulf War, leading to the dismantling of Saddam Hussein's forces; and the widespread use of drones in Russia's war on Ukraine underscores its continued significance.[2]

In the military lexicon, electromagnetic warfare is typically included within electronic warfare. For instance, the GoC's terminology bank describes electronic warfare as "warfare in which electronics are used to exploit the electromagnetic and acoustic

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[1] NASA, "Anatomy of an Electromagnetic Wave," n.d., https://science.nasa.gov/ems/02_anatomy/; John R. Hoehn, Jill C. Gallagher, and Kelley M. Sayler, "Overview of Department of Defense Use of the Electromagnetic Spectrum," Congressional Research Service, August 10, 2021, 1.

[2] Commander In H. Ha, "Turning Point in the Atlantic," US Naval Institute, April 2018, https://www.usni.org/magazines/naval-history-magazine/2018/april/turning-point-atlantic; Larry Greenemeier, "GPS and the World's First 'Space War,'" Scientific American, February 8, 2016, https://www.scientificamerican.com/article/gps-and-the-world-s-first-space-war/; Roslyn Layton, "Spectrum Supremacy: Reclaiming America's Edge in a Contested Domain," War on the Rocks, April 21, 2025, https://warontherocks.com/2025/04/spectrum-supremacy-reclaiming-americas-edge-in-a-contested-domain/.

environments."[3] In other words, electronic warfare is divided into the use of electronic systems in the electromagnetic operating environment (EMOE) – surface – and the acoustic environment – subsurface – and includes electronic attack, support, and protection for both.[4]

Given the significance of electromagnetic warfare in modern conflicts, both allied and competitor countries are investing heavily in their electromagnetic capabilities. A major challenge for all countries is that electromagnetic waves have also driven rapid technological progress in civilian sectors and have enabled critical systems such as phones, computers, and Wi-Fi. Consequently, the growing needs of new users now complicate the maintenance of existing spectrum allocations. Therefore, it is vital for Canadian decision-makers to understand the electromagnetic spectrum and recognize the importance of the mid-band for both communication and radar systems.

The Electromagnetic Spectrum

Electromagnetic waves are typically classified based on frequency, which is measured in hertz. The frequency of a signal where one wave passes a fixed point in one second is called a hertz (Hz), 1,000 Hz is a kilohertz (kHz), 1,000 kilohertz is a megahertz, and 1,000 megahertz is a gigahertz.[5] The entire range of electromagnetic waves is called the electromagnetic spectrum (see Figure 2).

The RF spectrum is the subset of electromagnetic waves that falls within the range of 3 kHz to 300 GHz, sometimes 400 GHz.[6] The RF spectrum is further subdivided into three bands: the low band, the mid-band, and the high band. Low-band frequencies are those below 1 GHz, mid-band frequencies are those between 1 and 10 GHz, and high-band frequencies are those between 10 and 300 GHz.[7] Given the range of activities within the mid- and high bands, these bands are often further subdivided using letter

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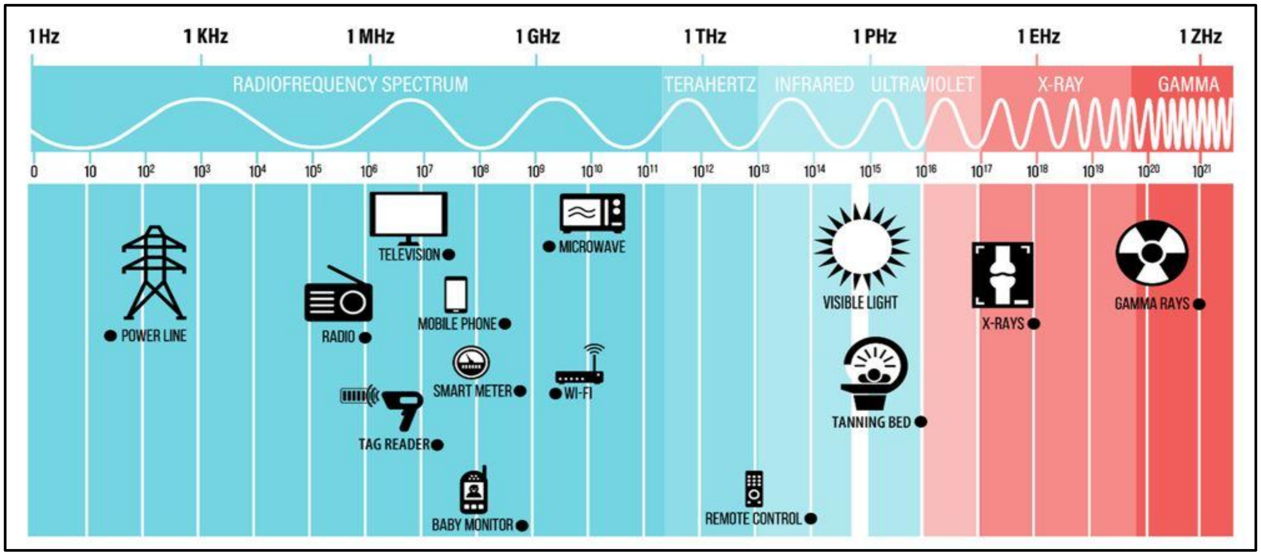
[3] Government of Canada, "Electronic Warfare, Termium Plus," May 1, 2023, https://www.btb.termiumplus.gc.ca/tpv2alpha/alpha-eng.html?lang=eng&i=1&srchtxt=Electronic+warfare&codom2nd_wet=1#resultrecs.
[4] J.B. Lange and S. Jette-Charbonneau, "The Taxonomy of Electronic Warfare," Defence Research and Development Canada, 2024, 7–25.
[5] Innovation, Science and Economic Development Canada (ISED), "An Introduction to the Radio Frequency Spectrum," Government of Canada, last modified August 23, 2024, https://ised-isde.canada.ca/site/spectrum-management-telecommunications/en/licences-and-certificates/introduction-radio-frequency-spectrum.
[6] IEEE, "521-2019 – IEEE Standard Letter Designations for Radar-Frequency Bands," 2020, 2, https://ieeexplore.ieee.org/document/8999849/versions#versions; Department of National Defence (DND), "DAOD 6002-4, Radio Frequency Spectrum Management," Government of Canada, last modified May 8, 2025, https://www.canada.ca/en/department-national-defence/corporate/policies-standards/defence-administrative-orders-directives/6000-series/6002/6002-4-radio-frequency-spectrum-management.html.
[7] ISED, "Introduction to the Radio Frequency Spectrum."

designators, namely L-band (1–2 GHz), S-band (2–4 GHz), C-band (4–8 GHz), X-band (8–12 GHz), Ku-band (12–18 GHz), K-band (18–27 GHz), Ka-band (27–40 GHz), V-band (40–75 GHz), W-band (75–110 GHz), and mmWaves (110–300 GHz).[8] These details are provided in Table 1.

Figure 2: The Electromagnetic Spectrum



Source: Innovation, Science and Economic Development Canada, "An Introduction to the Radio Frequency Spectrum," Government of Canada, last modified August 23, 2024, https://ised-isde.canada.ca/site/spectrum-management-telecommunications/en/licences-and-certificates/introduction-radio-frequency-spectrum

The physics of electromagnetic waves enables key trade-offs for systems operating at specific frequencies. For instance, some very low frequency radio waves can travel long distances and penetrate seawater but are limited in the amount of data they can transfer; therefore, they are useful for communicating with submarines.[9] Conversely, mid-band radio waves have a shorter range and are more affected by objects such as walls and trees but can carry more data; therefore, they are used for radar and satellite communications.[10] Understanding the reasons for these trade-offs is fundamental to explaining the increasing demand for mid-band RF assignments.

[8] Merrill Skolnik, *Radar Handbook*, 3rd ed. (New York: The McGraw-Hill Companies, 2008), chapter 1, https://dl1.icdst.org/pdfs/files/dd1d87efd51a5c188cab901b5b32457c.pdf.
[9] Hoehn, Gallagher, and Sayler, "Overview of Department of Defense Use of the Electromagnetic Spectrum," 2.
[10] Hoehn, Gallagher, and Sayler, "Overview of Department of Defense Use of the Electromagnetic Spectrum," 2.

Table 1: Frequency Band Designator

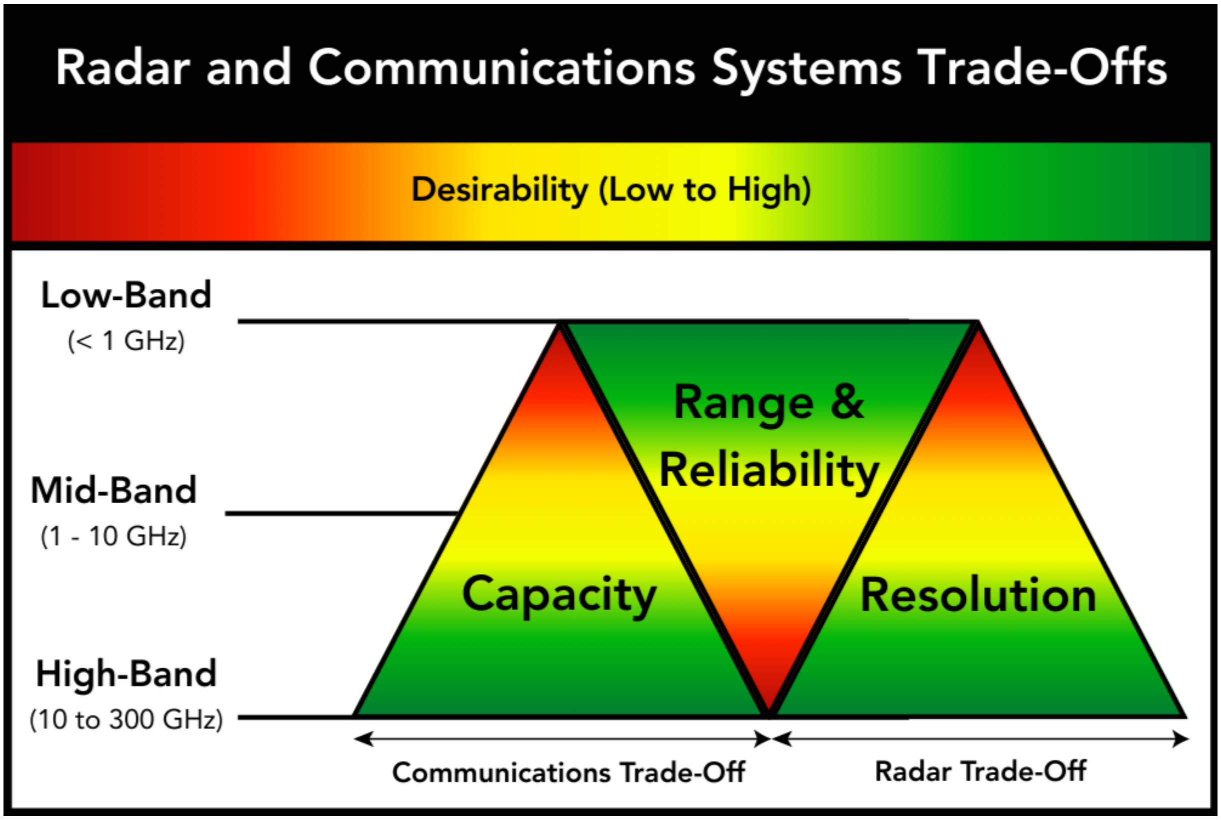
Band	Designator	Range	Wavelength	Letter Designator
Low (< 1 GHz)	Extremely Low Frequency	30–300 Hz	10,000–100,000 kilometres (km)	ELF
	Voice Frequencies	300–3,000 Hz	1,000–100 km	VF
	Very Low Frequency	3–30 kHz	100–10 km	VLF
	Low Frequency	30–300 kHz	10–1 km	LF
	Medium Frequency	300–3,000 kHz	1 km–100 metres (m)	MF
	High Frequency	3–30 MHz	100–10 m	HF
	Very High Frequency	30–300 MHz	10–1 m	VHF
	Ultra High Frequency	300–3,000 MHz	1 m–10 centimetres (cm)	UHF
Mid (1-10 GHz)				L-Band (1–2 GHz)
				S-Band (2–4 GHz)
	Super High Frequency	3–30 GHz	10 cm–1 cm	C-Band (4–8 GHz)
				X-Band (8–12 GHz)
High (> 10 GHz)				Ku-Band (12-18 GHz)
				K-Band (18–27 GHz)
				Ka-Band (27–40 GHz)
	Extremely High Frequency	30–300 GHz	1 cm – 1 millimetre (mm)	V-Band (40–75 GHz)
				W-Band (75–110 GHz)
				mmWave (110–300 GHz)

Source: Author's Compilation of Information Provided by IEEE, "521-2019 – IEEE Standard Letter Designations for Radar-Frequency Bands," 2020, https://ieeexplore.ieee.org/document/8999849/versions - versions; John A. Stine and David L. Portigal, "Spectrum 101: An Introduction to Spectrum Management," MITRE Technical Report, March 2004, https://www.mitre.org/sites/default/files/pdf/04_0423.pdf; Merrill Skolnik, *Radar Handbook*, 3rd ed. (New York: The McGraw-Hill Companies, 2008), https://dl1.icdst.org/pdfs/files/dd1d87efd51a5c188cab901b5b32457c.pdf

Physics and the Trade-Offs for RF Systems

While many factors influence the use of RF systems within individual bands, for the purposes of this report, an understanding of four key properties is necessary. These include capacity, range, reliability, and resolution. Communications systems (phones, satellites, radios) trade off the initial three properties, while radar systems trade off the latter three. The trade-offs are summarized in Figure 3 below.

Figure 3: Radar and Communications Systems Trade-Offs



Source: Author's Own Work

Capacity

Capacity refers to the number of devices that can be hosted, the amount of data that can be transferred, and the speed at which individual devices operate, expressed as upload/download throughput. Capacity is influenced by bandwidth (channel sizes) and wavelength. For bandwidth, in the same way a wider road means you can use more lanes to support more traffic, wider bands mean you can add more channels to support higher capacity.[11] Channel sizes are larger at higher frequencies; therefore, to achieve higher capacity, one must operate at higher frequencies.[12] Additionally, capacity is influenced by wavelength, such that shorter wavelengths allow more antenna elements to be supported in the same physical space within a device. The benefit of more

[11] GSMA, "Introducing Radio Spectrum – Spectrum Primer Series," February 2017, 14, https://www.gsma.com/connectivity-for-good/spectrum/wp-content/uploads/2017/04/Introducing-Radio-Spectrum.pdf.

[12] Peter W. Moo and David J. DiFilippo, "Considerations for Development of Naval Multifunction Radio Frequency (RF) Systems," Defence Research and Development Canada Scientific Report, May 2018, 11–12, https://publications.gc.ca/collections/collection_2019/rddc-drdc/D68-2-038-2018-1-eng.pdf.

antenna elements is higher antenna gain, which in turn yields better coverage and more accurate beamforming, thereby increasing capacity.[13] Overall, because wavelengths are shorter and bandwidths are larger in higher frequencies, capacity is positively associated with frequency: as frequency increases, so does capacity.

Range and Reliability[14]

Range denotes the maximum operating distance of a communication or radar system, whereas reliability refers to how atmospheric conditions, weather, and physical obstructions affect the performance of these systems. As electromagnetic waves propagate, signal power decreases due to free-space path loss.[15] Additionally, as electromagnetic waves travel, they are negatively impacted by physical obstructions, atmospheric gases, and atmospheric aerosols such as haze, fog, clouds, and rain.[16] These conditions scatter and absorb electromagnetic energy; the combined effect is known as attenuation which affects the reliability and performance of RF systems under varying conditions. Overall, the combined effects of free-space path loss and attenuation mean that the range and reliability of RF systems are inversely related to frequency: as frequency goes up, range and reliability – especially in bad weather – go down.[17]

Resolution

Resolution describes the level of spatial detail captured by radar systems. Essentially, it indicates the radar's ability to distinguish objects such as missiles from other items, such as debris or countermeasures. As with capacity, radar resolution is determined by bandwidth and wavelength. That is, the accuracy of a radar's range measurement depends on the radar signal bandwidth: the wider the bandwidth, the greater the accuracy. Larger bandwidths are crucial for resolving targets in range, for accurate measurement of range to a target, and for providing limited capacity to distinguish one

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[13] 5G Americas, "The 6G Upgrade in the 7-8 GHz Spectrum Range: Coverage, Capacity and Technology," October 2024, 11, https://www.5gamericas.org/the-6g-upgrade-in-the-7-8-ghz-spectrum-range/.
[14] Mutually reinforcing and inclusive, these are therefore included together.
[15] NASA, "Chapter 6: Electromagnetics," n.d., https://science.nasa.gov/learn/basics-of-space-flight/chapter6-1/.
[16] C.C. Chen, "Attenuation of Electromagnetic Radiation by Haze, Fog, Clouds, and Rain," A Report Prepared for United States Air Force Project Rand, April 1975, https://www.rand.org/content/dam/rand/pubs/reports/2006/R1694.pdf.
[17] An important note: As discussed in the capacity section, as frequency increases, the physical size of antennas also decreases. This reduction in size makes it more difficult to generate large transmitter power. While technology can partially mitigate this trade-off, as noted by Skolnik in the *Radar Handbook* (2008), the range performance of radars at frequencies above X-band is generally lower than that of radars operating at or below X-band.

target type from another.[18] Additionally, because the beamwidth affects the radar's ability to distinguish between two objects, wavelength also plays a crucial role in radar resolution, with shorter wavelengths contributing to a radar's ability to distinguish smaller objects.[19] Overall, because wavelengths are shorter and bandwidths are larger in higher frequencies, resolution is positively associated with frequency: as frequency increases, so does resolution.

These four properties represent the fundamental trade-offs for all RF systems and influence the use cases for each system within individual bands. These trade-offs also illustrate why the mid-band is highly sought after for communication and radar systems; the bands within the 1–10 GHz range strike an ideal balance between capacity, range, reliability, and resolution. With the overview of trade-offs now complete, this paper will move to discussing the important topic of interference.

Interference

All electromagnetic waves exist in the same space, and when two or more waves meet at a receiving antenna, they can collide and degrade the quality of the signal.[20] This interference disrupts the performance of systems utilizing the electromagnetic spectrum.[21] Interference can be naturally occurring – attenuation – or man-made – deliberate interference by opposing forces or unintentional interference by friendly or neutral forces. Notably, 4G Long Term Evolution (LTE) and 5G technologies have been shown to cause interference for systems operating within or adjacent to their frequency bands. For instance, despite a 200 MHz guard band, Transport Canada concluded that there is a possibility of interference with and disturbances to certain radio altimeters operating in the 4.2–4.4 GHz range from 5G radio waves operating in the 3.45–3.98 GHz range.[22] The result of this interference was that aircraft not considered to be radio altimeter-tolerant were prohibited from conducting certain operations.[23]

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[18] Skolnik, *Radar Handbook*, 1.8–1.9.

[19] Simone Fontana and Federica Di Lauro, "An Overview of Sensors for Long Range Missile Defense," *Sensors* 22, no. 24 (2022): 8, https://doi.org/10.3390/s22249871.

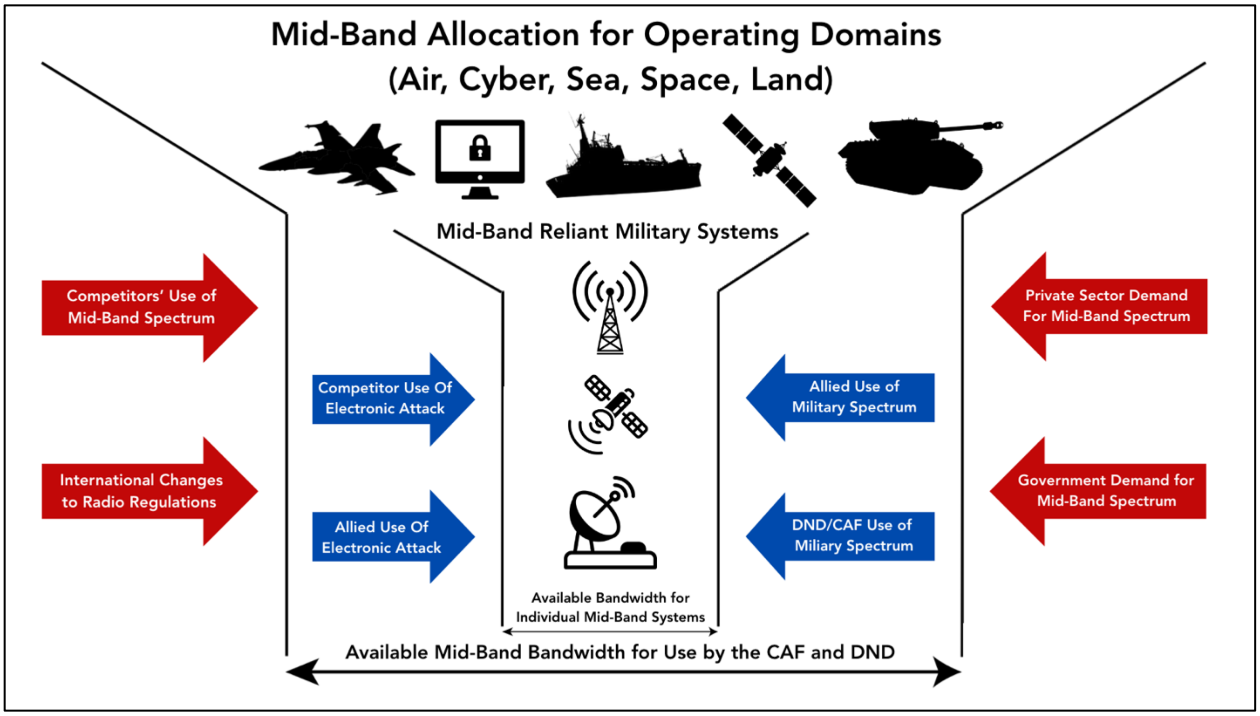
[20] John A. Stine and David L. Portigal, "Spectrum 101: An Introduction to Spectrum Management," MITRE Technical Report, March 2004, https://www.mitre.org/sites/default/files/pdf/04_0423.pdf.

[21] ISED, "Interference," Government of Canada, last modified August 22, 2025, https://ised-isde.canada.ca/site/spectrum-management-telecommunications/en/safety-and-compliance/interference.

[22] Transport Canada, "Potential Risk of Interference of 5G Signals on Radio Altimeter – Civil Aviation Safety Alert (CASA) No. 2024-25," Government of Canada, last modified October 6, 2025, https://tc.canada.ca/en/aviation/reference-centre/civil-aviation-safety-alerts/potential-risk-interference-5g-signals-radio-altimeter-civil-aviation-safety-alert-casa-no-2024-05.

[23] Transport Canada, "Potential Risk of Interference of 5G Signals on Radio Altimeter – Clarification on RadAlt Retrofit Mandate – Civil Aviation Safety Alert (CASA) No. 2025-5," Government of Canada, last

Figure 4: The Mid-Band Operating Environment



Source: Author's Own Work Based on a US Government Accountability Office Figure[24]

This increase in the potential for interference complicates the EMOE for the CAF, and the mid-band will increasingly become contested, congested, and constrained. The risks associated with this congestion are that, as shown in Figure 4, increased use by new users reduces the available bandwidth for military use, whereas increased military electromagnetic use reduces the available bandwidth for individual RF systems. In other words, international radio regulations, as well as the entry of new users, can influence domestic departments to reallocate portions of military bandwidth or reduce the military's available slice. Relatedly, the increased use of electromagnetic waves by the CAF or allies in military operations in Canada, as well as potential jamming or countermeasures by competitor nations, can reduce the available bandwidth for individual RF systems. For instance, in 2015, the US armed forces were victims of more

modified October 6, 2025, https://tc.canada.ca/en/aviation/reference-centre/civil-aviation-safety-alerts/potential-risk-interference-5g-signals-radio-altimeter-clarification-radalt-retrofit-mandate-civil-aviation-safety-alert-casa-no-2025-05.

[24] Government Accountability Office, "Electromagnetic Spectrum Operations: DOD Needs to Address Governance and Oversight Issues to Help Ensure Superiority," United States Government Accountability Office Report to the Committee on Armed Services, House of Representatives, December 2020, 7, https://www.gao.gov/assets/720/711469.pdf.

than 261 satellite communications jamming events, the majority of which were self-inflicted.[25]

As new users increasingly lobby the GoC to release more mid-band spectrum, it is essential for decision-makers to recognize that the CAF requires sufficient bandwidth to complete its mission. Beyond the reasons mentioned above, bandwidth enables RF systems to have a wider tunable range – the ability to change (tune) the signal frequency over a wide range of available spectrum.[26] The wider the bandwidth, the more systems that can be hosted within a given area, and the more resilient those systems are to hostile actions by the enemy.[27] Conversely, the smaller the bandwidth, the fewer systems that can operate, and the greater the risk that enemy jamming and countermeasures will degrade the effectiveness of the CAF.

Thus, as the EMOE becomes increasingly contested, congested, and constrained, the likelihood that interference harms the effectiveness of the CAF increases dramatically. To mitigate the risks to Canadian national security from harmful interference and take full advantage of the RF spectrum, an understanding of how spectrum is managed internationally, domestically, and within DND is necessary.

Spectrum Management

To minimize interference, receiving antennas must be able to isolate the desired frequencies from other electromagnetic waves. To do so, states coordinate internationally to delegate certain activities to specific frequency bands and then implement those decisions at the domestic level. The world's ability to fully exploit the electromagnetic spectrum depends heavily on these spectrum management activities. Therefore, this section focuses on how spectrum is managed internationally, domestically, and within the CAF and DND.

International – International Telecommunication Union

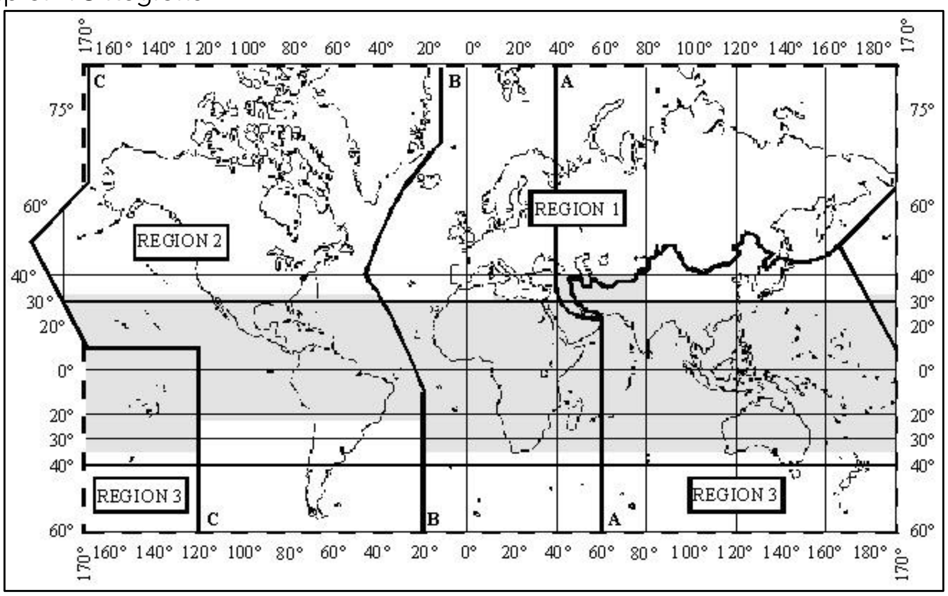
Given that electromagnetic waves cross national boundaries, the decisions of one state can interfere with those of its neighbours, and vice versa. Therefore, international coordination is an essential element of effective spectrum management. To that end, the International Telecommunication Union (ITU), a United Nations specialized agency,

[25] Major Stéphane Ricciardi and Major Cédric Souque, "Modern Electromagnetic Spectrum Battlefield: From EMS Global Supremacy to Local Superiority," *Prism* 9, no. 3 (November 2021): 127, https://ndupress.ndu.edu/Portals/68/Documents/prism/prism_9-3/prism_9-3_122-139_Ricciardi-Souque.pdf?ver=UQX3LAq2ZJtNwy7J6fs4fg==.
[26] Skolnik, *Radar Handbook*, 1.8–1.9.
[27] Skolnik, *Radar Handbook*, 1.8–1.9.

is the institution responsible for managing RF policy in coordination with all member states. This coordination culminates in the World Radiocommunication Conferences (WRCs), which review and, if necessary, revise the international radio regulations.[28]

At the ITU, the world is subdivided into three regions, with Canada included in Region 2 with the US and the rest of North and South America (see Figure 5). All three regions differ somewhat in their radio allocations, particularly in the bands being explored for future telecommunications, which will be discussed further below. In addition to coordination with the ITU for Region 2, Canada and the US have a separate agreement to further mitigate the risk of interference along the Canada-US border.[29]

Figure 5: Map of ITU Regions



Source: ISED, "Canadian Table of Frequency Allocations (2022)," Government of Canada, 2022, last modified January 27, 2023, https://ised-isde.canada.ca/site/spectrum-management-telecommunications/en/learn-more/key-documents/consultations/canadian-table-frequency-allocations-sf10759

Domestic – Innovation, Science and Economic Development Canada

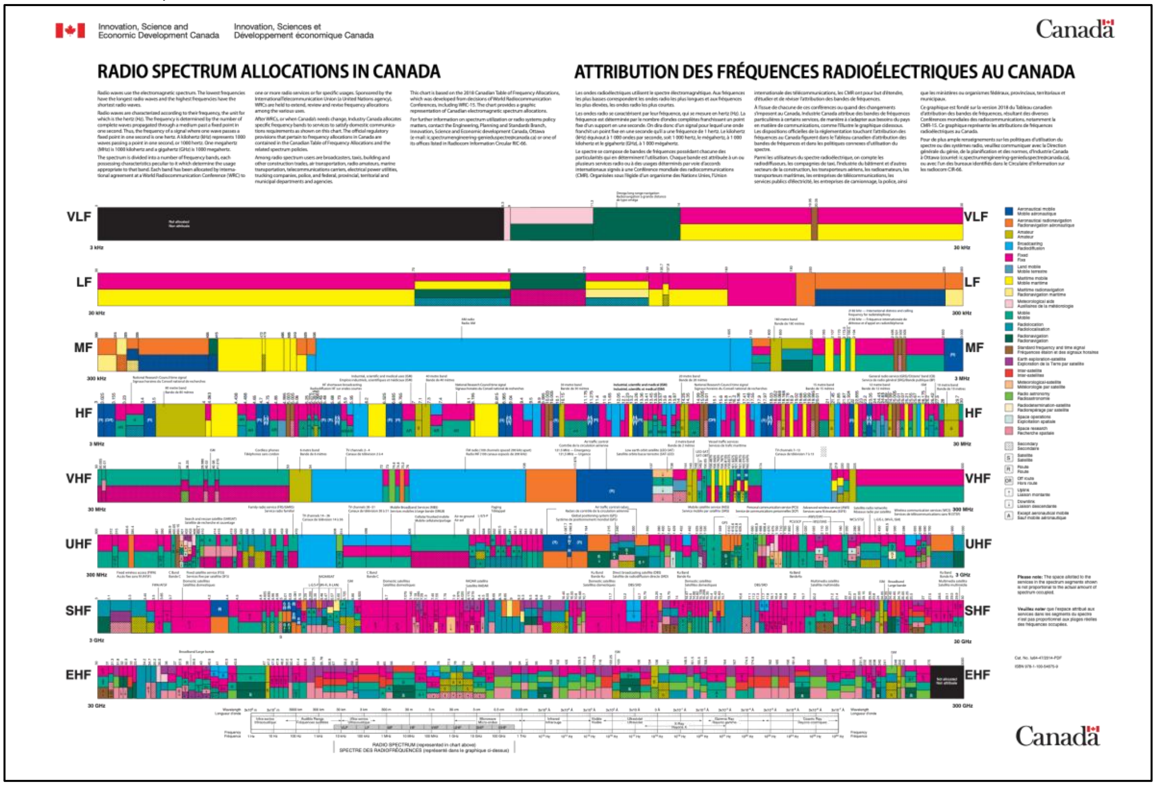
In Canada, spectrum management is the responsibility of Innovation, Science and Economic Development Canada (ISED) and the Minister of Industry. This responsibility

[28] ITU, "World Radiocommunication Conferences (WRC)," n.d., https://www.itu.int/en/ITU-R/conferences/wrc/Pages/default.aspx.

[29] Government of Canada, "General Coordination Agreement Between Canada and the United States of America on the Use of the Radio Frequency Spectrum by Terrestrial Radiocommunication Stations and Earth Stations," last modified March 24, 2021, https://ised-isde.canada.ca/site/spectrum-management-telecommunications/en/official-publications/legislation-regulations-and-treaties/terrestrial-radiocom-agreements-and-arrangements-traa/canada-united-states/general-coordination-agreement-between-canada-.

includes setting national policies for spectrum management and is guided by the *Spectrum Policy Framework,* which states that the objective of the spectrum program is to maximize the economic and social benefits that Canadians derive from the use of the RF spectrum.[30] To that end, Canada, in coordination with ITU Region 2 decisions, categorizes services across the RF spectrum, as shown in its entirety in Figure 6.

Figure 6: Radio Spectrum Allocations in Canada[31]



Source: ISED, "Canadian Table of Frequency Allocations (2022)," Government of Canada, 2022, last modified January 27, 2023, https://ised-isde.canada.ca/site/spectrum-management-telecommunications/en/learn-more/key-documents/consultations/canadian-table-frequency-allocations-sf10759

ISED also publishes all terrestrial and satellite RF assignments within Canada through the SMS. This system contains over 30 million data points on specific radio frequencies, defined as the authorization granted by an administration to a radio station to use a

[30] ISED, *Spectrum Policy Framework for Canada* (June 2007), 8, https://ised-isde.canada.ca/site/spectrum-management-telecommunications/sites/default/files/attachments/2022/spf2007e.pdf; ISED, "Spectrum Outlook 2023 to 2027," Government of Canada, August 11, 2023, https://ised-isde.canada.ca/site/spectrum-management-telecommunications/en/spectrum-allocation/spectrum-outlook-2023-2027.

[31] This is included here to give the reader a sense of the scale of activities conducted across the RF spectrum. The PDF can be found at https://ised-isde.canada.ca/site/spectrum-management-telecommunications/sites/default/files/attachments/2022/2018_Canadian_Radio_Spectrum_Chart.PDF.

radio frequency channel under specified conditions.[32] Based on these data, this report can present information on the types of services offered in specific geographic areas and the licence holders for those assignments. As Table 2 highlights, Canada's total RF assignments as of December 2025 are 998,285, across 115,883 locations and 35,533 licensees, with the circumpolar region (55° N) accounting for just under 10% of each category. Furthermore, as Figure 7 shows, the most heavily utilized bands today are those in the high low band and low mid-band, with the highest being the UHF band (440,971), the VHF band (403,161), and the SHF band (138,908).[33]

Importantly, by far the largest licence holders in Canada are the national telecommunications companies – Bell, Rogers, TELUS – which collectively hold 18% of all RF assignments in Canada. As Figures 8 and 9 show, these assignments are concentrated in the mid-band (lower S-band) for Bell and TELUS, whereas Rogers has a relatively higher concentration in the high band. With an increasingly digitized economy, the percentage of RF assignments held by telecommunications companies, particularly in the mid-band, is likely to increase, the details of which are discussed below.

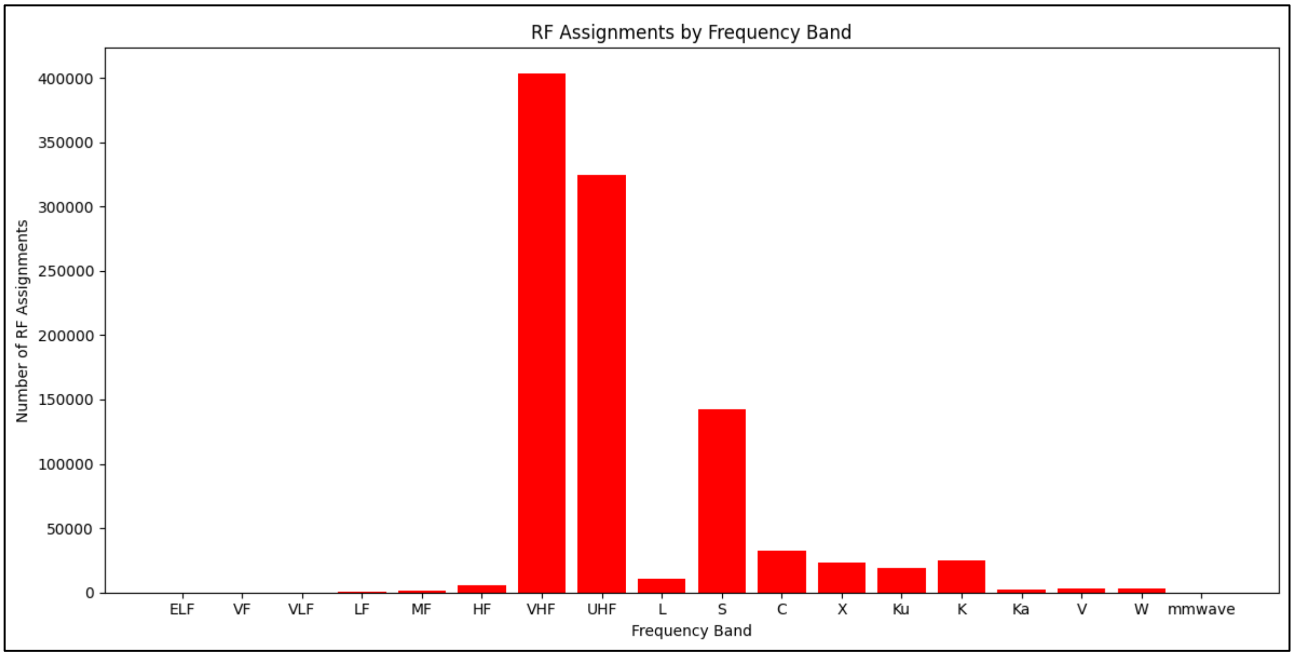
Table 2: RF Spectrum Assignments, Locations, and Licensees in Canada

Description	Count
RF Spectrum Assignments	998,285
RF Assignments (Circumpolar Region)	93,341
Unique Locations	115,883
Unique Locations (Circumpolar Region)	11,797
RF Licensees	35,533
RF Licensees (Circumpolar Region)	2,747

Source: Author's Own Work Using SMS Data

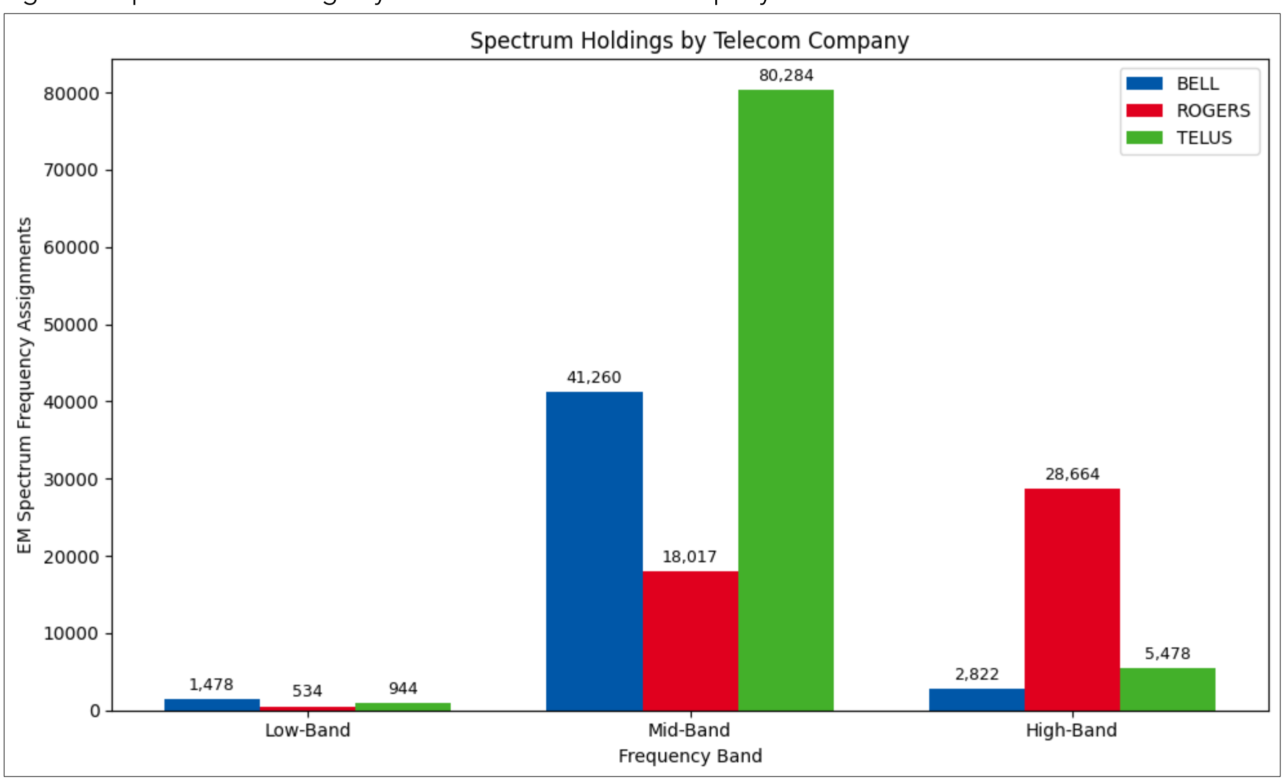
[32] ISED, "Canadian Table of Frequency Allocations (2022)," Government of Canada, 2022, last modified January 27, 2023, https://ised-isde.canada.ca/site/spectrum-management-telecommunications/en/learn-more/key-documents/consultations/canadian-table-frequency-allocations-sf10759.
[33] UHF: 300–3,000 MHz, VHF: 30–300 MHz, and SHF: 3,000–30,000 MHz.

Figure 7: RF Assignments in Canada by Frequency Band



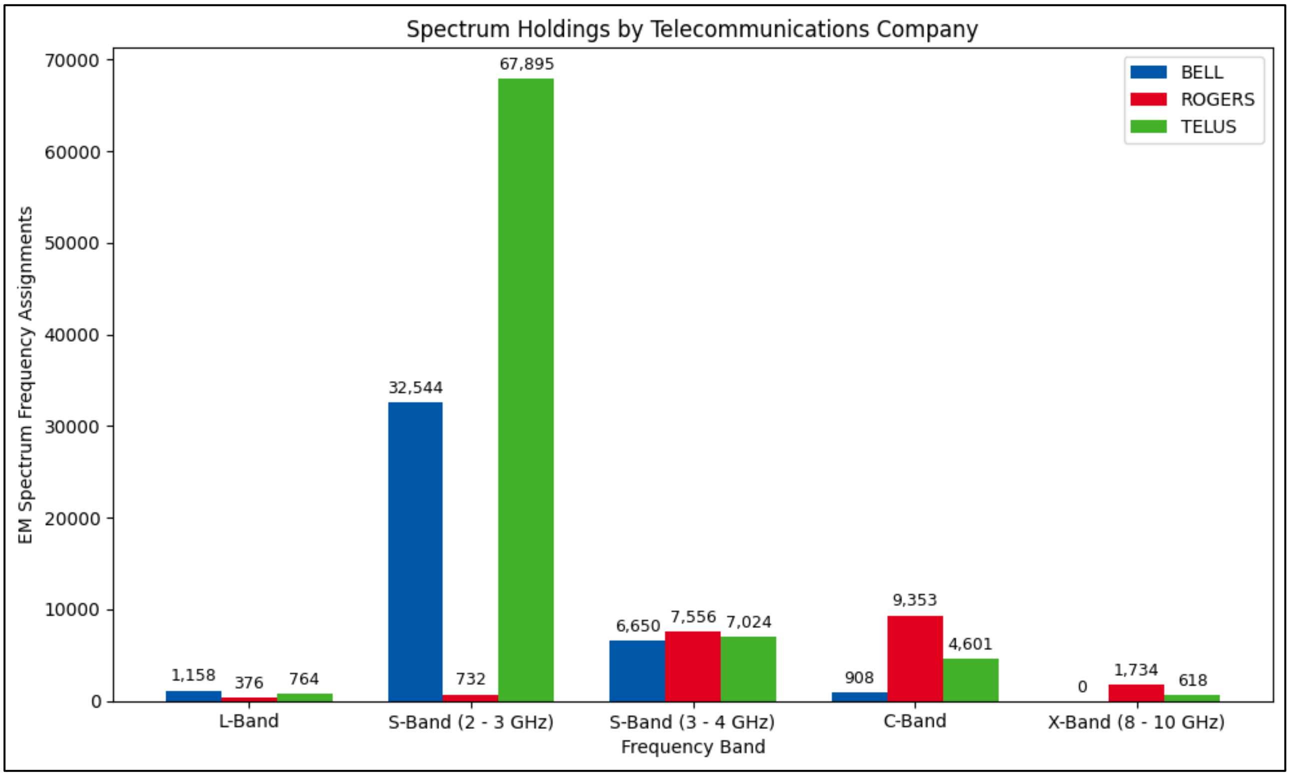
Source: Author's Own Calculations Using SMS Data

Figure 8: Spectrum Holdings by Telecommunications Company



Source: Author's Own Work Using SMS Data

Figure 9: Spectrum Holdings by Telecommunications Company



Source: Author's Own Work Using SMS Data

Canadian Armed Forces – Department of National Defence

As the GoC oversees a significant recapitalization of the CAF, sufficient bandwidth will be necessary to ensure the effectiveness and resilience of those systems in the face of interference. As previously discussed, this will require the GoC and ISED to allocate sufficient bandwidth to the CAF. Therefore, the CAF and DND are vital stakeholders in RF spectrum decision-making at both the international and domestic levels, and ensuring the appropriate bandwidth for the CAF will require a significant degree of political effectiveness from both.[34] That said, there is limited information on how DND coordinates with ISED to ensure this access. One of the few publicly available documents is *DAOD 6002-4, Radio Frequency Spectrum Management*. This document provides a snapshot of the importance of the RF spectrum to the CAF, as well as the key responsibilities of federal spectrum management (FSM) section heads,

[34] Political effectiveness: "Hence, the effort to obtain resources for military activity and the proficiency in acquiring those resources constitute political effectiveness… depending on the regime and circumstances, military services will face objections from civilian departments that other needs are more crucial to national welfare. In this limited sense, a military organization's political effectiveness depends on the ability to articulate its need more persuasively than its competitors can articulate their[s]." Allan R. Millett and Williamson Murray, *Military Effectiveness – Volume 1: The First World War* (Boston: Allen & Unwin, 1988), 4.

commanders, and users in ensuring effective spectrum management and minimizing interference to friendly and civilian systems.[35]

To obtain more information on DND-ISED RF spectrum coordination, the author interviewed a DND FSM section head. This FSM section head stated that DND has a memorandum of understanding that permits DND FSM to be embedded within ISED in the same building and to access ISED's spectrum management tools. Additionally, two ISED engineers work alongside DND FSM personnel to conduct equipment evaluations and studies to ensure that no radio interference is caused by or experienced as a result of DND and CAF operations. With respect to the WRCs, DND FSM participates in the Canadian Preparatory Committee and sends two representatives with the Canadian delegation. The head of the Canadian delegation from ISED holds a security clearance and is regularly briefed by DND FSM on sensitive matters that could be affected by ITU decisions. DND FSM also coordinates with North Atlantic Treaty Organization (NATO) and Five Eyes partners to communicate military interests to Canadian RF administrators. Finally, as in Canada, many allied countries also deploy members of their military spectrum management team to the WRCs to ensure that ITU decisions do not adversely affect the deterrent capabilities of Western forces.

Overall, this coordination is essential to ensuring that the CAF has the necessary spectrum access to meet its mission while enabling Canada's private sector to make full use of the mid-band spectrum. An important note is that, while beyond the scope of this paper, an area of future study should be the People's Republic of China's (PRC) influence at the ITU and its impact on CAF bandwidth access. That is, American officials often accuse the PRC of pushing an international standard at the ITU while maintaining different domestic rules, thereby maintaining its military effectiveness while degrading that of its neighbours or competitors. This is particularly problematic in the 3.3–3.45 GHz range, which, as the next section shows, is a critical band for radar systems. The PRC advocates for flexible use in this band while maintaining 5G domestically for indoor-only applications.[36] Moving on, this report now discusses the influence of the mid-band on key Canadian national security priorities.

[35] DND, "DAOD 6002-4, Radio Frequency Spectrum Management."
[36] Tom Karako, "Why Auctioning Military S-Band Spectrum Is a Bad Idea," Center for Strategic and International Studies (CSIS), June 9, 2025, https://www.csis.org/analysis/why-auctioning-military-s-band-spectrum-bad-idea.

Strategic Competition and the Role of the Mid-Band

The international security environment is undergoing its most significant change since the collapse of the Soviet Union, with many of the norms, institutions, and relationships upon which Canadian national security policy has been built changing rapidly. In this new security environment, Canada faces escalating threats across multiple vectors, challenging its priorities at home, on the continent, and around the world. In response, the GoC has made significant investments over the past year to ensure the maintenance of Canadian sovereignty, national security, and influence in key regions worldwide. This section emphasizes the critical role of the mid-band in enabling the GoC to pursue its objectives of economic security, air and missile defence, and Arctic sovereignty.

Economic Security and the Role of the Mid-Band in Resiliency and Potential

A key feature of modern strategic competition is that international economic interdependence has enabled states, especially great powers, to use economic tools to achieve geopolitical objectives with greater effectiveness. The use of economic tools in this way, sometimes referred to as geoeconomics, has elevated economic security as a chief national security concern for the GoC. For this report, economic security is understood to include two mutually reinforcing elements: resiliency and potential. Resiliency refers to Canada's capacity to withstand international shocks inevitably arising from the use of geoeconomics between great powers, as well as the use of geoeconomics against Canada. Potential refers to Canada's capacity to leverage its economic resources to achieve strategic objectives, such as establishing new economic and security relationships or enhancing the lethality and deterrent capabilities of the CAF.

Enhancing Canada's economic security will play an important role in deterring hostile action against Canada and in preparing the country should such action be taken. In the modern era, effective economic security is intrinsically tied to maintaining a technological edge, particularly through emerging technologies such as artificial intelligence (AI), quantum computing, and cloud computing.[37] *Budget 2025* recognized the importance of emerging technologies to the Canadian economy and invested $12 billion for emerging technology support for AI, quantum, and electric

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[37] James A. Lewis, "Spectrum Allocation for a Contest with China," CSIS, June 2023, 1, https://csis-website-prod.s3.amazonaws.com/s3fs-public/2023-06/230607_Lewis_SpectrumAllocation_China.pdf?VersionId=fSex_xlxHVd.iZcM8zUk8MFeMB_vMAK9.

vehicles, as well as $13 billion for a productivity super-deduction to make it more attractive for businesses to invest in productivity-enhancing assets.[38]

While these investments are undoubtedly needed, an underdiscussed aspect is the need for networks with greater capacity to optimize these technologies in business settings. In this case, 5G and 6G networks will have a synergistic relationship with emerging technologies in critical industries. That is, AI, the Internet of Things (IoT), edge computing, and 5G/6G will enable the real-time, high-performance data processing that is vital for optimizing critical industries such as manufacturing, mining, and shipping. In practice, AI would help analyze the massive amounts of data generated by IoT devices, edge computing would process the data locally, and 5G/6G would provide the capacity for fast, secure, and reliable communication between devices and edge servers.[39]

Therefore, as noted in Canada's *Spectrum Outlook 2023 to 2027*, the spectrum policy will need to ensure sufficient spectrum to meet the needs of privately owned and operated networks.[40] *Budget 2025* further emphasized that the GoC will ensure that industry has access to quality spectrum, including by releasing additional spectrum, consulting on a modernized Spectrum Licence Transfer Framework in late 2025–26, and continuing to use the streamlined framework for residual spectrum acquisitions established in 2021.[41] To ensure this access, the GoC will have to release more mid-band spectrum to meet this demand. That is, according to industry estimates, while a mix of low-, mid-, and high-band spectrum will be necessary, mid-band spectrum will be the most significant driver of 5G's economic benefits.[42]

Moreover, while unlicensed spectrum technologies, such as Wi-Fi, will play a role in enabling next-generation industrial applications, recent industry and academic studies suggest that these technologies are ill-suited for mission-critical applications.[43] For

[38] Department of Finance, *Canada Strong: Budget 2025* (2025), 21–84, https://budget.canada.ca/2025/report-rapport/pdf/budget-2025.pdf.
[39] Sobhan Pratha and Vanishree Mahesh, "Private 5G – Trends and Outlook," Infosys, 2025, 8, https://www.infosys.com/iki/documents/private-5g-trends-outlook.pdf; Leefke Grosjean et al., "5G-Enabled Smart Manufacturing," 5G-SMART, August 2022, 5, https://5gsmart.eu/wp-content/uploads/2022-5G-SMART-Booklet.pdf.
[40] ISED, *Spectrum Policy Framework for Canada*, 8; ISED, *Spectrum Outlook 2023 to 2027*.
[41] Department of Finance, *Canada Strong: Budget 2025*, 114.
[42] GSMA, "The Socio-Economic Benefits of Mid-Band 5G Services," February 2022, https://prod-cms.gsmaintelligence.com/research-file-download?confluenceId=69042280&filename=230221-Mid-band-5G-spectrum-benefits.pdf.
[43] Troy M. Morley, "The Promise of Private 5G in Defense and Public Safety: Mitigating Radio Frequency Challenges While Increasing Safety, Security, and Success," Frost & Sullivan, 2024, https://iscointl.com/wp-content/uploads/2024/09/Frost-Paper-Promise-of-5G-in-Defense-and-Public-Safety-FINAL-08-26-2024.pdf; Christian Arendt et al., "Towards Future Industrial Connectivity:

instance, in the manufacturing sector, Wi-Fi networks have been shown to be prone to unpredictability, latency fluctuations, and scalability restraints, making them ill-suited for critical industrial applications.[44] The extent to which this will further drive private demand into the military mid-band spectrum is currently unknown; however, the evidence suggests that more mid-band spectrum will be needed to support industrial applications.

Furthermore, beyond being a critical enabler of Canada's nation-building projects, mid-band 5G and 6G will also have military applications. For instance, 5G is a critical enabler of a modular factory, enabling machines to be quickly reconfigured to optimize production because it does not require wiring or any form of cable connections.[45] In this case, civilian manufacturing could be rapidly converted to defence production during periods of heightened tensions or war, thereby contributing to Canada's deterrent and war-fighting capabilities. Additionally, a 5G-enabled harbour and Royal Canadian Navy can communicate with one another quickly, thereby relieving satellite communications and enabling rapid exchanges of data-intensive information with headquarters.[46]

Overall, the mid-band will play a crucial role across key industries in Canada, including mining, ports/shipping, and manufacturing, thereby contributing significantly to Canada's economic security. The role of 5G and 6G in these commercial applications will drive mid-band access, which is at odds with the next application of mid-band spectrum: air and missile defence.

Air and Missile Defence and the Role of the Mid-Band in Continental Defence

Russia's war on Ukraine, the Iran-Israel conflict, and the Houthis' attacks on maritime shipping in the Red Sea all continue to emphasize the escalating role that offensive missiles have in modern conflict.[47] In particular, Russia and the PRC increasingly see offensive missiles as a means of coercing and intimidating their neighbours both in

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Evaluation of Private 5G and Wi-Fi Networks in Professional Industrial Environments," *2025 IEEE 21st International Conference on Factory Communication Systems*, Rostock, Germany, 2025, https://ieeexplore.ieee.org/document/11077629/authors#authors.

[44] William O'Brien et al., "Performance Benchmarking of Private 5G Networks," *Computer Networks* 272 (November 2025), https://www.sciencedirect.com/science/article/pii/S1389128625006358.

[45] GMSA, "Socio-Economic Benefits of Mid-Band 5G Services."

[46] D. Zmysłowski et al., "Naval Use Cases of 5G Technology," *International Journal of Marine Navigation and Safety of Sea Transportation* 17, no. 3 (2023): 600, https://www.transnav.eu/Article_Naval_Use_Cases_of_5G_Technology_Zmysłowski,67,1331.html.

[47] Brigadier General Houston Cantwell (Ret.), "Homeland Sanctuary Lost: Urgent Actions to Secure the Arctic Flank," Mitchell Institute *Policy Paper* 61 (September 2025): 7–8, https://www.mitchellaerospacepower.org/app/uploads/2025/08/61_Arctic_Security-FINAL.pdf.

peacetime and in crisis.[48] For North America, competitors' long-range precision-strike capabilities have afforded them new tools to threaten critical infrastructure in Canada and the US. In practice, these weapons serve as a means to alter decision-makers' calculus, test the public's appetite for foreign military operations, and delay or deter action on NATO's flanks or in the South China Sea.[49] Given that the shortest path for a missile to reach North America is through the Arctic, Canada's geography once again places it in the line of fire for great power competition.

Recognizing the growing threat posed by long-range precision strikes, Canada and the US approved a joint statement in 2021 to strengthen the North American Aerospace Defence Command (NORAD) against evolving threats, and in 2022, the GoC pledged $38.6 billion to modernize NORAD.[50] More recently, Canada has expressed interest in the US Golden Dome initiative, with Minister of National Defence David McGuinty confirming in July 2025 that the GoC has removed all historical restrictions on air and missile defence for Canada.[51]

While limited information exists on Canada's role in the Golden Dome (or the Canadian Shield, as it is sometimes called), the US describes the initiative as a means to field a system of systems capable of defending against hypersonic, ballistic, and cruise missiles, as well as airborne threats such as drones.[52] Notably, while the Golden Dome initiative has only recently been announced, the Royal Canadian Air Force general in charge of Canada's NORAD modernization effort, Major-General J.D. Smith, has emphasized that the Air Force has been preparing for the Golden Dome for years as

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48 Tom Karako et al., "North America Is a Region, Too," CSIS, July 14, 2022, 1, https://www.csis.org/analysis/north-america-region-too.

49 Cantwell, "Homeland Sanctuary Lost," 7–8; Caitlin Lee with Aidan Poling, "Bolstering Arctic Domain Awareness to Deter Air & Missile Threats to the Homeland," Mitchell Institute *Policy Paper* 41 (June 2023): 6, https://www.mitchellaerospacepower.org/app/uploads/2023/06/41-Bolstering-Arctic-Domain-Awareness-FINAL.pdf.

50 P. Whitney Lackenbauer, "NORAD Modernization, Golden Dome, and/or 'Canadian Shield'?: Canada Needs Its Own Narrative," North American and Arctic Defence and Security Network (NAADSN) *Quick Impact*, October 9, 2025, 1, https://www.naadsn.ca/wp-content/uploads/2025/10/25oct9-NORADmod-NDDN-lackenbauer-QI.pdf; Government of Canada, "NORAD Modernization Project Timelines," last modified November 22, 2024, https://www.canada.ca/en/department-national-defence/services/operations/allies-partners/norad/norad-modernization-project-timelines.html.

51 Alexander Panetta, "Canada Wants to Join Golden Dome Missile-Defence Program, Trump Says," CBC News, May 20, 2025, https://www.cbc.ca/news/world/golden-dome-trump-us-missile-defence-canada-1.7539390; DND, News Release, "Minister McGuinty Visits NORAD," Government of Canada, July 16, 2025, https://www.canada.ca/en/department-national-defence/news/2025/07/minister-mcguinty-visits-norad.html.

52 Bryan Clark, "The US Military Will Need More, Not Less, Access to Electromagnetic Spectrum," Hudson Institute, February 19, 2025, https://www.hudson.org/defense-strategy/us-military-will-need-more-not-less-access-electromagnetic-spectrum-bryan-clark.

part of its work to shore up Canada's military presence in the Arctic and modernize North America's air defences.[53]

Two key factors fuel investment in NORAD modernization. First, as testified by P. Whitney Lackenbauer, deterrence by punishment – relying solely on the threat of retaliation – is no longer sufficient, and NORAD needs to be able to deter by denial, requiring Canada and the US to be able to detect and defeat threats before they reach the shores of the continent.[54] Second, due to the physics involved, L-band North Warning Systems radars are increasingly limited in their ability to detect the range of new threats to the continent.[55] These emerging threats include advanced countermeasures employed by ballistic missiles, as well as the new threats posed by hypersonic cruise missiles and hypersonic glide vehicles.

Each of these missiles, as shown in Figure 10, has a distinct flight path and manoeuvrability. Ballistic missiles follow a parabolic trajectory, with flight divided into three phases: boost, midcourse, and re-entry. Modern ballistic missiles also feature manoeuvrable re-entry vehicles, independently targetable re-entry vehicles, decoys, and jamming, all of which complicate their identification, discrimination, and engagement.[56] Hypersonic glide vehicles are a special type of re-entry vehicle that do not travel in a parabolic shape but instead, once released, start to 'glide' at hypersonic speeds to their targets with greater manoeuvrability than ballistic missiles.[57] Finally, hypersonic cruise missiles operate within the atmosphere and have less efficient flight trajectories than ballistic missiles. However, like hypersonic glide vehicles, they are far more manoeuvrable and unpredictable in their trajectories.[58] Importantly, each missile can be equipped with conventional or nuclear capabilities and launched from the air, land, sea, or undersea.[59] Finally, a key consideration for cruise missile defence is that,

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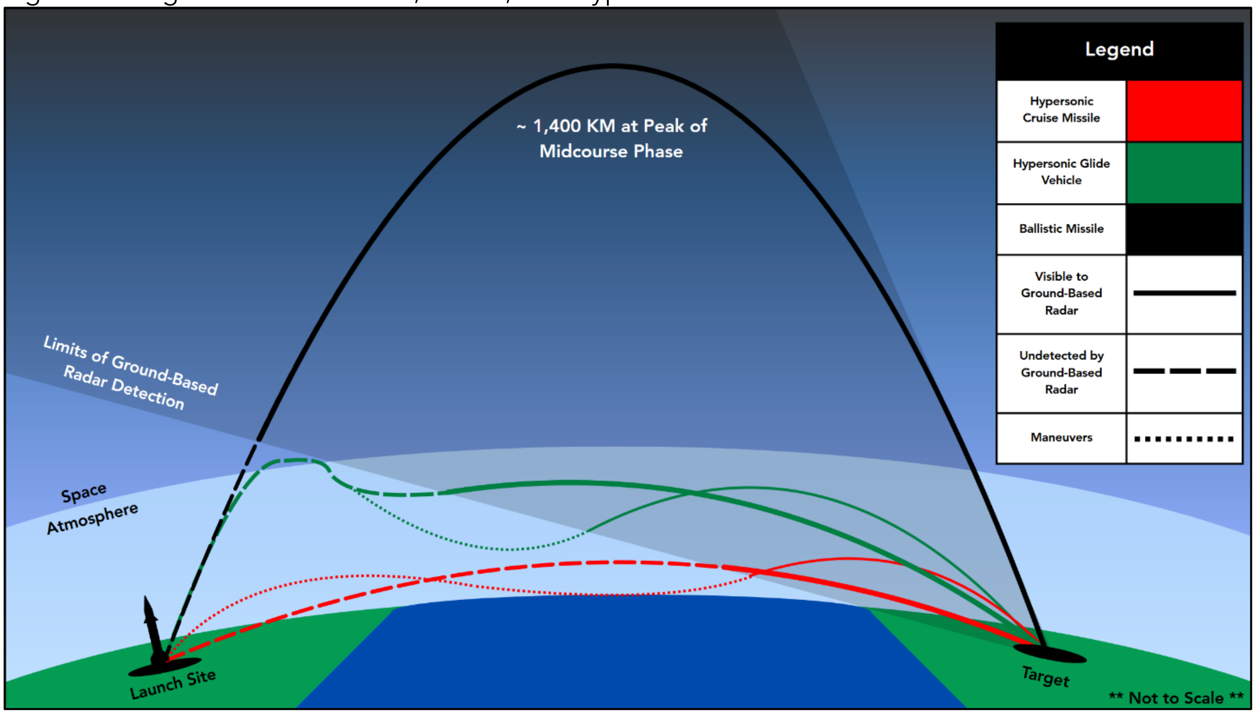
[53] Gavin John, "Canada Has Been Working for Years to Prepare for Golden Dome, Air Force General Says," *The Globe and Mail*, October 8, 2025, last modified October 9, 2025, https://www.theglobeandmail.com/canada/article-canada-prepare-golden-dome-air-force-general/.
[54] Lackenbauer, "NORAD Modernization, Golden Dome, and/or 'Canadian Shield'?," 1; Government of Canada, "NORAD Modernization Project Timelines."
[55] House of Commons, "A Secure and Sovereign Arctic: Report of the Standing Committee on National Defence" (44th Parliament, 1st Session, April 2023), 34, https://www.ourcommons.ca/Content/Committee/441/NDDN/Reports/RP12342748/nddnrp03/nddnrp03-e.pdf.
[56] Fontana and Di Lauro, "Overview of Sensors for Long Range Missile Defense," 4–9.
[57] Fontana and Di Lauro, "Overview of Sensors for Long Range Missile Defense," 4–9.
[58] Fontana and Di Lauro, "Overview of Sensors for Long Range Missile Defense," 4–9; Steve Lambakis, *Space Sensors and Missile Defense* (Fairfax: National Institute Press, August 2023), 3, https://nipp.org/wp-content/uploads/2023/08/Space-Sensors-2023.pdf.
[59] Andrea Charron, "Golden Dome and Canada: The 'New' Age of Integrated Air and Missile Defence," CDA Institute, August 25, 2025, https://cdainstitute.ca/golden-dome-and-canada-the-new-age-of-integrated-air-and-missile-defence/.

while ballistic missiles provide decision-makers with tens of minutes to respond to threats, cruise missiles – depending on their launch locations – reduce that response time to just over two minutes.[60]

Figure 10: Flight Paths for Ballistic, Cruise, and Hypersonic Glide Vehicles



Source: Author's Own Work Based on the Figures Produced by the Economist and the US Government Accountability Office Documents[61]

A key reason for this reduced response time is that most radars cannot see beyond the horizon. The only radar capable of this mission is high-frequency (HF) Over-the-Horizon Radar (OTHR). These radars are thus ideal for early warning, hence the GoC's investment in two, which are expected to be operational by 2033.[62] However, for the mission of target tracking, discrimination, and illumination for interceptors, higher resolution and accuracy are required. Therefore, mid-band radars will be crucial. In particular, because of the relationship between range, reliability, and resolution, S-band and X-band radars are crucial to air and missile defence. X-band radars provide

[60] Karako et al., "North America Is a Region, Too," 6.
[61] *The Economist*, "What Are the 'Hypersonic' Missiles Russia Has Used in Ukraine?," March 22, 2022, https://www.economist.com/what-are-the-hypersonic-missiles-russia-says-it-used-in-ukraine; Jon Ludwigson, "Hypersonic Weapons: DOD Should Clarify Roles and Responsibilities to Ensure Coordination Across Development Efforts," United States Government Accountability Office Report to Congressional Addressees, March 2021, 4, https://www.gao.gov/assets/720/713180.pdf; Government Accountability Office, "Missile Defense: Better Oversight Needed for Counter-Hypersonic Development," United States Government Accountability Office Report to Congressional Committees, June 2022, 11, 40, https://www.gao.gov/assets/gao-22-105075.pdf.
[62] Government of Canada, "NORAD Modernization Project Timelines."

the higher resolution necessary to illuminate targets, whereas S-band radars are less attenuated by adverse weather, making them useful for missile engagement under such conditions. Both radars are used extensively in the US's existing ballistic missile defence initiative, including the Long-Range Discrimination Radar in Alaska (S-band) and the sea-based X-band radars.[63]

One key feature of mid-band radars is that their antennas are sufficiently small to allow them to be mounted on mobile platforms, thereby increasing the over-the-horizon range of their radars. For example, in the air domain, the Erieye Extended Range S-band radar is featured on Saab's GlobalEye airborne early warning and control (AWAC) platform, and Canada's CP-140 utilizes the AN/APS-508 X-band radar.[64] In the sea domain, the Aegis Combat System aboard US naval vessels typically employs the SPY-6 radar, which uses S-band for volume and horizon search and X-band for the terminal illumination of targets.[65] For Canada, the new River-class destroyer is expected to feature the SPY-7 radar, which operates solely in the S-band and has been shown to independently discriminate and illuminate targets for interceptors.[66]

Overall, the key takeaway from this section is that continental air and missile defence and NORAD modernization will be a spectrum-intensive task and a major driver of mid-band spectrum demand. Given the physics involved, the functions of S-band and X-band radars cannot be replaced or relocated, and the CAF will require sufficient access to these bands and their bandwidths to detect, deter, and defeat threats to the continent. Moreover, this same mid-band spectrum will also be crucial for the next GoC priority: ensuring Arctic sovereignty.

Arctic Sovereignty and the Role of the Mid-Band in Domain Awareness

As climate change warms the Earth, the Canadian Arctic is becoming increasingly accessible to state and commercial interests. This access will help close the spatial socio-economic gap in Canada by generating new economic activities in mining,

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[63] Government Accountability Office, "Missile Defense."
[64] Thomas Newdick, "Saab GlobalEye Set to Challenge Boeing E-7 as Canada's New Radar Plane," TWZ, May 28, 2025, https://www.twz.com/air/saab-globaleye-set-to-challenge-boeing-e-7-as-canadas-new-radar-plane; Martie M. Goulding et al., "The CP140 Imaging Radar System AN/APS-508: Architecture and Early Flight Test Results," *2009 IEEE Radar Conference*, Pasadena, CA, 2009, 2, https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=4977034.
[65] Moo and DiFilippo, "Considerations for Development of Naval Multifunction Radio Frequency (RF) Systems," 6; Fontana and Di Lauro, " Overview of Sensors for Long Range Missile Defense," 8.
[66] Royal Canadian Navy (RCN), "River-Class Destroyer," Government of Canada, n.d., https://www.canada.ca/en/navy/corporate/fleet-units/surface/river-class-destroyer.html; Lee Willett, "Live Tracking Test Demonstrates SPY-7 Capability and Scalability," Naval News, January 15, 2025, https://www.navalnews.com/event-news/sna-2025/2025/01/live-tracking-test-demonstrates-spy-7-capability-and-scalability/.

fishing, and tourism, but it will also increase the risk of unauthorized or unregulated vessels engaging in illegal activities or preparing for hostile actions against Canada.[67] To maximize the economic prospects for Arctic communities while reducing the security threats to Canada, effective domain awareness will be crucial. To that end, the GoC, through *Our North, Strong and Free,* the *Arctic Foreign Policy*, and *Budget 2025,* has made ensuring Canada's Arctic sovereignty through domain awareness a priority. Key investments include the replacement of the CP-140 Aurora, the Enhanced Satellite Communications Projects, and the Arctic Infrastructure Fund to support dual-use transportation projects.[68]

Effective domain awareness will require a system of systems that encompasses a range of equipment – from navigation aids to satellites – enabling communications and Arctic imagery. Many of these systems require mid-band access to function. For example, as the 10th-largest spectrum holder, the Canadian Coast Guard (CCG), as shown by Figure 11, operates a range of mid-band communications systems, radars, and navigational aids that are crucial for ensuring safety and awareness in the Arctic. Of particular note, the CCG fixed-base RF assignments in Inuvik, Hay River, Resolute Bay, Cambridge Bay, Coral Harbour, Sainte-Flavie, Heath Point, Killiniq, and Iqaluit all use C-band fixed satellite service (FSS) for internet connectivity and communications. Additionally, in accordance with the International Convention for the Safety of Life at Sea (SOLAS) regulations requiring all vessels above 3,000 tonnes to have S-band and X-band navigation radars, the CCG operates several fixed-base station radio navigation beacons (RACONs) at these frequencies to provide safe navigation throughout the Canadian Archipelago.[69]

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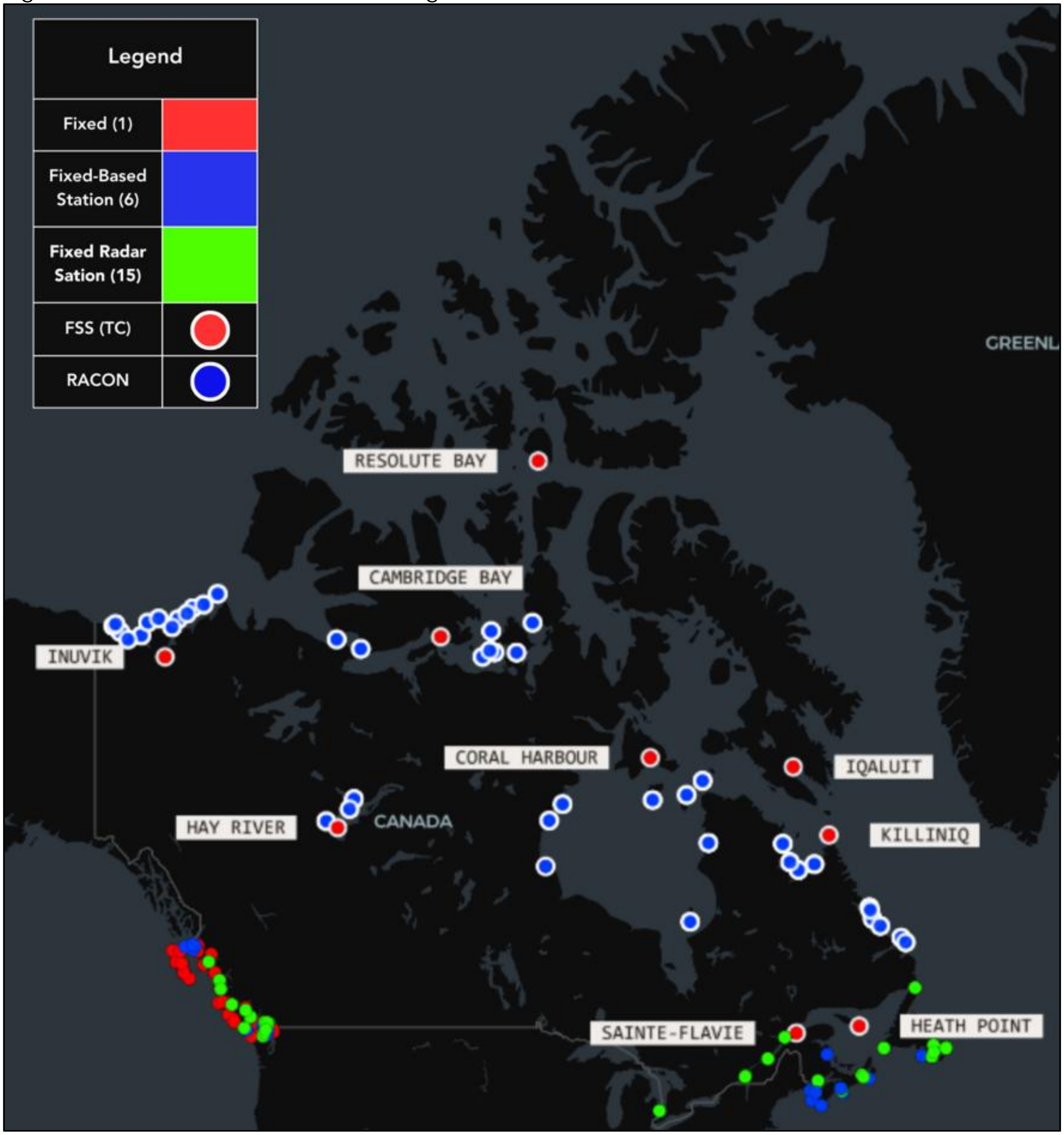
[67] Office of the Auditor General of Canada, "Arctic Waters Surveillance," 2023, https://www.oag-bvg.gc.ca/internet/English/att__e_44160.html#hd5c.
[68] Government of Canada, *Canada's Arctic Foreign Policy* (2024), 18, https://www.international.gc.ca/gac-amc/assets/pdfs/publications/arctic-arctique/arctic-policy-politique-en.pdf; DND, "Enhanced Satellite Communications Project – Polar," Government of Canada, last modified December 1, 2024, https://apps.forces.gc.ca/en/defence-capabilities-blueprint/project-details.asp?id=1279; Department of Finance, *Canada Strong: Budget 2025*, 27, 137.
[69] International Maritime Organization (IMO), "Annex 34: Resolution MSC.192(79)," December 6, 2004, 5, https://wwwcdn.imo.org/localresources/en/KnowledgeCentre/IndexofIMOResolutions/MSCResolutions/MSC.192(79).pdf; Department of Justice Canada, "Navigation Safety Regulations, 2020," last modified December 20, 2023, 14, https://laws-lois.justice.gc.ca/PDF/SOR-2020-216.pdf.

Figure 11: Canadian Coast Guard RF Assignments in the Mid-Band



Source: Author's Own Work Using SMS Data

The Royal Canadian Navy also contributes to Arctic maritime domain awareness through the Canadian Arctic and Offshore Patrol Vessels (AOPVs), which perform a range of tasks, including surveillance operations in the Canadian Arctic.[70] In

[70] DND, "Arctic and Offshore Patrol Ships," Government of Canada, last modified February 27, 2025, https://www.canada.ca/en/department-national-defence/services/procurement/arctic-offshore-patrol-ships.html.

accordance with SOLAS requirements, Canada's AOPVs are equipped with Kelvin Hughes Sharpeye X-band and S-band navigation radar systems.[71] The Royal Canadian Air Force contributes to Arctic domain awareness through aerial patrols conducted by the CP-140 Aurora.[72] The CP-140 operates the AN/APS-508 X-band detection, tracking, and imaging radar for weather avoidance and maritime- and ground-mapping missions.[73] Similarly, the replacement aircraft, the P-8A Poseidon, features an X-band AN/APS radar for ultra-high-resolution imaging modes in maritime and overland operations.[74]

Satellites also play a crucial role in domain awareness by providing imagery, relaying Automatic Identification System signals, and providing internet and connectivity for Arctic communities and CAF operations. Of particular note, with the absence of terrestrial backhaul, FSSs provided by the C-band are crucial to supporting voice, video, and data services across the Canadian Archipelago.[75] To convey the importance of these bands for Arctic communities, take Kate Todd's July 2025 *Canadian Arctic Maritime Infrastructure Assessment* (CAMIA), which provided a comprehensive inventory of Arctic infrastructure that could support future CAF operations.[76] Figure 12 cross-references this list of communities with those communities with FSS assignments in the 3.7 – 4.0 GHz range - which as of March 2025, only satellite-dependent communities are allowed to operate in. As the figure shows this band is heavily utilized for FSS across the Canadian Arctic and will likely be crucial for supporting future CAF operations.

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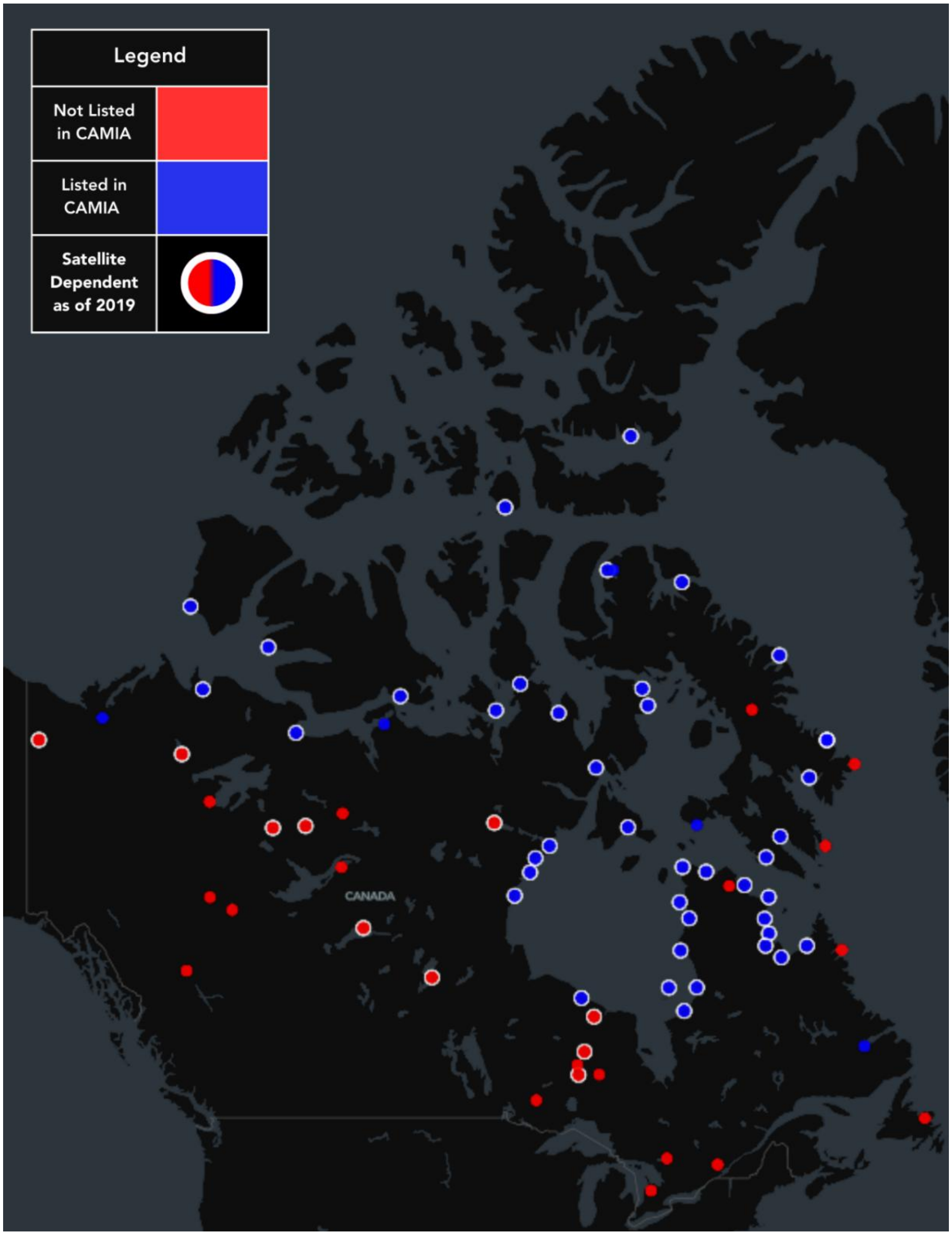
[71] Lieutenant (N) Ken Tse, "Combat Suite Overview for the Arctic and Offshore Patrol Vessels," *Maritime Engineering Journal* (Fall 2022): 35–37, https://www.canada.ca/content/dam/dnd-mdn/documents/mej/42-071-maritime-engineering-journal-102.pdf.
[72] Office of the Auditor General of Canada, "Arctic Waters Surveillance."
[73] DND, "CP-140 Aurora Fleet Modernization and Life Extension," Government of Canada, last modified June 30, 2023, https://www.canada.ca/en/department-national-defence/services/procurement/cp-140-aurora.html.
[74] John Keller, "Raytheon to Provide Airborne Surveillance Radar Imaging Capability for Navy P8-A Poseidon Patrol Aircraft," Military Aerospace Electronics, June 25, 2024, https://www.militaryaerospace.com/sensors/article/55090142/raytheon-technologies-corp-airborne-surveillance-radar-imaging; Gu Min Chul, "South Korean Navy Receives First P8-A Poseidon Aircraft," Defence Blog, June 21, 2024, https://defence-blog.com/south-korean-navy-receives-first-p-8a-poseidon-aircraft/; DND, "Canadian Multi-Mission Aircraft Project," Government of Canada, last modified January 9, 2026, https://www.canada.ca/en/services/defence/defence-equipment-purchases-upgrades/air-equipment-procurement/canadian-multi-mission-aircraft-project.html.
[75] ISED, *Spectrum Policy Framework for Canada*, 8; ISED, *Spectrum Outlook 2023 to 2027*.
[76] Kate E. Todd, *Canadian Arctic Maritime Infrastructure Assessment*, 1st ed. (Canadian Maritime Security Network, September 2025), https://www.cmsn.ca/_files/ugd/0bcbee_ddf2cdb7dc1e41f08b47596fe2c61c1b.pdf.

Figure 12: CAMIA Communities with FSS Assignments in the 3.7–4.0 GHz Range



Source: Author's Own Work Using Information Gathered from SMS Data, Canada's High-Speed Access for All Connectivity Strategy, and CMSN's CAMIA Report[77]

[77] Todd, *Canadian Arctic Maritime Infrastructure Assessment*; ISED, *High-Speed Access for All: Canada's Connectivity Strategy* (2019), https://ised-isde.canada.ca/site/high-speed-internet-canada/en/canadas-connectivity-strategy/high-speed-access-all-canadas-connectivity-strategy.

For the CAF, X-band FSS provides crucial communications and connections for future Arctic operations. Currently, CAF/DND X-band communications rely on US satellites (the Wideband Global SATCOM and the Advanced Extremely High Frequency constellation), but in the future, the CAF will use two military satellites through the Enhanced Satellite Communications Project – Polar.[78] This project's satellites will be in highly elliptical orbit and provide wideband communications at X- and Ka-band frequencies, as well as UHF narrowband communications over the North Pole.[79] Additionally, Telesat's Lightspeed constellation, comprising 198 low-Earth-orbit (LEO) satellites scheduled for launch in 2026, is expected to play a key role in supporting Canadian domain awareness and CAF communications in the Arctic.[80]

Finally, for satellite imaging and Automatic Identification System signal relay, the GoC relies primarily on the Canadian RADARSAT-2 and RADARSAT Constellation Mission satellites.[81] This mission depends on the S-band for command and telemetry reception, the C-band for radar imaging, and the X-band for data reception and station operations.[82] Currently, the RADARSAT mission is at full capacity and struggles to accommodate all demands from federal organizations for radar imaging in Canadian territory.[83] That said, the CAF's reliance on the RADARSAT mission is set to be replaced by a CAF/DND-specific asset in the Defence Enhanced Surveillance from Space Projects, which will likely use similar mid-band frequencies as the RADARSAT mission.[84]

Overall, the key to this section is that, as with economic security and air and missile defence, the mission of domain awareness in the Canadian Arctic will be a mid-band,

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[78] Elinor Sloan, "Communications Satellites in Canadian Security Policy: History and Prospects," *International Journal* 76, no. 2 (June 2021): 213–215, https://journals.sagepub.com/doi/epub/10.1177/00207020211016476.

[79] Sloan, "Communications Satellites in Canadian Security Policy," 215; DND, "Enhanced Satellite Communications Project – Polar."

[80] Karen L. Jones and Lina M. Cashin, "Space-Enabled Capabilities for Connecting and Collaborating in the Arctic," Center for Space Policy and Strategy, October 2024, 8, https://csps.aerospace.org/sites/default/files/2024-11/04c_Arctic_Jones-Cashin_20241104.pdf; Prime Minister of Canada, "High-Speed Internet Across the Country with Canada's Largest Space Program," September 13, 2024, https://www.pm.gc.ca/en/news/news-releases/2024/09/13/high-speed-internet-across-country-canadas-largest-space-program.

[81] Office of the Auditor General of Canada, "Arctic Waters Surveillance."; Canadian Space Agency, "RADARSAT Satellites: Technical Comparison," Government of Canada, last modified January 12, 2021, https://www.asc-csa.gc.ca/eng/satellites/radarsat/technical-features/radarsat-comparison.asp; Canadian Space Agency, "Components and Specifics," Government of Canada, last modified December 19, 2019, https://www.asc-csa.gc.ca/eng/satellites/radarsat/technical-features/components.asp.

[82] Canadian Space Agency, "RADARSAT Satellites"

[83] Office of the Auditor General of Canada, "Arctic Waters Surveillance."

[84] DND, "Defence Enhanced Surveillance from Space – Project (DESSP)," Government of Canada, last modified December 1, 2024, https://apps.forces.gc.ca/en/defence-capabilities-blueprint/project-details.asp?id=1791.

spectrum-intensive undertaking. This band is critical for providing connectivity to Arctic communities, enabling radar aboard aircraft and naval vessels, and ensuring accurate satellite imaging of Canadian territory.

The Mid-Band Spectrum Standoff

As the previous section showcased, access to the mid-band will be critical for a range of GoC national security priorities. However, these priorities will at times conflict over access to spectrum, necessitating the GoC to make difficult decisions on mid-band spectrum allocation. This section's purpose is to provide an overview of how Canada has responded to the spectrum standoff, why this response may be inadequate moving forward, and the key differences between Canada's response and those of Australia, the UK, and the US.

Canada's Response to the Spectrum Standoff

Over the past 35 years, the number of mobile device users worldwide has dramatically increased. In 1990, there were approximately 12 million subscribers to mobile networks; by 2025, that number was projected to reach 50 billion.[85] Despite the more efficient use of the RF spectrum with each successive generation of mobile networks, each generation has required greater spectrum to meet demand. Third-generation used 5 MHz, fourth-generation (4G) used 20 MHz, 5G uses 100 MHz, and 6G is expected to need 400 MHz.[86] The increasing use of higher frequencies has, as previously discussed, also enabled new industrial applications, with experts likening the transition from 4G to 5G to that from the typewriter to the computer.[87] In the words of one commentator, not prioritizing 5G and 6G would be like deciding in the 19th century not to build railroads and telegraph networks.[88]

In response to the national security imperative for commercial access to the mid-band, the GoC has made mid-band spectrum available through both auctions and non-competitive licences (NCLs).[89] Consistent with the global ecosystem, Canada has

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[85] GSMA, "Introducing Radio Spectrum"; ITU, "5G – Fifth Generation of Mobile Technologies," last modified August 2024, https://www.itu.int/en/mediacentre/backgrounders/Pages/5G-fifth-generation-of-mobile-technologies.aspx.
[86] 5G Americas, "6G Upgrade in the 7-8 GHz Spectrum Range," 11.
[87] NI, "The Future of 5G and AI in Telecommunications," May 13, 2024, https://www.ni.com/en/solutions/5g-6g/future-5g-ai-telecommunications.html.
[88] Lewis, "Spectrum Allocation for a Contest with China," 1.
[89] First-come, first-served licences that must be held by the licensee. ISED, "Non-Competitive Local Licensing (NCLL)," Government of Canada, last modified May 14, 2025, https://ised-isde.canada.ca/site/spectrum-management-telecommunications/en/licences-and-certificates/non-competitive-local-licensing-ncll.

focused on the 3.5 GHz band (3.3–4.2 GHz) and, at the time of writing this report, has allocated 530 MHz of this band for 5G. This includes auctions of 200 MHz in the 3.45-3.65 GHz range and 250 MHz in the 3.65-3.90 GHz range, as well as an additional 80 MHz in the 3.90-3.98 GHz range made available through NCLs.[90]

Of particular note for economic security, the 3.94–3.98 GHz range is available only to small commercial mobile providers and non-traditional users (i.e., mining, manufacturing, public safety, and health care).[91] According to the SMS, licensees that have acquired spectrum in this range include mining licensees such as Trans Mountain Pipeline LP, Varis Mine Technology Ltd., and Rio Tinto, as well as GoC departments such as the Canadian Centre for Cyber Security (CCCS). This band should be viewed as the initial rollout of 'Private 5G' networks, which are dedicated and purpose-built for private use.[92] As shown in Table 3, there are numerous types of private 5G networks, many of which will be deployed in tandem with larger commercial networks. Importantly, these networks are crucial to enabling the activities mentioned in the economic security section above.

[90] ISED, "Auction: 3500 MHz," Government of Canada, last modified March 24, 2022, https://ised-isde.canada.ca/site/spectrum-management-telecommunications/en/spectrum-allocation/spectrum-auctions/spectrum-auction-publications/auction-spectrum-licences-3500-mhz-band; ISED, "Auction: 3800 MHz," Government of Canada, last modified June 5, 2024, https://ised-isde.canada.ca/site/spectrum-management-telecommunications/en/spectrum-allocation/spectrum-auctions/spectrum-auction-publications/auction-spectrum-licences-3800-mhz-band; ISED, "Decision on a Non-Competitive Local Licensing Framework, Including Spectrum in the 3900-3980 MHz Band and Portions of the 26, 28 and 38 GHz Bands," Government of Canada, May 2023, 63, https://ised-isde.canada.ca/site/spectrum-management-telecommunications/sites/default/files/attachments/2023/ncldecisionpaper2023-en-v2023jun.pdf.
[91] ISED, "Decision on a Non-Competitive Local Licensing Framework," 63.
[92] Government of Canada, "Private 5G Networks (ITSAP.80.117)," April 2025, https://www.cyber.gc.ca/en/guidance/private-5g-networks-itsap80117.

Table 3: Deployment Models for Private 5G Networks

Deployment Model	Description	Benefits	CCCS Recommendations
Standalone	Fully isolated and controlled by the organization, including the radio access network (RAN) and core functions. The organization deploys, owns, and operates the networks while overseeing subscriber management and authentication mechanisms.	Complete isolation from public networks. Most secure option.	High-security applications and critical infrastructure. Large organizations with resources and expertise that want complete control.
Shared RAN	Combine elements of private and public 5G networks. Uses the existing RAN infrastructure of a mobile network operator (MNO) while keeping control of core function and user plane traffic.	Large-scale deployments, such as utility metre connectivity, emergency services, and mobile devices requiring seamless roaming.	Suitable for organizations looking to balance control and cost.
Share RAN and Control Plane	Uses the MNO's RAN infrastructure, control plane, and core functions while retaining the user plane.	Reduces network operations and management efforts, allowing organizations to focus on the functional and operational aspects of their business.	Suitable for organizations looking to balance control and cost.
Network Slicing	Creates isolated virtual networks within a public 5G infrastructure. This means organizations can have their own dedicated slice of the public 5G network.	Lowest-cost option with the quickest time to market.	Suitable for organizations focused on developing multiple types of applications or on providing services with distinct performance requirements.

Source: Government of Canada, "Private 5G Networks (ITSAP.80.117)," April 2025, https://www.cyber.gc.ca/en/guidance/private-5g-networks-itsap80117.

In line with international spectrum developments, the GoC has also announced plans to auction high-band spectrum, specifically in the 26 GHz and 38 GHz range, which falls within the Ka-band.[93] However, moving forward, an important consideration in 5G development is the relationship between frequency and range. That is, high-frequency bands will be essential for providing high capacity in industrial applications, but they have limited range and are more adversely affected by attenuation. In this case, the evidence suggests that overreliance on high band will increase costs and delay the rollout of 5G for Canada. More specifically, as the GSMA has noted, the cost of 5G rollout, without additional mid-band spectrum, is expected to be 3 to 5 times higher and its carbon footprint 1.8 to 2.9 times higher.[94]

Beyond the specific spectrum allocations, the GoC also publishes Spectrum Outlooks every several years. The most recent of these documents, the *Spectrum Outlook 2023 to 2027*, highlights that Canada's spectrum policy is guided by five key themes to inform ISED's spectrum management activities: spectrum as an economic driver and enabler of Industry 4.0; rural connectivity in the wake of COVID-19; Indigenous connectivity; spectrum, wireless technology, and climate change; and competition and wireless affordability. While these policy themes are important, the document omits a larger discussion of the crucial role of spectrum in national defence and, critically, underestimates the spectrum requirements expected for 5G.

Future Bands for 5G and 6G

Based on capacity demands from both public and private networks, as well as from fixed wireless access technologies, experts have recommended that governments plan to allocate, on average, an additional 2 GHz of mid-band spectrum for 5G.[95] In particular, while legacy mobile spectrum in the low-band and lower S-band can help meet 5G demands, industry experts estimate that most of the capacity-intensive spectrum will have to come from the 3–7 GHz range. The bands specifically highlighted

[93] ISED, News Release, "Government of Canada Announces Additional Spectrum to Support Improved Connectivity and Innovative 5G Applications," Government of Canada, March 6, 2025, https://www.canada.ca/en/innovation-science-economic-development/news/2025/03/government-of-canada-announces-additional-spectrum-to-support-improved-connectivity-and-innovative-5g-applications.html; Stefan Zehle and David Tanner, "Estimating the Mid-Band Spectrum Needs in the 2025-2030 Time Frame," Coleago Consulting Ltd., July 2021, https://www.coleago.com/insights/estimating-mid-bands-spectrum-needs-for-2025-30-timeframe/.
[94] Zehle and Tanner, "Estimating the Mid-Band Spectrum Needs in the 2025-2030 Time Frame," 2.
[95] Fixed wireless access is Wi-Fi provided by 5G radio signals. Zehle and Tanner, "Estimating the Mid-Band Spectrum Needs in the 2025-2030 Time Frame."

include the 3.3–4.2 GHz, 4.8–5.0 GHz, 5.925–6.425 GHz, and 6.425–7.125 GHz ranges.[96] Notably, at the time of writing this report, Canada is not considering the latter three for deployment.

In addition to these spectrum allocations, WRC-27 has identified the 4.4–4.8 and 7.125–8.4 GHz ranges as candidates for 6G and will begin exploration at the next WRC; however, for Region 2, only the 7.125–8.4 GHz range is being explored.[97] A key consideration for the deployment of 6G is that the band selected has to be close enough to 5G bands to reuse existing cell sites without network degradation – to lower costs and also for energy savings and sustainability purposes – and due to the propagation characteristics in higher-frequency bands not being suitable for wide area deployments.[98]

Overall, the accuracy of the 2 GHz figure for Canada is unclear, given that the study that reported this figure examined cities with much higher population densities than Canada. However, the evidence suggests that further reallocation of existing mid-band spectrum to accommodate 5G will be necessary. This process will not be easy, given the range of radar and communications services currently being conducted by the CAF and GoC departments within the mid-band.

Allied Responses to the Mid-Band Spectrum Standoff

While a comprehensive overview of how allied countries are responding to the policy challenge of mid-band congestion is a worthy subject for future research, this report focuses on the specific spectrum policies of three countries: Australia, the UK, and the US. More specifically, this report examines how spectrum is discussed in key government documents, in contrast to its discussion in Canada.

Australia

Australia has released two significant documents relevant to this report. The first, released in 2019, is the *Australian Government Held Spectrum Report,* which provides an overview of the RF spectrum licences held by the Australian government's departments and agencies, including the Australian Defence Force. Across specific frequency bands, the document emphasizes the critical role of the RF spectrum for vital services, including air and maritime safety, climate and weather monitoring, national

[96] GSMA, "Vision 2030: Insights for Mid-Band Spectrum Needs," February 2025, https://www.gsma.com/connectivity-for-good/spectrum/wp-content/uploads/2025/02/Insights-for-Mid-band-Spectrum-Needs.pdf.
[97] ITU, "Resolution 256 (WRC-23)," 2, https://www.itu.int/dms_pub/itu-r/oth/0c/0a/R0C0A0000110007PDFE.pdf.
[98] 5G Americas, "6G Upgrade in the 7-8 GHz Spectrum Range."

security, and humanitarian response and disaster recovery.[99] In October 2025, the Australian Communications and Media Authority released the *Five-Year Spectrum Outlook*. This report emphasized the critical need to collaborate with the Department of Defence to ensure the Defence Force has access to the RF spectrum and recognized that the Department of Defence is investing heavily in new capabilities, many of which require spectrum across various bands allocated to mobile, radiolocation, radionavigation, fixed, and aeronautical services.[100]

United Kingdom

In 2023, the UK released the *Spectrum Statement,* which, like Australia, highlighted the role of the RF spectrum as a critical enabler for military success and, as a result, emphasized that the societal and non-economic benefits of the RF spectrum must be compared directly with its economic and commercial benefits.[101] More recently, in July 2025, the Department for Science, Innovation, and Technology released the *Public Sector Spectrum Framework,* which aimed to establish a framework for the efficient access and use of spectrum by the public and private sectors. Moreover, this document emphasized that, going forward, government departments and agencies holding RF spectrum licences will be required to maintain and provide up-to-date overviews of their current and expected spectrum use at least once every WRC cycle.[102]

The United States

With the largest and most technologically capable military in the world, the US has released several key documents outlining the importance of spectrum for effective homeland defence and expeditionary missions. Recent notable documents include the *National Spectrum Strategy* (2023) and the *Emerging Mid-Band Radar Spectrum Sharing (EMBRSS) Feasibility Assessment Report* (2023). The *National Spectrum Strategy* sought to improve coordination between the public and private sectors to address spectrum access.[103] In line with this strategy, the Department of Defense (DoD)

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[99] Australian Government, Department of Communications and the Arts, *Australian Government Held Spectrum Report* (April 2019), 10, https://www.infrastructure.gov.au/sites/default/files/australian-government-held-spectrum-report_0.pdf.
[100] Australian Communications and Media Authority, *Five-Year Spectrum Outlook* (2025), 25–26, https://www.acma.gov.au/five-year-spectrum-outlook.
[101] Government of the United Kingdom, Department for Science, Innovation & Technology, "Policy Paper – *Spectrum Statement*," April 11, 2023, https://www.gov.uk/government/publications/spectrum-statement/spectrum-statement.
[102] Government of the United Kingdom, Department for Science, Innovation, and Technology, "Policy Paper – *Public Sector Spectrum Framework*," July 9, 2025, https://www.gov.uk/government/publications/public-sector-spectrum-framework/public-sector-spectrum-framework.
[103] The White House, *National Spectrum Strategy* (November 13, 2023), 2, https://www.ntia.gov/sites/default/files/publications/national_spectrum_strategy_final.pdf.

conducted the most significant feasibility study to date, the *Emerging Mid-Band Radar Spectrum Sharing (EMBRSS) Feasibility Assessment Study*, and the public document was released in 2023, although heavily redacted. The study sought to assess the feasibility of commercial spectrum sharing with military S-band radars in the 3.1–3.45 GHz range. The study found that spectrum sharing in this band may be possible, but it must adhere to strict conditions, including that DoD retains regulation primacy; national emergency pre-emption policy is continued; the Citizens Broadband Radio Service (CBRS) sharing framework and technology (DSS Capacity) are expanded and improved; the United States government is not liable for damage to commercial systems; the Defence Industrial Base retains band access for testing and experimentation; current and future federal systems are accommodated equally; interference safeguards are established; and resource requirements are addressed.[104]

Overall, there are key differences in how spectrum is discussed in these allied countries compared to Canada. Australia, the UK, and the US are increasingly planning for a future scenario in which commercial demands and military systems converge in the mid-band, and they are developing frameworks and government working groups to address this challenge. Moreover, these documents also serve as crucial awareness-raising materials for government departments and the public, helping to build understanding of the critical importance of the RF spectrum across society.

Mid-Band Spectrum Analysis

Eventually, advancements in antenna technology, software, and potential AI integration may enable spectrum sharing, allowing users to occupy the same frequency bands and more easily address shortages.[105] However, for now, the GoC faces difficult choices regarding the allocation and reallocation of spectrum for national security priorities. The purpose of this section is twofold. First, it will highlight key spectrum policy changes in the US, which, given shared geography and extensive military cooperation, will have a significant impact on Canada. Second, it will provide an overview of the services across the mid-band frequencies that are likely to be targeted for 5G and 6G, as well as the risks associated with reallocation. Notably, Canada lacks detailed information on the defence activities within specific bands; therefore, this section assumes the need for interoperability with NATO and Five Eyes

[104] US Department of Defense, *Emerging Mid-Band Radar Spectrum Sharing (EMBRSS) Feasibility Assessment Report* (September 2023), https://dodcio.defense.gov/Portals/0/Documents/Library/DoD-EMBRSS-FeasabilityAssessmentRedacted.pdf.
[105] Lewis, "Spectrum Allocation for a Contest with China," 4.

partners, specifically the US, to attempt to provide a detailed overview of each frequency band.

US Policy Changes

Since the announcement of the Golden Dome initiative, the spectrum standoff in the US has continued to escalate behind the scenes. Key senators, military officials, and policy analysts have discussed the risks of both failing to allocate RF spectrum for 5G and 6G and reallocating defence bands. There are two principal risks associated with not allocating – or being slow to allocate – mid-band spectrum for 5G and 6G, as outlined by James A. Lewis. First, countries that make the infrastructure and devices to service the mid-band market will have an advantage in setting technology standards and building the infrastructure on which the global network will depend. If countries such as the PRC manufacture mid-band equipment within the frequency bands allocated to 5G or 6G by other governments, they will gain greater market share as governments purchase equipment compatible with their national spectrum allocations. Second, countries that allocate more mid-band spectrum to 5G will achieve better network performance and, by extension, greater economic competitiveness in emerging technology applications in key critical industries.[106] Put simply in the context of the US spectrum policy, Lewis states, "the rest of the world will not accommodate the idiosyncrasies of US spectrum allocations; having struggled mightily to limit the use of Chinese infrastructure for 5G, the US would lose any gains through its spectrum decisions."[107] In this case, while Canada has taken steps to prohibit the use of Huawei and ZTE products and services in its telecommunications systems, the lack of a market alternative may force it to rely on these products for its 5G and 6G technologies.[108]

Conversely, key military officials such as General Gregory Guillot, Commander of US Northern Command (USNORTHCOM) and NORAD, and Lieutenant General John Caine, Commander of the Joint Chiefs, have testified on the risks associated with the reallocation of military spectrum bands, particularly the lower 3 GHz and 7–8 GHz bands. Gen. Guillot testified to Congress, stating, "I would suggest [Congress] be very concerned [about the potential auction of DoD spectrum], especially in the key ranges that your military experts will help describe to ensure that we [do not] lose or share that spectrum because of the importance of our missions."[109] Similarly, when asked about

[106] Lewis, "Spectrum Allocation for a Contest with China," 4.
[107] Lewis, "Spectrum Allocation for a Contest with China," 4.
[108] Public Safety Canada, "Parliamentary Committee Notes: Fifth Generation Wireless Networks (5G)," last modified March 3, 2025, https://www.publicsafety.gc.ca/cnt/trnsprnc/brfng-mtrls/prlmntry-bndrs/20250226-1/12-en.aspx.
[109] US House Armed Services Committee, "Full Hearing: US Military Posture & National Security Challenges in North & South America," April 1, 2025, https://www.youtube.com/live/Mx99nRaBKq8.

the national security risks associated with DoD being forced to vacate the S-band and X-band, Lt. Gen. Caine responded that "some of that may be reserved for a conversation in closed session … but certainly, if we lose portions of that spectrum, [we will] lose some exclusivity related to our combat capability."[110]

In response to the growing risks posed by both sides of the spectrum in the allocation debate, a compromise was reached during negotiations on the One Big Beautiful Bill (OBBB). Five key spectrum provisions were included in this bill:

1. The Federal Communications Commission (FCC) was reauthorized to auction spectrum until September 30, 2034.
2. The 3.1–3.45 GHz and 7.4–8.4 GHz ranges were excluded from consideration for auctions in the 'covered band' – 1.3–10.5 GHz – until 2034.
3. The FCC must auction not less than 300 MHz within two years, with 100 MHz coming from the 3.98–4.2 GHz range.
4. The FCC was instructed to identify an additional 500 MHz within the covered band for the purpose of commercial mobile use.
5. A $50-million appropriation was made for the FCC to conduct spectrum analysis for the spectrum within the 2.7–2.9 GHz, 4.4–4.9 GHz, and 7.125–7.4 GHz ranges.[111]

In an op-ed, Senators Mike Rounds and Deb Fischer defended their push to exempt the 3.1–3.45 GHz and 7.4–8.4 GHz ranges by stating that DoD "requires these bands to keep Americans safe… [Excluding] portions of the 3, 7, and 8 GHz bands … enable[s] our missile defence radars and sensors to shield the homeland and track incoming intercontinental ballistic missiles… the bands are essential to keeping our troops safe and supporting satellite surveillance that underpins our military's operational planning, targeting, and force protection measures."[112]

Mid-Band Spectrum Analysis

The renewed effort to reallocate and auction spectrum in the US will have significant implications for Canada's military cooperation with the US and for Canada's relative

[110] United States Senate, "Stenographic Transcript Before the Committee on Armed Services United States Senate to Consider the Nomination of: Lieutenant General John D. Caine, USAF (Retired) to Be General and Chairman of the Joint Chiefs of Staff," April 1, 2025, 26, https://www.armed-services.senate.gov/imo/media/doc/412025fullnom1.pdf.
[111] United States Congress, "H.R.1 – An Act to Provide for Reconciliation Pursuant to Title II of H. Con. Res. 14.," July 4, 2025, https://www.congress.gov/119/plaws/publ21/PLAW-119publ21.pdf.
[112] Mike Rounds and Deb Fischer, "Sens. Fischer, Rounds: Setting the Record Straight on How We Protected Defense Spectrum in the 5G Era," Breaking Defense, July 9, 2025, https://breakingdefense.com/2025/07/sens-fischer-rounds-setting-the-record-straight-on-how-we-protected-defense-spectrum-in-the-5g-era/.

economic competitiveness. Amid an escalating trade war and an uncertain economic partnership, maintaining relative economic competitiveness with the US to attract investments and talent is a national security imperative. Therefore, this section provides an overview of the 2.7–2.9 GHz, 3.1-3,45 GHz, 3.7–4.2 GHz, 4.4–4.94 GHz, and 7.125–8.4 GHz frequency ranges. This section relies on the author's understanding of the physics involved, the SMS data to characterize the types of services within these bands, and the US National Telecommunications and Information Administration's (NTIA) reports on frequency bands to build as accurate a picture as possible of the uses within each band in Canada, as well as the risks associated with reallocation. Notably, as far as the author can tell, the military systems employed by the CAF are not included in the SMS for national security reasons.

The 2.7–2.9 GHz Range

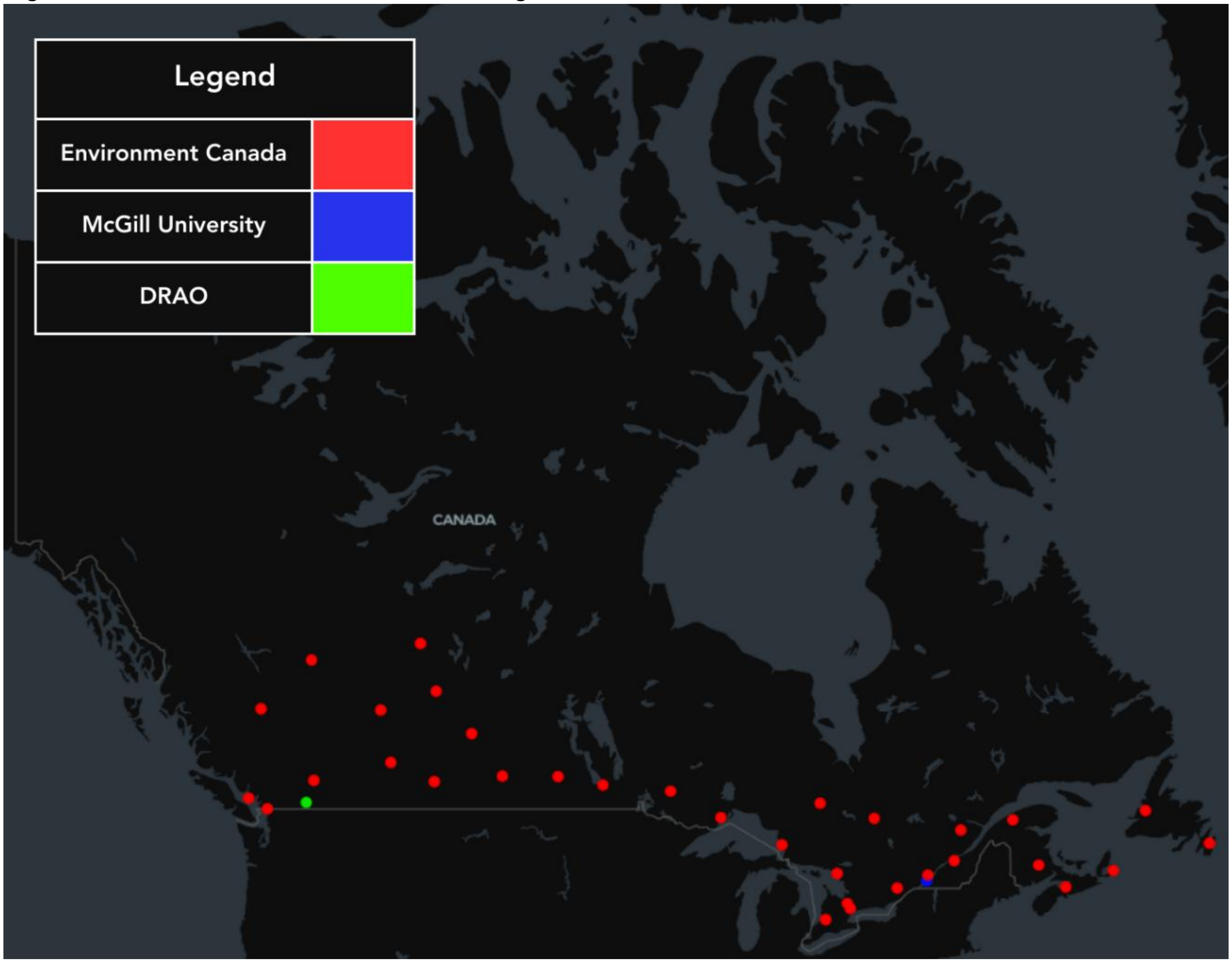
In Canada, the 2.7–2.9 GHz range is allocated for aeronautical radionavigation as the primary service and radiolocation as the secondary service, with several footnotes attached therein.[113] According to the SMS data, Canada has 69 assignments within this range, across 35 locations and three licensees. The largest spectrum holder is Environment and Climate Change Canada, which operates a network of weather radars across the country, as shown in Figure 13.

According to the NTIA report on this band, no viable technologies exist to replace the air traffic control, weather surveillance, and national security missions of radar systems operating in the 2.7–2.9 GHz range.[114] Furthermore, the report emphasizes that "access to this band for tactical systems is critical to national defence and will continue for the foreseeable future."[115] In Canada, the C-band weather radars were replaced in 2023 by

[113] Note: In ISED's Canadian Table of Frequency Allocations, where a band is indicated as allocated to more than one service, services are listed in the following order: primary services are printed in capital letters (FIXED), and secondary services are printed in normal characters (Amateur). Additional remarks are printed in normal characters (MOBILE except aeronautical mobile). For each category, stations are listed in alphabetical order by French-language name, but this order does not indicate relative priority. Stations of a secondary service: Shall not cause interference to stations of primary service to which frequencies are already assigned or to which frequencies may be assigned at a later data; cannot claim protection from harmful interference from stations of a primary service to which frequencies are already assigned or may be assigned at a later date; and can claim protection, however, from harmful interference from stations of the same or other secondary service(s) to which frequencies may be assigned at a later data. ISED, "Canadian Table of Frequency Allocations (2022)"; ISED, "Spectrum Allocation Tool," Government of Canada, last modified April 10, 2025, https://ised-isde.canada.ca/sat-oas/en/ctfa?band=11&page=1.
[114] NTIA, "2700–2900 MHz," NTIA Spectrum Compendium, February 2021, 10, https://www.ntia.gov/files/ntia/publications/compendium/2700.00-2900.00-02092021.pdf.
[115] NTIA, "2700–2900 MHz," 10.

S-band Precipitation-Extended (PRECIP-ET) radars; therefore, it appears unlikely that this range is suitable for sharing or reallocation for commercial use.[116]

Figure 13: Locations of 2.7–2.9 GHz RF Assignments in Canada



Source: Author's Own Work Using SMS Data

The 3.1–3.45 GHz Range

In Canada, the 3.1–3.45 GHz band is divided into two sub-bands: 3.1–3.3 GHz and 3.3–3.45 GHz. The 3.1–3.3 GHz range is allocated to radiolocation as the primary service and to Earth exploration-satellite (active) and space research (active) as secondary services, with all administrations urged to take all practical steps to protect the radio astronomy service from harmful interference.[117] The 3.3–3.45 GHz band is allocated to radiolocation as the primary service and to amateur as the secondary service, with the

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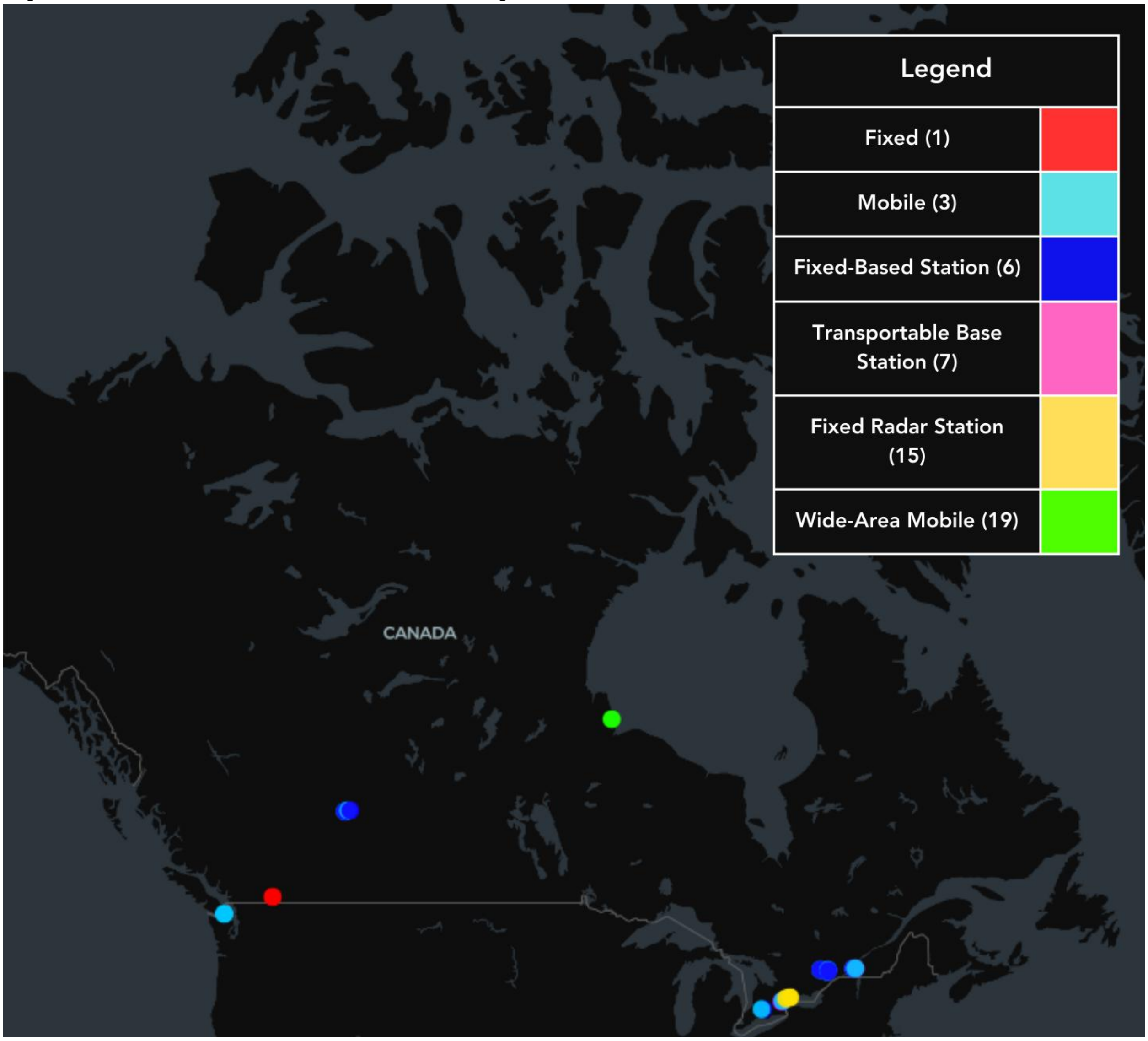
[116] Environment and Climate Change Canada (ECCC), "About Canadian Historical Weather Radar," Government of Canada, last modified March 20, 2025, https://www.canada.ca/en/environment-climate-change/services/weather-general-tools-resources/radar-overview/about.html.
[117] ISED, "Spectrum Allocation Tool."

radiolocation service reserved for the exclusive use of the GoC.[118] According to the SMS data, Canada has 63 RF assignments within this range across 24 locations and 14 licensees – as shown in Figure 14.[119]

Figure 14: Locations of 3.1–3.45 GHz RF Assignments in Canada



Source: Author's Own Work Using SMS Data

As previously discussed, this range is critical for long-range precision targeting and discrimination and has been used extensively by the US in recent years to track the Democratic People's Republic of Korea's intercontinental ballistic missile tests, intercept Houthis drones in the Red Sea, and track the 500 drones and missiles that

[118] ISED, "Spectrum Allocation Tool."
[119] Note: This range included the RF assignments in the 3.1–3.499 GHz band, as 5G systems occupy the exact 3.5 GHz band.

Iran launched against Israel in early 2025.[120] In his written testimony to the US Senate, Lt. Gen. Caine highlighted that:

> The S-Band … is a critical frequency range for various DoD Systems, including radar [and] electromagnetic systems… its loss or disruption could have significant impacts on military effectiveness, affecting the defence of the Homeland from strategic and missile attack… For example, the loss of the S-band could impact the performance of the Navy's Aegis Combat System, which relies on S-band radar to detect and engage airborne targets. Similarly, the loss of this band could disrupt the operation of the Army's Patriot air defence system, which uses S-band radar to detect and track incoming missiles. Furthermore, the loss of the S-band spectrum could also impact the DoD's ability to conduct electronic warfare [EW], as many EW systems, such as the Navy's SLQ-32 and the Air Force's ALQ-211, rely on the S-band spectrum to detect and disrupt enemy radar and communication systems.[121]

Additionally, Gen. Guillot highlighted that "having full use of the [3.1–3.45 GHz] band is essential for homeland defence based on the variety of sensors that must work together to build a network of detection and defeat capabilities … [and] because of the physics… you [cannot] move to another part of the spectrum and get the same capability."[122]

Given recent changes in US policy, the direction of the Canada-US defence partnership remains unclear, which may mean that, in the future, Canada may have to pursue a strictly national capability to defeat missile threats. In this scenario, access to this band for the CAF will be crucial to defending key critical infrastructure and regions, such as the National Capital Region. That said, even if Canada does not participate in the interception of air and missile threats, S-band radars will remain crucial for NORAD defence and for any theatre missile defence within the national territory. For instance, at the Canadian Seapower Conference in October 2025, Vice-Admiral Angus Topshee outlined his vision for Canada's future Navy, wherein Canadian corvettes would hunt

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[120] Rebecca Grant, "Trouble Ahead for Military Radars at S-Band," RealClear Defense, 2024, https://www.realcleardefense.com/articles/2024/11/06/trouble_ahead_for_military_radars_at_s-band_1070271.html.

[121] Senate Armed Services Committee, "Advance Policy Questions for Lieutenant General John Daniel Caine (USAF), Retired, Nominee for Appointment to Grade of General and to the Position of Chairman of the Joint Chiefs of Staff," 2025, 64, https://www.armed-services.senate.gov/imo/media/doc/caine_apq_responses.pdf.

[122] US House Armed Services Committee, "Full Hearing: US Military Posture & National Security Challenges in North & South America."

submarines to the ice edge, the River-class destroyer providing the air defence to protect those corvettes, and the Protector-class would sustain both.[123]

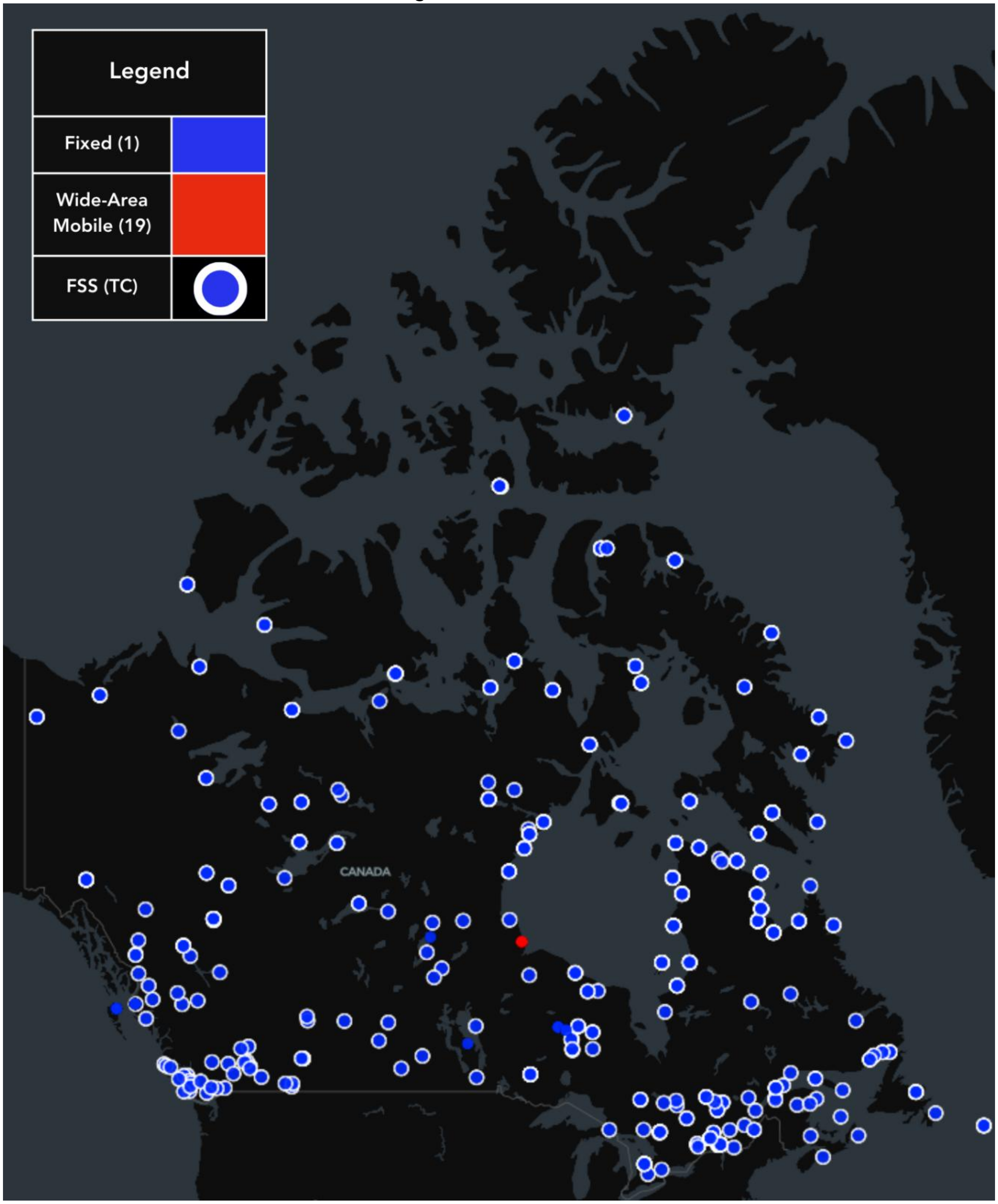
Overall, given that missile defence is 'hitting a bullet with a bullet,' any interference within this band, or a reduction in bandwidth, would entail an unacceptable risk not only to Canada but also to the international security environment. That is, any reduction in the capability of the CAF or NORAD to detect and defeat incoming threats increases the likelihood of miscalculation by Russia and the PRC, potentially leading to conflict between great powers. Therefore, this band is unsuitable for sharing or reallocation.

The 3.7–4.2 GHz Range

In Canada, the types of services offered in the 3.7–4.2 GHz band vary by region and are therefore, for this report, subdivided into three bands. For satellite-dependent communities, the 3.7–4.0 GHz range is allocated to fixed, fixed-satellite (space-to-Earth), and mobile – except aeronautical mobile – services, with no secondary services.[124] For non-satellite-dependent communities, as of March 2025, FSS will no longer be licensed within this range, and any earth stations operating in these areas will be on a no-protection basis. The 4.0–4.2 GHz range is allocated for fixed and fixed-satellite (space-to-Earth) services, with no secondary services. The 3.98–4.0 GHz band was also designated as a guard band for FSS operating in the 4.0–4.2 GHz band.[125] According to the SMS data, Canada has 16,652 RF assignments within this range across 325 locations and 137 licensees, as shown in Figure 15.

[123] Adam Lajeunesse and Corah Lynn Hodgson, "Canadian Seapower Event Report," Canadian Maritime Security Network, 2025, 11, https://www.cmsn.ca/_files/ugd/0bcbee_c350567f9b23450da72c88112fe56970.pdf.
[124] ISED, "Spectrum Allocation Tool."
[125] ISED, "Decision on the Technical and Policy Framework for the 3650-4200 MHz Band and Changes to the Frequency Allocation of the 3500-3650 MHz Band," May 2021, 9, https://ised-isde.canada.ca/site/spectrum-management-telecommunications/sites/default/files/attachments/2022/SLPB-002-21a12021-06EN.pdf.

Figure 15: Locations of 3.7–4.2 GHz RF Assignments in Canada



Source: Author's Own Work Using SMS Data

As previously discussed, the critical element in this band is the reliance on C-band FSS to enable voice, data, and video transmission for remote and Arctic communities. However, as the trend toward higher-frequency satellites for data-intensive applications intensifies, pressure will likely grow on the GoC and DND to vacate this entire band to provide more bandwidth for 5G services. That said, DND has already stated that it does not plan to replace its current C-band FSS sites in the short or medium terms.[126] Additionally, the NTIA report on this range simply states that "federal use of the band is expected to increase."[127]

Overall, this band is likely going to be targeted for reallocation in Canada, especially given that the US FCC has been instructed to release 100 MHz of spectrum from this band within two years. Moreover, mobile operators in Canada, such as TELUS and Rogers, have previously supported extending mobile services to the 4.2 GHz band.[128] Therefore, the evidence suggests that DND will likely be required to vacate completely, share, or operate on a smaller slice of the C-band FSS bandwidth in the future, and further research is needed to assess the associated risks.

The 4.4–4.94 GHz Range

In Canada, the 4.4–4.94 GHz band is divided into five subsections, with services allocated across the 4.4–4.95 GHz range. However, the key point is that many military systems authorized for operation typically operate in the 4.4–4.94 GHz tuning range.[129] There are also limitations placed on mobile, fixed, and FSS within this range. That is, the entire band is allocated to the fixed and mobile services for the exclusive use of the Government of Canada, and in the 4.5–4.8 GHz frequency band, the use of fixed and mobile services by the GoC in the vicinity of major military bases has priority over the use of FSS.[130] According to the SMS data, Canada has 51 RF assignments in this range across 10 locations and six licensees, as shown in Figure 16.

There is limited information on the activities of the GoC and CAF within this band, with DND simply stating in a 2015 document that the 4.4 – 4.94 is "used by air and land forces".[131] That said, the NTIA reports within this band highlight their use by the DoD

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[126] ISED, "Comments in Response to Notice No. SLPB-002-20", Canada Gazette, 3, https://ised-isde.canada.ca/site/gestion-spectre-telecommunications/sites/default/files/attachments/2022/SLPB-002-20-Department-of-National-Defense-comments.pdf,

[127] NTIA, "3700–4200 MHz," May 1, 2015, 4, https://www.ntia.gov/files/ntia/publications/compendium/3700.00-4200.00_01DEC15.pdf.

[128] ISED, "Decision on the Technical and Policy Framework for the 3650–4200 MHz Band and Changes to the Frequency Allocation of the 3500–3650 Mhz Band," 18–19.

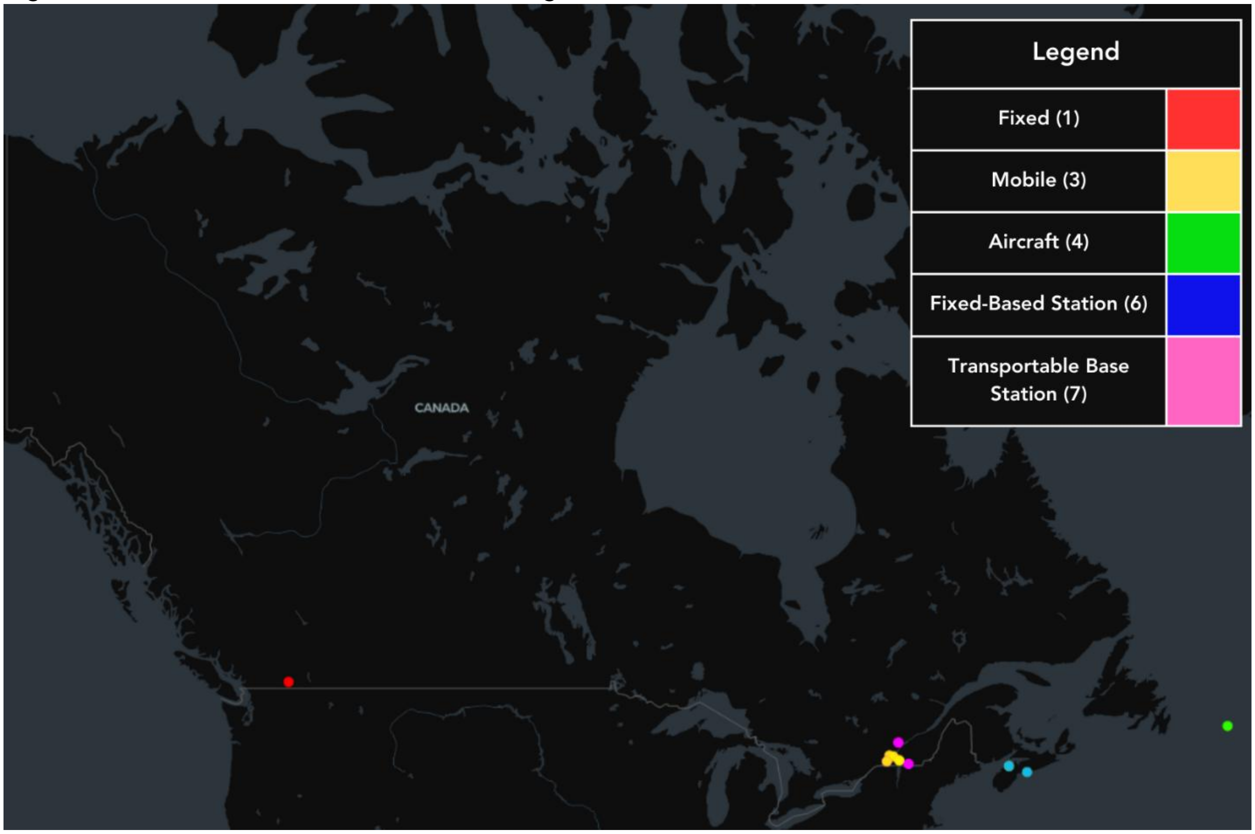
[129] NTIA, "4400–4500," December 1, 2015, https://www.ntia.gov/files/ntia/publications/compendium/4400.00-4500.00_01DEC15.pdf.

[130] ISED, "Spectrum Allocation Tool."

[131] Red Mobile Consulting, "Study of Future Demand for Radio Spectrum in Canada 2011 – 2015", 2015, 157, https://ised-isde.canada.ca/site/spectrum-management-telecommunications/sites/default/files/attachments/2022/FutureDemandRadioSpectrum2011-2015.pdf.

Note: the NATO Joint Civil/Military Frequency Agreement (NJFA) also lists the uses within this band as: aeronautical, land, and maritime military systems and telemetry/telecommand (military). NATO, "NATO the NATO Joint Civil/Military Frequency Agreement (NJFA), 2017, 1-17, for military training, line-of-sight, transportable, fixed point-to-point microwave systems, drone vehicle control, and telemetry systems.[132] These reports also emphasized in 2015 that this band will be used to develop Unmanned Ground Systems (UGS) and Unmanned Aerial Systems (UAS) to support a variety of missions, increase combat effectiveness, and enhance personnel safety.[133] Moreover, the documents state that the DoD will require extensive use of systems within the band.[134]

Figure 16: Locations of 4.4–4.94 GHz RF Assignments in Canada



Source: Author's Own Work Using SMS Data

Overall, the evidence suggests that this band will be a target for reallocation, sharing, or reduction. Given the limited information, it is difficult to ascertain the associated risks using open sources. That said, with the increased use of drones in modern combat, it

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https://english.nmhh.hu/document/211426/NATO_Joint_Civil_Military_Frequency_Agreement_NJFA.pdf.

[132] NTIA, "4400 – 4500 MHz", 1; NTIA, "4500 – 4800 MHz", December, 2015, 1, https://www.ntia.gov/files/ntia/publications/compendium/4500.00-4800.00_01DEC15.pdf; NTIA, "4800 – 4940 MHz", NTIA Spectrum Compendium, December 2015, 1, https://www.ntia.gov/files/ntia/publications/compendium/4800.00-4940.00_01DEC15.pdf.

[133] NTIA, "4400 – 4500 MHz", 1; NTIA, "4500 – 4800 MHz", 1; NTIA, "4800 – 4940 MHz", 1

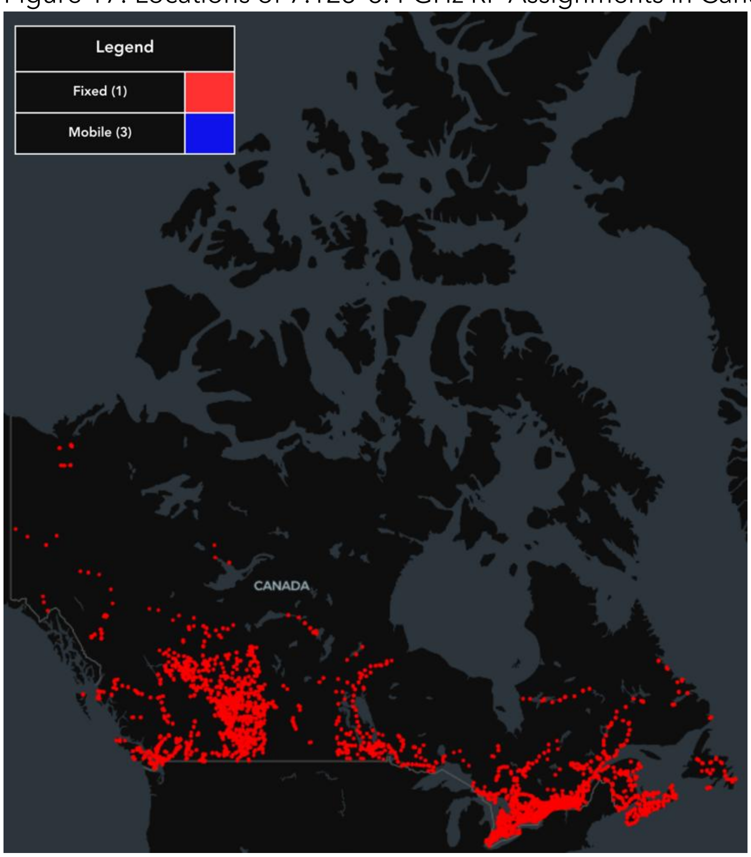
[134] NTIA, "4400 – 4500 MHz", 1; NTIA, "4500 – 4800 MHz", 1; NTIA, "4800 – 4940 MHz", 1

appears likely that any reduction in military bandwidth in this range will diminish the CAF's combat effectiveness.

The 7.125–8.4 GHz Range

In Canada, the 7.125–8.4 GHz range is subdivided into nine bands, which are allocated to, for instance, fixed-satellite (space-to-Earth), fixed-satellite (Earth-to-space), meteorological-satellite (space-to-Earth), Earth exploration-satellite (space-to-Earth), and Earth exploration-satellite (Earth-to-space) services.[135] The key elements within this band are the 7.25–7.75 GHz and 7.9–8.4 GHz frequency ranges, which support mobile-satellite service for the exclusive use of the GoC.[136] In other words, these frequency bands provide the CAF with X-band military communications, with the 7.25–7.75 GHz range used for reception and the 7.9–8.4 GHz range used for transmission. According to the SMS data, there are 13,806 RF assignments within this band across 2,516 locations and 71 licensees, as shown in Figure 17.

Figure 17: Locations of 7.125–8.4 GHz RF Assignments in Canada



Source: Author's Own Work Using SMS Data

[135] ISED, "Spectrum Allocation Tool."
[136] ISED, "Spectrum Allocation Tool."

These X-band ranges will be crucial for the CAF operating in the Arctic and worldwide, and the GoC has pledged more than $5 billion for the Enhanced Satellite Communications Project – Polar to facilitate this connection.[137] However, this band is currently being explored for 6G deployment at WRC-27. The extent to which sharing or reallocation is possible is unclear, and it is unlikely that the band can be completely cleared for mobile deployment in the next 5–7 years, the expected deployment time frame for 6G.[138]

That said, the evidence suggests that, in the short term, a reallocation of this band is likely, with uplink services being moved to the 7.4–7.9 range and the 7.125–7.4 GHz range being explored for possible 6G deployment. However, this still falls short of the 400 MHz per network needed to realize the full potential of 6G. Further research into the risks associated with sharing or reallocation within this band is needed.

In summary, this section focused on the services within bands likely to be targeted for reallocation and emphasized the associated risks. It identified the 4.0–4.2 GHz range, as well as portions of the 4.4–4.94 GHz and 7.125–8.4 GHz ranges, as the most likely bands to be targeted for reallocation for commercial use. Overall, the GoC will face increasing pressure to release more mid-band spectrum across all ranges; therefore, this section now turns to policy recommendations to enhance spectrum policy in Canada.

Policy Recommendations

In the face of escalating demands for access to the mid-band spectrum for commercial, government, and military activities, this report proposes three concrete policy recommendations to prepare Canada for the mid-band spectrum standoff. These recommendations include removing the 3.1–3.45 GHz band from consideration for flexible use, requiring government departments to report their current and projected spectrum needs, and updating Canada's *Spectrum Policy Framework*.

Remove the 3.1–3.45 GHz Band from Consideration for Flexible Use

Following the global ecosystem for 5G technologies, Canada's *Spectrum Outlook 2023 to 2027* included the 3.1–3.45 GHz range as a potential band for reallocation for flexible use (priority 3), noting that "ISED will monitor relevant international developments, in particular those in the US."[139] However, as previously discussed, the functions of this

[137] DND, "Enhanced Satellite Communications Project – Polar."
[138] 5G Americas, "6G Upgrade in the 7-8 GHz Spectrum Range," 11.
[139] ISED, *Spectrum Outlook 2023 to 2027*.

band are critical for military radars, and any reallocation or reduction in the bandwidth afforded to the CAF will include unacceptable risk not only to Canada and continental security but also to the international security environment. That is, any reduction in NORAD's combat capability to detect and defeat incoming missile threats risks strategic stability along NATO's borders, in the South China Sea and the Middle East. Canada and the US must be able to demonstrate that they can reliably counter incoming threats to ensure stability and reduce the likelihood of a miscalculation that could lead to conflict between great powers.

On top of this imperative, with the recapitalization of the CAF to include new platforms like the River-class destroyer, a fleet of AWACs, and the Canadian Multi-Mission Aircraft, the CAF will likely not only use the existing bandwidth to support the operations of these platforms but may also require more bandwidth for their exclusive use further into the 3.1–3.3 GHz range. Finally, as previously discussed, the US OBBB excludes the 3.1–3.45 GHz band from auction, reallocation, modification, or withdrawal. Therefore, to ensure the effectiveness of the CAF, Canadian national security, deterrence on the continent, and international stability, the GoC should instruct ISED to remove the 3.1–3.45 GHz band from consideration for flexible use in the next *Spectrum Outlook*.

Require Government Departments to List Projected Spectrum Needs

As of December 2025, the GoC has exclusive use of the following services in the following bands:

- Fixed, mobile, and radiolocation services in the 1.35–1.39 GHz range;
- Mobile services in the 1.78–1.85 GHz range;
- Mobile services in the 2.025–2.110 GHz range;
- Mobile services in the 2.2–2.29 GHz range;
- Mobile services in the 2.29–2.3 GHz range;
- Radiolocation services in the 3.3–3.45 GHz range;
- Fixed and mobile services in the 4.4–4.94 GHz range;
- And FSS in the 7.25–7.75 GHz and 7.9–8.4 GHz ranges.[140]

However, GoC departments also rely on other bands for key services, such as the 5.25–5.570 GHz range for Earth exploration-satellite services (RADARSAT).[141] As commercial demand for mobile access increases and the CAF requires greater bandwidth to support more platforms, devices, and sensors, it is increasingly important that the GoC

[140] ISED, "Canadian Table of Frequency Allocations (2022)."
[141] ISED, *Spectrum Outlook 2023 to 2027*.

be able to predict public-spectrum requirements. Therefore, following the UK's lead, the GoC should instruct all departments to maintain up-to-date records of existing and projected spectrum needs to ensure the effective functioning of government services. Importantly, this should be conducted at least once every WRC cycle to ensure that the GoC has the information necessary to make informed decisions, as well as to allow ISED to more accurately ensure that the needs of Canadians are met at the ITU.

Update Canada's Spectrum Policy to Align with Modern National Security Needs

A critical area of concern for Canada's RF policy moving forward is that ISED's spectrum management policy is guided by the *Spectrum Policy Framework*, which was released 18 years ago. The increasing digitalization of the Canadian economy, as well as the emergence of new national security threats, necessitates revisions to how spectrum management is conducted in Canada. In particular, two areas should be focused on when updating Canada's spectrum policy: the objective of spectrum management and the use of set-asides.

The GoC should begin with the objective of spectrum policy in Canada, which states that spectrum management should maximize the economic and social benefits that Canadians derive from the use of the RF spectrum.[142] Given the contemporary threats to Canada and the increasing likelihood that commercial operators will seek access to military systems, it is essential to revise the spectrum management mandate to include explicit language on national security. The US DoD's policy on spectrum sharing is instructive for these purposes, stating that "sharing of spectrum shall be accomplished: (1) without degradation of the DoD mission, (2) in a manner that affords current and future DoD users with sufficient regulatory protections, and (3) with minimal risk that such sharing will result in loss of access to the spectrum necessary to perform the DoD mission."[143] Similar language should be explored for inclusion in Canada's spectrum management objective.

Second, Canada has often used set-asides – reserving a minimum amount of spectrum to be available for smaller telecommunications providers – as a pro-competitive measure. ISED used these measurements to reserve 40% of the AWS-1 band in 2008, 60% of the AWS-3 band in 2015, and 42% of the 3,500 MHz band in 2021.[144] While competitiveness is a chief concern for Canadian consumers, with each iteration of telecommunications networks requiring more spectrum, particularly in the mid-band,

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[142] ISED, *Spectrum Policy Framework for Canada*, 8.
[143] US Department of Defense, *Emerging Mid-Band Radar Spectrum Sharing (EMBRSS) Feasibility Assessment Report*, 17.
[144] ISED, *Spectrum Outlook 2023 to 2027*.

questions remain about whether this policy still serves the national interest. Currently, Canada is the only Organisation for Economic Co-operation and Development (OECD) country to repeatedly use this policy, and there are two chief concerns therein. First, the use of set-asides raises spectrum prices at Canadian auctions and may limit or delay the adoption of 5G in business contexts.[145] Second, with each successive mobile network requiring more spectrum to operate effectively, the use of set-asides means that the GoC will have to allocate more mid-band spectrum than necessary to ensure that the national telecommunications companies can achieve the 100 MHz sequential bands for 5G or the 400 MHz band for 6G. For instance, due to the use of set-asides, no single national telecommunications provider was able to meet the ITU recommendations of 100 MHz of continuous spectrum following the 2021 3.45-3.65 GHz auction.[146] Instead, Bell, TELUS, and Rogers were delayed until the 2023 3.65 – 3.9 GHz auction to meet the 100 MHz required and deploy true 5G.[147] Overall, as the mid-band becomes increasingly congested, it is vital that Canada include national security language in its spectrum management objectives and discuss whether the continued use of set-asides in auctions continues to serve the national interest.

Conclusion

In conclusion, this report argued that Canada's future depends on the GoC's ability to effectively balance the mid-band spectrum needs of both the private sector and the CAF. To support this argument, this report was separated into six sections. Section One discussed the concept of electromagnetic warfare, situated the mid-band within the electromagnetic spectrum, and overviewed the trade-offs inherent in all electromagnetic systems. Section Two broke down the international and domestic institutions responsible for ensuring minimal interference and the effective management of the RF spectrum. Section Three analyzed the vital role the mid-band

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[145] TELUS, "Reforming Canadian Spectrum Policy for 5G and Beyond," n.d., https://assets.ctfassets.net/fltupc9ltp8m/1oe0oJ7TyUkHgwLXLihr0X/3c4da2b9bf4fd7794500cc4f3f5cc153/22-1343_Spectrum_White_Paper_Full_Final.pdf; Analysys Mason, "Falling Behind: Comparing 5G Spectrum Policies in Canada and OECD Countries," 2021.
[146] TELUS, "Reforming Canadian Spectrum Policy for 5G and Beyond"; Analysys Mason, "Falling Behind."
[147] TELUS, "TELUS Secures Critically Important 3800 MHz Spectrum Licences, Unleashing the Full Potential of 5G," November 30, 2023, https://www.telus.com/en/about/news-and-events/media-releases/telus-secures-critically-important-3800-mhz-spectrum-licences-unleashing-the-full-potential-of-5g; Rogers, "Rogers Acquires 3800 MHz 5G Spectrum Across Canada," November 30, 2023, https://about.rogers.com/news-ideas/rogers-acquires-3800-mhz-5g-spectrum-across-canada/; Bell, "Bell Secures the Most 5G+ Spectrum Nationwide with Acquisition of 3800 MHz Licenses," November 30, 2023, https://www.bce.ca/news-and-media/releases/show/Bell-secures-the-most-5G-spectrum-nationwide-with-acquisition-of-3800-MHz-licenses?page=1&month=&year=&perpage=25.

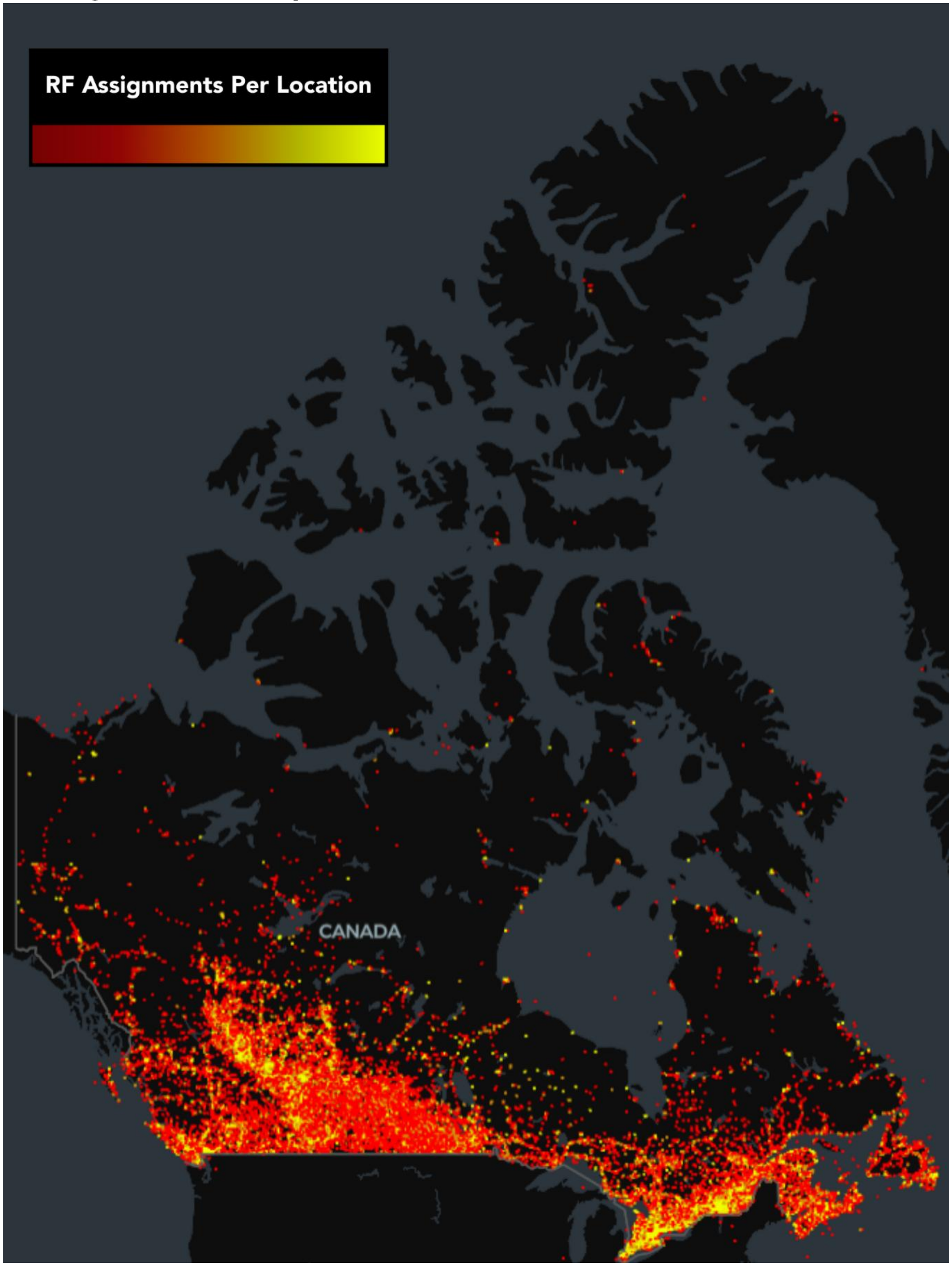
will play in the core Canadian national security objectives of economic security, air and missile defence, and ensuring Arctic sovereignty. Section Four contrasted the Canadian response to the mid-band spectrum standoff with that of key allies and highlighted the bands most likely to be targeted for future reallocation for mobile use. Section Five analyzed the individual bands likely to be targeted for reallocation, highlighting the services allocated to those bands and the associated risks of reallocation. Section Six forwarded the policy recommendation to remove the 3.1–3.45 GHz band from consideration, to require government departments to maintain up-to-date information on their current and expected future RF spectrum usage, and to update Canadian spectrum policy.

As the mid-band becomes increasingly contested, congested, and constrained, the GoC will have to make difficult decisions on who gets what spectrum, where, and under what considerations. This will be a significant policy challenge, requiring extensive knowledge of the EMOE to ensure Canada remains safe, secure, and prosperous. To that end, this report was intended as a policy primer to equip Canadian decision-makers with the information necessary to make informed decisions regarding the future allocation of spectrum.

Beyond informing decision-makers, this report was also intended to serve as a starting point for greater discussion in Canada on the importance of electromagnetic warfare in the modern age. As modern-day threats continue to challenge Canada across both the economic and military domains, greater attention must be paid by the military, academia, and industry to this crucial area. Future research on the topic should address questions concerning the establishment of a trusted ecosystem for 5G and 6G equipment to safeguard critical infrastructure and, in the future, Western bases. Additionally, it should be explored how countries' spectrum allocations in key operating regions, such as Europe and the Indo-Pacific, will affect the future operations of the CAF. Overall, how Canada and our allies address this critical issue will determine the extent to which the deteriorating international security environment can be managed without risking open conflict or the erosion of the hard-won values secured over two World Wars, the Cold War, and the post-Cold War period.

Annex 1 – Data

RF Assignment Heat Map



Source: Author's Own Work Using SMS Data

Top 10 Spectrum Licence Holders in Canada

Licensee	Position	Spectrum Held
TELUS Communications Inc.	1	86,690
Rogers Communications Canada Inc.	2	47,086
Bell Mobility Inc.	3	45,478
Xplore Inc.	4	15,718
His Majesty the King in Right of the Province of Ontario (GMCB)	5	15,058
Alberta Sustainable Resources Development – Forest Protection Division	6	9,848
Canada Natural Resource Ltd.	7	9,825
Vale Canada	8	8,585
Freedom Mobile Inc.	9	8,288
Fisheries and Oceans Canada – Canadian Coast Guard (Including Auxiliary and Arctic Region)	10	8,000

Source: Author's Own Work Using SMS Data

Total Count of RF Assignments by Type of Station (Canadian Designation)

Type of Station	Description	Count
1	Fixed	114,749
2	Transportable	667
3	Mobile	385,458
4	Aircraft	28,933
5	Ship	3,403
6	Fixed-Based Station	190,422
7	Transportable Base Station	44,984
8	Fixed Repeater Station	82,691
9	Transportable Repeater Station	1,056
10	Fixed Hub Station	8,119
11	Fixed Remote Station	16,253
12	Transportable Remote Station	6,622
13	Fixed Beacon	25
14	Transportable Beacon	10
15	Fixed Radar Station	1,628
16	Transportable Radar Station	84
17	Transmit Fixed-Based Station	1,109
18	Receive Fixed-Base Station	754
19	Wide-Area Mobile	45,951
20	Wide-Area Transportable	10,366
Unlisted:		55,001

Source: Author's Own Work Using SMS Data

Total Count of RF Assignments by ITU Class of Station (ITU Designation)

ITU Class of Station	Description	Count
AL	Aeronautical Radionavigation Land Station	2,132
BC	Broadcasting Station, Sound	4,416
BT	Broadcasting Station, Television	473
EC	Space Station in the Fixed Satellite Service	3
ET	Space Station in the Space Operation Service	3
FA	Aeronautical Station	9,230
FB	Base Station	117,782
FC	Coast Station	5,714
FD	Aeronautical Station in the Aeronautical Mobile (R) Service	6
FG	Aeronautical Station in the Aeronautical Mobile (OR) Service	8
FL	Land Station	2
FP	Port Station	2
FX	Fixed Station	333,420
LR	Radiolocation Land Station	4,519
MA	Aircraft Station	28,981
ML	Land Mobile Station	431,094
MO	Mobile Station	229
MR	Radiolocation Mobile Station	48
MS	Ship Station	3,405
NL	Maritime Radionavigation Land Station	416
OE	Oceanographic Data Interrogating Station	6
RA	Radio Astronomy Station	84
RN	Radionavigation Land Station	1
SM	Meteorological Aids Base Station	424
SS	Standard Frequency and Time Signal Station	6
TA	Earth Station in the Amateur-Satellite Service	2
TC	Earth Station in the Fixed-Satellite Service	4,927
TD	Space Telecommand Earth Station	37
TE	Satellite EPIRB in the Mobile-Satellite Service	62
TH	Earth Station in the Space Research Service	22
TK	Space Tracking Earth Station	5
TM	Earth Station in the Meteorological-Satellite Service	9
TR	Space Telemetering Earth Station	31
TT	Earth Station in the Space Operation Service	76
TW	Earth Station in the Earth Exploration-Satellite Service	446
UE	Earth Station in the Standard Frequency-Satellite Service	4
UV	Earth Station in the Broadcasting-Satellite Service (TV)	128
VA	Land Earth Station	2
Unlisted:		50,129

Source: Author's Own Work Using SMS Data

The 2.7–2.9 GHz Range

General Information

Description	Count
RF Assignments	69
Unique Locations	35
Licensees	3

Source: Author's Own Work Using SMS Data

Licensees

Licensee	Count
Environment Canada	66
McGill University	2
LNRC, Dominion Radio Astrophysical Observatory	1

Source: Author's Own Work Using SMS Data

Total Count of RF Assignments by Type of Station (Canadian Designation)

Type of Station	Description	Count
1	Fixed	1
15	Fixed Radar Station	68

Source: Author's Own Work Using SMS Data

Total Count of RF Assignments by ITU Class of Station (ITU Designation)

Type of Station	Description	Count
LR	Radiolocation Land Station	68
RA	Radio Astronomy Station	1

Source: Author's Own Work Using SMS Data

The 3.1–3.449 GHz Range

General Information

Description	*Count*
RF Assignments	63
Unique Locations	35
Licensees	14

Source: Author's Own Work Using SMS Data

Licensees

Licensee Name	Count
Northwestel Inc.	79
KEEWAYTINOOK OKIMAKANAK FIRST NATION	48
Telesat Canada - Domestic Coordination and Licensing	32
Kativik Regional Government	16
NAV CANADA - NUNAVUT	3
SaskTel	2
NAV CANADA - NEWFOUNDLAND and LABRADOR	1
Nav Canada	1
Inmarsat Solutions (Canada) Inc.	1
Canadian Royalties Inc.	1

Source: Author's Own Work Using SMS Data

Total Count of RF Assignments by Type of Station (Canadian Designation)

Type of Station	Description	Count
1	Fixed	3
3	Mobile	29
6	Fixed-Base Station	17
7	Transportable Base Station	4
15	Fixed Radar Station	4
19	Wide-Area Mobile	2
Unlisted		4

Source: Author's Own Work Using SMS Data

Total Count of RF Assignments by ITU Class of Station (ITU Designation)

Type of Station	Description	Count
FB	Base Station	10
FX	Fixed Station	11
LR	Radiolocation Land Station	4
ML	Land Mobile Station	31
RA	Radio Astronomy Station	3
Unlisted		4

Source: Author's Own Work Using SMS Data

The 3.7–4.0 GHz Range

General Information

Description	Count
RF Assignments	184
Unique Locations	84
Licensees	10

Source: Author's Own Work Using SMS Data

Top 10 Licence Holders in Canada

Licensee Name	Count
TELUS Communications Inc.	4,344
Bell Mobility Inc.	3,526
Rogers Communications Canada Inc.	2,414
Lemalu Holdings LTD MCSnet	1,096
Vidéotron	972
Bragg Communications Inc.	512
CityWest Mobility Corp.	284
Ecotel Inc.	232
Trans Mountain Pipeline LP	222
Cogeco Connexion Inc.	216

Source: Author's Own Work Using SMS Data

Total Count of RF Assignments by Type of Station (Canadian Designation)

Type of Station	Description	Count
1	Fixed	204
3	Mobile	30
6	Fixed-Base Station	26
7	Transportable Base Station	6
Unlisted		15,794

Source: Author's Own Work Using SMS Data

Total Count of RF Assignments by ITU Class of Station (ITU Designation)

Type of Station	Description	Count
FB	Fixed Base	22
FX	Fixed Station	30
ML	Land Mobile Station	30
TC	Earth Station in the Fixed-Satellite Service	184
Unlisted		15,794

Source: Author's Own Work Using SMS Data

The 4.0–4.2 GHz Range

General Information

Description	Count
RF Assignments	595
Unique Locations	281
Licensees	34

Source: Author's Own Work Using SMS Data

Top 10 Licence Holders in Canada

Licensee Name	Count
Telesat Canada	149
Northwestel Inc.	135
Kativik Regional Government	87
Infosat Communications LP	55
Bell Media Inc.	22
SOCIÉTÉ DE TÉLÉDIFFUSION DU QUÉBEC (TÉLÉ-QUÉBEC)	16
Nav Canada – Quebec	12
KEEWAYTINOOK OKIMAKANAK FIRST NATIONS	11
Fisheries and Oceans Canada – Canadian Coast Guard	11
Bell MTS	11

Source: Author's Own Work Using SMS Data

Total Count of RF Assignments by Type of Station (Canadian Designation)

Type of Station	Description	Count
1	Fixed	522
19	Wide-Area Mobile	2
Unlisted		71

Source: Author's Own Work Using SMS Data

Total Count of RF Assignments by ITU Class of Station (ITU Designation)

Type of Station	Description	Count
FX	Fixed Station	14
ML	Land Mobile Station	2
TC	Earth Station in the Fixed-Satellite Service	506
UE	Earth Station in the Standard Frequency-Satellite Service	2
Unlisted		71

Source: Author's Own Work Using SMS Data

The 4.4–4.94 GHz Range

General Information

Description	Count
RF Assignments	51
Unique Locations	10
Licensees	6

Source: Author's Own Work Using SMS Data

Top 10 Licence Holders in Canada

Licensee Name	Count
Ultra Electronics TCS Inc.	36
Transport Canada – Aircraft Services Technical Library – AAFBAA	4
Rheinmetall Canada Inc.	4
NRC, Dominion Radio Astrophysical Observatory (DRAO)	3
Provincial Airspace	2
Kraken Robotic Systems Inc.	2

Source: Author's Own Work Using SMS Data

Total Count of RF Assignments by Type of Station (Canadian Designation)

Type of Station	Description	Count
1	Fixed	3
3	Mobile	15
4	Aircraft	2
6	Fixed-Base Station	3
7	Transportable Base Station	28

Source: Author's Own Work Using SMS Data

Total Count of RF Assignments by ITU Class of Station (ITU Designation)

Type of Station	Description	Count
FB	Base Station	3
FX	Fixed Station	28
MA	Aircraft Station	2
ML	Land Mobile Station	13
MO	Mobile Station	2
RA	Radio Astronomy Station	3

Source: Author's Own Work Using SMS Data

The 7.125–8.4 GHz Range

General Information

Description	Count
RF Assignments	13,809
Unique Locations	2,516
Licensees	71

Source: Author's Own Work Using SMS Data

Top 10 Licence Holders in Canada

Licensee Name	Count
Rogers Communications Canada Inc.	3,468
BC Hydro (Fixed)	1,664
Hydro-Quebec	1,390
TELUS Communications Inc.	1,286
AltaLink	1,064
ATCO Electric Fixed Transmission	924
Manitoba Hydro (Microwave Radio)	604
Nova Scotia Power Inc.	484
Bell Canada	464
NB Power Transmission Corporation	412

Source: Author's Own Work Using SMS Data

Total Count of RF Assignments by Type of Station (Canadian Designation)

Type of Station	Description	Count
1	Fixed	13,773
3	Mobile	2
Unlisted		34

Source: Author's Own Work Using SMS Data

Total Count of RF Assignments by ITU Class of Station (ITU Designation)

Type of Station	Description	Count
ET	Space Station in the Fixed Operating Service	1
FX	Fixed Station	13,620
ML	Land Mobile Station	2
TC	Earth Station in the Fixed-Satellite Service	34
TD	Space Telecommand Earth Station	5
TM	Earth Station in the Meteorological-Satellite Service	8
TR	Space Telemetering Earth Station	1
TW	Earth Station in the Earth Exploration-Satellite Service	104
Unlisted		34

Source: Author's Own Work Using SMS Data