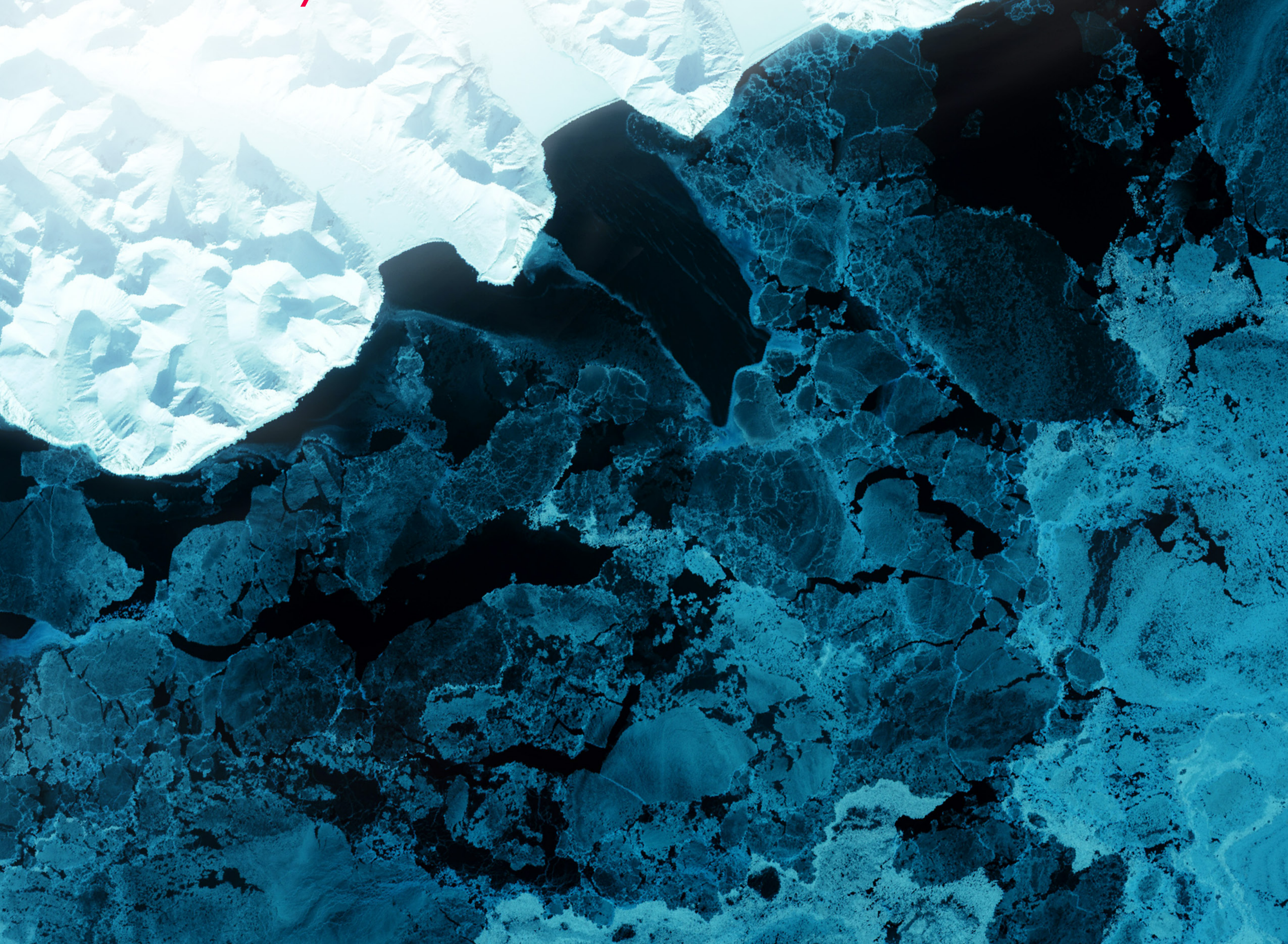
Centre for International
Governance Innovation

CIGI Papers No. 303 — September 2024

Outer Space and the Arctic
Connections, Opportunities, Challenges

Michael Byers



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About the Author

Michael Byers holds the Canada Research Chair in Global Politics and International Law at the University of British Columbia. Michael has been a fellow of Jesus College, Oxford University; professor of law at Duke University; visiting professor at the universities of Cape Town, Tel Aviv, Nord (Norway) and Novosibirsk (Russia); and senior global fellow at the University of St Andrews. He is the author of *International Law and the Arctic* (Cambridge University Press, 2013) and the co-author of *Who Owns Outer Space?* (Cambridge University Press, 2023). Both volumes were awarded the Donner Prize for the best book on public policy by a Canadian.

Executive Summary

Satellites support communications, navigation, security, search and rescue and scientific research across the Arctic. The number of satellites is growing quickly, creating opportunities for growth and development. However, the increased use of space also carries risks for national and regional governments, local communities, Indigenous organizations and companies. Satellites are vulnerable to system failures, deliberate attacks and natural forces such as solar storms. Redundancies of all kinds are needed to protect against these risks. For instance, ground-based navigational aids to aviation should be maintained, notwithstanding the cost-saving attractions of GPS. At the same time, satellites contribute to Arctic security through an enhanced understanding of what potential adversaries are doing — or not doing. One of the great geopolitical risks in the Arctic involves security dilemmas, where states feel compelled to build up their military capabilities in an escalating series of responses to suspected increases by others. Satellites help to prevent unnecessary escalations, accidents and arms races.

Introduction

Humanity is expanding quickly into outer space ("space") as a result of new technologies and a dramatic increase in the capabilities of private space companies. These developments create opportunities for growth and development in the Arctic, where satellites already support communications, navigation, surveillance, security, search and rescue, disaster relief, forest firefighting, weather forecasting, fishing, prospecting, education, health care and environmental research.

Moreover, most Earth observation satellites, used for everything from intelligence gathering to sea-ice monitoring, are placed in polar orbits. These orbits are roughly perpendicular to the equator and therefore converge over the Arctic. For this reason, the world's largest satellite ground station is located in the region, on the Norwegian archipelago of Svalbard (Filipova and Fountain 2021), while two smaller ground stations are located at Inuvik, Northwest Territories (Kongsberg Satellite Services [KSAT] 2019).[1] Ground-based infrastructure is another way that developments in space can spur growth and development in the Arctic.

At the same time, a growing reliance on space also carries risks, including system failures, deliberate attacks and natural forces such as solar storms. National and regional governments, local communities, Indigenous organizations and companies should embrace the opportunities presented by developments in space, while planning for risks and maintaining terrestrial systems as backups.

Space and the Arctic both play a role in global security, although there is little evidence of an arms race in space, and no reason to believe that Russia or China pose major threats to Canada's Arctic sovereignty. Satellites are an important tool for maintaining peace and stability in the region.

Space and the Arctic

Space and the Arctic are closely connected in multiple ways, from astrophysics to culture, communications, navigation, search and rescue and environmental science.

The Arctic Only Exists Because of Space

The Arctic environment only exists because of space, since the extreme seasons that define the region are a consequence of Earth's orbital mechanics, most notably the tilt of the planet as it orbits the sun.[2] This leads to the absence of sunlight in winter and to 24-hour sunlight in summer in the Earth's polar regions. The Arctic's connections with space are also visible in the aurora borealis, created when charged particles from the sun slam into Earth's magnetic field and are redirected northward, interacting with the upper atmosphere to create a dynamic luminescence.[3] Another

1 See https://natural-resources.canada.ca/research-centres-and-labs/satellite-receiving-stations/satellite-facilities/inuvik-satellite-station-facility/10953.

2 See https://nsidc.org/learn/parts-cryosphere/arctic-weather-and-climate/science-arctic-weather-and-climate.

3 See www.asc-csa.gc.ca/eng/astronomy/northern-lights/what-are-northern-lights.asp.

connection with space is visible in the extreme tides of eastern Nunavut and northern Quebec (Oceans North 2018, 33), which result from the Earth's interaction with the moon's gravity.

The Inuit, who live in harmony with the seasons, are fully aware of their relationship with space. Kenojuak Ashevak's *Nunavut (Our Land)* celebrates the 1993 Nunavut Land Claims Agreement, which led to a new majority-Inuit territory in Canada in 1999. The 4 m wide lithograph chronicles the annual cycle of Inuit life in a circle revolving around the sun, the moon and the stars.[4]

Arctic Communications Depend on Satellites

In 1962, Canada became the third country with a satellite in orbit.[5] Alouette-I was designed to study a layer of the upper atmosphere, called the ionosphere, to understand why Arctic radio communications were disrupted by solar storms. It was named after the folksong voyageurs sang as they paddled the trade routes of northern Canada. Although the satellite was turned off after a decade of scientific service, it remains in orbit today, a piece of Canadian history in the sky (Canadian Space Agency 2023).

In 1972, Anik A1 was launched into geosynchronous orbit, about 36,000 km above the equator.[6] The world's first domestic communications satellite, it enabled the CBC to broadcast from coast to coast to coast. "Anik" means "little brother" in Inuktitut.

Even today, Nunavut, the largest of Canada's three northern territories, is entirely dependent on satellites for communications. These have facilitated health care, education, economic development and governance, but there been limitations, because connectivity with the rest of the territory, country and world has been expensive, unreliable and slow (Rabouam 2023).

Although satellites like Anik A1 were game changers for the Canadian Arctic, connectivity from geosynchronous orbit suffers from latency, i.e., small delays in reception and transmission, due to the distance that the radio signals have to travel (Seal and Ritchie 2023). Satellite signals from geosynchronous orbit also encounter line-of-sight challenges above about 70° north, and generally cannot reach above 75° north. This poses a problem for some communities in Nunavut, notably Pond Inlet (72°), Resolute Bay (74°) and Grise Fiord (76°), while Canadian Forces Station Alert is located at 82° north.

Connectivity from geosynchronous orbit has improved somewhat over the decades, due to improved technologies, but an explosion in internet usage has still left operators struggling to meet demand. In 2018, Ottawa-based Telesat launched Telstar 19 VANTAGE (Rogers 2018). This single satellite provided a five-fold increase in broadband connectivity to the Canadian Arctic. Then, in 2021, SSi Canada signed a deal with Luxembourg-based SES to redirect an existing satellite toward northern Canada, providing competition and additional capacity (McKay 2021). However, these improvements have been offset by problems. In 2022, Anik F2, an 18-year-old satellite operated by Telesat, began to fail. The company announced that it would purchase another existing satellite, from an unnamed operator, and redirect it toward the Arctic to maintain capacity (Rainbow 2022).

Communications satellites in geosynchronous orbit are now being supplemented, and may soon be supplanted, by "mega-constellations" of satellites in low-Earth orbit (Boley and Byers 2021). Located at much lower altitudes, these systems offer lower latency. They also provide greater coverage of the Arctic, because some of the satellites are placed on polar orbits, which brings them within line of sight at all locations. However, because the satellites are at low altitudes and move relative to the Earth's surface, hundreds, even thousands of them are needed to provide continuous coverage.

SpaceX's Starlink is the current market leader and its terminals, each about the size of a pizza box, are appearing outside homes and businesses across the North (Charron-Leclerc 2023). SpaceX's ability to compete is augmented by its reusable Falcon 9 rockets and the flat packing of up to 60 satellites, each more than 350 kg, into a single payload fairing — the cargo hold on the top of a rocket. SpaceX, which currently has more than 5,500 Starlink satellites in orbit (Pultarova and Howell 2024), is the new game changer for the Canadian Arctic. Heath care, education and commerce will all be advanced. Inuit and First Nations youth can now work for global tech companies or create start-ups of their own.

4 See www.historymuseum.ca/blog/nunavut/.

5 See www.asc-csa.gc.ca/eng/satellites/alouette.asp.

6 See www.asc-csa.gc.ca/eng/multimedia/search/image/156.

However, the improvements in latency and coverage also come with costs, as Célestine Rabouam (2023, 10) observes: "SpaceX does not participate in any way in the economy of the Arctic territories, nor does it contribute to initiatives aimed at strengthening reconciliation with Indigenous populations. And secondly, by taking over part of the users in Nunavut, the Yukon and the NWT, Starlink increases the dependence of remote communities, and of Canada in general, on American telecommunications infrastructures. Starlink's capture of part of the market also has the effect of strengthening the geographical concentration of digital organizational decision-making power in the South, while Indigenous populations aspire to relocate these skills locally."

SpaceX now has a direct competitor in low-Earth orbit: the originally British company OneWeb, now part of the French company Eutelsat, with a constellation of more than 600 satellites.[7] In 2023, Ontario-based Galaxy Broadband Communications contracted with OneWeb to provide connectivity across Canada, including 25 communities in Nunavut (Eutelsat OneWeb 2023).

Meanwhile, Amazon has received a licence from the US Federal Communications Commission for 3,000 satellites that will form its Project Kuiper constellation (Jones 2023a). Two companies linked to the Chinese government also have plans for satellite constellations: the 13,000-satellite Guowang (SatNet) and the 12,000-satellite G60 Starlink projects (Jones 2023b).

There is even a real prospect of a Canadian competitor. Ontario-based Telesat has long-standing plans to enter the low-Earth-orbit market with a 198-satellite constellation, Lightspeed. After a recent injection of $2 billion in federal and Quebec government support, the system is now scheduled to launch in mid-2026, with connectivity across the Arctic by 2027 (Telesat 2023).

The Canadian government's April 2024 defence policy update includes the following paragraph: "To allow the Canadian Armed Forces to communicate securely and reliably with our deployed forces, allies and partners, we will acquire a comprehensive worldwide satellite communication capability. Working with our allies, we will jointly develop updated access to the satellite constellations that enable the military to operate effectively around the world, including by better defending its communications against jamming or disruptions by adversaries while deployed" (Department of National Defence 2024, 28).

Later in the same document, the government commits to "enhanced long-term Arctic satellite communications, providing coverage at extreme northern altitudes" (ibid., 34). Telesat Lightspeed should be central to these plans, given that it will include satellites in polar orbits and is already receiving more than $1 billion in federal funds.

Global Positioning System

Another essential space-based service is the Global Positioning System (GPS),[8] which has been operational for three decades. GPS provides a highly accurate position, navigation and timing service from a constellation of 32 satellites in mid-Earth orbit, at an altitude of about 20,000 km. The system is owned and operated by the US military but is very widely used by civilians.

GPS is no longer the only global position, navigation and timing satellite system, with the European Union, Russia and China having their own systems: Galileo, GLONASS and BeiDou, respectively (Lieberman 2021). But GPS is the dominant system in North America, and is heavily used by the commercial aviation industry — including for navigation and landings in cloud and fog.

Although GPS is widely used in the Arctic, it is less reliable there than at lower latitudes, for two reasons. First, GPS satellites follow one of six orbital planes, all at an inclination of roughly 55°. At Arctic latitudes, several satellites will still be visible at any given time, but there might be only three of them, rather than the four the system usually requires. This, and the fact that the satellites will be low on the horizon, makes it more difficult to obtain accurate "trilateration," which is the basis for the system. Second, the Arctic experiences a great deal of ionospheric activity — the interaction of charged particles from the sun with Earth's magnetic field and the upper atmosphere. The same activity can cause signal "scintillation" for GPS and therefore timing errors, which in turn creates errors with positioning calculations. For these reasons, governments and companies should maintain redundant systems in the Arctic,

7 See https://oneweb.net/about-us/our-story.

8 See www.gps.gov/systems/gps/.

including inertia reference systems on aircraft and non-directional beacons on the ground.

Satellite-Supported Search and Rescue

GPS satellites and some other satellites carry receivers and transmitters in support of search and rescue. Across the Arctic, hunters, prospectors and adventurers carry handheld beacons that can be used to send distress signals to them. Similar beacons are required on ships and aircraft, and these send emergency signals automatically when submerged or subject to unusual g-forces. All this takes the "search" out of search and rescue, saving time, lives and money. The network, called the International Cospas-Sarsat Programme, was created in 1979 by the United States, the Soviet Union, Canada and France (Public Safety Canada 2020).

In addition to the United States' GPS satellites, satellites supporting the Cospas-Sarsat Programme today are owned and operated by Russia, Canada, France, the European Union and the European Organisation for the Exploitation of Meteorological Satellites.[9] More than 200 countries and territories benefit from the service, which is provided at no cost, either to the owners of the beacons or to the governments receiving notice — including the precise location — of any beacon activated on their territory or off their coastline. Canada plays a major role in the Cospas-Sarsat Programme, as it hosts the secretariat of the organization in Montreal.

The Cospas-Sarsat Programme is an example of successful international cooperation and is often overlooked because it works so well. However, like all systems, it could falter or fail, for instance, if relations with Russia worsen, or if some or all of the satellites were lost during a severe solar storm. For this reason, "search" capabilities should still be maintained where possible, and hunters, prospectors and adventurers should always be fully prepared. Nobody should count on a prompt rescue just because they are carrying a beacon.

Earth Observation Satellites

Earth observation satellites take images of the planet's surface, supporting science, prospecting, fishing, forest firefighting, surveillance and disaster relief. Synthetic aperture radar satellites, developed in Canada for the seasonally sunless Arctic, can take images at night and through clouds.[10] They can also measure the thickness and density of sea ice, making them essential tools for Arctic navigation, security and sovereignty. Being able to monitor ships from space, and map the presence and thickness of ice, is a necessary complement to having naval patrol vessels, Coast Guard icebreakers and helicopters available to interdict foreign vessels. The same kind of satellite imagery supports safe travel by Arctic residents, through an innovative project called SmartICE.[11]

Canada's first synthetic aperture radar satellite, RADARSAT-1, operated from 1995 until 2013, with the Canadian Ice Service being one of its largest users.[12] Its successor, RADARSAT-2, was launched in 2007 and remains operational today.[13] RADARSAT-2 is owned and operated by a private company, MDA, with the Canadian government as its largest customer.

RADARSAT Constellation was launched in 2019.[14] The three government-owned satellites that make up the system provide near-constant coverage of Canada's territory and maritime zones for tracking ships, measuring sea ice and guiding disaster relief.

RADARSAT Constellation is designed to operate until 2026 only, which means that the procurement of replacement satellites needs to begin now. Moreover, RADARSAT-2 and RADARSAT Constellation are vulnerable to attack — in particular because of their involvement in a foreign armed conflict, as discussed below. For this reason, the federal government should maintain other forms of Arctic surveillance to provide redundancy, such as long-range crewed aircraft and drones.

Satellite Ground Stations

Most Earth observation satellites are in polar orbits, roughly perpendicular to the equator, and the data they obtain must be downloaded through government-owned or commercial ground stations. Since polar orbits converge near the poles, many of these ground stations are located at northern latitudes. The world's largest ground

9 See https://cospas-sarsat.int/en/about-us/participants.

10 See www.earthdata.nasa.gov/learn/backgrounders/what-is-sar.

11 See https://smartice.org/.

12 See www.asc-csa.gc.ca/eng/satellites/radarsat1/.

13 See www.asc-csa.gc.ca/eng/satellites/radarsat2/.

14 See www.asc-csa.gc.ca/eng/satellites/radarsat/.

station, composed of about 150 large antennas, is operated by the Norwegian company KSAT on Norway's Svalbard archipelago, 800 km north of the Norwegian mainland at 78° north (Bousquette 2023).

Natural Resources Canada (NRCan) operates the Inuvik Satellite Station Facility, located at 68° north. It hosts antennas owned by the German AeroSpace Centre, the Swedish Space Corporation, the French Centre national d'etudes spatiales and the Canadian Research and Development Corporation.[15] NRCan also owns and operates its own 13 m antenna in support of MDA's RADARSAT-2 as well as RADARSAT Constellation and several other Canadian government-owned satellites.

KSAT is developing a separate ground station at Inuvik, after a long delay in licensing caused by the out-of-date Canadian Remote Sensing Act (Byers 2018). The ground station initially focused on downloading data from the European Space Agency's Sentinel satellites, as well as from satellites owned by Planet, a California-based company with a wide range of civilian and military customers (KSAT 2019).

In April 2024, the Canadian government's defence policy update promised an Arctic ground station: "To enable the Canadian Armed Forces to deploy assets and transmit information from space-based intelligence, surveillance, and reconnaissance quickly and seamlessly, we will build a new satellite ground station in the Arctic" (Department of National Defence 2024, 25). Since a fibre-optic link is needed to operate an effective, large-volume ground station, we can expect this facility to also be located at Inuvik.

Fibre-Optic Cables

The Svalbard Satellite Station is connected to the Norwegian mainland by two fibre-optic subsea cables that were paid for mostly by the US government (Buchanan, Cabell and McCrary 2006). In January 2022, one of the two cables suffered a disruption at a location where the ocean depth drops to 2,700 m. Since the second cable was not disrupted, the only loss was redundancy, which KSAT was able to restore 11 days later. The next month, the Norwegian police stated: "Preliminary investigations strengthen our hypothesis about human impact leading to the loss of communication in one of the cables" (Staalesen 2022). Whoever interfered with the cable probably could have caused a complete disruption, had they wished to do so.

Canada has a similar vulnerability, in the form of a fibre-optic cable that runs more than 1,000 km down the Mackenzie River Valley, connecting the ground stations at Inuvik to southern Canada and beyond.[16] Completed in 2017, the cable is an important piece of national security infrastructure and needs to be understood and protected as such. It is also vulnerable, running along or near the surface of remote and rarely policed land. In August 2023 and May 2024, the cable was damaged by forest fires. Fortunately, some redundancy is now being provided by the Dempster Fibre Project, which links Inuvik to Dawson City, Yukon, where a pre-existing cable connects to British Columbia and beyond.[17] Additional steps should be taken to protect the cables from fires and human interference, for instance, by running them across the bottom of lakes — including Great Slave Lake, south of Yellowknife — where possible.

Space and Arctic Security

Space and the Arctic are both connected to global security risks, but there is little evidence of an arms race in space, and no reason to believe that Russia or China have designs on the Canadian Arctic. Both regions are militarized, not weaponized.

Militarized but Not Weaponized

The connections between the Arctic and space, and the similarities and differences between the two regions, cast some useful light on a widespread assumption, namely, that Russia and China pose major threats to Canada's Arctic sovereignty. This section of this paper will begin with a brief history of the use of space and the Arctic for military purposes.

From the late 1950s, the United States and the Soviet Union developed and deployed

15 See https://natural-resources.canada.ca/research-centres-and-labs/satellite-receiving-stations/satellite-facilities/inuvik-satellite-station-facility/10953.

16 See www.mvfl.ca/.

17 See https://yukon.ca/en/dempsterfibreproject.

intercontinental ballistic missiles (ICBMs) designed to fly through space, with most of the intended flight paths passing over the Canadian Arctic. These missiles provided deterrence through "mutually assured destruction." However, since the ICBMs would have passed through space and over the Canadian Arctic, they never contributed to the weaponization of either region.

Instead of being substantially "weaponized," both space and the Canadian Arctic are "militarized." Militarization involves the use of a region for the transportation of weapons or personnel as well as the placement of supporting equipment, whereas weaponization involves the actual placement of weapons (Sheehan 2007). Consider the following facts: Canada's three northern territories make up 40 percent of its landmass, but only about 300 of Canada's authorized force size of 71,500 full-time military personnel are based in that large, remote, environmentally challenging region (Standing Senate Committee on National Securitiy, Defence and Veterans Affairs 2023). Indeed, the remoteness and environmentally challenging nature of the Canadian Arctic help to explain why so few troops are needed. As Canada's then chief of the defence staff, General Walter Natynczyk, explained in 2009: "If someone were to invade the Canadian Arctic, my first task would be to rescue them" (quoted in Deshayes 2009).

Another chief of the defence staff, General Wayne Eyre, confirmed this assessment in 2022, telling the House of Commons Standing Committee on National Defence: "I see no real threat today to our territorial sovereignty; nor do I see one in the near future" (House of Commons 2022). The fact is, neither Russia nor China have anything to gain by invading the Canadian Arctic: the former is already the largest country in the world, with uncontested title over about half of the circumpolar Arctic, while the latter has a long record of using trade and foreign investment to secure the resources that it needs.

In April 2024, the Canadian government released a new defence policy update, *Our North, Strong and Free*, which asserts that:

> Canada's Northwest Passage and the broader Arctic region are already more accessible [due to climate change], and competitors are not waiting to take advantage — seeking access, transportation routes, natural resources, critical minerals, and energy sources through more frequent and regular presence and activity. They are exploring Arctic waters and the sea floor, probing our infrastructure and collecting intelligence. We are seeing more Russian activity in our air approaches, and a growing number of Chinese dual-purpose research vessels and surveillance platforms collecting data about the Canadian North that is, by Chinese law, made available to China's military.
>
> For decades, we aimed to manage the Arctic and northern regions cooperatively, as a zone free from military threats. Yet Russia continues to modernize and build up its military presence in their Arctic, investing in new bases and infrastructure. It is highly capable of projecting air, naval and missile forces both in and through the broader Arctic region. Russia also possesses a robust Arctic naval presence with submarines, surface combatants and an icebreaker fleet much larger than those of other Arctic powers.
>
> Similarly, despite not being an Arctic nation China seeks to become a "polar great power" by 2030 and is demonstrating an intent to play a larger role in the region. The steady growth of its navy, including its conventional and nuclear-powered submarine fleet, will support this ambition. China is also expanding its investments, infrastructure and industrial scientific influence throughout the Arctic region. (Department of National Defence 2024, 4)

However, none of these concerns are specific to Canada, apart from the statement about "probing our infrastructure and collecting intelligence." And even those two concerns are not specific to the Canadian Arctic; they also apply in the south of the country. Given the lack of actual evidence of Arctic threats behind the new defence policy update, one could easily think that the Liberal government of Justin Trudeau has realized, just as the Conservative governments of John Diefenbaker and Stephen Harper did in 1958 and 2015, respectively, that talking up threats to Canada's Arctic sovereignty is good electoral politics — and nothing more.

The European Arctic is different, with North Atlantic Treaty Organization states having land borders and maritime boundaries with the Soviet Union (and later Russia), and with the preponderance of the Soviet Union and later Russia's nuclear forces being located on submarines, bombers and ICBMs based on the Kola Peninsula — alongside Norway, Sweden and Finland. When discussing Arctic security, it is important to distinguish between these two very different regions: the relatively low-tension, militarized-but-not-weaponized Canadian Arctic; and the high-tension, militarized-and-weaponized European Arctic, which includes the Barents Sea, the Norwegian Sea and the "Greenland-Iceland-UK Gap."[18]

In the Canadian Arctic, militarization-but-not-weaponization prominently included two lines of radar stations designed to identify and track incoming bombers and ICBMs: the Distant Early Warning (DEW) Line, which operated from 1957 to 1993, and the North Warning System, which replaced the DEW Line and remains operational today. The radar stations that make up the North Warning System are one of the most visible connections between the Canadian Arctic and space, with two of the long-range stations being located just outside the communities of Cambridge Bay and Hall Beach, Nunavut, complete with large white domes protecting the radar dishes inside.

Another powerful radar station, located at Thule, Greenland, was recently upgraded by the US military to enable the identification and tracking of satellites in addition to aircraft and missiles. After the upgrades, Thule Air Force Base was transferred to the US Space Force and renamed Pituffik Space Base.

In 2022, the Canadian government announced a $38.6 billion plan to modernize the North American Aerospace Defence Command (NORAD). The plan includes an Arctic over-the-horizon radar system "to provide early warning radar coverage and threat tracking from the Canada-United States border to the Arctic Circle" and a polar over-the-horizon radar system "to provide early warning radar coverage over and beyond the northernmost approaches to North America, including the Canadian Arctic archipelago," with the two systems becoming operational in the early 2030s.[19] Additional funding would be provided by the United States, which would operate the systems jointly with Canada — as it does with the North Warning System today.

Further to this, a portion of the $38.6 billion was earmarked for the completion of a "space-based surveillance project" that the Canadian government had first announced in 2017 (ibid.).

Today, space is heavily militarized, with thousands of satellites having been launched by militaries for communications, navigation, surveillance, situational awareness and targeting since the 1950s (Sheehan 2007). Modern militaries depend on satellites to the point where fifth-generation fighter jets and armed drones cannot operate to their full capabilities without space-based broadband (Thompson, Gagnon and McLeod 2018). Meanwhile, GPS is a key component of precision-guided missiles, bombs and artillery (Gettinger 2022). Yet if space has ever been weaponized, this only occurred with the testing of anti-satellite (ASAT) weapons during the Cold War. These weapons ranged from ground-based missiles, lasers and jammers to space-based killer satellites designed to crash into other satellites, capture them or nudge them off course (Moltz 2011). As fragile pieces of equipment that follow predictable trajectories, satellites are vulnerable to attack, and yet there is no evidence that any ASAT weapons are currently deployed in space. Nor has any such weapon ever been used against a satellite from another country.

Space and the Arctic are hardly immune from Great Power competition and potential armed conflicts. As the next section will show, both regions are connected to global security risks. However, there is little evidence of an arms race in space, and no reason to believe that Russia or China pose major threats to Canada's Arctic sovereignty. Space and the Arctic are militarized, not weaponized.

Connections with Global Security Risks

The January 2022 interference with a subsea cable connecting the Svalbard Satellite Station is one example of how space-related activities in the Arctic are subject to global security risks. Several other examples have become more apparent during the war in Ukraine, including the risk of cyberattacks.

The US company Viasat was using geosynchronous satellites to provide communications services to

18 The Greenland-Iceland-UK Gap is a naval choke point in the North Atlantic Ocean, formed by the relative proximities of three landmasses.

19 See www.canada.ca/en/department-national-defence/services/operations/allies-partners/norad/facesheet-funding-norad-modernization.html.

the Ukrainian military when, on February 24, 2022, it suffered a cyberattack — at the very moment that Russia launched its full-scale invasion (Viasat 2022). The attack exploited a misconfiguration in a virtual private network appliance to target ground-based modems, forcing tens of thousands of the modems off the network and causing irreparable damage to many of them. The ultimate target of the cyberattack was almost certainly the Ukrainian military (Page 2022), and as for the identity of the responsible party, this was hardly in doubt. In May 2022, the European Union and its member states issued a joint statement to "strongly condemn the malicious cyber activity conducted by the Russian Federation against Ukraine, which targeted the satellite KA-SAT network, operated by Viasat" (Council of the European Union 2022).

Two days after the cyberattack, Elon Musk, the CEO of SpaceX, announced that his company was providing coverage in Ukraine from its mega-constellation of Starlink satellites and urgently delivering ground terminals there (Musk 2022a). When Russia tried to jam the signals, SpaceX engineers updated their software (Duffy 2022). On March 25, 2022, Musk tweeted, "Starlink, at least so far, has resisted all hacking & jamming attempts" (Musk 2022b). By June 2022, 15,000 ground terminals had been delivered to Ukraine (Musk 2022c). Many of the small terminals are employed at frontline positions, where they send and receive up-to-date imagery and other information used in targeting (Miller, Scott and Bender 2022). As one Ukrainian soldier said, "Starlink is our oxygen." [Without it,] "our army would collapse into chaos" (*The Economist* 2023).

In the face of the Russian invasion, the Ukraine government also appealed for Earth imagery from Western companies. MDA, the Canadian company that owns and operates RADARSAT-2, responded to the call. As the company's CEO explained in a press release: "Images captured by MDA's SAR technology, which is unique for its ability to see through all weather and cloud conditions, will be merged and analyzed with other sources of imagery from commercial Earth observation companies to develop comprehensive near real-time intelligence reports for Ukrainian government officials" (MDA 2022).

However, MDA's support for the Ukrainian military also made RADARSAT-2 a potential target. In October 2022, Russian Ambassador K. V. Vorontsov told the United Nations General Assembly that the use of commercial satellites to support the Ukrainian military was "provocative" and "an extremely dangerous trend" and that such "quasi-civilian infrastructure may be a legitimate target for a retaliatory strike" (Faulconbridge 2022). Russia is certainly capable of destroying or disabling Western satellites, whether by individually targeting them with ground-based missiles, or by targeting one of its own satellites in the middle of a mega-constellation such as Starlink (Boley and Byers 2024). As a result, governments, companies and other users of these satellite systems in the Canadian Arctic are at some risk of losing access due to armed conflicts or other geopolitical developments in distant parts of the world.

That said, there are at least three reasons to consider the geopolitical risks to satellites — and therefore Arctic security — as moderate rather than extreme.

Space Debris

"Direct-ascent" ASAT weapons are launched from the Earth's surface. They can include missiles developed for other purposes, including air, sea or ground-based ballistic missiles, as well as anti-ballistic missiles such as the Russian PL-19 Nudol (US Congress 1985). When employed as an ASAT weapon, these missiles use a high-speed impact to destroy the target. The impacts from this or any other type of "kinetic" ASAT weapon can create many thousands of pieces of dangerous space debris and place them on a wide variety of elliptical orbits, crossing the altitudes of many other satellites (Byers and Boley 2023, 262–74). Debris generation, especially at altitudes above 600 km, can affect future satellite operations for decades. It is also possible that a kinetic ASAT weapon could trigger a collisional cascade, as the resulting debris causes more collisions and so on (Billings 2015).

Spacefaring states are aware of the long-term risks associated with debris and have, for decades, exercised considerable restraint with regard to these weapons. As James Clay Moltz (2011) explains, the United States and the Soviet Union "gradually accepted mutual constraints on deployable weapons in return for safe access to the space environment for military reconnaissance, weather forecasting, tracking, early warning, and a range of civilian uses." In 2015, the view of the US military was summed up by General John Hyten, the commander of the US Air Force Space Command: "Kinetic [anti-satellite weaponry] is horrible for the world…the one limiting factor is no debris. Whatever you do, don't create debris" (quoted in Billings 2015). Widespread awareness and concern about debris help to explain why no state has ever used a kinetic ASAT weapon against a satellite from another state.

Satellites Help Prevent "Security Dilemmas"

With space-based technologies, it is relatively easy to gather information about military activities, especially in the Arctic where there are relatively few human activities or trees, buildings and other objects that might offer concealment. One example concerns synthetic aperture radar satellites, which — as discussed above — can identify and track ships, even at night and through clouds.[20] Another example involves thermal imaging satellites, which are most effective in detecting human activity when temperatures are cold.[21]

This ability to gather information from space helps to prevent a "security dilemma," where one state, uncertain about the actions and motives of another, feels compelled to increase its military capabilities. This can lead to an escalating and destabilizing series of responses, even if the initial response was based on incorrect information or assumptions (Herz 1950; Booth and Wheeler 2007). For instance, the re-opening and expansion of Cold War-era military bases in the Russian Arctic has prompted concern, mostly in the Western media (Williams and Novak 2023). Yet it is relatively easy, including with publicly available Google Earth or low-cost Planet imagery, to observe that the changes are modest in scale and appear defensive in character (Walsh and Dean 2022).

The tracking of submarines is a more complex matter (Byers 2013, 245), although satellites can be used to detect departures and arrivals in port. Sometimes, synthetic aperture radar satellites might be able to identify changes in wave patterns caused by submerged submarines. However, nuclear missile submarines are the core of the US and Russian nuclear deterrents, as the assets most likely to survive a surprise "first strike." In other contexts, satellite surveillance can bring greater stability to international relations by helping to prevent security dilemmas, but nuclear missile submarines are different — not being able to track them continuously from space is probably a good rather than a bad thing.

Russia and Western States Still Cooperate in Space

Russia has long cooperated with Western states in the Arctic. This cooperation began during the Cold War, as exemplified by the 1973 Polar Bear Treaty among Canada, Denmark, Norway, the Soviet Union and the United States.[22] By prohibiting the use of helicopters and icebreakers for hunting polar bears, the treaty arrested a sharp decline in bear populations around the region. In 1982, the Soviet Union and the United States led the negotiation of the United Nations Convention on the Law of the Sea, a "constitution for the oceans" containing provisions of direct relevance to the Arctic, such as article 234 on pollution prevention in ice-covered waters and article 76 on coastal state rights over continental shelves extending more than 200 nautical miles from shore).[23] In 1987, Soviet leader Mikhail Gorbachev prompted a process of institution building that, after additional Finnish and Canadian leadership, led to the Arctic Environmental Protection Strategy in 1991[24] and the Arctic Council in 1996.[25] Although the Arctic Council does not deal with security matters, during the 2010s it grew into the central governance mechanism for the region, initiating the negotiation of the 2011 Arctic Search and Rescue Agreement[26] and other new treaties on oil spill preparedness and response[27] and scientific

20 See www.earthdata.nasa.gov/learn/backgrounders/what-is-sar.

21 See https://crisp.nus.edu.sg/~research/tutorial/infrared.htm.

22 *Agreement on the Conservation of Polar Bears*, Canada, Denmark, Norway, Union of Soviet Socialist Republics and the United States, 15 November 1973, 30 ILM 13.

23 *United Nations Convention on the Law of the Sea*, 10 December 1982, 1833 UNTS 397 (entered into force 16 November 1994).

24 *Arctic Environmental Protection Strategy*, Canada, Denmark, Finland, Iceland, Norway, Sweden, Union of Soviet Socialist Republics and the United States, 4 June 1991, 30 ILM 1624.

25 *Declaration on the Establishment of the Arctic Council*, Canada, Denmark, Finland, Iceland, Norway, Sweden, the Russian Federation and the United States, 19 September 1996, 35 ILM 1387.

26 Arctic Council, *Agreement on Cooperation on Aeronautical and Maritime Search and Rescue in the Arctic*, Canada, Denmark, Finland, Iceland, Norway, the Russian Federation, Sweden and the United States, 12 May 2011, online: <https://oaarchive.arctic-council.org/handle/11374/531>.

27 Arctic Council, *Agreement on Cooperation on Marine Oil Pollution Preparedness and Response in the Arctic*, Canada, Denmark, Finland, Iceland, Norway, the Russian Federation, Sweden and the United States, 15 May 2013, online: <https://oaarchive.arctic-council.org/items/ee4c9907-7270-41f6-b681-f797fc81659f>.

cooperation.[28] In 2017, the five Arctic Ocean states along with China, Japan, South Korea, Iceland and the European Union signed a treaty prohibiting commercial fishing in the central Arctic Ocean until scientific evidence supports its opening.[29]

A similar history of cooperation exists in space. During the early Cold War, while the Soviet Union and the United States were building intercontinental ballistic missiles designed to fly through space, they were also negotiating four multilateral treaties setting out rights and duties for spacefaring states: the Outer Space Treaty, the Rescue Agreement, the Liability Convention and the Registration Convention (United Nations Office for Outer Space Affairs 2017). In 1975, the Soviet Union and the United States cooperated in the Apollo-Soyuz Test Project, which saw a docking between two spacecraft and a famous handshake in orbit.[30] Another marker of cooperation came in 1978 after Cosmos 954, a Soviet nuclear-powered reconnaissance satellite, malfunctioned and re-entered the atmosphere with more than 50 kg of Uranium-235 on board (Volynskaya 2013). The debris was scattered across the Northwest Territories and, after an expensive recovery effort, Canada requested $6 million in compensation. The Soviet Union denied legal responsibility but paid half of the requested amount.[31] Later, in the 1990s, Russia was invited to be a full partner in the International Space Station (ISS), as part of the United States' more general policy of proactively cooperating with its former adversary during the early post-Cold War period (Sheehan 2007).

Russia and Western states have continued to cooperate in space after the 2022 invasion of Ukraine. The ISS has been functioning normally, with some Western astronauts travelling there in Soyuz spacecraft, and some Russian cosmonauts travelling in SpaceX Crew Dragons. The Cospas-Sarsat Programme of satellite-supported search and rescue is also functioning normally. One explanation for this continued cooperation concerns the "cold, dark, and dangerous" character of both the Arctic and space (Byers 2019). In every region, natural factors such as geography, climate and the presence or absence of resources play a role in national interests and policy preferences. In the Arctic and space, a combination of remoteness and extreme conditions makes almost any activity risky and extremely expensive, and this creates an incentive for cooperation and burden sharing.

Natural Risks

Forest fires, which can damage fibre-optic cables, are not the only natural threats to space-based services in the Arctic. A more serious threat comes from space itself, in the form of solar storms.

Solar storms occur with some frequency, and most cause little interference. But a "coronal mass ejection" can be an entirely different matter. Composed of electrons, protons and other particles, these powerful storms are unpredictable in severity, timing, speed and direction. At some point — perhaps next year, perhaps decades from now — the path of a severe coronal mass ejection will coincide with Earth's orbital position.

When that happens, the deluge of high-energy particles will produce an exceptionally strong aurora. In 1859, in what was called the Carrington Event, people in Hawaii could see the Northern Lights (May and Dobrijevic 2022). At the same time, powerful currents will be produced in long conductors. Power grids, telephones and the internet could be rendered inoperable for weeks, months, perhaps even years. Northern countries such as Canada, and especially their Arctic regions, are particularly vulnerable to these effects because Earth's magnetic field bends inward near the poles.

The scale of the damage is directly proportional to a society's reliance on technology: the more electronics we use, the greater the risk. In 1859, telegraph operators received shocks through their equipment. In 1921, a coronal mass ejection disrupted train services in the United States, while telephone switchboards in Sweden caught fire. In 1989, a much smaller storm, just one-tenth the strength of the 1921 event, overloaded the Hydro-Québec grid and left the entire province in darkness for nine hours (Morton 2022). In May 2024, another relatively small storm disrupted GPS signals to

28 Arctic Council, *Agreement on Enhancing International Arctic Scientific Cooperation*, Canada, Denmark, Finland, Iceland, Norway, the Russian Federation, Sweden and the United States, 17 May 2017, online: <https://oaarchive.arctic-council.org/items/9d1ecc0c-e82a-43b5-9a2f-28225bf183b9>.

29 *Agreement to Prevent Unregulated High Seas Fisheries in the Central Arctic Ocean*, Canada, China, Denmark, European Union, Iceland, Japan, Norway, Russia, South Korea and the United States, 2018, online: <www.dfo-mpo.gc.ca/international/agreement-accord-eng.htm.>

30 See www.nasa.gov/mission_pages/apollo-soyuz/astp_mission.html.

31 *Protocol on Settlement of Canada's Claim for Damages Caused by "Cosmos 954,"* Canada and Union of Soviet Social Republics, 2 April 1981, 20 ILM 689.

farm tractors across North America, delaying the all-important spring planting (Albeck-Ripka 2024).

Satellites themselves are at risk. When the magnetic field becomes energized, it raises the atmosphere, which increases the drag in low orbits. If a satellite's on-board thrusters are not powerful enough to counter this effect, it can be dragged down, back to Earth. In 2022, a relatively small solar storm caused the loss of 49 SpaceX satellites that had just been deployed to their initial altitude of about 216 km (Andrews 2022). The deluge of high-energy particles from a coronal mass ejection could also damage the electronics on satellites, rendering them defunct. Satellites at all altitudes, including GPS satellites, are exposed to this risk.

The odds of a coronal mass ejection striking Earth are about 12 percent per decade (Riley 2012), with the likelihood increasing near the peak of the approximately 11-year solar cycle. During the 2012 peak, a coronal mass ejection narrowly missed Earth. In May 2024, a relatively small coronal mass ejection created large auroras and had some disruptive effects. This could almost be expected: the current solar cycle is predicted to peak in 2025.[32]

There is good news. It is possible to build resilience into power grids and, in some places, this has already been done. After the 1989 solar storm, Hydro-Québec installed converters that provide some protection against sudden influxes of "direct current" on its transformers. Resilience can also be built into satellites, for instance, with better propulsion systems and shielding against influxes of high-energy particles. All these measures raise costs, which governments and publicly owned companies such as Hydro-Québec can absorb, but which private companies might not incur unless required to do so by regulators.

Most crucially, governments and companies can plan for the deliberate turning-off of power grids, fibre-optic networks and satellites — effectively putting them into "safe mode" — before a severe solar storm arrives (Byers 2022). Such a shutdown would have to be initiated as soon as a warning is received: while robotic spacecraft stationed near the sun would provide one, it would arrive only a few hours before the storm itself. For this reason, Canada needs a robust, well-tested national protocol for taking drastic-but-necessary action as soon as a severe solar storm is detected on a path toward Earth. Satellite companies need similar protocols, including foreign companies such as SpaceX that increasingly provide essential service to remote communities. Without such protocols, communities across Canada, and especially in the Arctic, could lose communications for weeks, months or even years.

Conclusion

New space technologies and a dramatic increase in commercial space capabilities create exciting opportunities for Arctic governments, communities and companies. Northern residents can now access the internet at a bandwidth, latency and cost comparable to the residents of large cities in the South, enabling them to access telehealth and online education and to participate fully in the national and global economies. The Arctic, once isolated, is now part of the digital world.

At the same time, synthetic aperture radar satellites have made it safer for ships and snowmobiles to navigate sea ice, the Cospas-Sarsat Programme has removed the "search" from search and rescue, and satellites of all kinds are supporting communications, aviation, surveillance, security, disaster relief, forest firefighting, weather forecasting, fishing, prospecting, education, health care and environmental research.

Militaries also benefit greatly from satellites for positioning, navigation, surveillance and situational awareness, as well as for the all-important search and rescue mission. Satellites are necessary to operate fifth-generation fighter jets and long-range drones. But perhaps the most important contribution of satellites to militaries is an enhanced understanding of what potential adversaries are doing — or not doing. One of the great geopolitical risks in the Arctic involves security dilemmas, where states feel compelled to build up their military capabilities in an escalating series of responses to suspected increases by others. Satellites help to prevent unnecessary escalations, accidents and arms races. They are thus an important tool for maintaining peace and stability — the best form of security.

32 See www.swpc.noaa.gov/products/solar-cycle-progression.

The Arctic is more connected to space than any other region. Yet connectivity can create dependency and therefore exposure to new risks, which in the case of satellites include system failures, deliberate attacks and natural forces such as solar storms. Redundancies of all kinds are needed to protect against these risks. For instance, it is safer to have multiple satellite companies providing Arctic communications, rather than a potential monopoly provider such as SpaceX. Similarly, ground-based navigational aids to aviation should be maintained, notwithstanding the cost-saving attractions of GPS. Last but not least, national and regional governments, Indigenous organizations, communities and companies should all be prepared to shut down their electrical systems quickly, if notified of an incoming severe solar storm.

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