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Digital Policy Hub — Working Paper

Canada's Alliance Politics and the Revolution in Quantum Military Affairs

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Key Points

- Participation in alliances has long been an important strategy for Canada to pursue initiatives on the world stage. Just as Canada's key alliances are facing new geopolitical pressures, the country's standing within these alliances is facing new challenges, often due to lagging investments.
- Canada has recognized the importance of the next generation of quantum technologies for a variety of applications; however, Canada's level of public investment remains somewhat modest compared to other leading nations.
- Increased public investment in quantum science and technology can help secure Canada's position within its alliance politics, not only because general investment will alleviate allies' concerns about budgetary allocations, but also because specific quantum technologies are poised to address the unique challenges facing Canada's key alliances.

Introduction

Worldwide, innovators are researching new technologies that leverage the unique properties of quantum mechanics. Already labelled the revolution in quantum military affairs (Der Derian and Wendt 2020), the significance that the rollout of quantum computing, cryptography, sensing and other technologies will have on international security is difficult to overstate (see, for example, Owen 2020; Lindsay 2020; Der Derian and Waters 2024). Canada boasts a strong foundation of research expertise in quantum science and technology (S&T), an innovative start-up ecosystem, and a highly educated population — all of which make Canada competitive in the quantum revolution (Sussman et al. 2019). The Canadian government's overall approach to navigating quantum S&T has been outlined in its National Quantum Strategy (Government of Canada 2022). This strategy sets out pillars for increasing research efforts, developing talent through an expansion of science education and commercializing field-ready technologies (ibid.). The Department of National Defence/Canadian Armed Forced (DND/CAF) has also released a road map for itself, first through the Quantum S&T Strategy (Gunther, Mason and Lefebvre 2021) and subsequently the Quantum 2030 implementation plan (Government of Canada 2023). These documents show how DND/CAF plans to develop deployable defence capabilities out of quantum technologies, which partnerships will make this possible and how the different initiatives and missions of the strategic approach fit together. The intensification of threat and acceleration language from the 2022 strategy to the 2023 implementation plan (Murphy and Parsons 2024) reveals just how hotly contested the quantum S&T domain is.[1]

These strategic documents set out the high-level targets and timelines for public investments in quantum S&T. However, recent commentary suggests that further

1 The defence policy update, *Our North, Strong and Free* (Government of Canada 2024b), does not discuss quantum S&T in detail, although a number of its key areas will benefit from the integration of quantum S&T.

investment is needed if Canada wishes to seize the quantum moment. Tracey Forrest, Paul Samson and Raymond Laflamme (2024) have argued that there is a golden opportunity for Canada to redouble its efforts to support research and development (R&D) of quantum technologies. They argue that, with an increasingly volatile security environment and political uncertainty, new technologies will be crucial to Canada's future. This working paper examines the context of Canada's quantum S&T posture within alliance politics, outlining how further investment in R&D can address key challenges facing alliances and help bolster Canada's standing within them.

Canada's International Alliance Politics

Canada is a member of many bilaterial, multilateral and international arrangements at various levels of formalization. This working paper will focus on three of Canada's most important relationships: the North Atlantic Treaty Organization (NATO), the North American Aerospace Defence Command (NORAD) and the Five Eyes intelligence alliance.

NATO is a 75-year-old military alliance designed to provide collective security against the threat of the Soviet Union in the wake of the Second World War. Canada was among the founding nations of this alliance and a deeply committed member in its early years. Joseph T. Jockel and Joel J. Sokolsky (2009, 316) identify three main benefits of NATO participation: "a seat at the most important allied table in the world," the deterrent of collective security that has lessened the need to allocate large sums to defence and insulation from domestic critique of defence policy given international commitments. Today, NATO faces the pressures of a resurgent Russia launching a military invasion on its doorstep, the spectre of an isolationist America and fracturing along the lines of military contributions. In particular, Canada is under fire for failing to meet the threshold for NATO nations to spend at least two percent of their GDP on defence (Maddison, Fraser and Cowan 2024), with both international allies and domestic business fearing that Canada's continued underfunding of defence may leave it isolated on the world stage (Brewster 2024a). Although Anessa L. Kimball (2023) and others have criticized the reduction of NATO burden-sharing to the single figure of two percent, this funding remains a salient pressure in Canada's alliance politics. NATO is active in promoting R&D in the defence applications of emerging technologies, especially through its Defence Innovation Accelerator for the North Atlantic (DIANA) network, which now features a regional office in Halifax that will help Canadian technology innovators access NATO resources.

NORAD is a binational military command structure in which the United States and Canada collaborate on the shared pursuit of continental defence. Spurred by the threat of Soviet Union bombers, binational coordination of early warning radar systems formalized into NORAD in 1957 (Garrard 2023). After a brief period of lower attention following the end of the Cold War, NORAD undertook a variety of functions related to homeland defence, including transnational crime, infrastructure protection, counterterrorism and cyberthreats (Charron 2015), although its core missions remain aerospace warning and control, as well as maritime warning. While conventional direct military threats to the Arctic are currently seen as unlikely, there are a variety of likely threats "through, to, and in the Arctic" (Lackenbauer 2021) that serve as pressures to increase the capacity of NORAD. As the climate warms, the Arctic will become increasingly important for shipping traffic (Charron 2015), which has led to increased Russian and Chinese interest in the region (Hughes, Fergusson and Charron 2024). In addition to responding to criticism from south of the border regarding Canada's undercontribution to NORAD (Panetta 2023), scholars have also highlighted that a number of economic benefits could be realized through a renewal of the Canada-based North Warning System (Berkok and Secrieru 2024; Stone 2024). As in the case of NATO, Canada faces pressures from American partners regarding NORAD, both in terms of its level of investment as well as its capabilities on offer. Although Canada has stated a commitment to NORAD modernization, the details on this commitment remain sparse and doubts surrounding it remain.

The Five Eyes intelligence-sharing alliance grew out of a UK-US bilateral collaboration pact in the years following the Second World War. Although active in gathering signals intelligence (SIGINT) during the war, Canadian SIGINT capacity was nearly extinguished with the onset of peace (Wark 2019). However, Canadian investment in SIGINT capacity development made Canada a valuable partner in the arrangement that would become Five Eyes when Australia and New Zealand joined (Robson 2020). Today, the variety of intelligence-related units in the Canadian defence and security establishment make Canada a valuable partner of the Five Eyes partnership, despite a lack of a dedicated foreign intelligence service for human intelligence.[2] Although generally regarded positively by its intelligence service partners, the Five Eyes alliance faces a number of challenges, including public criticism of undue surveillance, data breach issues and cybersecurity vulnerabilities (Pfluke 2019). These vulnerabilities only become more pronounced as advancements in cyber capabilities increase the chances of attacks on and decryption of highly classified material (see, for example, Forrest, Samson and Laflamme 2024). It is perhaps for this reason that a recent Five Eyes summit — held in the heart of Silicon Valley and focused on the nexus of emerging technologies and security innovation — welcomed technology entrepreneurs and academic researchers to join government and intelligence leaders (FBI 2023). The recognition of the importance of preparedness against the novel cyberthreat posed by quantum computing in particular was, along with submarine cooperation, a driving force for the formation of AUKUS, an enhanced security partnership between Australia, the United Kingdom and the United States (see Vucetic 2023) that notably does not include the two Five Eyes members lagging in emerging technology integration, namely New Zealand and Canada (Salt and Wilner 2024). In addition to the shared threats facing the alliance as a whole, Canada also risks being left in the dust if AUKUS participants exclude the other two eyes from critical defence conversations.

These three alliances — NATO, NORAD and Five Eyes — are crucial to Canadian defence. In fact, Sokolsky once went so far as to argue that "Canada's alliance relationships... constitute nearly the sum total of Canadian defence policy" (1989, 11). This working paper argues that public investment in quantum S&T will be crucial for the promotion of a Canadian national interest, not only because reaching the two percent floor for NATO membership will silence critics of Canadian underinvestment, but also because specific quantum technologies can solve the unique problems facing NATO, NORAD

2 For an overview of Canada's intelligence ecosystem, see Leuprecht and McNorton (2021, chap 5).

and Five Eyes. Timely and substantial public investment[3] can place Canada in a leading position to contribute to the global development of these technologies as well as to influence their ethical and responsible use.

Quantum Solutions for Alliance Problems?

At first blush, quantum S&T might simply be seen as one among a number of potential targets for increased investment at a time when Canada faces sharply intensifying calls to increase spending on many defence and security matters. But reflection on specific technologies reveals that this proposed allocation is not merely a matter of spending for the sake of spending; rather, there are opportunities for specific spending priorities to benefit Canada's alliance politics. This section reviews the overall benefit of increased investment in quantum S&T research from a top-line budgetary perspective, before outlining its potential influence on four specific areas: cryptology, sensing, computing and social relations.

As discussed above, Canada is facing increasing pressure from its allies in NATO to increase its spending on defence by meeting or even exceeding the threshold of two percent of its GDP. In a recent update released during the 2024 NATO summit, Canada's Parliamentary Budget Office projected that "Canada's military expenditures will rise from 1.29% of GDP in 2024–25 to a peak of 1.49% of GDP in 2025–26 before falling and stabilizing at 1.42% by 2029–30" (Creighton and Kho 2024), expenditures that remain entirely below the requisite two percent threshold. In addition to a risk of political marginalization within the alliance (Brewster 2024b), Canadian business leaders are becoming increasingly concerned that "diplomatic isolation" caused by a continued failure to meet the threshold "will have broad ramifications for all Canadians" (Hyder 2024). In addition to the potential costs of not meeting the two percent figure, Tracey Forrest, Paul Samson and Raymond Laflamme (2024) have highlighted that there is an opportunity to demonstrate an international willingness to engage by earmarking substantial funds toward quantum S&T as a DND allocation. Most importantly, Forrest, Samson and Laflamme note that many of these technologies are dual use in nature, meaning that they have both military and civilian applications. Dual-use technologies are significant in the context of rising defence research expenditures because the benefits of technological development will not be limited to the defence sector. Instead, R&D costs incurred by the defence budget can in turn spur a whole host of high-value applications in the civilian economy. Therefore, a sustained increase in funding for the military side applications would provide a shot in the arm for the Canadian innovative technology sector, whose confidence has been shaken in recent months with major cuts to the Innovative Solutions Canada program and significant procurement challenges identified by an internal audit on DND's Innovation for Defence Excellence and Security program (Reevely 2023; Council of Canadian Innovators 2024; Hemmadi 2024a, 2024b). Therefore, the logic is that substantial investments in quantum S&T research would provide a boost to Canada's political standing by making progress toward the two percent threshold, while also mitigating the economic risks of ostracism and opening up new opportunities for major economic development as civilian applications spin off of defence-funded R&D. NATO's DIANA initiatives are explicitly open to the development of

3 Combined with the fortuitous timing of Canada's Group of Seven chair, which could also be used to promote quantum S&T, as Forrest, Samson and Laflamme (2024) note.

dual-use technologies, further linking the potential for targeted investments in quantum technology research, providing benefits to Canada's military alliances while also creating new economic opportunities.[4]

Calls for improvements to cryptography in light of the cyberthreats posed by quantum computers are at a level of intensity not likely appreciated by the general public. Andy Majot and Roman Yampolskiy (2015, 18) suggest that the rise of quantum computing without proper cryptography presents "catastrophic threats [that] need to be examined and avoided at all costs," including the effective end of privacy and security online.[5] In order to avoid the worst possible outcome, current encryption protocols must be updated — they draw particular attention to the use of digital certificates for software updates and website authentication as vectors for malware enabled by quantum computing (ibid., 19). With every day that passes without an updated encryption protocol, data is at risk of being scooped for future decryption by a quantum computer.[6] Fazal Raheman (2022, 3) notes that "some data with a long shelf life — such as classified government documents, personal health data, or corporate trade secrets — will still be valuable when the first quantum computers are expected to become available." This should place entities reliant on protecting information, including governments, militaries, intelligence agencies, financial institutions and businesses developing new technology or medications on high alert. The two leading protocols to replace current encryption are post-quantum cryptography (PQC) and quantum key distribution (QKD) (Mosca and Munson 2019), and it is imperative that sensitive domestic and allied communications move to one of these secure formats as soon as possible.[7] PQC is available now and deployable on current hardware, and the National Institute of Standards and Technology (NIST) just released[8] three new algorithms that are supposed to be secure against both classical and quantum computer attacks. However, we will not know for sure whether these protocols are secure until we have a quantum computer to try hacking PQC. The only 100 percent theoretically secure protocol is QKD, but this technology is still in the process of being developed and commercialized. Quantum random number generation is a mature technology that is deployable now and could help improve security in current classical protocols. For the Five Eyes intelligence sharing network, a failure to develop quantum-safe encryption would make the transmission of intelligence practically impossible without adversaries having complete access. Although offline storage would remain an option for local intelligence gathering, a zero-permission model would be required to keep that data safe without a quantum encryption option (Raheman 2022). The consequences of this development would be catastrophic for Canada's alliances, as the networks that permit coordination and communication between NATO entities would be severed at risk of infiltration. No further electronic intelligence sharing would be possible between Five Eyes nations without that same intelligence being readily available to adversaries. The images and early warning system readings of NORAD would also be vulnerable to exfiltration.

4 As of March 2024, two accelerators and 13 test centres in Canada have joined the DIANA network (Government of Canada 2024a).

5 A recent RAND report suggests that private communication and financial transactions "would become impossible" and email would be rendered "useless" (Parker 2021, 26).

6 A strategy known as "harvest now, decrypt later."

7 Kristen Csenkey and Nina Bindel (2023) note the central role of NIST in PQC. Further Canadian participation in workshops and calls for proposals at NIST can bolster Canada's standing in this domain of quantum technology research.

8 See NIST (2024).

Without a quantum-safe encryption protocol, it is difficult to imagine how anything connected to the internet could be considered safe.

The significance of updating encryption for a quantum-enabled world is difficult to overstate. However, as Forrest, Samson and Laflamme (2024) highlight, Canada's existing strengths in cryptography include a critical mass of experts and innovators working on this topic. This strength represents an important window of opportunity in which substantial public investments may not only offer an improvement in the defence of Canada's domestic government platforms and economic institutions, but might also permit Canada to play a leading role in shoring up the cybersecurity of its allies and alliances. Closer collaboration with leading agencies in allied nations and sustained funding through to 2030 would position Canada as a leader in bolstering allies' cybersecurity, mitigating accusations of the country being a weak ally, while also helping Canadian quantum cryptography and cybersecurity firms to undertake major and meaningful expansion, thereby contributing high-value and high-productivity growth to the Canadian economy.

Another quantum technology that offers direct benefit to Canada and its alliances is quantum sensing, specifically radar and light detection and ranging (LiDAR).[9] These quantum-enabled technologies typically use entangled photon pairs to conduct precise sensing and ranging (although a variety of specific protocols are being researched). Entanglement is a special quantum property that can be harnessed to reduce background noise, improve image quality and increase measurement sensitivity beyond what is possible with current sensing technology. Early experiments on quantum radars demonstrated a tenfold increase in reading speed (Chang et al. 2019) and promise to "not only overcome interference such as clutter, jammers, and noise, but potentially even defeat stealth technology of modern military aircraft" (Hill 2022, 2). Radar and LiDAR technologies will greatly enhance aerospace tracking of missiles and planes, while other quantum-sensing technologies, such as gravitometers, accelerometers and gradiometers, will permit the tracking of submarines under water or safeguard navigation systems against jamming (Gamberini and Rubin 2021). Applications also extend into space, where quantum radar-enabled satellites have already been discussed as potentially forming a "global early warning system" (Krelina 2023, 3; Lanzagorta and Uhlmann 2015). These technologies are directly relevant to the needs of NORAD, as concerns about stealth capabilities, submarine intrusions into Arctic waters and previously undetectable missiles are key vulnerabilities that modernization efforts hope to address. By investing in the development of technological solutions for NORAD's key challenges, Canada can not only address its alliance-related pressures, but also foster a world-leading quantum-sensing industry.

Quantum computing promises to be a revolutionary technology, although the deployment of fully quantum computers may only come after encryption protocols and sensing technologies are already online. The development of quantum cryptography and sensors are further along compared to a fault-

9 Quantum sensing also includes navigation technologies that promise multi-environment applicability and increased fidelity; see https://qvideaslab.ca/technology/position-navigation-and-timing/.

tolerant quantum computer. As noted above, quantum computers in the hands of adversaries represent a potentially catastrophic threat to our society, economy and security as we know them (Parker 2021). Canadian strategic documents frequently mention that the same technologies that are threatening in the hands of an enemy represent immense capabilities in Canadian hands (see, for example, Government of Canada 2023, 2, 4). Quantum computing promises a large number of applications through its potential for improved processing speeds, pattern recognition capacity and ability to solve complex system problems. For example, quantum optimization has been shown to help with complex problems such as transportation and logistics and these algorithms can run on today's quantum hardware. Of particular interest for military applications are quantum's capabilities for analyzing situational awareness data, executing scenario simulations, detecting patterns in big data, processing intelligence and surveillance data and accelerating machine learning/artificial intelligence (Krelina 2021, 26–7; Neumann et al. 2021; Śliwa and Wrona 2023). These technologies are not yet field ready, although many nations and private firms are devoting substantial capital to these projects. Both Ajey Lele (2021) and George Takach (2024) have identified quantum technology development as a key feature of a potential new Cold War arms race. Although Canada cannot compete on dollar-for-dollar terms with the so-called great powers, its highly skilled workforce and strong economy mean that the country is positioned to punch above its middle-power status when it comes to quantum computing. Indeed, there is already a strong quantum computing ecosystem in Canada (Sussman et al. 2019), and a significant expansion of public research funding on quantum computing would enable Canadian researchers to have more available resources as they explore the cutting edge. As a technological world leader, Canada's technological capacity for information processing would be highly valued by the Five Eyes intelligence partnership, as well as NORAD's early warning system and NATO's command-and-control efforts.

Given the intense scrutiny placed on the raw number of dollars allocated to defence and security by the Canadian government, one argument for increased investment in quantum S&T could simply be that each additional allocation would curry favour with allies demanding that Canada spend more. However, specific benefits will accrue if cryptography, sensing and computing can address the direct needs of Canada's alliances as well as the pressures that Canada faces within alliances. Taking a leading role in the development of these technologies would also lend greater credibility to Canada's ability to shape discussions around the responsible and ethical use of these technologies.

Recommendations

- First and foremost, this working paper joins Forrest, Samson and Laflamme (2024) in arguing that a substantial increase in investment in quantum S&T research should be funded, including through the DND. Rather than the uncertainty of protracted procurement processes, stable and significant research funding should be allocated on an annual basis at least through to the year 2030.

- Given their direct applicability to Canadian alliances and Canada’s standing within alliances, these substantial investments in quantum S&T should specifically target the development of dual-use technologies in the domains of quantum cryptography, sensing and computing. This must include improvements to the commercialization and procurement aspects of the IDEaS (Innovation for Defence Excellence and Security) program at DND.
- Experts agree that the next generation of quantum technologies entering the domains of security and economics will cause massive disruptions to domestic and international politics. As Canada increases its budgetary allocations to quantum S&T research, corresponding research on the social impacts of these technologies must be part of the conversation. This will allow for better understanding of the future security threats that may emerge from social disruptions and inform guidelines for ethical and responsible use.[10]

Conclusion

Alliance politics are central to Canada’s navigation of international affairs and its alliances are under pressure. At the same time, Canada faces pressure within those alliances for chronic underinvestment in defence. A substantial increase to funding for dual-use quantum technology research through the defence budget would directly address concerns about raw underfunding. More importantly, targeting these investments into key technologies of the revolution in quantum military affairs would place Canada in a leadership role in solving key challenges facing its alliances, while also providing a significant boost to a high-value domestic industry. Perhaps it is time for Canada to take a quantum moonshot.

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10 Potential guidelines for ethical and responsible use of quantum S&T will be the subject of the author’s third Digital Policy Hub working paper.

About the Author

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