Centre for International
Governance Innovation

CIGI Paper No. 333 — September 2025

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Michael P. A. Murphy, Tracey Forrest and Paul Samson

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He is a former Digital Policy Hub fellow at the Centre for International Governance Innovation (CIGI) and was a Banting post-doctoral fellow at Queen's. Michael's current research interests include quantum science and technology policy, security studies and international relations theory.

He is the author of *Quantum Social Theory for Critical International Relations Theorists* (Palgrave, 2021) and *Weak Utopianism in Education* (Routledge, 2024), more than 40 peer-reviewed articles and numerous book reviews and chapters, receiving more than 2,000 citations. Michael is an international award-winning educator with a range of teaching experience in international relations, Canadian politics, political theory and public administration.

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Tracey is a professional engineer, adjunct professor at the University of Waterloo and former board member of technology and environmentally focused organizations. Over the course of a career in both academia and industry, Tracey has become an authority on thoughtfully bridging emerging technology to high-value applications. She formerly served as a member of the Federation of Canadian Municipalities Green Municipal Fund Council, director of the Transformative Quantum Technologies program at the University of Waterloo, and advisory board chair of the National Research Council of Canada's Nanotechnology Research Centre.

Tracey completed a B.A.Sc. in environmental (chemical) engineering at the University of Waterloo, and a master's degree in energy and environmental economics at the Scuola Mattei, Italy. She completed professional training in topics such as quantum, data science and sustainable business strategy at Harvard University and the Massachusetts Institute of Technology.

Paul Samson is president of CIGI and has more than 30 years of experience across a range of global policy issues, working with international partners from around the world. He is currently focused on the impact of transformative technologies on the global economy, and scenarios for international order and institutions.

During 24 years with the Government of Canada, Paul's positions included director general of strategic policy at the former Canadian International Development Agency and assistant deputy minister-level roles with Global Affairs Canada and with International Trade and Finance, Finance Canada. At the Privy Council Office, he held several positions during the tenure of three different prime ministers. Previously, he worked at Natural Resources Canada and Environment Canada. His last position was as associate deputy minister with Agriculture and Agri-Food Canada.

Paul served as director for Canada, Egypt and Ethiopia at the Asian Infrastructure Investment Bank (2018–2019). He served as Canada's deputy for finance at the Asia-Pacific Economic Cooperation forum from 2015 to 2019 and frequently led Canadian delegations for meetings with multilateral development banks, the International Monetary Fund, the United Nations and the Global Environment Facility. He was co-chair of the G20 Framework Working Group on the global economy from 2015 to 2019. During 2018–2019, Paul served as co-manager of the Canada-UK Policy Forum on the Modern Economy, which focused on the emerging digital economy. He also previously served on the Board of Directors of CIGI.

Paul completed a doctorate and an M.A. in international relations at the Graduate Institute, University of Geneva, and a B.A. at the University of British Columbia. He completed post-doctoral studies in global environment assessment at Harvard University.

Acronyms and Abbreviations

AI	artificial intelligence
BOREALIS	Bureau of Research, Engineering and Advanced Leadership in Science
BRICS	Brazil, Russia, India, China and South Africa
CAF	Canadian Armed Forces
DARPA	Defense Advanced Research Projects Agency
DIANA	Defence Innovation Accelerator for the North Atlantic
DND	Department of National Defence
DRDC	Defence Research and Development Canada
EDTs	emerging and disruptive technologies
G7	Group of Seven
IP	intellectual property
IQC	Institute for Quantum Computing
NATO	North Atlantic Treaty Organization
NQS	National Quantum Strategy
OGD	other government department
QBI	Quantum Benchmarking Initiative
R&D	research and development
S&T	science and technology
SMEs	small and medium-sized enterprises
STO	Science and Technology Organization

Executive Summary

In an age of geopolitical and technological disruption, defence spending is increasingly viewed not merely as a security imperative but also as a strategic lever for industrial renewal and longer-term economic resilience. The North Atlantic Treaty Organization's (NATO's) 2025 Hague Summit Declaration calls for a new five percent of GDP commitment, split between 3.5 percent for core defence requirements and 1.5 percent, including broader innovation and industrial base development. This evolution recognizes the growing centrality of *dual-use* technologies — those with both civilian and military applications — such as quantum, cyber and artificial intelligence (AI).

While the focus of this paper is on Canada, much of the same analysis and conclusions hold for other NATO members and other industrialized nation-states.

Canada has long fallen short of NATO's previous two percent target, partly due to a constantly evolving NATO definition of what can be included as spending, and partly due to Ottawa's conservative approach to eligible expenditures and accounting practices. Recent commitments by the Government of Canada in 2025 to meet the two percent threshold by the 2025–2026 fiscal year and reach five percent by 2034–2035 indicate a critical pivot. However, success will depend on recognizing and investing in dual-use technologies across a *whole-of-government* approach in ways that Ottawa has not done in more than a half-century.

Quantum technologies are a case in point. As a dual-use innovation, quantum technologies can offer both new defence applications (for example, enhanced surveillance and navigation) and potential major civilian benefits (for example, materials discovery and data protection). Canada's National Quantum Strategy (NQS) ($360 million[1] over seven years) supports research, talent and commercialization but has not yet been fully integrated into defence accounting. Aligning existing strategies such as the NQS with permissible NATO definitions would immediately boost Canada's reported defence spending without additional cost and help get it on track for future targets.

Building on this reframing of defence spending, the authors propose focused action on four key tracks: research and development (R&D) funding stream; joint dual-use initiatives; commercialization support; and intellectual property (IP) strategy and research security.

Overall, Canada must reposition itself fundamentally and move beyond the great "peace dividend" that followed the end of the Cold War, to a new "defence dividend" that matches the new geopolitical and technological order currently unfolding. This requires a shift in approach that views strategic investment in innovation as essential to sovereignty, resilience and growth. With sustained and serious coordinated policy directions, Canada can position itself to simultaneously meet NATO commitments, strengthen its national industrial base and defence capabilities, and secure a leadership position in a range of critical emerging technologies.

Introduction

The impact of new technological developments is felt across society and can be especially pronounced in shaping national defence and security. Indeed, "offence-defence theory" holds that technological change has always been a primary cause of shifts in the international security environment (Lieber 2000; Jervis 1978). Given the long-standing recognition that technological advantage can set the grounds for military advantage, it should come as no surprise that serious defence strategies often include robust research and development (R&D) efforts. The internet — now a ubiquitous feature of human life — arose from one such R&D project. But the framing of this discussion of defence spending and technological innovation has now changed in the current environment. Heightened geopolitical tensions and fundamental challenges to the institutions of the liberal international order (Ikenberry 2024) are arising against a backdrop of complex overlapping crises (Lawrence et al. 2024). The current generation of emerging and disruptive technologies (EDTs) is already recognized as a powerful tool for "reshaping the global balance of power" (Araya and Mavinkurve 2022, 2) and as being significant for national security interests (The White House 2024). Although a technological

1 All dollar figures in Canadian dollars unless otherwise noted.

advantage has always been a relevant consideration for defence and security, this relationship is becoming increasingly important and fraught.

The relationship between technological development, on the one hand, and defence and security, on the other, is also being reshaped by three ongoing trends. The first is increasing attention to national defence spending levels and, especially in NATO countries, growing pressure to prioritize significantly increased defence spending. The two percent of GDP defence spending threshold that many NATO countries struggled to reach in the decade after the Wales Summit Declaration of September 2014 was replaced by a more ambitious target of five percent in June 2025 — more than double the original. Second, the pace and scale of change in technologically advanced defence capabilities have led to an increasing importance for armed forces to keep pace with new developments. This involves not only the support of existing actors in a defence industrial base but also the nurturing of new firms developing innovative technologies. Third, a growing role of private sector-led development of dual-use technologies has reshaped the way that new technologies are emerging. Although the co-emergence of increasing pressures to spend and requirements to acquire costly technologies may give the appearance that navigating the technology-security relationship is merely a matter of spending enough, this view misses the unique features of dual-use and private sector-driven development.

Considering these three trends driving the continued evolution of the technology-security relationship, this paper argues that a new approach to dual-use technology is required in defence policy. Changing the government's approach to dual-use technology requires policy change, modernization of defence accounting and increased investment in innovation. To do this, the authors discuss the changing context of defence spending, the role of dual-use emerging technology and the implications for Canada. In order to illustrate the practical impacts of these changes, the authors analyze the case study of the quantum science and technology (S&T) sector as a paradigmatic example of a class of critical and emerging dual-use technologies.

Rising Defence Spending

Within the current international political environment, where international tensions are rising and international institutions are facing new challenges in their ability to backstop collective security, there is a general trend toward states increasing their defence-spending allocations. This upward pressure on defence spending is particularly pronounced within NATO countries. NATO leaders signed a declaration at the 2014 Wales Summit, wherein allied nations already spending two percent of national GDP on defence committed to maintaining or exceeding that level, while countries spending less than two percent annually committed to maintaining their defence spending with an aim to meet the threshold within a decade (NATO 2014; but see Kimball 2023, 2024). "Defence spending" is a technical term within the alliance that is often used as an assessment, or sometimes a proxy, of a country's commitment to collective security. In addition to defence spending changing through increases in overall levels, there has also been a focus on equipment and R&D efforts taking a larger percentage of defence-spending amounts as states actively pursue the cutting edge of technological advancement.

The common definition of "defence expenditure" shared by NATO members is "payments made by a national government (excluding regional, local and municipal authorities) specifically to meet the needs of its armed forces, those of Allies or of the Alliance."[2] This includes cross-domain armed forces financed from within the national ministry of defence, but also forces managed under the auspices of another ministry to the extent that they "can, realistically, be deployed outside national territory in support of a military force."[3] Military procurement for direct use or stockpiling war reserves, military portions of civilian-military operations and military financial assistance also factor into the calculation of national defence expenditures. There is great variability from country to country in terms of what budget lines are currently included in this accounting, and NATO has regularly updated the definitions, which adds shades of grey. For example, Canadian defence accounting has remained notably conservative in

2 See www.nato.int/cps/en/natohq/topics_49198.htm.

3 Ibid.

its definitions compared to other nations that have more expansive visions of "total defence forces" (Berndtsson, Goldenberg and von Hlatky 2023). For example, Estonia's January 2025 increase to defence spending was allocated, in part, to police reserves, border security and emergency stockpiles (Republic of Estonia 2025), whereas the Canadian Border Security Agency and police services — including federal policing — fall outside of the current accounting of Canadian defence spending. The authors are not suggesting that Canada has completely neglected improving its accounting, but there is good scope for improvement.

Given the recognition of the pace of technological change in military affairs, NATO also explicitly noted that "research and development (R&D) costs are included in defence expenditure."[4] Crucially, this includes not only R&D projects with fieldable military capabilities as direct outputs, but "R&D costs also include expenditure for those projects that do not successfully lead to production of equipment."[5] Continued investment into R&D is understood to be a critical contribution to the endurance of collective security through NATO. Given the increasing impact of technology in military contexts, understanding trends and ensuring access to cutting-edge innovation are critical missions for the alliance. R&D is becoming an increasingly competitive environment, with a recent NATO Science & Technology Organization (STO) report highlighting that although the United States spent roughly double China's R&D investment in 2009, the gap had shrunk to a 20 percent advantage by 2021 (NATO STO 2025, 18).[6] By including R&D in the official definitions of defence spending, NATO recognizes the value that access to technological advancements offers members of the alliance, as the intensity of R&D competition elicits comparisons to arms-race dynamics (see, for example, Takach 2024).

The 2025 Hague Summit Declaration marked an important change in the debate on defence spending within the alliance for at least two significant reasons. First, there is a substantial change to the threshold in paragraph 2, where "Allies commit to invest 5% of GDP annually on core defence requirements as well as defence- and security-related spending by 2035 to ensure our individual and collective obligations" (NATO 2025a). But when this is discussed in greater detail in the subsequent paragraph, the authors find a second significant expansion: scope. The declaration separates this five percent figure into two elements. Allies committed to "at least 3.5% of GDP annually based on the agreed definition of NATO defence expenditure by 2035 to resource core defence requirements, and to meet the NATO Capability Targets" (ibid.). As noted above, there was already a reasonable degree of flexibility within this definition. But the scope is expanded even further within the second category: "Allies will account for up to 1.5% of GDP annually to *inter alia* protect our critical infrastructure, defend our networks, ensure our civil preparedness and resilience, unleash innovation, and strengthen our defence industrial base" (ibid.). This explicit extension beyond the existing definition of defence spending is especially significant for R&D. Table 1 highlights key developments in terms of core defence requirements, R&D and the broader category of defence- and security-related spending.

Alongside the increase in defence-spending commitments, a major development in NATO circles of direct relevance to this paper is the development of NATO's Defence Innovation Accelerator for the North Atlantic (DIANA), which now consists of regional offices in London, UK, and Halifax, Canada, as well as a hub in Tallinn, Estonia. DIANA has 20 accelerator sites and 180 test centres across alliance countries, and it issues an annual set of industry challenges that ask "innovators to develop deep tech dual-use technologies."[7] Innovators then receive grants and access to accelerator and test sites to further develop their technologies. From its first announcement in the Brussels Summit Communiqué in 2021, the DIANA program has recognized the importance of civil-military collaboration in developing the next generation of defence technologies (NATO 2021). As the terminology of "dual use" entered NATO parlance, the centrality of dual use to innovation policy was rapidly recognized (NATO 2022, 7, 8, 12). Just as the definition of defence spending has broadened to even more explicitly recognize the significance of supporting innovation and industrial development outside of strictly defence-related expenditures, the growth of the DIANA program

4 Ibid.

5 Ibid.

6 US R&D investment reported at US$806 billion, with Chinese R&D investment at US$668 billion (NATO STO 2025, 18).

7 See www.nato.int/cps/en/natohq/topics_216199.htm?selectedLocale=en; www.diana.nato.int/accelerator-programme.html.

Table 1: NATO Defence-Spending Categories

	Core Defence Requirements (Wales, 2%/The Hague, 3.5%)	Defence- and Security-Related Spending (The Hague, 1.5%)
Key points on description	Defence expenditure is defined by NATO as payments made by a national government (excluding regional, local and municipal authorities) specifically to meet the needs of its armed forces, those of allies or of the alliance.	"And Allies will account for up to 1.5% of GDP annually to *inter alia* protect our critical infrastructure, defend our networks, ensure our civil preparedness and resilience, unleash innovation, and strengthen our defence industrial base."
Key points on R&D and technology	R&D costs are included in defence expenditure. R&D costs also include expenditure for those projects that do not successfully lead to production of equipment.	"We reaffirm our shared commitment to rapidly expand transatlantic defence industrial cooperation and to harness emerging technology and the spirit of innovation to advance our collective security."

Source: NATO (2025a, 2025b).

demonstrates a keen awareness of the necessity of bridging public-private and civilian-military divides in order to pursue technological advantage.[8]

Although the increase of the headline number for defence spending marks a major difference between commitments made in Wales (2014) and The Hague (2025), the expanding scope is even more important. This development forces NATO nations to fundamentally rethink their framework for understanding defence spending as a whole-of-government project undertaken in partnership with industry and academic partners. Being guided by the concept of dual-use defence-spending policy in a "NATO five percent era" can bring more coherence to public investments, spur innovative industrial development and protect technological sovereignty. The increasing importance of dual-use emerging technologies in civilian and defence contexts alike will ensure that innovation remains at the forefront of government agendas.

8 This discussion continues in the section titled "Dual-Use Technologies and the Changing Public-Private Relationship."

Defence Spending in Canada

The history of defence spending in Canada through the "NATO two percent era" is one of dependable underfunding and conservative accounting. Table 2 presents Canadian defence-spending figures from the period 2021–2024, including the department-level contributions to total defence spending. Where possible in an unclassified context, other government department (OGD) expenses are explained to provide greater insight into the current practices of defence accounting employed in Canada. As noted in the earlier discussion of defence accounting practices, the table reveals the generally conservative approach taken by Canada in identifying defence-related expenditures by OGDs.

As of 2023, Canada was the only NATO country that fell short of both the "two percent of GDP" total defence-spending pledge as well as the secondary pledge to allocate at least 20 percent of its defence budget to equipment or R&D. Although Canada's commitment to reaching the two percent threshold was restated in the preface to the 2024 defence policy update (*Our North, Strong and Free*), the actual spending plan outlined in the document has an estimated ceiling of 1.76 percent by 2029–2030 (Government of Canada

Table 2: Canadian Defence Spending, 2021–2024

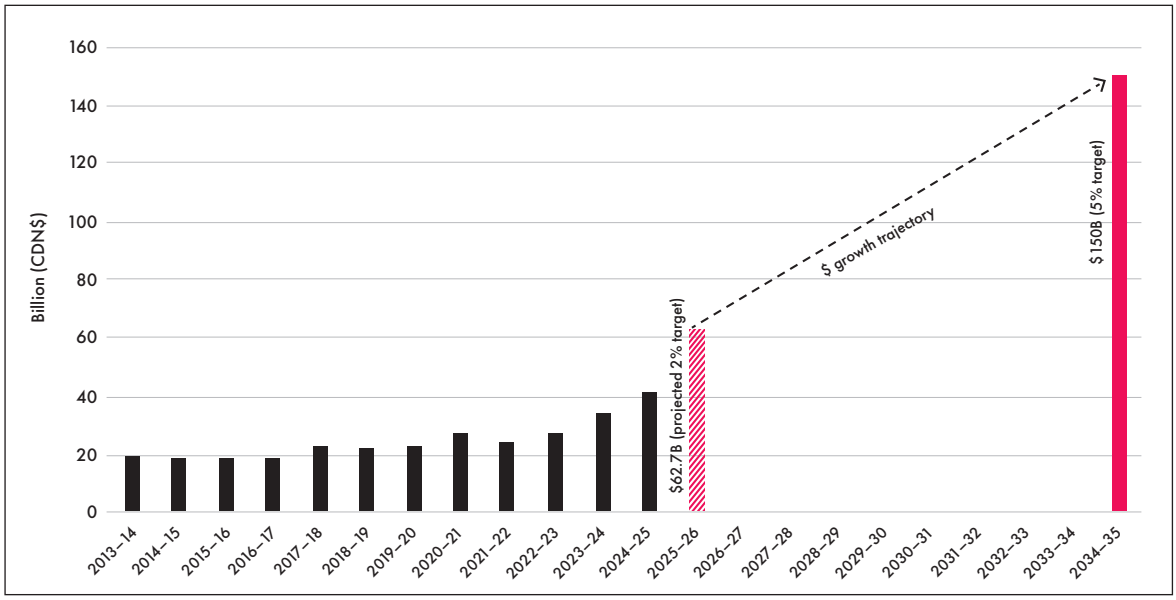
	2021–2022	2022–2023	2023–2024	Explanation of Contribution to Defence
DND	$24,126,144,961	$26,930,160,095	$33,469,476,787	
Veterans Affairs Canada	$3,808,379,187	$3,765,049,061	$4,170,691,000	Direct payments to retired CAF personnel
Treasury Board Secretariat	$368,959,042	$382,240,770	$412,708,825	Centrally funded personnel costs (principally employee benefits plan)
Global Affairs Canada	$438,608,000	$343,456,404	$367,570,184	UN and NATO contributions, peacekeeping, support to DND/CAF
Shared Services Canada	$405,804,955	$489,133,755	$553,644,009	Information technology support to DND/CAF
Canadian Coast Guard	$315,987,452	$337,125,199	$559,608,293	Canadian Coast Guard defence-related activities
OGDs	$992,217,410	$1,191,642,744	$1,297,679,107	For reasons of national security and to protect operational integrity, detailed information on OGD contributions cannot be provided in an unclassified total manner without compromising national security.
DND expenditure as % of defence spending	75.45	79.89	88.58	
% of GDP	1.27	1.20	1.31	

Sources: The figures and explanations are collected from Auger and Léon (2025) and the Office of the Government House Leader (2024).

Note: CAF = Canadian Armed Forces; DND = Department of National Defence.

2024, 306). Analysis by Canada's Office of the Parliamentary Budget Officer reveals that the situation may be even worse, projecting a peak of planned defence spending at only 1.58 percent of GDP by 2029–2030 (Penney 2024, 5). In addition to mounting international pressure for Canada to increase its defence spending to maintain its status as an ally in good standing within the NATO alliance, persistent underinvestment has led to lagging capability acquisition as well as significant program integrity issues (for example, replacement of infrastructure and parts well beyond their normal life can be extra costly and are sometimes not available at all). Paul Maddison, David Fraser and John Scott Cowan (2024, 2) argue that an often-overlooked benefit of consistent expansions to meet the defence-spending target is that "additional defence capability, capacity and preparedness [will be] aggregated over time," leading to a compounding effect on policy progress

Figure 1: Canada's Defence Spending (Past and Projected)



Sources: For 2013–2024, see https://hillnotes.ca/defence-spending-table-a/; for 2024–2025, see Penney (2024); for 2025–2026, see Lagassé (2025); for 2035, see Brewster and Zimonjic (2025).

in national security. They argue that consistent and increased investment in emerging technologies on the path to the two percent threshold will permit strategic investment in crucial capabilities (ibid., 10). However, despite this long-standing shortfall below the two percent threshold, a multi-party political consensus emerged in the winter of 2024–2025, and the first major defence-spending announcement of the Carney government included a pledge to reach two percent by the end of the 2025–2026 fiscal year (see Figure 1) (Brewster 2025a) before committing to a plan to achieve five percent a fortnight later (Brewster and Zimonjic 2025). The immediate injection in spending for 2025–2026 will undoubtedly include a ramp-up of personnel-related costs since that is necessary to deliver future ambition and can be immediately booked in the fiscal framework. Forthcoming plans, nascent and not yet publicly known, will require sustained massive spending over the next decade, and that level of funding will have transformational implications across the whole defence ecosystem, and beyond.

The June 2025 Supplementary Estimates included six major initiatives that would expand defence spending by $9 billion in the current fiscal year. Two commitments of $2.1 billion each were earmarked for recruitment, retention and support programs and expansions at Defence Research and Development Canada (DRDC); $2 billion was committed to additional military aid to Ukraine; $1 billion for the development of new military capabilities (with a focus on the Arctic); $833.7 million for new and existing equipment purchases; and $550.2 million for digital tools and capabilities to support expanded cyber capabilities and interoperability.[9] These measures raise the likelihood of Canada reaching the two percent threshold within the 2025–2026 fiscal year. However, it is also important to note that they fall within the context of the standing practice of conservative accounting principles in Canadian defence spending, and each new accounted dollar will require new government expenses. Reaching a 3.5 percent or five percent threshold under these accounting principles would present a major budgetary pressure and may not be feasible under Canada's current fiscal framework.

As noted in the previous section, however, substantial increases to defence spending require

9 See www.canada.ca/en/treasury-board-secretariat/services/planned-government-spending/supplementary-estimates/supplementary-estimates-a-2025-26.html#ToC2.

a rethinking of an approach and the related ecosystems to maximize the benefits of these investments. In the Canadian case, an increased focus on R&D support to emerging technologies with dual-use applications would offer a particularly efficient mechanism for approaching the in-year target of two percent as well as the mid-range target of five percent. Unlike notoriously slow procurement timelines for capital expenditures, R&D grants through DND could be absorbed at speed by existing research infrastructure and the emerging technology industry, permitting more rapid progress while also developing new partnerships to facilitate the acquisition of new capabilities. The government could also pursue a formal recognition of expenditures[10] in other ministries that support the development of technologies with dual-use applications as forming part of Canada's overall defence spending counting toward its NATO obligations. The dual-use nature of these technologies means that R&D costs fall clearly within the core defence-spending obligation that will eventually have a threshold of 3.5 percent; however, *potential* dual-use technologies, basic research with future potential for application over longer payoff scales, and industrial development supports could and should be included within the broader 1.5 percent support envelope under the goal to "unleash innovation, and strengthen our defence industrial base" (NATO 2025a). Recognizing the dual-use impacts of technology, Canada should not only connect applicable R&D spending across the whole of government to defence for accounting purposes but also to accelerate capability acquisition, leverage opportunities for collaboration and strengthen partnerships.

10 This includes in-house research, contracted research services, grants, incentives, public-private partnerships, and beyond.

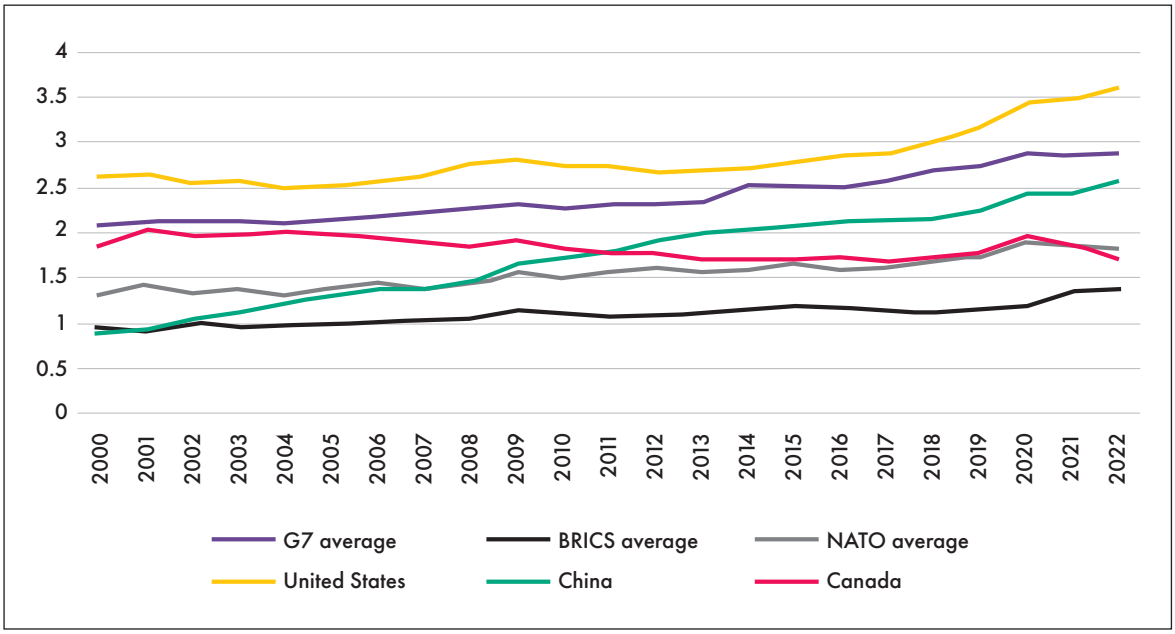
Dual-Use Technologies and the Changing Public-Private Relationship

The concept of dual-use defines technologies that have the potential for both civilian and defence applications. There has long been a recognition that insights from R&D projects can spill over from one domain to another in complex ways, while some apparent benefits may also not be fully realized across the divide (Molas-Gallart 1997, 369–70). The concept is important, however, because it helps to clarify the stakes of technological development. The recognition of military and civilian use cases can inform government involvement in technological development, including regulations, export controls and research security concerns.[11]

As recognized in the 2024 report *Critical Dual-Use Technologies: Commercial, Regulatory, Societal and National Security Challenges* by Harriett Baldwin, rapporteur to NATO's Economics and Security Committee, an important shift has taken place in recent years. Instead of the prior model of defence-industrial development achieving technological insights that would then inform commercial applications, "more and more, militaries depend on technologies developed initially for commercial markets and then spun into the defence sector" (Baldwin 2024, i; c.f. Molas-Gallart 1997, 368). This industry-first model is particularly advantageous for governments experiencing budgetary pressures (i.e., most NATO countries), as they can reap the rewards of innovation without directly bearing all of the associated R&D costs. Baldwin continues: "There are implicit savings to defence budgets simply because a significant share of the research and development costs for these advances are covered during the initial commercial development phase. This slashes development costs and shortens timelines to produce military applications and to deliver new and powerful capabilities quickly to forces in the field. Moreover, because firms initially develop these technologies for commercial

11 Some may raise the concern that focusing on defence-sector use cases may lead to the further militarization of society. However, it is also worth considering that given the broad recognition that emerging technologies have military applications, ignoring dual-use policy is less a matter of stopping militarization than of ignoring it.

Figure 2: International Comparison of R&D Spending as a Percentage of GDP



Source: Chart data from the World Bank (see https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS) and author calculations.

markets, scale economies emerge that further drive down unit costs" (Baldwin 2024, 1).

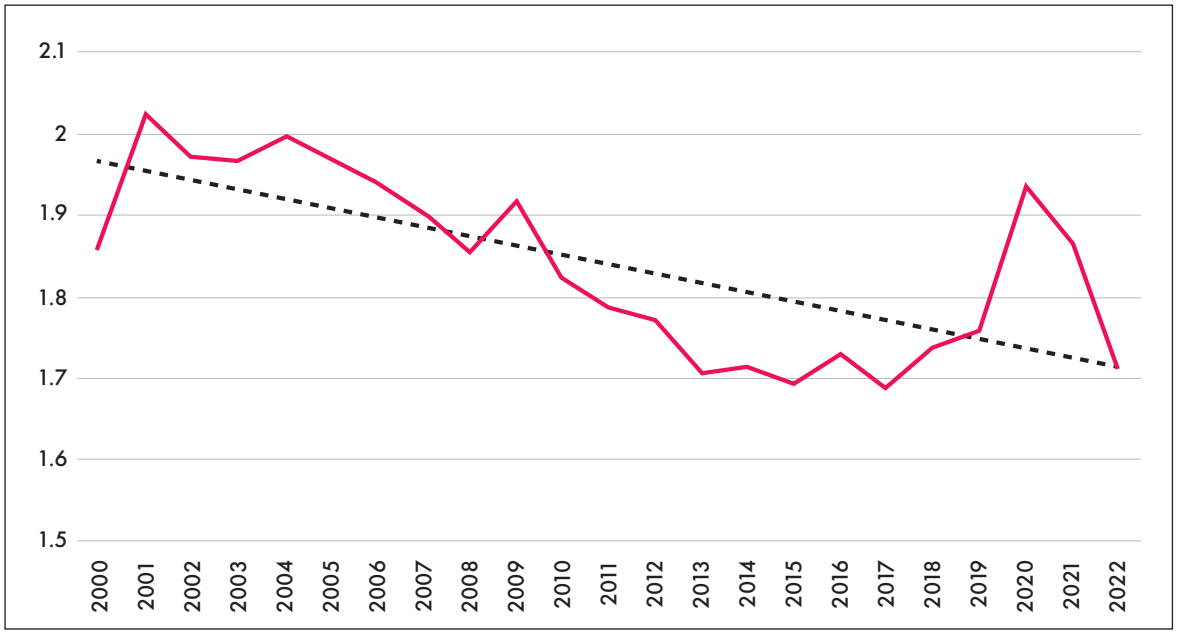
Given the increasing pace and scale of technological dependence and development, the ability of governments to more efficiently realize new capabilities through private sector-led R&D of dual-use technologies can mark a substantial fiscal benefit. Public investments take on a role of catalyzing rather than fully funding the research stages.

The embrace of a catalytic role has not, however, led to a global reduction in R&D expenditures by governments in recent decades. Reflecting the significance of advanced research in contemporary society, the period of a growing role of partnered investment has simultaneously witnessed increasing investment, especially among many leading nations. Data on government R&D spending as a percentage of GDP (presented in Figure 2) reveals increased average expenditures among Group of Seven (G7), NATO and BRICS (Brazil, Russia, India, China and South Africa) member states, with US investment increasing from 2.6 percent to 3.6 percent and China's investment rising from 0.9 percent to 2.5 percent. The NATO STO (2025, 12) notes that the rapid increase in China's R&D investment has intensified the pressure on the United States (and allied nations) to invest in order to avoid losing technological advantage. Current dynamics see the United States and China largely unmatched in terms of competing for global leadership in R&D, with other nations incentivized to focus on specialization in target areas (ibid., 16). By counting R&D expenses in the core defence spending and supporting an increased allocation to "unleash innovation," NATO (2025a) signals the importance of member states contributing to collective security through investment in R&D.

With a focus on the Canadian line in the figure above, the authors note that Canada's progress has diverged from the pattern observed across all highlighted groups (NATO, G7, BRICS), the United States and China. Over the 2000–2022 period where all these entities increased investment in R&D, Canadian public investment in R&D decreased as a share of GDP. Although uneven on a year-over-year basis, the annual average decrease was just over 0.01 percent of GDP per year.[12] This trend (illustrated in Figure 3) is particularly troubling, given its inverse relationship to the

12 See https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS.

Figure 3: Canadian Trend in R&D as a Percentage of GDP



Source: https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS.

growing significance of emerging technologies over this period, both in military contexts and in the everyday lives of civilians.[13]

As an organization, NATO has recognized the significance of expanding R&D efforts — both in the sense of increasing investments as well as broadening the scope of activities to include greater collaboration between public and private actors. Internally, the need for a new policy approach was recognized even in 2022, when the Advisory Group on Emerging and Disruptive Technologies reported that "to be successful, DIANA will need to operate in a manner that is markedly different from other entities within NATO, adopting an agile, risk-tolerant and flexible approach that will allow it to be responsive to nascent technology developments" (NATO 2022, 10). This flexibility extends even to the point of recognizing civilian-sector impacts as a success indicator for the project, as "multiplicity of use represents higher potential returns on investment for DIANA's portfolio and, therefore, a greater draw for scale-up investors" (ibid., 12). DIANA provides early-stage, high-impact capital; connects innovators with end-users in defence; supports testing and developing; and recognizes that successes outside of defence use cases are crucial for the viability of scale-up efforts to stand on their own. Other NATO-led efforts, such as the NATO Innovation Fund and the NATO Innovation Hub, leverage the ability of public capital to catalyze private activity in R&D. Box 1 discusses some of the risks associated with this increased private activity. Smart deployment of capital alongside network opportunities relaxes demands on the public purse. This principle is most powerful when the allocation increases along with its tendency to seek multiplier-effect opportunities.

Canada's Quantum Sector and the Road to Five Percent

Focusing specifically on the context of Canada's quantum sector can help illustrate how Canada can adopt a new approach to dual-use emerging technologies. Quantum technologies incorporate

13 Despite the overall trend, strategic investments in quantum S&T during this period were nevertheless impactful (Briggs 2024).

Box 1: Confronting the Risks of Growing Private Sector Influence

Baldwin's report offers a road map for NATO's private-sector engagement in the context of dual-use technologies and clearly introduces the R&D cost benefit that countries can realize by adopting this strategy. However, there is also a recognition that governments have an important role to play in guiding the sector through incentives, regulations and controls (Baldwin 2024, 3 and passim). It is worth considering the risks introduced by a private sector-led model of technology development. This box provides a non-exhaustive profile of some key risks.

- **Interoperability and innovation:** There is a tension between the requirement for allied nations to maintain interoperability in critical systems, on the one hand, and the divergent technical approaches that innovators may take in developing their technologies, on the other. For example, a privately developed technology may be designed to integrate primarily with proprietary systems (see, for example, Bremond 2024), or digital platforms may serve a gatekeeping function (see, for example, Guggenberger 2021). Issues of national divisions across different national defence industries have been noted in munitions and other systems, and slow progress has limited interoperability (Cordesman 2022). Dominance by one corporation, or additional costs to render technologies interoperable *ex post*, may result in a reduction of savings promised by private-sector development because of strengthened market position of certain firms.

- **Fast-follower deference:** If public actors rely increasingly on private firms to be "first movers" in technological innovation, then they adopt a role of "fast follower," where innovative application rather than revolutionary design becomes the key focus (Pearson 2015). As defence strategists adopt the lesson of "first-mover disadvantage" (Boulding and Christen 2001) and become increasingly deferential to product and strategic decisions made by technology firms, there is a risk that the unique needs of military users may be overlooked. Further, alignment with national security priorities or a nation's values or its key alliances may not be considered in product development.

- **Reduction in basic research:** Overreliance on private sector R&D can lead to an imbalance in the proportion of basic to applied (or even developmental) research conducted in a country. Private funding for research often skews heavily in the direction of short-term, low-risk bets rather than basic research (Mandt, Seetharam and Cheng 2020, 48), potentially limiting the overall benefits that basic research can bring over longer horizons (Forrest and Guggenberger 2025).

- **Incumbent influence:** The presence of large incumbent corporations within a sector can hamper competitive innovation through strategic acquisitions and co-opting disruptive competitors (Forrest and Guggenberger 2025; Lemley and Wansley 2025). Advocacy for regulations that undercut competition or impose costs that only large incumbents can bear, slow the pace of innovation (Lemley and Noti-Victor, forthcoming 2026; Lemley and Wansley 2025), and governments have an important role to play in counterbalancing these dynamics through pro-competition regulation (Forrest and Guggenberger 2025).

- **Oversight limits:** Offloading the responsibility of R&D to private actors may also introduce more nebulous risks that follow from a lack of oversight from national institutions and international alliances that have undertaken commitments related to international norms and treaty obligations. A range of risks arise due to critical technologies and infrastructure being controlled by actors outside of national or alliance oversight, including ensuring preferential access and shoring up technological sovereignty and collective security.

a range of specific capabilities with defence and civilian applications. Quantum computers promise an exponential increase in calculation speeds for select problems and new material insights through quantum simulation; quantum sensors provide significant capability increases for the detection of signals amid noisy environments and overcoming jamming obstructions; and quantum-safe communications protocols offer secure modes of communication through a revolutionary advancement over classical encryption (Krelina 2021; Gamberini and Rubin 2021; Hill 2022; Murphy 2024; Śliwa and Wrona 2023). This class of technologies is poised to offer many disruptive applications through their military uses, including defensive efforts to improve early warning systems, secure communications and threat detection, as well as offensive capabilities such as surveillance efforts, cyber operations and targeting. At the same time, these advances will have manifold civilian applications, ranging from quantum sensors in critical resource development to quantum simulators for material discovery, to quantum-secure communications providing better protection for critical data including IP.

Public investment in quantum S&T as part of the DND/CAF's *Quantum S&T Strategy* has followed this dual-use approach of catalyzing work through targeted leveraging of civilian partners. The first pillar of the *Quantum S&T Strategy* directly states that "to ensure operational requirements are met, DND/CAF will engage with the Canadian quantum community, including those in government, in advancing quantum sensors towards integration into current DND research endeavours and eventual CAF application" (DND/CAF 2021, 11). Similarly, in the case of quantum computing, the role for DND is not so much to build a parallel research apparatus *de novo* but instead "to provide sandboxes and exploit S&T field trials" (ibid., 12). Action plans for further pillars include the development of partnerships with actors across government, academic and industry networks to collaborate on research efforts and expand direct funding initiatives "to help stimulate the growth and transition of promising work and foster the emerging Canadian quantum industry" (ibid., 14). However, the lack of a dedicated budgetary allocation to the strategy meant that these efforts would compete with other priority areas for previous defence-spending allocations.

The whole-of-government NQS set out a vision for public support of the quantum S&T sector, including $360 million over seven years (Government of Canada 2022, 9).[14] The NQS has three core pillars (ibid., 3):

- **Research:** Supporting basic and applied research to realize new solutions and new innovations.
- **Talent:** Developing, attracting and retaining the critical talent from within Canada and around the world to build the quantum sector.
- **Commercialization:** Translating research into scalable, commercial products and services that can benefit Canadians, our industries and the world.

Through these pillars, the strategy seeks to build on a strong foundation of a highly qualified population and innovative start-up community.[15] More recent comments by Minister of Artificial Intelligence and Digital Innovation Evan Solomon have indicated that an increasing focus on emerging technology policy is maintaining technological sovereignty by keeping IP, leadership and innovation in Canada (Scott 2025). Similarly, Prime Minister Mark Carney's high-profile June 9, 2025, announcement on defence spending named emerging technologies — specifically "artificial intelligence, cyber, quantum, and space" — as priority areas to build capacity (Prime Minister of Canada 2025). Although quantum work under way at DRDC or funded under the auspices of DND programs is understood to fall within the ambit of the NQS, the policy approach appears to see defence objectives as discrete components of broader government policy rather than an essential aspect of work across departments.

The growing realization within NATO defence-spending conversations that a broader vision of dual-use objectives and innovative industrial development is essential to achieve collective security — alongside the explicit calls within the DIANA program and other EDT policy circles to value civilian commercial successes as key

14 The figure supporting AI announced in the 2024 Budget was $2.4 billion over five years (Government of Canada 2024, 14), leading to nearly 10 times the annual spending: $51.4 million per year for quantum versus $480 million per year for AI.

15 Although provincial government expenditures fall beyond the scope of this paper, it is important to recognize that education is a provincial competency. There is a need for provincial governments to make further investments to maintain and expand the domestic talent pool.

Table 3: Alignment of NQS Pillars with NATO Five Percent Categories

Pillar	Core Defence Requirements (3.5%)	Defence- and security-related spending (1.5%)
Research	Some	All
Talent	Some	All
Commercialization	Unlikely	All

Source: Authors.

indicators for NATO's technology innovation aims — requires a radical reimagining of Canadian government support for quantum S&T (and peer sectors). In addition to a growing consensus that recognizes quantum S&T as an essentially dual-use sector, NATO's own quantum strategy explicitly recognizes quantum technologies as dual-use (NATO 2024a, paragraph 6). Therefore, all NQS investments should be understood, at the very least, to directly contribute to the NATO mission to "unleash innovation, and strengthen our defence industrial base" (NATO 2025a, 2024b), and many specific disbursements may more accurately be understood as core defence spending, as they relate to R&D for capabilities that are likely to have defence applications (NATO 2025b). Foregrounding dual-use as a core policy frame for government engagement in quantum and other emerging technologies will be an important step to bring greater coherence to Canada's defence posture (Murphy, Forrest and Samson 2025). To demonstrate the potential impact of this policy frame from the perspective of defence spending, Table 3 outlines the alignment of current NQS pillars to NATO spending categories.

An immediate impact of this modernization of defence accounting to align with NATO's recognition of dual-use technologies will be that virtually all dollars spent in support of quantum S&T R&D within the NQS will be reported as defence expenditures by eligible OGDs. By more accurately reflecting government investment in a sector understood by NATO doctrine to be defence spending, one result will be an increase in the reported defence spending by Canada without the need for new dollars to be spent.[16] The proposed Bureau of Research, Engineering and Advanced Leadership in Innovation and Science (BOREALIS) could play an important role in coordinating whole-of-government efforts to invest in emerging technologies and also to track DND and OGD expenses to ensure that they are appropriately accounted for in Canada's defence-spending reports. The ability of BOREALIS to function as a Canadian equivalent of the American Defense Advanced Research Projects Agency (DARPA) will depend, in part, on the scale of funding earmarked for innovation but also on this crucial coordinating and accounting role (ibid.).[17] Although a full consideration of potential roles of BOREALIS exceeds the scope of this paper, there is a significant opportunity for this organization to fill the role of domestic technology incubator, with different rounds of support for R&D from lab to market.

If a modernization of defence accounting related to dual-use emerging technology investment is a first step, then a second will be to learn from existing institutions that are designed to catalyze research (DIANA, NATO Innovation Fund, DARPA) in order to ensure that public funds are complemented with collaborative wraparounds. Domestic initiatives such as BOREALIS should be designed to work with allied and joint efforts, advancing specific national priorities that may not be included or may not be as high priority for collaborative endeavours. Further interdepartmental coordination can help to identify how more targeted government programs similarly support eligible objectives related directly to dual-use technology R&D or

16 This recommendation aligns with Prime Minister Carney's estimate that up to $50 billion of the total $150 billion annual commitment reflects "spending on things that quite frankly we're already doing to build the resilience of our economy" (Brewster 2025b).

17 Kyle Briggs (2025a) has also noted that a key part of DARPA's strategy, absent from Canadian initiatives, has been the acceptance of failure among funded projects: "To make this possible, we first need to embrace risk and recognize that aggregate value creation is more important than individual project success or profit. To do so the Canadian public sector must accept that a high failure rate is an essential and intentional feature of an effective innovation ecosystem and adopt a mission-driven, whole-of-government approach to enacting this in its innovation strategy."

to broader supports for defence via emerging technology ecosystem development. This approach will help integrate efforts across government and may result in less duplication of efforts as DND human resources will not be required to engage on every defence-spending dollar.

Modernization: Defence Spending to Strengthen Economic Growth and Defence Effectiveness

The strategic pivot discussed in this paper involves both a modernized approach and an expansion of defence spending as well as public investment in emerging technologies, notably in the quantum sector. Recognizing the essentially dual-use nature of these technologies means that policy approaches must consider both economic and security-related implications (Murphy and Forrest 2025). This call to action aligns with the Carney government's efforts to strategically develop high-value industry through its defence spending — a paradigm shift where Canada seeks economic benefit not through the peace dividend but through the defence dividend (DND 2025; Lang 2025). Whereas the measures discussed in the previous section focused on existing programs that could be reclassified and expanded, the four measures covered in this section would be new initiatives. When working together, these proposals will support the reinforcement of Canadian technological sovereignty.

R&D Funding Stream for Dual-Use Technologies

A new funding stream to support R&D related to dual-use technologies, administered directly by BOREALIS and housed within DND, would provide grant-based transfers to public and private actors engaging in relevant research projects. This funding stream would not replace the challenge-based Innovation for Defence Excellence and Security program or existing R&D programs supported by government (for example, Innovation, Science and Economic Development Canada; the Natural Sciences and Engineering Research Council of Canada; the National Research Council Canada) but instead provide an opportunity for field-initiated R&D that provides high-quality technological information to DND/CAF and expands institutional capacity to field test. In collaboration with DRDC defence scientists and relevant CAF end-users, this program should offer opportunities to sandbox prototypes to provide valuable operational testing and evaluation data to innovators (in addition to the financial contribution).[18] The program should be funded sufficiently so that it can absorb failures for many selected projects, recognizing that outsized value is likely to come from a relatively small proportion of efforts,[19] but that these are not always predictable in the early stages (Briggs 2025a). Because NATO defence-spending guidelines recognize that R&D expenditures fall within the bounds of core defence requirements — even if the military applications of identified potential dual-use technologies are not realized — all expenses within this program would be eligible for the core defence requirements (3.5 percent) commitment. However, given the potential for this program to strengthen the defence industrial base and the innovation ecosystem in Canada, expenditures could also be reasonably justified under the broader category of defence- and security-related spending.

Joint Dual-Use Initiatives

A second proposed course of action involves deepening Canadian engagement within the defence team — perhaps through DRDC or BOREALIS — and in partnership with public and private research entities within the context of joint international dual-use initiatives. Significant platforms for such cooperative work include NATO and the Canada-EU partnership. In light of the commitment to defence industrial base development in The Hague Declaration, NATO allies have a framework for pursuing joint procurement, co-investment in R&D and co-production of assets (Karlson, Paraskevopoulos and Dudas 2025). In addition to facilitating economies of scale that can increase the efficiency of such investments, these collaborative efforts also provide important opportunities to promote interoperability of mission-critical systems and mutual market access. The new Canada-EU

18 This may complement or find synergies with existing NATO innovation programs.

19 Akin to the power law distribution seen in venture capital investments.

Security and Defence Partnership[20] also provides a framework for collaboration on issues of joint concern. The partnership has already identified the significance of cooperation on economic issues related to security and defence, with the Canada-EU Economic Security Dialogue as an identified forum for coordination of efforts. New funding explicitly earmarked for collaborative research endeavours on dual-use technologies raised through this forum provides another opportunity to build R&D capacity in areas of common priority. As with the proposal above, the dual-use nature of initiatives following from these platforms would mean that all expenditures would be eligible for consideration under the core defence requirements. When private actors are involved, or when broader commercial benefits within the defence industrial base may be realized, expenditures may also be considered for accounting under the defence- and security-related spending category.

Commercialization (Start-Up/ Scale-Up)

Support for commercialization of emerging technologies with dual-use applications is a third proposal that will support the twin goals of economic growth and defence effectiveness. Firms at the start-up and scale-up stages have important roles to play in bringing new technologies to market, especially in the context of increasing private-sector leadership in R&D. However, to reach a successful stage of commercialization, firms must first pass through the "valley of death," where insufficient capital and other risks can lead to the failure of innovators (Fiott 2019, chapter 3). When defence spending is lagging or uncertain, firms may perceive dual-use classification as a regulatory risk without sufficient benefit to carry through the critical "valley of death" period. For small and medium-sized enterprises (SMEs) to realize their full potential in terms of contributing to national economic growth and defence effectiveness, public support may be required. Some solutions for commercialization can be regulatory, such as the acceleration of procurement processes for start-up/scale-up innovators or the provision of temporary regulatory exemptions to facilitate acquisition of emerging technologies (European Commission 2025, 10). In Canada, this might take the form of a program that identifies domestic emerging technology firms to provide an accelerated procurement pathway for relevant technologies, perhaps following from R&D costs supported through public grants. One policy framework that may help guide this reorientation of procurement policy is Mariana Mazzucato's (2020) "mission-oriented" model for public procurement, which recognizes the market-building power of procurement policy and the ability of public priority-setting to attract activity and investment of private sector firms. In addition to revenue-based support, investment in dual-use technologies is needed through the development of a fund similar to the European Innovation Council's TechEU scale-up fund, which has been proposed as a joint venture between public investment and private bank reserves to acquire significant equity stakes in promising innovative ventures (Blenkinsop 2025; Greenacre 2025). A similar Canadian institution could involve public investment in partnership with private institutions in Canada, including the nation's large pension funds. The introduction of targeted dual-use technology funding streams to be allocated by Canada's Regional Development Agencies could further help to develop technological and defence industrial base elements from coast to coast to coast. Although regulatory changes may facilitate expenditures, they are unlikely to contribute directly to either category of defence expenditures. Public support for commercialization initiatives may contribute to the defence industrial base targets noted in the category of broader defence- and security-related spending, especially when involving support for start-up/ scale-up firms developing dual-use technologies.

IP Strategy

Governance of IP in the context of emerging technologies is a difficult matter, given the competing considerations of incentivizing creative and innovative work while also maintaining an open and competitive environment (Kop, Aboy and Minssen 2022). Finding this balance is especially important in the context of defence-related IP, as recent analysis by RBC posits that the economic multiplier of defence IP results in greater gains than services, construction or machinery and equipment (Leach and Zanzana 2025). Both a regulatory review informed by expert consultations and direct support for IP retention for SMEs developing dual-use technologies will be necessary to progress toward a balance. As a recent expert panel in Ontario recommended, government

20 See www.international.gc.ca/world-monde/international_relations-relations_internationales/eu-ue/security-defence-securite-defense.aspx?lang=eng.

Table 4: Alignment of Policy Proposals with NATO Five Percent Categories

Proposals	Core Defence Requirements (3.5%)	Defence- and Security-Related Spending (1.5%)
R&D funding stream for dual-use technologies	All	All
Joint dual-use initiatives	All	Some
Commercialization (start-up/scale-up)	Unlikely	Some
IP strategy	Unlikely	Some

Source: Authors.

efforts to promote IP literacy among innovators and to develop centralized resources to provide IP expertise and education to the start-up/scale-up community would provide a boost to firms' readiness to compete in the "intangibles" economy (Expert Panel on Intellectual Property 2020, 28–32). As the DND develops BOREALIS, the establishment of an office with a mission on defence and dual-use IP services would provide a major competitive advantage for developing the Canadian defence industrial base, promoting economic growth and achieving improvements in defence effectiveness. Given the complexity of different IP elements in the quantum sector as well as the tension between proprietary control and the system benefits of openness (Lenarczyk, Aboy and Minssen 2025), such an office would be well advised to incorporate an expert advisory council into plans for centralized IP services so that national advice can remain agile in the face of changing incentives and best practices. An important defensive aspect relating, in part, to IP protections is the threat of international espionage and research security not only from foreign governments' intelligence agencies but also from state-directed public and private actors presenting risks to Canadian researchers (Leuprecht 2023). These associated expenditures would clearly align with the category of defence- and security-related spending.

As summarized in Table 4, the proposals for new government policy around dual-use technologies directly support Canada's progress toward its new commitments to NATO. Crucially, these proposals are not defence expenditures for the sake of defence expenditures but highly productive investments in the expansion of Canadian industry. As Box 2 discusses, the actions are also critical to shore up technological sovereignty as countries around the world compete for innovators. By supporting the shift in Canada's defence-spending posture from "peace dividend" to "defence dividend" (Lang 2025), these proposals represent high-value opportunities to accomplish economic growth and defence effectiveness goals simultaneously.

Conclusion

Within a context of rising geopolitical tensions, countries around the world are announcing plans to increase defence spending. This trend has been especially significant in the context of the NATO alliance, where member states are broadening their spending plans not only through an increased allocation to defence and security but also through a widened scope of affairs considered relevant to defence. A laggard throughout the entire "two percent era," Canada's recent history of defence spending has been characterized by consistent underfunding and conservative accounting practices. Recent announcements of rapid increases in defence spending — accompanied by a focus on developing a domestic defence industrial base and taking seriously emerging technologies — mark an important pivot in Canadian defence strategy. Critical to this pivot will be Canada's navigation of dual-use technology, especially in terms of private sector engagement to achieve critical objectives and

acquire novel capabilities. New thinking is required to build and protect technological sovereignty.

As Canadian R&D spending has declined in recent decades, rethinking of existing policy and adoption of new tools will be required. The proposed BOREALIS could play a crucial role in driving modernization of existing programs and launching new initiatives. Drawing on the example of Canada's NQS, this paper examined how a dual-use policy framework can help modernize defence accounting and recognize defence-relevant expenditures in emerging technologies across the whole of government. The authors then considered how new policy tools can further contribute to the twin goals of economic growth and defence effectiveness as the government pursues an ambitious defence reinvestment program.

The coinciding forces have created a window of opportunity for the Canadian government to spur high-value economic development while also improving its standing on the world stage by meeting its ambitious defence-spending targets and shoring up technological sovereignty. These efforts are not without risks, but successful navigation will lead to significant economic and security benefits. The proposals outlined in this paper present meaningful opportunities to modernize existing policies and introduce high-impact new initiatives to achieve this ambitious agenda.

Box 2: Case Study — Quantum Benchmarking, DARPA and Canadian Technological Sovereignty

Commentators within the innovation policy area have suggested that the Canadian government must learn from the case of AI, where public support for basic research, training and start-up R&D left the country, seeing the high-value scale-up and commercialization activities enrich another country. This sectoral example is offered as proof of the risk of quantum technologies being another missed opportunity for national prosperity. However, firm-specific examples already demonstrate the proximity of this risk for Canada, as illustrated by the case of Quantum Benchmark Inc.

DARPA's Quantum Benchmarking Initiative (QBI) is a program that "aims to discover if any company is on the path to creating an industrially useful quantum computer by 2033," culminating with full system testing and evaluation to either prove its viability or disprove its possibility (Altepeter 2024, 9). The QBI program is recognized as a landmark process that "may shape the next generation of high-performance computing" (Swayne 2025) and has drawn attention from internationally leading firms to testing grounds in the United States. Notably, four of the 18 companies selected for QBI are Canadian; although this is cause for celebration for the advanced standing of Canada's quantum industry, this also raises major questions about the retention of IP and headquarters for these innovators, as DARPA has indicated that its investment per successful company will be roughly equal to the entire commitment of Canada's NQS (Briggs 2025b).

In late 2003, *Science* published an article offering a novel method for generating pseudo-random operators (Emerson et al. 2003), which was immediately recognized as an important contribution toward the future ability to test quantum computers (Smalley 2004). The lead author on the paper, Joseph Emerson, moved to the Perimeter Institute and then to the Institute for Quantum Computing (IQC), both in Waterloo, Ontario, Canada. His continued work on the topic, in collaboration with Joel Wallman (first a post-doctoral fellow and subsequently an assistant professor at IQC), spun off to the start-up Quantum Benchmark Inc. in 2017. This Canadian start-up was a leader in performance validation but was ultimately acquired four years later by the international validation solutions company Keysight Technologies (IQC 2022). Although clearly identifying a critical need for the global quantum sector, this Canadian company was bought out; benchmarking efforts — and even the acronym QBI — will now be associated with a DARPA program rather than with Canadian leadership.

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