PUBLIC POLICY FORUM

DECEMBER 2021

# NEW NORTH STAR III

## THE CASE FOR A CANADA ADVANCED RESEARCH PROJECTS AGENCY

ROBERT ASSELIN SEAN SPEER


PPF

# CONTENTS

PUBLIC POLICY FORUM
FORUM DES POLITIQUES PUBLIQUES

PPF

**ABOUT PPF**

The Public Policy Forum builds bridges among diverse participants in the policy-making process and gives them a platform to examine issues, offer new perspectives and feed fresh ideas into policy discussions. We believe good policy makes a better Canada.


1400 - 130 Albert Street
Ottawa, ON, Canada, K1P 5G4
613.238.7858

www.ppforum.ca | @ppforumca

## THANK YOU TO OUR PARTNERS

Business Council of Canada

CEDEC

Johnson & Johnson FAMILY OF COMPANIES IN CANADA

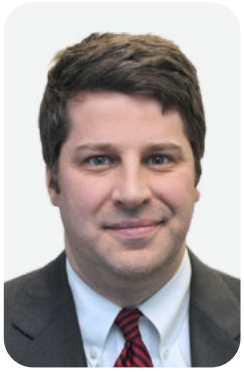
MDA

Scotiabank.

# ABOUT THE AUTHORS

Robert Asselin

Robert Asselin is Senior Vice-President, Policy at the Business Council of Canada. From 2017-2020, he was Senior Global Director, Public Policy at Blackberry. In 2017, he was appointed Senior Fellow at the Munk School of Global Affairs and Public Policy at the University of Toronto and Fellow at the Public Policy Forum. From 2015 to 2017, he served as Policy and Budget Director to Canada's Finance Minister. From 2007 to 2015, Mr. Asselin was the Associate Director of the Graduate School of Public and International Affairs at the University of Ottawa. In 2014, he was a Visiting Public Policy Scholar at the Woodrow Wilson International Center for Scholars in Washington, D.C. Mr. Asselin was a Policy Advisor to Prime Ministers Paul Martin and Justin Trudeau.



Sean Speer

Sean Speer is the PPF Scotiabank Fellow in Strategic Competitiveness at the Public Policy Forum. His latest research explores the perceptions and realities shaping the Urban-Rural divide in Canada, and the implications for policymakers and leaders. He is also an assistant professor at the University of Toronto's Munk School of Global Affairs and Public Policy. He previously served as a senior economic adviser to former Prime Minister Stephen Harper.

## INTRODUCTION

Canada's prosperity has relied too heavily on the here and now of deficit spending, booming real estate and debt-financed household consumption. We must instead redirect investment to the wealth and well-being of the future, particularly our ability to invent and innovate, generate world-leading technologies and firms and ultimately capture global markets. The invention and adoption of new products, services and processes must be the foundation of rising productivity and long-term prosperity.

The idea that the process of invention and innovation is a key ingredient for national wealth and prosperity is neither new nor novel. As U.S. President Harry S. Truman put it in his 1949 inaugural address:

**"Greater production[1] is the key to prosperity and peace. And the key to greater production is a wider and more vigorous application of modern scientific and technical knowledge."[2]**

Canada's performance on the application of modern science and technology – sometimes characterized as the "innovation continuum" – requires greater policy attention. Building a modern economy that lifts up Canada and Canadians will depend on the ability of domestic firms to create new products and services that are competitive in the global economy. Invention and innovation must therefore be major inputs into this positive-sum process of greater competitiveness, higher productivity and, ultimately, rising living standards.[3]

The benefits of new ideas and technologies are not just limited to material gains. They are also key drivers of solutions to environmental, national security and social challenges, ranging from climate change to public health to the digital divide. The process of catalyzing breakthrough ideas and technologies and then bridging them across the innovation process to their market-based application can, for instance, lead to new vaccines for tackling future pandemics, emerging clean technologies for greening the economy, and the application of digital solutions to everything from farming to health care.

As a nation suffused with ambition to matter in the world and run with the best, we need to do better on breakthrough ideas and technologies – more instances like insulin and fewer scrambling for vaccines developed and produced elsewhere. Increasingly the laggards on breakthrough ideas and technologies will be left with the breadcrumbs in an economy fueled by invention, innovation and intangibles.

Yet Canada is not maximizing these potential outcomes for its economy, society or place in the world. The Brookfield Institute for Innovation + Entrepreneurship's and Innovation Policy Lab's 2020 Inclusive Innovation Monitor points out, for instance, that "innovation in Canada has been lackluster compared with our international peers."[4] A 2018 Brookings Institution report similarly showed that our advanced industries – namely, those sectors with high-value innovation and technology application that disproportionately drive national and regional prosperity – lag significantly compared with the United States.[5]

Diagnosing the problem is the easy part. We are not producing enough breakthrough inventions and failing to effectively transition the ones that the country does produce through the innovation process to commercialization, scale and, ultimately, global export. Canada is stuck in what has been described as a "low-innovation equilibrium."[6]

Solving these shortcomings is much more challenging. They are rooted in the structure of the economy, the design and implementation of many layers of government programs and policies, and the culture of incrementalism that tends to permeate Canadian business, universities and governments. It is difficult to overcome this combination of secular and structural factors that influence the pursuit of science, technology and progress.

A capacity for innovation is no longer merely a prerequisite for rising living standards. It is a fundamental **strategic advantage for dealing with various environmental, national security and social challenges**.

Yet there is a renewed urgency today to address Canada's innovation underperformance. The global race for invention and innovation is gathering speed in the new world of the intangibles economy. As we have outlined in our previous New North Star papers, the rise of intangible assets (including data, software and intellectual property), and their "winner-take-all" dynamic, is transforming where economic value is derived and which countries will shape the future.[7] Governments around the world are in turn enacting ambitious new strategies to boost science and technology in general and pursue breakthrough ideas and technologies in particular.

This point cannot be overemphasized: we are living in an era of paradigmatic change where a combination of the intangibles economy and growing geopolitical rivalry is requiring policymakers to rethink their basic policy strategies to support domestic invention and innovation. The growth of "dual-purpose" technologies that combine commercial and national security applications has contributed to what U.S. scholar Michael Lind has characterized as the "return of geoeconomics."[8] A capacity for innovation is no longer merely a prerequisite for rising living standards. It is a fundamental strategic advantage for dealing with various environmental, national security and social challenges.

This shift has led governments and politicians across the ideological spectrum to adjust their thinking on the strategic importance of domestic capacity in key sectors and technologies, the role of government in supporting invention and innovation, and the need for new public-private institutions to support progress in these areas. As Canadian-born, Washington-based innovation policy expert Robert Atkinson observed in a July 2021 paper, more than 50 countries have now established some form of a dedicated national technology agency.[9]

U.S. President Joe Biden's January 2021 letter to his new science advisor is a good example of this renewed commitment to science and technology.[10] The president's letter is reminiscent of former President Franklin Roosevelt's instruction to

Vannevar Bush in November 1944. That famous instruction led to the highly successful Endless Frontier Agenda, which ultimately contributed to U.S. leadership on science and technology for the subsequent 80 years and counting.[11]

Growing bipartisan support in Washington for greater public investments in science and technology in general, and in applied industrial research in particular, reflects a shared understanding of the modern economic imperative: countries that are able to generate and then fully capitalize (what former President Truman referred to as the "production" and "application") on their intellectual capital will be the ones that succeed in the 21st-century economy.

Canadian policymakers must therefore think bigger. Our middling innovation performance will not be solved by the creation of one-off programs or policies in this new era of intense global competition.[12] There is a national imperative to strengthen the country's overall capacity for invention and innovation. Canada must systematically address the structural weaknesses across the innovation continuum from basic research funding to scaling global firms. The country, in short, needs a new capacity to catalyze breakthroughs and bridge them to commercialization, scale and, ultimately, global export.

This ought to start with a recognition that our current models for supporting science and technology are inadequate. We need to augment our incremental approach, which mostly comprises a panoply of innovation policies and programs that have yielded sub-par outcomes, with a new high-risk, high-reward approach. Such a policy shift would have implications across the economy but perhaps nowhere more important than the goal of energy transition. Carbon pricing and other abatement policies should induce growing demand for new and different forms of energy. There is now a need for a greater focus on the technology side of the innovation equation to fulfil this incipient demand and achieve the goal of net-zero emissions by 2050. The main point is that governments have a key role to play in funding and facilitating applied R&D at scale and in the commercialization of the research for market-based application.

As part of its plan to address the country's innovation challenges, the federal government has put forward a plan to create the Canada Advanced Research Projects Agency (CARPA) to "unleash bold new research ideas, drive technological breakthroughs, protect Canada's competitive advantage and help Canadian companies grow and create highly skilled jobs."[13, 14] Although key details remain mostly unknown, the Liberal policy platform specifically cited the Defense Advanced Research Projects Agency (DARPA) in the United States as a model for the new organization.

The proposal has already generated considerable discussion and debate within innovation policy circles. Some have questioned whether a new agency dedicated to pursuing breakthrough ideas and technologies is the right response to the country's ongoing innovation challenges. Others have warned that Canada may lack the contingent characteristics – including a large-scale public procurement capacity – for a DARPA-like agency to ultimately be successful here. The idea has been characterized as far short of a silver bullet for Canadian innovation policy.

We understand some of these concerns. The design, governance, operational and programmatic details for a new CARPA will matter a great deal. If the government fails to get these basic building blocks right, there is a high probability that the new agency will underdeliver as the source of new breakthroughs or act as a bridge to their market-based application. The risk is, as its critics have noted, that CARPA essentially becomes just another innovation-related granting agency within the pre-existing federal panoply.

We are more optimistic, however, that CARPA can be a useful institutional addition to Canada's overall innovation ecosystem. A new agency dedicated to high-risk, high-reward projects with the potential to produce breakthroughs can help to continuously replenish Canada's innovation pipeline with a new

**The purpose of this paper is to set out an institutional and policy blueprint for the future CARPA.**

supply of promising ideas and technologies. It can tilt in favour of "wild card" innovation while most other government agencies and programs preference "safe bets." One might think of it therefore as a government agency singularly committed to pursuing the overriding goal of "zero to one" (radical innovation) rather than "1 to n" (incremental innovation) as polarizing yet highly successful Silicon Valley investor Peter Thiel has put it.[15]

But, as various innovation policy experts have rightly observed, this is a necessary yet insufficient condition for achieving more market-based innovation. CARPA will also need to incorporate into its projects and processes a capacity to help such ideas and technologies transition through the innovation process to market commercialization in the form of public procurement, access to private capital, and other public and private means to help these technologies ultimately secure domestic and global customers. CARPA must, in short, play a role in catalyzing breakthroughs and creating bridges for such breakthroughs to reach the market.

The purpose of this paper is to set out an institutional and policy blueprint for the future CARPA. We draw on a combination of primary research (including comparative analysis of peer jurisdictions) and our own policy experience to put forward the design, governance, operational and programmatic elements that we believe are crucial building blocks for CARPA.

**Section 1** discusses the differences between incremental and radical innovation, including the factors that can cause the market to produce fewer breakthrough ideas and technologies than we may need and the role for public policy to solve for this market failure.

**Section 2** examines DARPA and other advanced research projects agencies around the world to discern the key characteristics that contribute to their effectiveness as catalysts for breakthrough ideas and technologies and as a bridge to their market-based application.

**Section 3** analyzes Canada's existing innovation ecosystem and contextualizes the need for a DARPA-like agency to advance high-risk, high-reward projects and help promising ideas and technologies transition across the entire innovation continuum.

**Section 4** outlines the key design, governance, operational and programmatic elements that will determine CARPA's ultimate effectiveness as an institutional addition to Canada's overall innovation ecosystem.

**One final point:** while we recognize that CARPA will not be a silver bullet – one of us has, in fact, written that "a Canadian version [of DARPA] will not solve Canada's innovation challenges on its own"[16] – we also believe that a well-designed and well-structured agency can make a positive contribution to the country's innovation ecosystem by prioritizing breakthroughs over incrementalism. As a long-time Canadian policy practitioner said to us: "[CARPA] is the kind of thing that can shake up a sclerotic innovation ecosystem."[17] We agree.

There is reason to be energized by the growing momentum for different models of innovation policy in Canada. It is indeed time to shake up Canada's underperforming innovation ecosystem and recommit the country to the goals of innovation, technology and progress. CARPA can be a major part of such a renewed agenda. The following pages set out a blueprint for building Canada's first national agency dedicated to breakthroughs and bridges.

SECTION I:

# INCREMENTAL VERSUS RADICAL INNOVATION

The federal government's promise to establish a new Canada Advanced Research Projects Agency (CARPA), with a focus on breakthrough ideas and technologies, is hardly unique. Several other jurisdictions already have such agencies or have at least experimented with them.

The basic idea is straightforward: a combination of market forces and other political economy factors tend to push academic researchers and for-profit businesses in the direction of incremental innovation. This type of innovation is highly important for incumbent firms and technologies. It reflects a dynamic and ongoing process of improvement to pre-existing ideas, products, processes and technologies. Incremental innovation is a basic expression of the relentless dynamism of market capitalism.[18]

But it is not enough to overcome major environmental, national security and social challenges. There is also a need for radical innovation, which tends to produce more substantial changes to technologies and business models and often involves new firms gaining entry into a market or creating a new market altogether. This form of innovation therefore usually leads to comparative advantages and, in turn, can contribute to explosive growth.[19]

Yet, due to its inherent aberrancy and uncertainty, there is a risk that neither the market nor conventional research funding models will produce such outcomes. A weird mix of market failure on one side and academic "gatekeepers" on the other stands in the way of such progress.[20]

In the case of the former, the market will not produce enough radical innovation on its own because of the high levels of risk and lengthy timelines for potential investment returns. As for the latter, the peer-review process for academic research funding tends to preference prevailing topics, methodologies, and knowledge at the expense of breakthrough ideas and technologies.[21] The net effect is that we can end up with too few promising ideas in the innovation pipeline and too little commercialization and scale occurring in the private economy.

This under-investment in radical innovation can not only harm overall productivity, but also impede progress on solving major environmental, security or social problems. Take climate change for instance. Incremental innovation alone will not enable Canada to meet its ambitious net-zero emissions target by 2050. We are going to need significant, new scientific and technological breakthroughs if we are to achieve Canada's net-zero emissions target by 2050.

The Canadian Institute for Climate Choices estimates that "safe bets" such as electric vehicles, energy-efficiency equipment and electric heat pump and baseboard heaters can contribute at least one-third of the emissions reductions required to meet Canada's 2050 target. The rest of the progress will need to come from "wild card" technologies – different forms of radical innovation – that are currently undeveloped or may not yet even exist.[22]

These breakthrough ideas or technologies are what fundamentally drive progress, which is shorthand for what technologist Patrick Collison and economist Tyler Cowen have defined as the "combination of economic, technological, scientific, cultural, and organizational advancement that has transformed our lives and raised standards of living over the past couple of centuries."[23] They represent, in the words of the Canadian co-founder of Moderna, Noubar Afeyan, major scientific and technological "leaps" rather than mere incremental bounds.[24] A dynamic, growing economy cannot merely depend on incremental innovation. It also requires a steady supply of such breakthrough ideas and technologies in its innovation pipeline. Going from zero to one, according to Afeyan, requires the "permission to leap."

Yet most government programs and policies tend to prioritize incremental innovation. This is somewhat intuitive. Incremental innovation is, by definition, more commonplace than radical innovation. It also has a greater political constituency in the form of incumbent firms and academic researchers. Ideas and technologies that do not yet exist do not have advocacy voices.

The market is therefore at risk of underinvesting in high-risk, high-reward inventions and instead prioritizing safe, incremental progress. This can contribute to a sclerotic equilibrium in which the supply of breakthrough ideas and technologies starts to run dry in the innovation pipeline and ultimately impedes progress. Robert Atkinson has therefore argued in favour of a policy framework that is "tilting in favour of radical innovation."[25] Bill Gates has similarly made the case for investing in a capacity for "technological miracles."[26]

The key point is that if we want to catalyze more breakthrough ideas and technologies, we can neither rely on market forces nor traditional public research funding models. It will require new institutional arrangements with a disciplined focus on radical innovation to achieve them.

## SECTION II:

### LEARNING FROM THE BEST:

# WHAT IS AN ADVANCED RESEARCH PROJECTS AGENCY?

Many jurisdictions have come to recognize the need for such an institutional capacity and therefore created new government agencies, programs and policies explicitly dedicated to the goals of catalyzing breakthrough ideas and technologies. We have seen recent commitments to establish or augment government agencies focused on radical innovation. The U.K. government's legislation to create a new Advanced Research and Invention Agency (which passed all its House of Commons stages in July 2021) is a prime example.[27]

The pending U.K. agency and other comparator agencies around the world mainly derive their organizational insights from the Defence Advanced Research Projects Agency (DARPA) in the United States. It has, over its more than 60 years in existence, become the "global standard" for government agencies dedicated to high-risk, high-reward projects.[28]

DARPA has since spawned similar advanced research projects agencies in Asia, Europe and elsewhere. Even the U.S. government has sought to replicate the agency's success in other areas beyond defence-related innovation, including biomedicine (2006: Biomedical Advanced Research and Development Authority, BARDA); energy (2009: Advanced Research Projects Agency-Energy, ARPA-E); and, recently announced under the Biden Administration, health (2022: Advanced Research Projects Agency for Health, ARPA-H).

The point here is that the advanced research projects agency model is common across peer jurisdictions and increasingly prevalent with the shift to an intangibles economy and the high returns for breakthrough ideas and technologies.

It should be noted that while DARPA's aim is to catalyze defence and security technologies, most comparator agencies elsewhere do not share its specific sectoral focus. They are attempting to apply the design, governance, operational, and programmatic insights from DARPA to the economy as a whole or to other sectors such as biomedicine, climate change, energy and health. This distinction is important because, when we refer to a DARPA-like model, we are not implying that the Canadian government ought to establish an advanced research projects agency with the mandate of catalyzing breakthrough ideas and technologies in the defence sector.

Defence is neither a comparative advantage for Canada nor a galvanizing problem requiring technological solutions in the Canadian context. The key is for Canadian policymakers to understand the contingent factors that have enabled DARPA's strong performance and aim to replicate them, but with an orientation to a different set of problems, including, for instance, the energy-environment nexus.

### THE PENTAGON'S BRAIN

DARPA was founded in 1958 as the Advanced Research Projects Agency in response to the launch of Sputnik by the Soviet Union. The function of the new agency then and now is to ensure that the U.S. military is never surprised again by new and emerging technologies. By focusing on "Pasteur's quadrant" – use-inspired basic research that advances the quest for fundamental understanding as well as aiming for practical applications – DARPA over its lifetime has helped catalyze major breakthroughs from the internet to GPS to autonomous vehicles to mRNA therapeutics.

New research by scholars at the Washington-based Peterson Institute for International Economics evaluated the DARPA model as part of an overall

review of experiments with industrial policy in the U.S. over the past 50 years. The analysis shows that DARPA has indeed made a "spectacular contribution" to the cultivation of new technologies that have produced massive economic spillovers over the period. Of the various programs and agencies evaluated, they highlighted DARPA's model of applied industrial research as the one "outstanding success."[29]

This point is worth emphasizing: DARPA's success is not merely about "gadgets" or "stage one innovation" – that is, early-stage idea generation and mobilization – but rather because it sees its role as twofold: (1) catalyzing breakthroughs and (2) helping them bridge through the innovation process.[30] It is a successful model for applied industrial research precisely because it supports wild card technologies at every stage of the innovation continuum. It is, in short, in the business of bringing commercial and practical expression to radical innovation.

The main point here is that a DARPA-like agency can, in theory and practice, make a positive contribution to a jurisdiction's innovation ecosystem. The key, of course, is to ensure that policymakers think carefully about the contingent factors that are necessary preconditions for such an agency to be able to catalyze breakthroughs and bridge them to commercialization, scale and, ultimately, global markets.

Canadian policymakers can learn a lot from existing agencies and initiatives elsewhere in the world. In particular, our research shows that some key design characteristics are inherent to the DARPA model and other comparators.

## 1 They are inherently problem-solving organizations.

Advanced research projects agencies do not fund disparate or random projects: supporting interesting basic scientific research is not an end in itself. They fundamentally orient their operations and project selection around a set of well-defined challenges or problems. Although the overarching focus is high-risk, high-reward projects (as we discuss below), it is fundamentally applied research.

The idea here is that many contemporary problems depend on technological solutions. The goal of DARPA is to catalyze the development and testing of such problem-solving technologies and then to connect the dots between invention and innovation at a scale that can both address the underlying challenge and enable market-based commercialization for domestic and global sales.

So-called "moonshots" (shorthand for a challenge or problem that requires radical innovation to solve it) can therefore bring greater intentionality to government policy by organizing science and technology and innovation strategies around a set of overarching imperatives such as achieving net-zero emissions or finding cures for debilitating diseases. DARPA's modus operandi is, in short, an outcome-oriented strategy that seeks to catalyze and commercialize breakthrough ideas and technologies focused on solving a specific challenge or problem.

The agency leverages private-sector capital and know-how as well as academic researchers to conceive of technologies with large externalities. Any breakthrough technologies that emerge from DARPA programs will not just have the potential for significant commercial returns, but will also contribute to solving a broader challenge or problem. It would be wrong to view DARPA as some form of so-called "corporate welfare." Private-sector firms that participate in DARPA programs tend to invest significant dollars. They put "skin in the game" because of the potential upside and DARPA's support helps mitigate some of the inherent risk. There is also the signalling effect of DARPA engineers vetting and signing off on a company's project.[31] This amounts to a win-win whereby the government can leverage private capital and expertise in pursuit of projects that may ultimately have major defence and national security consequences.

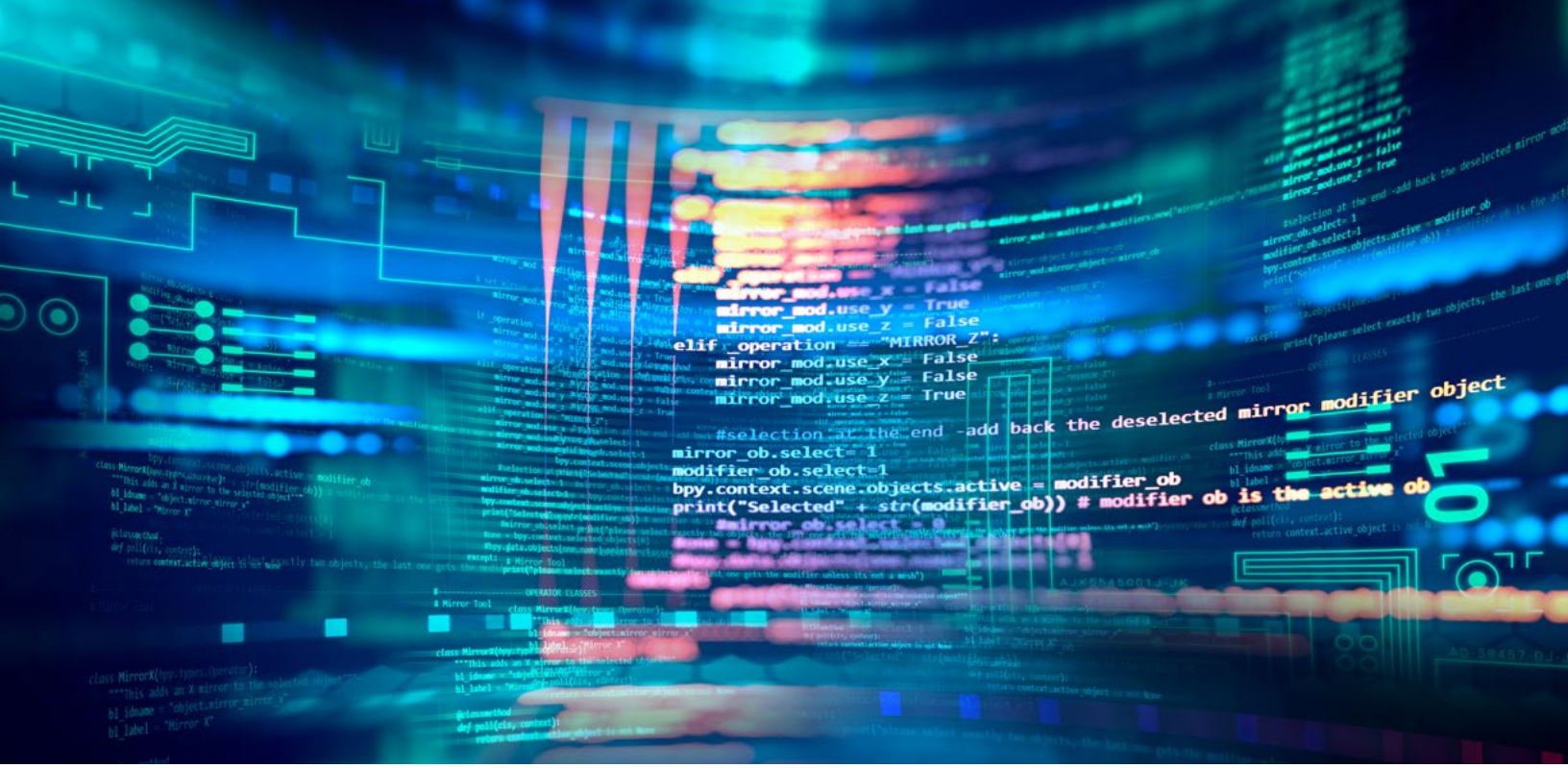
This notion of seeking out radical innovation in the name of solving a particular challenge or problem is hardly new. It is as old as the Manhattan Project or the Apollo Program and as recent as the U.S. government's Operation Warp Speed in pursuit of a COVID-19 vaccine.[32] As an organizing principle for innovation policy, it has received renewed policy and political attention in recent years. Various countries facing their own mix of environmental, national security and social challenges have begun to experiment with different innovation policy models to better support scientific and technological breakthroughs that can address these challenges and, in so doing, build up new comparative advantages in the intangibles economy. Canada can learn from these examples.

In basic terms, the pursuit of radical innovation will not succeed in Canada without the following: (1) federal government playing a proactive role in setting the high-level direction of innovation priorities, and (2) the full participation of willing partners in the private sector and academia. DARPA, for instance, identifies a set of big-picture challenges or problems and then mobilizes different firms and researchers to develop a portfolio of technology-based solutions. One innovation policy expert has described this model of public-private collaboration as "top-down problem generation and bottom-up solution generation."

Identifying the right challenges or problems to prioritize is therefore crucial to success. They should neither be too big nor too small. They must be ambitious enough to galvanize businesses and researchers to pursue breakthrough research but cannot involve goals or timelines that are self-evidently unrealistic.

The challenges or problems must similarly be bold, inspirational and, as a general rule, of wide societal relevance. As economist Mariana Mazzucato has argued, "It [the challenge or problem] must be clear in its intention to develop ambitious solutions that will directly improve people's daily lives, and it should appeal to the imagination."[33]

They also must be prone to technology-based solutions. This is a fundamental characteristic. Many challenges and problems in modern society – think poverty or racism – require far greater policy and




political attention but do not lend themselves to innovation and technology. These issues therefore would not be the purview of a DARPA-like agency.

The key, though, is that these challenges or problems necessitate breakthrough ideas or technologies. This is not about innovation on the margins. DARPA's mandate is to support high-risk, high-reward projects. It is, in short, fundamentally in the breakthrough business. The agency is even committed to funding so-called "wacky things" in the name of pushing innovation beyond incrementalism.[34] Only 5 to 10 percent of DARPA's programs ultimately produce successful outcomes, which reflects its high preference for risk in pursuit of radical innovation.

We will discuss this later in the paper, but it is worth addressing it here as well. DARPA's success rate (which of course means that most of its projects fail) may surprise some readers who might instinctively assume that it represents an indictment of its project selection. The goal, however, is not to support projects that are close to market readiness. It is to prioritize projects that have uncertain but transformative potential. DARPA's standard call for proposals even stipulates: "Specifically excluded is research that results in evolutionary improvements to the existing state of practice."[35]

Although it may seem counterintuitive, this institutional willingness to fail is key to DARPA's success. Any efforts to replicate DARPA must stay similarly disciplined on high-risk, high-reward projects. It is not to say incremental innovation is unworthy of public support. But there are already various funding streams for such projects. Projects that fail to meet a DARPA-like threshold may indeed be funded from these other departments, agencies and programs. A DARPA-like agency must be disciplined about only supporting breakthrough ideas and technologies. It must in short be singularly focused on the pursuit of radical innovation.

CARPA is not therefore a substitute for the existing panoply of departments, agencies and programs focused on innovation in Canada. It is a complement to the rest of the system. It would fill an important gap for projects that are too bold and risky for which the benefits and costs may be unclear and the timelines uncertain. A CARPA would be in the business of cultivating breakthrough ideas and technologies in the name of big challenges and problems.

One consequence of this complementary yet separate role for CARPA is that the experience of DARPA and similar agencies shows that it should be a stand-alone agency. Situating it within the National Research Council (NRC) or Sustainable Development Technology Canada (SDTC), or even Innovation, Science and Economic Development Canada itself, would fail to recognize its unique role in the overall innovation ecosystem.

The NRC's strengths are too far removed from applied research and SDTC operates at too small a scale to achieve the sense of urgency and boldness reflected in the idea of CARPA. The new agency will certainly need to work closely with these other programs and agencies including as possible partners on individual projects as well as potential sources of program managers. As we discuss next, however, the evidence shows that it is imperative that CARPA is a stand-alone agency with a high degree of autonomy.

## 2 They have a lean, agile and independent governance structure.

DARPA-like agencies tend to deviate from conventional governance structures in terms of the relationship to the political arm of the government or the permanent bureaucracy as well as overall interaction with the public. While governments may have an important role in setting the overall direction of innovation policy, these agencies must have the autonomy – including with respect to audit, human resources and day-to-day operations – to execute on their particular role in the innovation ecosystem. The world's most successful advanced research projects agencies are insulated from most bureaucratic and political processes.

DARPA operates with minimal oversight. It has considerable flexibility in its hiring as well as project selection. The model is effectively designed to minimize the role of politics and maximize the scope for high-risk, high-reward projects.

It does not, for instance, consider the regional distribution of its funding or, as discussed above, shy away from project failure. As former DARPA official John Launchbury has said: "If none of our programs fail, we are not stretching far enough."[36]

This autonomy also manifests in DARPA's hiring practices. The agency relies on a team of roughly 100 to 120 program managers with three- to five-year appointments to create and run programs to pursue high-level challenges or problems. The agency's enabling legislation permits it to bypass normal government hiring rules and procedures to select these term-limited appointees. This flexibility enables DARPA to attract ambitious, dynamic people on a fixed-term basis, free from the usual red tape and bureaucracy. Program managers are typically drawn from academia, business and government research laboratories.[37]

DARPA's autonomy is also reflected in its risk tolerance, which is a fundamental part of its ability to pursue radical innovation. As technologist Benjamin Reinhardt has put it: "opacity is important to DARPA's outlier success."[38] It enables the agency to avoid the typical political economy factors that tend towards politicized decision making, including a preference for incumbent firms and academic researchers, and ultimately an orientation towards safe bets.

Although it follows annual public reporting and abides by public-sector accounting rules, DARPA's day-to-day operations, including project selection, are highly autonomous and free from bureaucratic and political interference. Program managers are granted extraordinary authority to establish programs and fund projects without congressional or executive approval. They can also cancel projects and shift funding without requiring higher-up sign-offs or approvals.

The role of program managers is indeed a key part of the DARPA model. The agency's funding levels (which have averaged about US$3.2-3.5 billion over

the past several years) roughly amount to US$30 million per year per program manager, with each running a roughly three-year program with a research agenda of their own.[39] Project managers design programs by identifying a challenge or problem within the overall national defence mission. They then define a "technological white-space", an area in which little research is currently being done, but, if filled, could enable significant progress in addressing the challenge or problem. [40]

This priority-setting process is both highly decentralized and tilted towards radical innovation. The bottom-up structure empowers program managers and intentionally preferences breakthrough ideas and technologies rather than incremental innovation. It pushes back against the risk of group think, incumbency bias or stakeholder pressures. The transient nature of DARPA's workforce also protects against an institutional bias in favour of certain problems or technologies.[41] The combination of these various factors has led former DARPA employees to describe the agency as the "special forces" model of innovation.[42]

One means of maintaining this lean and disciplined operation is that DARPA does not carry out in-house research. It provides funding to external organizations, including businesses and academic researchers, to develop and test breakthrough technologies that solve practical challenges or problems. This outsourcing model enables DARPA to draw on experts and equipment across the United States on a project-by-project basis. It minimizes the agency's fixed costs and dependence on a particular set of partners. Analysis by the Congressional Research Service shows that about two-thirds of its research dollars are directed to private-sector partners.[43]

As discussed earlier, a CARPA model should sit outside of federal departments and agencies and have the flexibility to hire, contract and select projects with minimal central agency or political oversight. The idea is to establish a small yet powerful agency with a mandate to essentially

**A key role for DARPA, then, is to de-risk the early-stage development of ideas and technologies that would not be supported by market-based sources of capital or conventional research granting programs. It aims to fill a niche between market failure on one hand and the "gatekeeping" tendency of academic research funds on the other hand.**

do things differently, including creating an internal culture of risk-taking and research excellence. That requires a lean, agile and independent structure.

It is worth pointing out that there is no contradiction between a powerful agency and a lean one. DARPA only has about 220 employees, of which about half are term-limited program managers. Its budget is roughly US$3.5 billion per year, which is less than one percent of total U.S. public and private R&D spending annually.[44]

The idea for a CARPA is not therefore about building a vast, new, permanent bureaucracy. It is about creating an institutional platform to catalyze breakthrough technologies and then to bridge them to next stages of the innovation process including other government programs or agencies or market-based sources of capital.

CARPA will not require a large staff complement. An early goal might be to appoint 10 or 20 high-quality program managers and grow gradually over time. We are confident that there is plenty of talent in our companies, universities and government laboratories to fill these positions.

## 3 They follow a portfolio approach to managing risk and have a high tolerance for failure.

DARPA's programs pursue so-called "moonshots" in a technology-neutral way. Individual programs necessarily involve several projects with different firms and researchers to develop and test different technology-based solutions for a specific challenge or problem. At any given time, DARPA may have as

many as 2,000 grants, contracts and agreements with different companies, university researchers and government laboratories. Invariably most will fail. But the ones that succeed can lead to genuine breakthroughs. One of the responsibilities of program managers is to cultivate a portfolio of projects across this risk continuum.

The initial exploratory tranche of a DARPA program is approximately US$1.5 million. Most of this funding goes to "seedling projects" for academic researchers or companies to further develop a promising yet underdeveloped concept. Seedlings are three- to nine-month projects designed to "move concepts from 'disbelief' to 'mere doubt'."[45] Projects that show promise can receive additional funding for development and testing before transitioning from DARPA's purview into other government programs or market-based sources of funding.

Throughout this process, program managers work with funding recipients to measure individual projects against a set of milestones and metrics to determine if the risk is still worth the potential reward. Projects are thus continued with more (or less) funding, stopped or redirected. Constant readjustment across the program portfolio ensures that resources are always being allocated as strategically as possible.[46]

A key role for DARPA, then, is to de-risk the early-stage development of ideas and technologies that would not be supported by market-based sources of capital or conventional research granting programs. It aims to fill a niche between market failure on one hand and the "gatekeeping" tendency of academic research funds on the other hand.

This point is worth emphasizing: the type of high-risk, high-reward project that can produce radical innovation is not necessarily going to find support among incumbent firms and academic researchers. Those whose interests are aligned with pre-existing ideas, products, processes and technologies may indeed resist new and different ideas. The risk of course is that this comes to impair the pursuit and development of breakthrough ideas and technologies.

DARPA has stayed disciplined in prioritizing these high-risk, high-reward projects that may not find support elsewhere. This mandate necessarily involves a high degree of failure. As mentioned earlier, DARPA's success rate is reported to be somewhere between 5 and 10 percent, though, this is hard to fully determine because, as discussed above, program managers are granted significant autonomy to adjust and reallocate funding within a program. The agency's low success rate is not a sign of a failure. It is evidence of its commitment to radical innovation.

## 4 They help promising ideas and technologies transition from early-stage development to market readiness and application.

DARPA and similar agencies might be seen as the "first wave" of funding for a new technology. Other government programs (including demand-side levers such as public procurement) or venture capital and other forms of private investment are the "second wave." For the small fraction of DARPA projects that are ultimately successful, the agency has a role to play in helping them transition from early-stage development through these next stages of funding.

The idea here is that the program managers are responsible for supporting the firms or researchers to connect the dots with funding sources that enable them to take their ideas and technologies along the innovation continuum to commercialization, scale and global markets. The goal is to minimize the loss of promising ideas in the so-called "Valley of Death" between idea development and its transition to market-based application. DARPA is designed therefore to act as a bridge across the innovation continuum.

This view of DARPA's mission as extending from invention to innovation is a core strength that the Canadian government must seek to replicate in CARPA. The new agency must similarly see its role as spanning the entire innovation continuum, from idea to market, mobilizing and facilitating connections between supply- and demand-side policy levers that are typically siloed. This is a departure from normal innovation policy that has tended to distribute public funding to companies or academic researchers without sufficient attention to commercialization or scale.

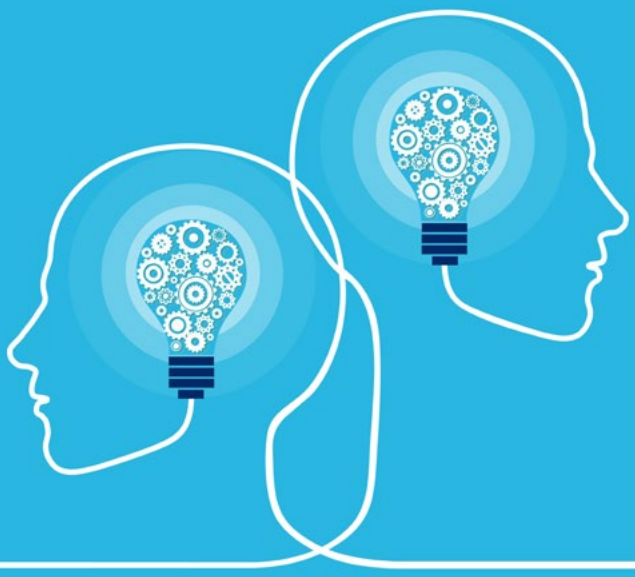
The policy toolkit to enable this end-to-end support is broad and can vary by a technology's proximity to its market-based application. But it will ostensibly involve a combination of more traditional levers such as R&D funding programs and research partnerships to help ideas and technologies further develop as well as demand-side levers such as public procurement, industrial standard setting, training support, tax incentives, regulatory measures and low-cost loans to facilitate adoption and diffusion.

The cumulative effect of these policy interventions is often to co-create markets for ideas and technologies that currently do not exist. Through all these policy measures, CARPA must aim to stitch together what is usually a fragmented policy landscape.

DARPA has generally distinguished itself for helping promising ideas and technologies transition through to commercialization. The U.S. Department of Defense's significant research and procurement budget (US$190 billion per year) is widely seen as a major contingent factor.[47] But even with this unique advantage, the agency still can have issues with transitioning projects through to market-based application. A 2014 Senate Armed Services Committee report noted, for instance, that:

> ...the committee is concerned that **some technology projects may be successfully completed, but fail to transition into acquisition programs of record or directly into operational use**. This may be because of administrative, funding, cultural, and/or programmatic barriers that make it difficult to bridge the gap from science and technology programs to acquisition programs, as well to the expected users of the technology.[48]

The point here is that even the most successful advanced research projects agency in the world can have problems bridging breakthrough ideas and technologies from early-stage development to market-based application. As Canadian policymakers develop the operational plan for CARPA, it will be crucial therefore that the new agency's mandate, structure and relationship with other government departments, agencies and programs support the transition of promising inventions through the innovation process. The notion of an "end user" is fundamental to DARPA's success. It must also therefore be part of CARPA's if it is to overcome the persistent commercialization problem that has bedevilled Canada's innovation ecosystem.



## SECTION III:

# WHY DO WE NEED CARPA?

Canada's innovation ecosystem has various strengths including a network of high-quality universities, high rates of educational attainment, a well-functioning immigration system, and sectoral advantages in agriculture and agri-food and energy and clean technology.

But we also have structural weaknesses in our innovation ecosystem. One way to think about these weaknesses is to consider an innovation ecosystem's fundamental purpose: to cultivate a steady pipeline of promising inventions and then have the right mix of talent, technical capacities and capital to enable some number of them to ultimately reach a market-based application.

The innovation process should rightly be viewed as a continuum from early-stage idea generation and mobilization through to commercialization and widespread adoption and diffusion. As we have outlined in previous papers, Canadian policymakers must take a continuum approach in evaluating and reforming the overall innovation ecosystem.[49]

In practice, this means evaluating how an ecosystem functions at each stage of the innovation continuum. It should, on one hand, generate a considerable number of promising inventions in universities, government laboratories and the private sector. It must then, on the other hand, have a mix of public and private actors, institutions and policies that can help them to bridge across the Valley of Death to reach their market-based application.

Canada's innovation policy framework is lacking in both areas. Although we perform relatively well at the beginning of the innovation continuum – in basic research and the start-up stage – there is still an overreliance on incremental innovation or safe bets. The influence of large, incumbent firms and leading researchers can bias the overall innovation system in this direction. The result is that various government agencies and programs underinvest in high-risk, high-reward inventions.

**Canada's innovation policy framework is lacking in both areas. Although we perform relatively well at the beginning of the innovation continuum – in basic research and the start-up stage – there is still an overreliance on incremental innovation or safe bets.**

This needs to change because, as we argued earlier, incremental innovation is inadequate to deal with the magnitude of modern challenges such as climate change and will not be sufficient to produce the explosion of new growth and productivity needed to boost relatively stagnant living standards.

The government must therefore augment its current scientific and technology strategy to build greater capacity to pursue radical innovation or wild card technologies. A pipeline of such breakthrough ideas and technologies is a crucial ingredient of generating valuable intellectual property within the country. Science and technology is the modern frontier of competitiveness and Canada needs a capacity to better compete for new ideas and technologies.

What makes the DARPA model so compelling is that it does not stop at the first stage of innovation. It recognizes that a pipeline of promising inventions is a necessary yet insufficient part of an overall innovation ecosystem. The pipeline must be matched with greater efforts to strengthen government policies across the innovation continuum to ensure that major breakthroughs are not stranded at the first stage.

This requires a greater coordination across federal policy levers – including R&D spending, regulatory policy and public procurement – as well as more engagement between different orders of government, the private sector and universities and colleges. Better support for breakthrough ideas and technologies across this continuum is fundamental to boosting Canada's innovation and productivity performance.

There is plenty of work needed across these later stages of the innovation process. Canada has long performed poorly at scaling small- and medium-sized enterprises (SMEs), growing global firms in non-protected and regulated sectors, and late-stage or patient capital financing. One result is that many promising companies leave the country, particularly in key sectors such as high-tech and

medical innovation. Another is that our overall innovation outcomes are marginal compared with international standards.[50]

As a whole, Canada's R&D spending as a share of gross domestic product (GDP) is declining and below average compared with other OECD countries.[51] But the level of investment is only one part of the problem. The bigger challenge is the weak link between publicly funded R&D and industry, which has contributed to poor technology transfer and commercialization for Canadian companies. One way to think about this challenge is that Canada's Valley of Death has generally been wider and more dangerous to promising ideas.

There is a false conception in Canada that funding basic research in disparate or random terms, without much consideration of overall economic and strategic interests or even outcomes, will produce innovation in itself. This has been matched by industrial research programs that provide subsidies and repayable loans to incumbent firms and fund the operation of "incubators" as the basis of a commercialization strategy. The net effect is that business expenditures on R&D (BERD) are less than one percent of GDP, which is barely half the OECD average and two or three times less than Israel and the United States.[52] This is not a healthy indicator of innovation, especially in an increasingly competitive global economy.

Canada must confront three undeniable realities in this paradigmatic moment in which governments are enacting ambitious, new science and technology strategies in general and establishing advanced research projects agencies in particular.

First, rational companies will not invest in breakthrough technologies however great the rewards if they involve high levels of risk and lengthy and uncertain R&D timeframes. A 2013 study for instance estimated that radical innovation only amounted to 10 percent of the average U.S. company's innovation portfolio.[53] This necessitates a more active role for government.

The internet, GPS, touch screen and Siri are the result of the interaction between the public and the private sectors to solve a problem—whether to get satellites to communicate in the case of the internet or to aim missiles better in the case of GPS systems. Would mRNA vaccines have been developed without BARDA and DARPA seed funding? Are there sufficient incentives in the current framework of the research granting councils to fund breakthrough ideas and technologies? The answer to both questions is undoubtedly no. CARPA needs to be largely "use-driven" research – that is, research directed at solving a practical problem with breakthrough technologies by solving for the market failure and gap in Canada's innovation ecosystem in applied industrial research.

Second, firms will not maximize innovation if they work in isolation. They need to closely collaborate with suppliers, customers, universities and research institutes to achieve the coordination necessary for the development and commercialization of breakthrough technologies. Such interactions take time, commitment and resources. There are virtually no mechanisms or institutions in Canada that perform this function well in the current ecosystem. The Superclusters have ambitions to play this role in certain regions and sectors though it is still too early to know if they will be successful. There is an ongoing need for focused coordination among multiple parties. CARPA can play that role.

Third, one of the main reasons that Canada is struggling on R&D spending and business investment is that its ratio of large firms versus SMEs is far too low. As a share of all business enterprises, there are over three times as many large enterprises in the United States than in Canada. To improve BERD performance, scaling Canadian firms will be paramount. This can happen with better demand-side levers such as using public procurement to create market demand and grow SMEs. Public-private institutions such as DARPA and NASA would have been much less successful if the U.S. government had not used public procurement to nurture their promising technologies and advanced industries.

Boeing and Lockheed Martin did not become the multinationals they are today by accident: they are living examples of the DARPA model of innovation matched with public procurement at scale.

In the previous New North Star papers, we outlined the need to think about innovation in a continuum framework – ranging from basic research to scaling global firms – that forms the foundation of an industrial strategy for Canada. Better supporting domestic innovation and technological development, not just in the invention stage but at the commercialization and adoption stages as well, is a central reason for a new advanced research projects agency in Canada.

These changes will not be easy in face of various obstacles including possible resistance from incumbent firms and academic researchers. The current laissez-faire model, which essentially outsources scientific funding decisions to the peer-review process and business support to indirect programs, may produce suboptimal outcomes for the country but will still find support among the beneficiaries who may therefore be resistant to change.

But better supporting breakthrough scientific and technological discoveries across this continuum is fundamental to the economic and social well-being of Canadians and the country's long-term national interests. We must make policy and institutional reforms now to catalyze these breakthroughs and fill a pipeline of promising ideas and technologies. It is ultimately how productivity will be driven and Canadian living standards boosted over the long run.

This will require a renewed sense of ambition, dynamism and progress. The next section outlines how to bring institutional expression to this urgency and boldness in the form of the key design, governance, operational and programmatic features of a new advanced research projects agency.

**Canada must confront three undeniable realities in this paradigmatic moment in which governments are enacting ambitious, new science and technology strategies in general and establishing advanced research projects agencies in particular.**

SECTION IV:

# HOW CAN WE SET CARPA UP FOR SUCCESS?

Drawing on the lessons from DARPA and other advanced research projects agencies around the world, one can identify a set of design, governance, operational and programmatic features that ought to be part of the creation of CARPA. A failure to incorporate these lessons could be fatal for the new agency. The risk of course is that it becomes just another innovation-related granting agency within the pre-existing federal panoply.

The government must be highly intentional in how it establishes the new agency. It must be singularly focused on catalyzing breakthrough ideas and technologies and then bridging them across the entire innovation continuum. At its core, CARPA's mission can be described as breakthroughs and bridges.

## Problem-solving mandate:

CARPA's mission should be dedicated to "use-driven" research, with funding oriented around pursuing technological solutions to a clear set of challenges or problems. This is a fundamental differentiator relative to current public R&D funding, which tends to be distributed along regional, sectoral or university lines without a clear framework or purpose.

The overall theme of these challenges and problems ought to be shaped by the government and its priorities. There is a good case, for instance, that, as its first overarching problem, CARPA should focus on helping catalyze the wild card technologies needed to achieve the government's legislated goal of net-zero emissions by 2050.

**CARPA's mission should be dedicated to "use-driven" research, with funding oriented around pursuing technological solutions to a clear set of challenges or problems. This is a fundamental differentiator relative to current public R&D funding, which tends to be distributed along regional, sectoral or university lines without a clear framework or purpose.**

Not only is the net-zero target a problem that necessitates radical innovation, but it is also a sector and range of technologies where Canada has pre-existing comparative advantages. There is also multi-partisan and intergovernmental support for public investments in climate-related technologies. A CARPA program that pursued net-zero technologies could then leverage federal and provincial programs such as Ottawa's recently announced Net Zero Accelerator or Alberta's Technology Innovation and Emissions Reduction Fund to support promising technologies at later stages of innovation.

But as for the focus and design of individual CARPA programs (which tend to be subsets of wider challenges or problems), those choices should be made by program managers free from bureaucratic and political interference. This is a clear lesson from the DARPA model. Empowering program managers to develop programs and select projects is a crucial part of staying disciplined on radical innovation.

## Radical innovation:

The federal government has dozens of programs and agencies that support incremental innovation at the firm level or among academic researchers. These projects can be useful and productive, but they are unlikely to produce breakthrough ideas or technologies that help solve environmental, security and social challenges and contribute to explosive growth and productivity.

CARPA must be disciplined about prioritizing high-risk, high-reward projects that have the potential for breakthrough ideas and technologies. But, as noted earlier, pursuing radical innovation comes with a higher likelihood of failure than conventional public funding programs.

Various factors, including politics, may try to push CARPA to weaken its commitment to high-risk, high-reward projects. If it compromises on this foundational principle, it will essentially become another innovation-related granting agency. In order to mitigate against this risk, CARPA should use a set of questions developed by former DARPA director, George H. Heilmeier, known as the "Heilmeier Catechism."[54] These questions can help program managers consider and evaluate proposed research programs and their projects.

- **What are you trying to do? Articulate your objectives using absolutely no jargon.**
- **How is it done today, and what are the limits of current practice?**
- **What is new in your approach and why do you think it will be successful?**
- **Who cares? If you are successful, what difference will it make?**
- **What are the risks?**
- **How much will it cost?**
- **How long will it take?**
- **What are the mid-term and final "exams" to check for success?**

## High degree of autonomy:

Consistent with a mission focused on high-risk, high-reward projects, CARPA must have a high degree of autonomy free from bureaucratic and political interference. It must be a stand-alone agency that does not reside in a government department or agency. It needs a similar degree of operational autonomy to the Bank of Canada or the Canada Pension Plan Investment Board. It should definitely not be modelled on the governance structure of the Canada Infrastructure Bank.

As discussed elsewhere, DARPA's organizational model of world-class program managers from

Consistent with a mission focused on high-risk, high-reward projects, **CARPA must have a high degree of autonomy free from bureaucratic and political interference.** It must be a stand-alone agency that does not reside in a government department or agency.

industry, academia, or elsewhere for term-limited appointments provides for unique mix of expertise, significant networks, and big ideas foundational to the agency's success. The program managers develop and manage their programs, select projects, actively engage with project proponents, apply thoughtful metrics and milestones, monitor progress and make adjustments. They have extraordinary autonomy to carry out this work within their respective programs.

In practice, this will require granting CARPA exemptions from conventional public-sector processes for hiring, financial authorities and public reporting. This operational autonomy cannot be compromised. It is core to DARPA's success and will need to be part of CARPA's modus operandi if the new agency is to overcome bureaucratic and political pressures.

## Lean organization:

CARPA must emulate DARPA's nimbleness, dynamism and ability to maintain a flat and non-bureaucratic organization. This encourages a culture that values a relentless drive for radical innovation and, in turn, a willingness to take bold risks. Notwithstanding its tremendous success, remember that DARPA is actually a small organization with 220 government employees in six technical offices, including nearly 100 program managers. Its budget is roughly $3.5 billion per year which is less than 1 percent of total U.S. public and private R&D spending annually.[55]

CARPA's role, as for DARPA, should be primarily a priority-setting and coordination function. The new organization should not directly perform research or operate any research laboratories, but rather

executes R&D programs mainly through contracts with industry, universities, non-profit organizations and federal R&D laboratories. This will enable it to choose the best partners for a project.

DARPA's team of term-limited project managers from industry and academia are core to its success. They bring a combination of expertise and rich networks of world-class experts known as "performers" from industry, government, research labs, and academia to carry out research and development activities. Program managers also handle budgeting, contracts, technical and execution issues, and customer relations.

One of the big questions for CARPA is whether there are a sufficient number of prospective program managers in the ranks of industry and universities in Canada. There is no reason for the new agency to aim for 100 program managers in the short- or even medium-term. The goal should be to prioritize quality over quantity even if this means fewer programs for the foreseeable future. Canadian Research Chairs may be one potential pool – though there must be attention paid to the risk of "gatekeeping."[56] Generally, though, we are confident that there is plenty of talent in our companies, universities and government laboratories to fill these positions.

## Culture of excellence:

The new agency must be headed by a respected leader, probably a scientist, with a strong private-sector background and perhaps experience in, or working with, government and academia. A key attribute is an ability to build partnerships across an array of sectors and recruit and energize a phenomenal team of experts. The team must then be given the autonomy and independence to carry out its vision. Only scientific excellence will allow the best researchers and industry leaders to work together on a time-limited basis to solve challenges and problems.

This will be particularly important at CARPA's origins. Simply appointing a career public servant

**CARPA's role, as for DARPA, should be primarily a priority-setting and coordination function. The new organization should not directly perform research or operate any research laboratories, but rather executes R&D programs mainly through contracts with industry, universities, non-profit organizations and federal R&D laboratories. This will enable it to choose the best partners for a project.**

will send the wrong signal about its ambitions. The government should even be prepared to look outside the country for the right person to stand-up the organization and create a culture of excellence.

Such a culture, by the way, must include tolerance for a high rate of failure. The cost of pursuing radical innovation is that not all programs or project will be successful – indeed the vast majority will not produce breakthrough ideas or technologies. But there are opportunities to learn from these failures as part of an ongoing process of applied discovery.

## Technology neutrality:

As discussed above, CARPA should adopt DARPA's portfolio approach, partly as a hedge against failure and partly designed to catalyze as many different technological solutions to a challenge or problem as possible. Since the program managers will not initially know what, if any, technologies may solve for a particular challenge or problem, there is reason to provide seed funding to any technology that holds out even a small chance of making a difference.

Most of these projects will fail. Some will succeed. But even those that fail may ultimately have future applications. The key point is that a problem-solving mandate requires testing different ideas rather than narrowing the options based on incumbent firms or leading academic researchers. CARPA should be prepared to provide seed funding to so-called "wacky things."

One of the benefits of the portfolio model is that it mitigates against biases in favour of incumbent firms or leading researchers. It enables different types of projects to come forward with potential solutions to the underlying challenge or problem. While CARPA's priority must be catalyzing breakthrough ideas and technologies, it should be agnostic on who or where the breakthroughs ultimately come from.

**CARPA should be prepared to provide seed funding to so-called "wacky things."** While CARPA's priority must be catalyzing breakthrough ideas and technologies, it should be agnostic on who or where the breakthroughs ultimately come from.

CARPA must seek to replicate DARPA's so-called "end-to-end" support from early-stage idea generation through to commercialization. In practice, **CARPA should focus both on catalyzing breakthrough ideas and technologies and on bridging them across the entire innovation continuum**

## Transitioning promising ideas:

CARPA must seek to replicate DARPA's so-called "end-to-end" support from early-stage idea generation through to commercialization. In practice, CARPA should focus both on catalyzing breakthrough ideas and technologies and on bridging them across the entire innovation continuum. This will require building strong relationships with sources of private capital including the country's venture capital sector, as well as more conventional means of private financing and the private sector more broadly.

There is, in our view, sufficient absorptive capacity within Canada's private sector for the promising technologies that CARPA helps to develop. A rising carbon tax will ostensibly create further demand over time. The past success of the Alberta Oil Sands Technology and Research Authority (AOSTRA) in using public-private partnerships to catalyze and commercialize technologies to develop the province's oil and gas resources is evidence that this model can indeed find private-sector partners in Canada.[57] University of Calgary professor Sara Hastings-Simon has argued that Canada needs a modern AOSTRA with a "disruptive goal" to partner with industry to develop next-generation energy technologies.[58]

In addition to building bridges to private-sector partners, CARPA will need to work within the federal government itself. Its program managers will need to be able to work with regulatory agencies and public funding sources to help technologies, for which it provides seed funding, to move to the next stage of the innovation process. This will require a clear message from the prime minister and the government that CARPA-funded projects ought to receive priority consideration under other programs. This may need to become a standard part of a new business support program.

**One area in which the government can directly support promising technologies is public procurement. For the DARPA model to work in Canada, the federal and provincial governments must be prepared to use their procurement powers to support promising technologies.**

## Public procurement:

One area in which the government can directly support promising technologies is public procurement. Companies and academic researchers need to have a sense that there will be a market for their innovations and public procurement can help create market demand for new technologies.

For the DARPA model to work in Canada, the federal and provincial governments must be prepared to use their procurement powers to support promising technologies. DARPA for instance has various carve-outs – such as prize competitions – for U.S. companies. There is also of course the Department of Defense's massive procurement budget.

We recognize that Canadian governments do not have the same procurement capacity as the U.S. Department of Defense. But between the government's net-zero legislation and growing private-sector financing plans for clean technology, there may indeed be a sufficient pool of capital to help take CARPA-funded projects to the next stages of the innovation continuum. As mentioned above, the carbon tax will also create demand from government and the private sector for lower-emitting technologies and sources of energy.

In the next sub-section, we consider how the government might select certain problems to guide CARPA's work. One consideration is to think about where and if governments have sufficient procurement capacity (for instance, energy, health care and infrastructure) and where they could have sufficient scale to be able to help create market demand for promising technologies.

For this goal, the federal and provincial governments will need to dedicate a portion of their procurement budgets to helping promising technologies transition to their market-based application. Some steps have been made in this direction including the Innovation Solutions Program, which aims to procure promising technologies from SMEs. Although these developments are promising, there should be a greater commitment to use procurement as a tool of innovation policy as we have previously written.[59]

This means, in practice, enabling broad and flexible procurement authorities rather than the inflexible Treasury Board processes. Just as subjecting CARPA to the Treasury Board's administrative and reporting requirements would undermine the agency's effectiveness, forcing its most promising projects to follow its slow and dysfunctional procurement processes is a recipe for failure.

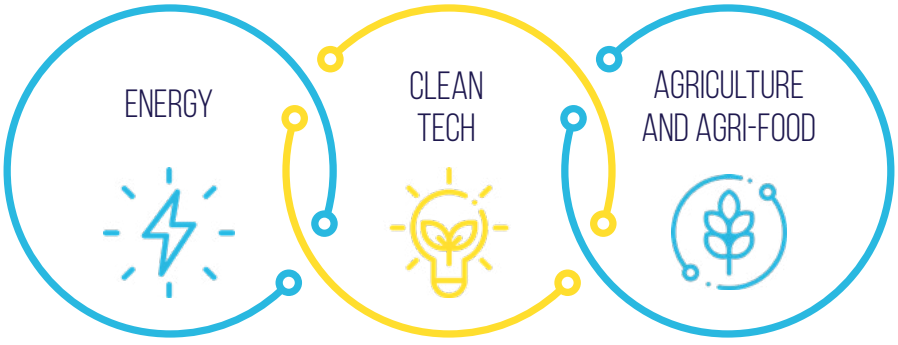
## Clear priorities:

For CARPA to be effective, especially in its early stages, it must be highly focused with limited sectoral priorities. In the United States, the advanced research projects agency model has been applied to various sectors: military and defence innovation, biomedical innovation, energy innovation and, most recently with the announcement of ARPA-H, health innovation. This is a sign that the U.S. government believes that DARPA can be replicated in other sectors with less public procurement capacity and fewer resources.

Two important government sponsored advisory councils, the Advisory Council on Economic Growth (chaired by Dominic Barton) and the Industry Strategy Council (chaired by Monique Leroux), have both made strong cases over the last few years for placing big policy bets on fast-growing sectors where Canada has a comparative advantage: energy and clean technology and agriculture and agri-food. These two sectors not only have a considerable private-sector absorption capacity for the kind of advanced research that CARPA might produce, but technology breakthroughs in these sectors will be key to fighting climate change and building Canada's presence in global markets. Infrastructure is also a sector in Canada with significant technical expertise (advanced materials for example) and private-sector capacity.

The upshot is that CARPA should not start as a general-purpose technology organization. It should instead prioritize a limited number of challenges and priorities – such as the target of net-zero emissions – that rest on a set of pre-existing comparative advantages for the country.

**For CARPA to be effective, especially in its early stages, it must be highly focused with limited sectoral priorities. Such sectors might include areas where Canada has comparative advantage, like:**



In particular, the new agency's goal should be to **support high-risk, high-reward projects – the wild card technologies –** and leave the safe bets to other federal departments, agencies and programs. CARPA must be in the business of radical innovation.

# CONCLUSION

Canadians' collective wealth and prosperity depend on new ideas and new technologies. That is ultimately how we will boost productivity and living standards over the long run. That is our path to progress.

The problem, though, is that the country's track record on invention and innovation – particularly radical innovation – has been underwhelming for years. A combination of market failures and academic gatekeeping prevents a steady supply of breakthrough ideas and technologies in the innovation pipeline for eventual commercialization, scale and, ultimately, global markets.

The federal government's commitment to establish CARPA is a major step to address these long-standing challenges of too few breakthroughs and too little commercialization. CARPA represents a different type of innovation agency that must be disciplined in its mission to catalyze radical innovation rather than incremental innovation.

In particular, the new agency's goal should be to support high-risk, high-reward projects – the wild card technologies – and leave the safe bets to other federal departments, agencies and programs. CARPA must be in the business of radical innovation.

This paper has set out the design, governance, operational and programmatic features that federal policymakers will need to account for in their development of the new agency. Our analysis and recommendations aim to help the government institutionalize a high-risk, high-reward capacity in Canada's innovation ecosystem. Just as importantly, though, we have also put forward how CARPA can help bridge the breakthrough ideas and technologies that it catalyzes across the entire innovation continuum.

CARPA will ultimately be judged on these two separate yet related goals: breakthroughs and bridges. This paper has set out a blueprint to make progress on both fronts.

# ACKNOWLEDGEMENTS

PPF would like to thank the **Brookfield Institute for Innovation + Entrepreneurship** for its collaboration on the **Canada's Moonshot** project. We are grateful for substantive discussions with **Sarah Doyle**, Brookfield's former Director of Policy and Research, as well as Research Lead Dr. **Thomas Goldsmith** and former research leads **Creig Lamb** and **Preet Mondair**.

We are particularly grateful for the continued support of our partners, the **Business Council of Canada (BCC)**, the **Community Economic Development and Employability Corporation (CEDEC)**, **Johnson & Johnson, MDA** and **Scotiabank**.

PPF would also like to thank **Canada's Moonshot Expert Advisory Council** for its valuable insights into moonshot-oriented innovation policies: **Ilse Treurnicht**, **Bill Tam**, **Armughan Ahmad**, **Michel Bergeron**, **Clement Bourgogne**, **Judy Fairburn**, **Carol Anne Hilton**, **Pari Johnston**, **Zayna Khayat**, **Adam Legge**, **Kendra MacDonald**, **Derrick Rossi**, **Nadia Theodore** and **Sara Wolfe**.

# ENDNOTES

1 The word "**productivity**" was added to the Oxford English Dictionary in 1950. See **Phillip Cross**, "We need leaders to focus on economic growth," Financial Post, August 27, 2021. https://financialpost.com/opinion/philip-cross-we-need-leaders-to-focus-on-economic-growth?utm_medium=Social&utm_source=Twitter#Echobox=1630070405

2 Inaugural address of **U.S. President Harry S. Truman**, January 20, 1949. https://avalon.law.yale.edu/20th_century/truman.asp

3 **Sean Speer** and **Robert Asselin**, "Want to combat populism? Innovation and positive-sum politics are key," The Hub, December 10, 2021. https://thehub.ca/2021-12-10/want-to-combat-populism-innovation-and-positive-sum-politics-are-key/

4 **Dan Munro**, An Inclusive Innovation Monitor for Canada Discussion Paper, Brookfield Institute for Innovation + Entrepreneurship and Innovation Policy Lab (Munk School), March 2020. https://brookfieldinstitute.ca/wp-content/uploads/An-Inclusive-Innovation-Monitor-for-Canada-ONLINE.pdf

5 **Mark Muro**, **Joseph Parilla**, and **Gregory M. Spencer**, Canada's Advanced Industries, Brookings Institution and Martin Prosperity Institute, 2018. https://www.brookings.edu/wp-content/uploads/2018/06/Canadas-Advanced-Industries_18-06-05_FINAL2.pdf

6 **Peter Nicholson**, "Canada's low-innovation equilibrium: Why it has been sustained and how it will be disrupted," Canadian Public Policy, Vol. 42, Issue S1, November 2016. https://www.utpjournals.press/doi/full/10.3138/cpp.2015-019

7 **Robert Asselin**, **Sean Speer**, and **Royce Mendes**, New North Star II: A Challenge-Driven Industrial Strategy, Public Policy Forum, April 2020. https://ppforum.ca/wp-content/uploads/2020/04/NewNorthStarII-PPF-APRIL2020-EN.pdf

8 **Michael Lind**, "The return of geoeconomics," The National Interest, October 13, 2019. https://nationalinterest.org/feature/return-geoeconomics-87826

9 **Robert Atkinson**, "Why the United States needs a national advanced industry and technology agency," ITIF, June 17, 2021. https://itif.org/publications/2021/06/17/why-united-states-needs-national-advanced-industry-and-technology-agency

10 White House, **A letter to Dr. Eric S. Lander**, the President's science advisor and nominee as the Director of the Office of Science and Technology Policy, January 20, 2021. https://www.whitehouse.gov/briefing-room/statements-releases/2021/01/20/a-letter-to-dr-eric-s-lander-the-presidents-science-advisor-and-nominee-as-director-of-the-office-of-science-and-technology-policy/

11 National Science Foundation, **A letter to Vannevar Bush**, the Director of the Office of Scientific Research and Development, November 17, 1944. https://www.nsf.gov/about/history/nsf50/vbush1945_roosevelt_letter.jsp

12 See the results of the **2020 Global Innovation Index**. https://www.globalinnovationindex.org/analysis-indicator

13 **Minister of Innovation, Science and Industry Mandate Letter**. December 16, 2021. https://pm.gc.ca/en/mandate-letters/2021/12/16/minister-innovation-science-and-industry-mandate-letter

14 As further evidence to the wide interest in a CARPA, both Liberal and Conservative parties included promises of a CARPA in their respective 2021 federal election platforms.

15 **Peter Thiel** (with Blake Masters), Zero to One: Notes on Start-ups, or how to Build the Future, (New York: Crown Book, 2014).

# ENDNOTES


16 **Robert Asselin**, "Canada needs a R&D powerhouse modelled on the successes of DARPA,"C.D. Howe Institute, March 22, 2021. https://www.cdhowe.org/intelligence-memos/robert-asselin-%E2%80%93-canada-needs-rd-powerhouse-modelled-successes-darpa

17 Author interview, September 3, 2021.

18 Innovation and Business Strategy: Why Canada Falls Short: Report of the Expert Panel on Business Innovation, Canadian Council of Academies, 2009. https://cca-reports.ca/wp-content/uploads/2018/10/2009-06-11-innovation-report-1.pdf

19 Author unknown, Breakthrough Innovation and Growth, PWC, September 2013. https://www.pwc.lu/en/advisory/docs/pwc-breakthrough-innovation-and-growth.pdf

20 **Sean Speer**, "The decades long resistance to mRNA vaccines shows the need for reform," The Hub, July 6, 2021. https://thehub.ca/2021-07-06/sean-speer-against-peer-reviewers/

21 **Marcia Malory**, "Peer review could reject breakthrough manuscripts, study shows," Phys.org, December 23, 2014. https://phys.org/news/2014-12-peer-breakthrough-manuscripts.html

22 **Jason Dion** et al., Canada's Net Zero Future: Finding our way in the Global Transition, Canadian Institute for Climate Choices, February 2021. https://climatechoices.ca/wp-content/uploads/2021/02/Canadas-Net-Zero-Future_FINAL-2.pdf

23 **Patrick Collison** and **Tyler Cowen**, "We need a new science of progress," The Atlantic, July 30, 2019. https://www.theatlantic.com/science/archive/2019/07/we-need-new-science-progress/594946/

24 **Conversations with Tyler:** Noubar Afeyan on the Permission to Leap, January 13, 2021. https://conversationswithtyler.com/episodes/noubar-afeyan/

25 Forthcoming Hub Dialogue with **Robert Atkinson**, The Hub, date unknown.

26 **Mark P. Mills**, "Making technological miracles: The case for curiosity-driven science – and a new way to think about R&D," The New Atlantis, Spring 2017. https://www.thenewatlantis.com/publications/making-technological-miracles

27 Government of the United Kingdom, Advanced Research and Invention Agency (ARIA): Policy Statement, March 19, 2021. https://www.gov.uk/government/publications/advanced-research-and-invention-agency-aria-statement-of-policy-intent/advanced-research-and-invention-agency-aria-policy-statement

28 **Carolyn Fu**, **Lars Frolund** and **Fiona Murray**, Enabling Mission Impact: Funding Strategies for High-Risk High-Reward Innovation, Policy Working Paper, MIT Innovation Initiative, February 2021. https://innovation.mit.edu/assets/Enabling-Mission-Impact-FINAL.pdf

29 **Gary Clyde Hufbauer** and **Euijin Jung**, Scoring 50 Years of US Industrial Policy, 1970–2020, Peterson Institute for International Economics, November 2021. https://www.piie.com/sites/default/files/documents/piieb21-5.pdf

30 **Alissa Mariello**, "The five stages of successful innovation," MIT Sloan Management Review, April 1, 2007. https://sloanreview.mit.edu/article/the-five-stages-of-successful-innovation/

31 Forthcoming Hub Dialogue with **Robert Atkinson**, The Hub, date unknown.

# ENDNOTES


32 The Hub staff, "Journalist **Brendan Borrell** spotlights the unsung heroes behind the COVID-19 vaccines," The Hub, November 17, 2021. https://thehub.ca/2021-11-17/journalist-brendan-borrell-spotlights-unsung-heroes-behind-the-coivd-19-vaccines/

33 **Mariana Mazzucato**, Mission Economy: A Moonshot Guide to Changing Capitalism, 2020, p. 121.

34 **Ben Reinhardt**, "Why does DARPA work?" Benjaminreinhardt.com, June 2020. https://benjaminreinhardt.com/wddw

35 DARPA, Creating Technology Breakthroughs and New Capabilities for National Security, 2019. https://www.darpa.mil/attachments/DARPA2015.pdf

36 "Innovation at DARPA", DARPA, July 2016, p.6. https://www.darpa.mil/attachments/DARPA_Innovation_2016.pdf

37 **Robert Asselin**, "Canada needs a R&D powerhouse modelled on the successes of DARPA," C.D. Howe Institute, March 22, 2021. https://www.cdhowe.org/intelligence-memos/robert-asselin-%E2%80%93-canada-needs-rd-powerhouse-modelled-successes-darpa

38 **Ben Reinhardt**, "Why does DARPA work?" Benjaminreinhardt.com, June 2020. June 2020. https://benjaminreinhardt.com/wddw

39 **Gary Clyde Hufbauer** and **Euijin Jung**, Scoring 50 Years of US Industrial Policy, 1970–2020, Peterson Institute for International Economics, November 2021. https://www.piie.com/sites/default/files/documents/piieb21-5.pdf

40 **Carolyn Fu**, **Lars Frolund** and **Fiona Murray**, Enabling Mission Impact: Funding Strategies for High-Risk High-Reward Innovation, Policy Working Paper, MIT Innovation Initiative, February 2021. https://innovation.mit.edu/assets/Enabling-Mission-Impact-FINAL.pdf

41 **Ben Reinhardt**, "Why does DARPA work?" Benjaminreinhardt.com, June 2020. https://benjaminreinhardt.com/wddw

42 **Regina E. Dugan** and **Kaigham J. Gabriel**, "'Special forces' innovation: How DARPA attacks problems," Harvard Business Review, October 2013. https://hbr.org/2013/10/special-forces-innovation-how-darpa-attacks-problems

43 Congressional Research Service, Defense Advanced Research Projects Agency: Overview and Issues for Congress, August 19, 2021. https://sgp.fas.org/crs/natsec/R45088.pdf

44 "DARPA 'lookalikes' must ground their dreams in reality," Nature, March 11, 2020. https://www.nature.com/articles/d41586-020-00690-5

45 **Ben Reinhardt**, "Why does DARPA work?" Benjaminreinhardt.com, June 2020. https://benjaminreinhardt.com/wddw

46 **Carolyn Fu**, **Lars Frolund** and **Fiona Murray**, Enabling Mission Impact: Funding Strategies for High-Risk High-Reward Innovation, Policy Working Paper, MIT Innovation Initiative, February 2021. https://innovation.mit.edu/assets/Enabling-Mission-Impact-FINAL.pdf

47 "DARPA 'lookalikes' must ground their dreams in reality," Nature, March 11, 2020. https://www.nature.com/articles/d41586-020-00690-5

48 Cited in Congressional Research Service, Defense Advanced Research Projects Agency: Overview and Issues for Congress, August 19, 2021. https://sgp.fas.org/crs/natsec/R45088.pdf

49 **Robert Asselin** and **Sean Speer**, A New North Star: Canadian Competitiveness in the Age of Intangibles, Public Policy Forum, April 2019. https://ca.rbcwealthmanagement.com/documents/1478023/1478039/New+North+Star-EN.pd.pdf/47c3d0cf-95ce-4b1a-9ae0-04f8a2817c7d

50 See the results of the 2020 Global Innovation Index. https://www.globalinnovationindex.org/analysis-indicator

51 See OECD data on gross domestic spending on R&D. https://data.oecd.org/rd/gross-domestic-spending-on-r-d.htm

# ENDNOTES


52 OECD, Table 24 – Business expenditure on R&D (BERD) as a percentage of GDP, in Main Science and Technology Indicators, Volume 19, Issue 2, OECD Publishing, 2020. https://doi.org/10.1787/83b74c19-en/

53 **David Küpper**, **Markus Lorenz**, **Andreas Maurer**, and **Kim Wagner**, "Managing the 'unmanageable': Radical innovation," Boston Consulting Group, September 25, 2013. https://www.bcg.com/publications/2013/innovation-lean-manufacturing-managing-unmanageable-radical-innovation

54 "The Heilmeier Catechism," DARPA, date unknown. https://www.darpa.mil/work-with-us/heilmeier-catechism

55 "DARPA 'lookalikes' must ground their dreams in reality," Nature, March 11, 2020. https://www.nature.com/articles/d41586-020-00690-5

56 **Kyle Siler**, **Kirby Lee**, and **Lisa Bero**, "Measuring the effectiveness of scientific gatekeeping," Proceedings of the National Academy of Sciences of the United States of America, January 2015. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4299220/

57 **Sean Speer**, **Kim Henderson** and **Katherine Feenan**, Climatetiveness: What it Takes to for Canada to Thrive in a Net Zero Exporting World, Public Policy Forum, October 2021. https://ppforum.ca/wp-content/uploads/2021/10/Climatetiveness-PPF-Oct2021-EN.pdf

58 **Sarah Hastings-Simon**, Industrial Policy in Alberta: Lessons from AOSTRA and the Oil Sands, University of Calgary School of Public Policy, November 2019. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3480703

59 **Robert Asselin** and **Sean Speer**, A New North Star: Canadian Competitiveness in the Age of Intangibles, Public Policy Forum, April 2019. https://ca.rbcwealthmanagement.com/documents/1478023/1478039/New+North+Star-EN.pd.pdf/47c3d0cf-95ce-4b1a-9ae0-04f8a2817c7d.


PUBLIC
POLICY
FORUM