Centre for International
Governance Innovation

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Canada Needs to Think about Extended Reality and AI

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About the Authors

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Susan directs the Digital Trade and Data Governance Hub at GWU. The Hub was founded in 2019 and educates policy makers, the press and the public about data governance and data-driven change through conferences, webinars, study groups, primers and scholarly papers. It is the only organization in the world that maps the governance of public, proprietary and personal data at the domestic and international levels. The Hub's research has been funded by foundations such as Ford and Minderoo.

Susan directs projects on defining AI protectionism; how governments may incentivize more accurate, complete and representative data sets; and how open-source AI builds trust. She regularly writes op-eds for *Barron's* and has been a commentor on economics for NPR's *Marketplace*, *All Things Considered* and *Morning Edition*, and for NBC, CNN, the BBC and PBS.

Previously, Susan was a guest scholar in economics at the Brookings Institution (1995–1999) and a research fellow at the World Trade Institute (2008–2012). Susan was also the Carvalho Fellow at the Government Accountability Project and held the Minerva Chair at the National War College. She has served on the business and human rights advisory board at Amnesty International and the advisory board of Human Rights under Pressure, a joint German and Israeli initiative on human rights.

In her spare time, Susan enjoys triathlons and ballet.

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Acronyms and Abbreviations

3D	three-dimensional
5G	fifth-generation
AI	artificial intelligence
AR	augmented reality
CSA	Canadian Space Agency
FDA	Food and Drug Administration
G7	Group of Seven
GAO	Government Accountability Office
IDEaS	Innovation for Defence Excellence and Security
IEEE	Institute for Electrical and Electronics Engineers
IoT	Internet of Things
MR	mixed reality
OECD	Organisation for Economic Co-operation and Development
PTSD	post-traumatic stress disorder
VIFF	Vancouver International Film Festival
VR	virtual reality
XR	extended reality

Executive Summary

Canada was the first nation to adopt an AI strategy, but Canadian officials can learn from what other nations are doing to advance a different key data-driven technology. In 2023, the XR Association funded the authors' research into extended reality (XR) competitiveness. Although Canada has many companies working in XR, it is not among the countries seen as highly competitive in XR. The authors sought to figure out why. In this paper, the authors delineate several reasons why Canadian officials should pay closer attention to the relationship between XR and AI. The authors argue:

- XR is already important to the Canadian and global economy.
- Many experts and world leaders believe that the combination of XR and AI will underpin the next iteration of the internet.
- A variant of XR, digital twins (digital models of people and/or objects), can help individuals and communities anticipate and model mitigating strategies for addressing complex problems (XR has a public-good nature).
- Other nations are investing heavily in XR components, infrastructure and research to gain a competitive edge. South Korea and China have adopted strategic plans that view AI, XR and the cloud as part of an evolving data-driven tech ecosystem.
- Some Canadians want the Government of Canada to pay greater attention and direct more funds toward digital twins.

This paper proceeds as follows. First, the authors define and describe immersive technologies, their components, infrastructural elements and underlying technologies.

Next, the authors assess the increasingly important relationship between XR and AI and why Canadian officials should pay attention to it. They then discuss why Canadian officials should focus more funding and attention on immersive technology and the convergence of XR with AI. Then the authors explain how Canada has thus far supported variants of XR and propose three recommendations. First, Canada should develop an XR strategy; second, Canada should develop plans and funding to nurture digital twins, a type of mixed reality (MR), which have enormous potential to enhance human welfare.

Introduction

Technology and digital ministers from the Group of Seven (G7) (Canada, the European Union, France, Germany, Italy, Japan and the United States) compete[1] as well as cooperate on data-driven technologies. These technological and digital officials have spent much of their recent meetings focusing on how to nurture and govern AI.[2] However, at their most recent meeting in May 2023, they discussed another emerging data-driven technology, stating, "We recognize the potential of immersive technologies, and virtual worlds, such as metaverses to provide innovative opportunities…as well as to promote sustainability" (G7 Leaders 2023, 28). In this paper, the authors argue that Canada should move beyond these words and direct attention and investment toward immersive technology (hereafter XR) in addition to AI for one simple reason: the two technologies are increasingly important and intertwined.

Immersive technologies use computer-generated virtual environments to enhance and extend human capabilities and experiences, while AI enhances the power of humans to analyze large pools of data to facilitate new discovery or broader understanding (Reiners et al. 2021). XR and AI are two of several new data-driven technologies, which include cloud computing, the Internet of Things (IoT), quantum computing and robotics, among others.[3] These technologies evolve separately and in tandem as part of a constantly changing data-driven (or digital) ecosystem

1 Co-author Susan Ariel Aaronson's research for a related project on XR competitiveness was funded by the XR Association in January 2023.

2 Aaronson reviewed all the documents, and the discussions have focused on digital divides, data flows, data governance, digitalization, cybersecurity, the cloud and AI.

3 See https://web-archive.oecd.org/2019-12-06/232540-data-driven-innovation.htm.

(Ciuriak 2019, 2022; Organisation for Economic Co-operation and Development [OECD] 2022).[4]

Canada has devoted a lot of attention to AI over the past decade. It was the first nation in the world to publish a national AI strategy.[5] The Canadian government also understood early on the importance of trust to the digital economy, and put forward a Digital Charter, designed "to ensure that privacy is protected, data-driven innovation is human-centred, and Canadian organizations can lead the world in innovations that fully embrace the benefits of the digital economy."[6] Some analysts have asserted that, over time, the strategy has resulted in economic and social benefits for Canadians (Laramée 2022).[7] However, other analysts say that the country has not effectively leveraged academic expertise to commercialize AI products and services, and hence has been unable to fuel long-term growth from AI (Silcoff and O'Kane 2023; Attard-Frost 2022).

Canada's focus on AI is understandable for several reasons. First, Canadian researchers developed foundational advances in deep-learning research, and Canada possesses a rich AI talent base due to its excellent research universities and flexible immigration policies (Gupta 2021; Deloitte (2023a, 4).[8] Second, scholars and policy makers now largely agree that certain forms and applications of AI can be considered general-purpose technologies. General-purpose technologies have many uses and effects upon society and the economy (Hötte et al. 2022; Crafts 2021; Madiega 2023). Policy makers want to encourage the diffusion of general-purpose technologies because these innovations are likely to increase productivity and human welfare (Schnitzer, Watzinger and Nadler 2021). Third, as the Canadian government notes, "Artificial intelligence (AI) systems are poised to have a significant impact on the lives of Canadians and the operations of Canadian businesses."[9]

Moreover, as the OECD notes, "as a general-purpose technology, AI enables and supports other emerging technologies," such as virtual and augmented reality (OECD 2022, 7). Hence, in this paper, the authors argue that Canadian policy makers should face reality. The authors provide several reasons why Canadian officials should think more broadly about how these two data-driven technologies are evolving and how best to support them:

- XR is already important to the Canadian and global economy.
- Many experts and world leaders believe XR (co-evolving with AI) may underpin the next iteration of the internet.
- XR can help individuals and communities anticipate and model mitigating strategies to complex problems (put differently, XR has a public-good nature).
- The European Union, the United States, South Korea, the United Kingdom and China are actively investing in XR components, infrastructure and research in the hopes of achieving competitive advantage in XR or XR and AI. Moreover, South Korea and China have developed strategies that present a vision of both technologies as part of an evolving data-driven technological ecosystem.
- Some Canadians want the government to direct more attention and funds toward a key XR application: digital twins (digital models of people and/or objects) (GAO 2023).

This paper proceeds as follows. First, the authors define and describe what they mean by immersive technologies (also called spatial computing). Next, the authors describe the increasingly important symbiosis between XR and AI. They then discuss why Canadian officials should direct more funding and attention toward immersive technology and the convergence of XR with AI. The authors then discuss how Canada has thus far

4 According to the OECD, "data-driven innovation forms a key pillar in 21st century sources of growth. The confluence of several trends, including the increasing migration of socio-economic activities to the Internet and the decline in the cost of data collection, storage and processing, are leading to the generation and use of huge volumes of data – commonly referred to as 'big data.' These large data sets are becoming a core asset in the economy, fostering new industries, processes and products and creating significant competitive advantages" (ibid.).

5 See https://cifar.ca/ai/.

6 See https://ised-isde.canada.ca/site/innovation-better-canada/en/canadas-digital-charter-trust-digital-world.

7 Deloitte found that Canada ranked first in the five-year average year-over-year growth rate in AI talent concentration compared to other G7 nations (Deloitte 2023a, 9), and Canadian AI researchers produced more AI publications per capita in 2022 than any other G7 nation (ibid., 10). In addition, see https://aibusiness.com/verticals/canada-s-code-a-global-leader-in-artificial-intelligence.

8 See https://ised-isde.canada.ca/site/innovation-better-canada/en/artificial-intelligence-and-data-act-aida-companion-document.

9 Ibid.

Box 1: The Three Types of Immersive Technologies and Their Uses

VR: Uses computers and head-mounted devices to replace or occlude a user's physical environment with a virtual one. VR is widely used in gaming, for example, in the online game Horizon Worlds.

AR: Uses computer graphics and visualization technology to layer digital content onto a user's view of their physical space. AR is widely used by retailers to help their customers try on jeans, shoes or makeup online.

MR: Blends AR and VR, allowing users to experience simulated content within their physical environment and to manipulate and interact with virtual elements in real time. Pilots, surgeons and welders, for example, use MR to practise their skills. Digital twins rely on a type of MR when they are three-dimensional (3D).

Source: GAO (2022).

supported variants of XR. Finally, they propose two recommendations — that Canada should, one, develop an XR/XR AI strategy and, two, develop plans and funding to nurture digital twins, a type of MR, which have significant potential to both enhance human welfare and spur economic growth.

Defining Immersive Technologies

The GAO defines *immersive technologies* as an umbrella term for technologies that enable integration of real and virtual worlds. Many today call this technology *spatial computing*. These technologies include augmented reality (AR), virtual reality (VR) and MR technologies, which provide different degrees of sensory immersion and interaction between the real world and digital content (GAO 2022) (see Box 1). Collectively, the types of immersive technologies are known as XR.

XR technologies are already widely used by many sectors of the Canadian, American and global economies. Canadian companies are investing in XR for health care, education, retail, construction, gaming and entertainment, and more.[10] XR technologies are key elements of digital twins (described above) and virtual worlds (what some call the "metaverse").[11]

What Are the Building Blocks of XR and How Are They Used?

Mark Zuckerberg, CEO of Meta, once described "fitting a supercomputer into the frame of normal-looking glasses" as "the hardest technology challenge of our time" and "the key to bringing our physical and digital worlds together" (IntelligentHQ 2021). Whether that proves to be true or not, Zuckerberg is right to say that XR is extraordinarily complex.

Immersive technologies are built using hardware components such as headsets, displays, sensors and semiconductors. They are supported by infrastructural elements such as broadband, fifth-generation (5G) technology and cloud storage. In addition, they evolve in tandem with underlying technologies, which can include AI (used to enhance user experiences) and content creation tools such as digital assistants (used to enable users and developers to craft immersive environments) (GAO 2022). Although these categories often overlap,

10 The authors were not able to find government statistics on XR in Canada. See https://canadasdigitaltwin.ca/about-2-2; https://research.facebook.com/quantifying-the-potential-economic-impact-of-the-metaverse/.

11 The authors do not focus on the metaverse in this paper. See Greener (2023a); www.frontiersin.org/research-topics/30020/exploring-synergies-between-the-digital-twin-paradigm-and-extended-reality.

the authors segment them here to provide a clear conceptual framework for understanding XR.

Developers are constantly trying to improve these components, infrastructural elements and underlying technologies. Headsets provide a good example (Johnson 2023; Ray 2023). Designers have spent years trying to make these devices smaller, lighter and more like eyeglasses. They believe their investments in these technologies will pay off because when users feel comfortable in these headsets, they will spend more time in immersive spaces (Brodsky 2022).

Many of these components of XR are already widely used in other popular devices such as smartphones and fitness wearables. For example, smartphone users rely on cameras to capture their environment. These same types of cameras in an XR device help users avoid falling or bumping into objects in the real world. XR devices also use inward-facing sensors to capture eye gaze, allowing the device to display content within the user's view. Moreover, like many fitness devices, XR devices use internal measurement units to support positional tracking, which also helps to accurately display digital content relative to the physical world.[12]

The components, infrastructures and technologies that underpin XR — and their co-evolution — illuminate the power of innovation, but they also present policy and societal dilemmas. XR companies such as Meta and HTC Corporation utilize these components to monitor users to enhance their online experience. But in so doing, these companies are relying on tools that can undermine human rights such as privacy and freedom of expression, as well as affect human autonomy — the ability to make decisions for one's self. Many of the firms providing XR services rely on a business model where they collect user data in return for providing these services for free. These firms may then utilize this data to improve their services, train other types of AI, make predictions about their data subjects and/or manipulate users' behaviour. They might also sell this data (Zuboff 2019; Foini 2023). Users of these firms' platforms have little awareness or ability to control the use or reuse of their data (Heller 2020; Rosenberg 2022; Rosenblatt 2023). Hence, to govern XR effectively, policy makers must find ways to regulate not only the collection of user data, its sale and reuse, but also the business practices, the risks and the potential uses of XR. The authors do not address governance concerns in this paper but believe they are worth mentioning because good governance facilitates trust and predictability; it may also contribute to competitive advantage in XR (Aaronson et al. 2023).

The Convergence of AI and XR

As noted above, some forms of AI can be considered general-purpose technologies that can affect growth and productivity in multiple sectors of an economy. In parts of the economy, XR is one such form of technology, as noted by the OECD. Immersive technologies "rely on AI-enabled prediction and personalisation, interaction support, speech recognition and language translation and low-latency connectivity to augment the immersive experience" (OECD 2022, 7). AI is also hastening technology's trend toward greater immersion, blurring the boundaries between the physical and digital worlds (Spivack and Berrick 2023; Sturman 2023).

For example, the US Food and Drug Administration (FDA) has approved the marketing and use of some VR and MR devices that can be used for pain management, psychological treatment and other clinical services — including some normally delivered only in clinics and hospitals — to patients in their homes or other non-clinical settings. The FDA notes, "this could enable patients, including the socioeconomically vulnerable and underserved communities, the elderly or disabled, to access needed health care services when accessing them in person would otherwise be difficult, and this could make it easier, and more likely, for patients to complete treatment and monitoring regimens."[13] In one specific example, the FDA allowed BehaVR to market and deliver an immersive therapy called gameChange, which helps patients with agoraphobia to experience and feel more comfortable in situations such as riding a bus or going to the doctor through MR scenarios. Importantly, the therapy is underpinned by a form of AI that can be designed to change specific scenarios and graphics, tailored to user needs (Abbott 2023).

12 See https://fpf.org/wp-content/uploads/2022/10/XR-Infographic-Screen-reader-friendly-version.pdf.

13 See www.fda.gov/medical-devices/digital-health-center-excellence/augmented-reality-and-virtual-reality-medical-devices#list.

XR and AI are complementary technologies. XR does not require AI, but AI can improve the efficacy, utility and quality of XR experiences (Reiners et al. 2021; Qayyum et al. 2022). Meanwhile, XR can also improve AI. One study found that "the main advantages of using XR for training AI systems are…1) the entire training can occur in XR without collecting data from the physical world, 2) learning in XR can be fast, and 3) XR allows AI developers to simulate novel cases for training AI systems" (Reiners et al. 2021).

Another 2023 study examined how XR and AI researchers use the two technologies. The study found that XR researchers employ AI to mitigate problems with object tracking and to predict VR sickness (similar to motion sickness), while AI researchers use XR technologies to address issues such as understandability, by visualizing neural networks in VR, and explainability, by providing immersive interfaces to train machine-learning models for non-experts (Hirzle et al. 2023). The two fields have become so intertwined that since 2018, both the Association for Computing Machinery and the Institute for Electrical and Electronics Engineers (IEEE) have held conferences to specifically address research at the intersection of XR and AI.[14]

Why Canadians Should Pay Greater Attention to XR and the Ecosystem That Enables It

XR is important to the global economy and to Canada. XR is not new — government and corporate entities have used variants of immersive technologies since the 1980s for training, research, gaming and marketing purposes. Nonetheless, researchers struggle to get accurate and consistent statistics on XR prowess and market power among firms and nations. In contrast with AI, statistics on the XR market and Canadian firms' global market share are hard to find. However, researchers do know that the XR market is large and growing rapidly. For example, Statista found that the global XR market reached US$29.26 billion[15] in 2022, and is predicted to rise to more than US$100 billion by 2026 (Alsop 2023; Vantage Market Research 2023).[16] PwC estimates XR will add as much as half-a-trillion dollars to the US GDP, and US$1.5 trillion to the global economy, by 2030.[17]

No one country has the lead in the many components and technologies that comprise XR. But firms from many nations, including Belgium, China, Finland, Taiwan, the United Kingdom and the United States, are actively producing XR hardware, software and/or services (GlobeNewswire 2023; Volpicelli 2023). US-based companies currently accrue the most revenue and dominate the market for headsets (Ubrani, Mainelli and Shirer 2022).[18] US companies have been at the forefront of XR innovation since they pioneered the development of immersive games, introduced serious games aimed at sensitizing people to different cultures or problems, and created the first virtual world (Zielke et al. 2009; Terdiman 2006). In addition, US researchers created the first digital twins, and the United States was the first nation to use digital twins in manufacturing (what some call Industry 4.0, or the industrial metaverse) (Miskinis 2019).

Statista projects that revenue in the Canadian AR and VR market will increase from US$699 million in 2023 to US$840 million in 2024.[19] Deloitte anticipates that variants of the metaverse could contribute $45.3 billion–$85.5 billion to Canada's annual GDP by 2035 (Deloitte 2023b, 4).

One 2023 study asserted that Canada is known as a breeding ground for VR start-ups, with companies particularly active in the gaming and health-care sectors (Barreca 2023). A June 2023 survey asserted that Canada has 256 VR startups, including foreign companies.[20] However, thus far these companies, in contrast with those focused on AI, are not attracting significant venture capital investments (Deloitte 2023a, 13).

14 See https://ieeexplore.ieee.org/xpl/conhome/1830004/all-proceedings; https://dl.acm.org/conference/aivr.

15 All dollar figures in Canadian dollars unless otherwise noted.

16 See www.pwc.com/seeingisbelieving.

17 Ibid.

18 See www.statista.com/outlook/amo/ar-vr/worldwide?currency=USD.

19 See www.statista.com/outlook/amo/ar-vr/canada.

20 See https://tracxn.com/d/explore/virtual-reality-startups-in-canada/__t_gDGmB1oIohzdVwv62ett5oY13_4slv_7fQUH0J7N8/companies.

The authors could find no studies about the current impact of XR on the Canadian economy. However, in 2022, UK Research and Innovation, a non-departmental public body of the UK government that directs research and innovation funding, examined how organizations developing or applying immersive technologies create economic, social and cultural value in the United Kingdom. It found that some 2,106 immersive technology companies in the United Kingdom employed more than 16,000 workers and achieved 83 percent growth in the previous five years, despite the impact of the COVID-19 pandemic during much of that period (Immerse UK, Oxford Insights and Data City 2022, 10, 12).

XR may become the next computing platform. Business leaders, scholars and policy makers have long argued about what will replace the computer and the smartphone as the gateway to computing and the internet (Anderson and Rainie 2022). In recent years, some observers have focused on XR as that platform. In a 2016 research report, Goldman Sachs proclaimed that immersive technologies would be the next major computing platform (Bellini et al. 2016, 16). In 2021, Wu Zhongze, the former vice minister of the Chinese Ministry of Science and Technology, said that the metaverse "will definitely become a wind vane of global technology development in the next decade, and will also become a new high ground of competition in the digital economy of all countries" (Hui 2021).[21] In 2021, the IEEE predicted that immersive technologies will revolutionize many aspects of everyday life, "enhancing productivity through mobile and virtual workspaces; supporting new immersive media experiences; augmenting and enhancing intelligence and perception; enabling telepresent communication and collaboration; and fundamentally transposing digital artificial intelligence (AI) assistants and applications from heads-down smartphones toward heads-up spatial virtual experiences" (McGill 2021, 6). In 2022, Apple CEO Tim Cook said, "I think AR is a profound technology that will affect everything....Zoom out to the future and look back, you'll wonder how you led your life without augmented reality. Just like, today, we wonder: 'How did people like me grow up without the internet?'" (Huddleston 2022).

However, some observers do not see XR as the essential future platform — instead, they see some combination of generative AI and browsers or AI and XR. For example, Microsoft and OpenAI have joined forces to combine generative AI, which is built on historical data, with Microsoft's Edge browser, which can provide more up-to-date information (Mehdi 2023). In another example, Zuckerberg sees the combination of XR and AI as virtual worlds becoming the computing platform of the future (Yadav 2021). In recent months, Zuckerberg pointed out that AI and XR will evolve together (Nix 2023; Pymnts 2023; Ramteke 2023; Carter 2022). Satya Nadella, CEO of Microsoft, also sees XR and AI as key to the future (*Harvard Business Review* 2021). The IEEE has stated that AI and AR will evolve together to "dramatically augment human intelligence... [and] rapidly become essential."[22] Other observers have also predicted that these technologies will combine to create gateways to the future internet (Kolo 2023; Carter 2020; Stern 2023; Cheng et al. 2022). In 2023, Apple introduced what it called a new type of computer: the first MR headset, the Apple Vision Pro. Some consider it an MR headset working as an AI platform (Murayama 2023; Copper Digital 2023; Sheikhansari 2023; Hackl 2023).[23]

The authors cannot resolve this debate over whether generative AI or generative AI plus XR will serve as the next platform. However, they can see the direction of corporate investments. Technologists at several companies are trying to redesign their products and services to use generative AI to assist their customers and capture new clients (Mickle and Metz 2023; Roose 2023). Roblox, for example, is a gaming platform and virtual world that allows users (who operate through avatars) to develop and create games (Jatasra 2023; Greener 2023b). The company recently announced plans to implement generative AI assistants to help its users create code and objects that can be used to populate their worlds (Garrett 2023; Stein 2023). Meta, in partnership with Ray-Ban, recently released its second-generation smart glasses, which use an AI assistant and LLM to assist users with impaired vision interact with the world (Waisberg et al. 2023). Other companies are working to make "wearables" such as smart glasses, pens, rings and watches more useful to users through XR and AI (Fried and Heath 2023; Mickle and Metz 2023).

21 See www.cmca.org.cn/#/PoliciesDetails/180.

22 See https://digitalreality.ieee.org/publications/artificial-intelligence-and-augmented-reality.

23 See www.apple.com/apple-vision-pro/.

Box 2: What Is a Digital Twin?

Digital twins are virtual models designed to accurately reflect a physical object, system or process. The object being studied (for example, a wind turbine) is outfitted with various sensors that produce data about different aspects of its performance, such as energy output, temperature, weather conditions and more. This data is then relayed to a processing system and applied to the digital copy. Developers integrate the "living" computational models with data from a physical twin, such that any changes made to the physical twin can automatically be made in the digital twin. Digital twins can be used to remotely maintain or monitor the physical twin or predict how it will perform. Digital twin data can also be analyzed using AI and machine learning to test different scenarios or make predictions for the physical twin.

Sources: See www.ibm.com/topics/what-is-a-digital-twin; GAO (2023).

Digital Twins Can Help Anticipate and Mitigate Complex Problems

Technologies such as XR can be considered public goods when they are used in the public interest (Nelson 1989; Esanu and Uhlir 2003). Many countries, firms and communities are increasingly using one type of XR — digital twins (see Box 2) — to anticipate and examine problems and develop mitigating strategies.

Digital twins could provide significant benefits for human welfare. The United States' most common and costly natural disasters are floods. In the first four months of 2023 alone, the United States experienced damaging floods in California, Florida, Kentucky, Nevada and West Virginia.[24] During a flood, people can drown, their property can be damaged, crops can be destroyed, and infrastructure and economic activities may be disrupted. Flood risk and its mitigation are hard for many people to visualize and understand. But by creating a digital twin of flood scenarios, officials can examine a virtual model and better assess potential effects of both the flood and relief interventions. Moreover, these officials may also enhance understanding, improve preparedness and increase resilience in the face of flooding events (George and Oliva 2019, 4).[25]

Digital twins can also assist with pandemic response. A hospital could use a virtual model of an emergency room to train staff on the optimal use of the space for response to emergencies, while maintaining the room's ability to support traditional patients.

Moreover, local government officials could use digital twins to team with medical personnel to evaluate potential pandemic mitigation strategies without endangering lives.

However, policy makers and governance have not yet caught up with the capabilities of digital twins, and industry and civil society groups are just beginning to develop standards and policy recommendations (GAO 2023).

Other Nations Are Developing Plans and Investing in XR

In an earlier report, the authors examined what five governments — China, the European Union, South Korea, the United Kingdom and the United

24 See https://floodlist.com/america/usa.

25 See www.chiefscientist.qld.gov.au/publications/understanding-floods/flood-consequences.

States — are doing to advance XR (Aaronson et al. 2023). The authors found significant activity.

National Strategies

Researchers have shown that when policy makers devise a technology strategy, such plans often inspire government and private sector investment (Aaronson 2022). In the authors' earlier competitiveness study, China, the European Union, South Korea and the United Kingdom have all developed national strategies for XR, digital twins and/or virtual worlds. Some governments have adopted strategies that recognize the evolving and complex ecosystem that enables XR, while others have focused specifically on digital twins.

Officials in China and South Korea have been the most active in introducing such strategies. Policy makers in these nations aim to enable domestic XR companies to flourish and compete globally; harmonize industry standards; diffuse technological adoption throughout the country; and ensure national technological leadership. These officials are ensuring that policy evolves as technologies, platforms and societal expectations change over time.

South Korea and the United Kingdom have made digital twins a central element of their plans for XR. In September 2021, the Korean ICT Strategy Committee issued a Digital Twin Activation Strategy (Park 2021). The government pledged to invest more than $230 million to support the production of 3D objects and make them widely available through an open online platform. In addition, the strategy included plans to introduce a digital twin-based simulations and warning system to help the government prevent disasters such as floods and industrial accidents (ibid.).

The United Kingdom first began to recognize the potential of digital twins in 2017, when the National Infrastructure Commission issued a report emphasizing that data troves are an essential component of the United Kingdom's infrastructure. The commission recommended that the government use digital twins to model the country's infrastructure to integrate and prioritize maintenance needs, optimize investments, clarify interdependencies, identify energy efficiencies and eventually acquire predictive capabilities (National Infrastructure Commission 2017, 61).

In response to the commission's report, the Department for Business, Energy & Industrial Strategy worked with the University of Cambridge to establish the National Digital Twin Programme at the Centre for Digital Built Britain[26] to coordinate and lead efforts to create a digital replica of the United Kingdom (University of Cambridge et al. 2020). In its 2021 Innovation Strategy, the UK government committed to public consultation on the "potential value of and options for a national capability in 'cyber-physical infrastructure'" (Department for Business, Energy & Industrial Strategy 2021, 104), which is defined as an ecosystem of advanced interconnected systems, including digital twins and smart robotic systems, that span the digital and physical worlds (Department for Business, Energy & Industrial Strategy 2022). British policy makers intend to use this system of cyber-physical infrastructure to solve complex problems, stimulate regional economic growth, and earn recognition as a science and innovation superpower (ibid.).

In March 2023, in a document responding to the consultation it held on the subject, the UK Department for Science, Innovation & Technology (2023a) presented a vision for an ecosystem of networked cyber-physical systems across the entire economy. To make this vision a reality, the department launched several funding competitions, including a competition awarding $340,000 for the development of a cyber-physical infrastructure ecosystem capability; an $853,000 initiative to establish a digital twin research hub focusing on decarbonization and enhanced integration of transport systems; and a $5.1-million fund to foster the growth of a digital twin research community.[27] In addition, the Alan Turing Institute, the United Kingdom's national institute for data science and AI, is currently establishing a hub to "[democratize] access to digital twin technology by providing open and reproducible computational and social tools."[28] The institute

26 See www.ukri.org/what-we-offer/browse-our-areas-of-investment-and-support/digital-twins-and-cyber-physical-infrastructure/.

27 See www.ukri.org/opportunity/leader-for-research-in-digital-twinning-for-decarbonising-transport/; www.ukri.org/opportunity/develop-a-uk-digital-twinning-research-community-with-a-networkplus/?utm_medium=email&utm_source=govdelivery.

28 See www.turing.ac.uk/research/harnessing-power-digital-twins/turing-research-and-innovation-cluster-digital-twins.

previously invested more than $44 million in digital twin research and innovation.[29]

The United States has not developed a strategy for XR, but Congress has designated XR, like AI, as a critical technology. A critical technology is essential or "critical" to both economic growth and US national security. The United States first designated variants of XR as critical technologies in 1995.[30] The US Department of Defense, the National Science Foundation and other research agencies have invested significant amounts of research and infrastructural funds in such critical technologies.

Investments in Research and Infrastructure

China, the European Union, South Korea, United Kingdom and United States and have invested and continue to invest taxpayer funds in XR research and infrastructure. According to EU statistics, as of 2020, EU research funds have supported more than 450 XR-related projects since the 1990s (European Commission 2020). More recently, EU policy makers allocated a total of $150 million for seven XR workstreams aimed at improving usability and accessibility, and fostering innovation, competitiveness and responsible governance of XR (European Commission 2022). The European Commission recently announced it would provide more than $14 billion in funding for critical technologies, including VR, as part of its Strategic Technologies for Europe Platform.[31] Meanwhile, the 2023–2024 Horizon Europe Work Programme includes three major funding streams, including $38 million for the development of "Next Generation eXtended Reality" (ibid., 388) and some $36 million for "eXtended Reality for Industry 5.0" (ibid., 390).

These same governments are investing in infrastructure that can safely move, store and process data. For example, the United Kingdom's Wireless Infrastructure Strategy aims to deliver 5G to all populated areas in the United Kingdom by 2030 (Department for Science, Innovation & Technology 2023b). The European Union's 5G Action Plan has been coordinating investment and deployment of 5G since 2016, and the 2023 budget for Digital Europe provided funding for common data spaces, cloud-to-edge infrastructure and AI testing.[32] Chinese companies as well as local and national government entities have invested heavily in 5G networks as part of recent widespread investment in so-called new infrastructure, a category that also includes other critical enabling elements such as AI and IoT data centres (Daye 2022; Wong 2020; China.org.cn 2020). Finally, the United States' National Strategy to Secure 5G details how the government will lead deployment of 5G (National Telecommunications and Information Administration 2021), and the Infrastructure Investment and Jobs Act (Pub L No 117-58) included US$87 billion for the expansion of high-speed internet. Many other key components of XR technology, such as semiconductors, are also included in industrial strategies, such as the Chips and Science Act in the United States[33] and the European Chips Act.[34] South Korea views 5G as a foundational technology essential for building a new industry of "convergence" products and services, a category that includes XR as well as smart cities and digital health care (Science and Technology Innovation Foundation Team 2021, 11; 4th 5G+ Strategy Committee 2021, 3, 4).

The authors found that among these case studies, South Korea has been the most proactive in nurturing XR. Policy makers there have developed several strategies, such as the Immersive Economy Development Strategy, which aimed to make the country a top player in the field and proposed XR-based solutions for disaster response and safety training (Ministry of Science and ICT 2020), and the Digital New Deal 2.0, which encouraged the development of convergence products and services that integrate XR with other technologies such as AI and 5G (Ministry of Science and ICT 2021). The Korean government has also created specialized

29 See www.turing.ac.uk/research/harnessing-power-digital-twins.

30 See the list of technologies at https://clintonwhitehouse3.archives.gov/WH/EOP/OSTP/CTIformatted/AppA/appa.html. XR elements appear several times in the "Information and Communications" category and under "Human Systems" in the "Living Systems" category. The list also includes many inputs into immersive technologies, such as AI and high-definition displays.

31 See https://commission.europa.eu/strategy-and-policy/eu-budget/strategic-technologies-europe-platform/target-investment-areas_en.

32 See https://digital-strategy.ec.europa.eu/en/activities/work-programmes-digital.

33 US, Bill HR 4346, *Chips and Science Act*, 117th Cong, 2022 (enacted), online: <www.congress.gov/bill/117th-congress/house-bill/4346/text>.

34 See https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-chips-act_en.

investment funds to support start-ups;[35] pledged to expand XR adoption in sectors such as defence, education and health care (Ministry of Science, ICT and Future Planning 2015); and supported content creators producing immersive cultural material (Ministry of Science and ICT 2022).

The UK government has also invested in XR through sectoral and economy-wide initiatives (Immerse UK, Oxford Insights and Data City 2022), and has provided support to XR companies through tax incentives, innovation grants and funding competitions. The United Kingdom has further fostered XR hubs throughout the country as part of its Creative Industries Clusters Programme.[36]

Canadians Want Canada to Do More to Nurture Digital Twins

The National Research Council Canada (2021) has encouraged Canada to recognize digital twins as an essential enabling component for science and technology. Moreover, academics in Canada propose that the country create a national, inclusive and multidisciplinary research consortium to devise a technical, cultural and ethical framework for building a digital twin of Canada.[37]

Canadian companies and governmental bodies already rely on digital twins for a wide range of purposes. The Vancouver International Airport uses a digital twin to optimize its operations and maintenance (Redins 2022). An association of Canadian architects, builders, construction companies and engineers is trying to create a digital twin of Canada, based on the notion that digital twin technology could improve and optimize the entire life cycle (design, construction, operation and management) of the built environment. In addition, they aim to "determine the plausibility of the concept, the level of effort required to see it realized, and to establish a national group that is posed to move forward in that realization."[38] In 2022, Sustainable Development Technology Canada partnered with Ecopia AI to create high-precision maps of the top 100 cities that will serve as the foundation for digital twins. Over time, these digital twins will allow the government to better understand the long-term sustainability of its cities (SmartCitiesWorld 2022). Capgemini, a global consulting company, found that more than 50 percent of Canadian companies see digital twins as useful tools for sustainability (Balsara 2022). In 2021, the National Research Council Canada issued a short report on digital twin technologies, outlining their potential. It noted that the global digital twin market was valued at US$3.1 billion in 2020 and projected to reach US$48.2 billion by 2026. The council asserted that the technology would have economic, environmental, social and defence spillovers. However, it also noted, "there is no standardized approach to digital twin modelling." It warned that policy makers will need to encourage standards and best practices (National Research Council Canada 2021, 2).

What Has Canada Done to Advance XR?

Canada has an innovative and internationally competitive XR sector, and policy makers are beginning to see XR as a tool to mitigate complex problems. In the 2021 update to the Investment Canada Act, in the Guidelines on the National Security Review of Investments, policy makers notably included "Neurotechnology and Human-Machine Integration" along with "Next Generation Computing and Digital Infrastructure" in a roster of Sensitive Technology Areas.[39]

The government already relies on XR for a range of tasks. Global Affairs Canada (2019), the government's diplomatic and consular relations department, uses VR to showcase Canada through

35 The funds include the "Digital Content Fund," "Content Venture Investment Fund," "Small Business Venture Investment" and "Overseas Expansion Support Investment" funds, and the "SME Venture Business Growth Support Fund."

36 See https://creativeindustriesclusters.com/clusters/xr-stories/.

37 See https://canadasdigitaltwin.ca/about-2-2/.

38 Ibid.

39 See https://ised-isde.canada.ca/site/investment-canada-act/en/investment-canada-act/guidelines/guidelines-national-security-review-investments.

360-degree videos at missions worldwide. The Canadian Space Agency (CSA) also promotes some XR projects. It provided $483,000 in funding to a Montreal-based company to develop and commercialize VR camera technology for space exploration (CSA 2021). The CSA also used VR in a science experiment called Vection to study how microgravity affects astronauts' perception of motion.[40] Lastly, the Parliament of Canada partnered with Carleton University to develop a virtual tour of the Senate and other parliamentary buildings (Shared Services Canada 2019, 7).

The Canadian government has also invested in XR projects for military use. For example, in 2013, the government invested $9.5 million in NGRAIN, a Vancouver-based software company, to develop the company's 3D AR platform (Marketwired 2013). Lockheed Martin uses this platform to maintain fighter jets, resulting in reduced maintenance time and errors. The Canadian Armed Forces are also investing directly in XR, primarily for training purposes, with contractors developing MR simulations. As of 2019, the military had more than 230 simulators across Canada. The military is also exploring VR for treating post-traumatic stress disorder (PTSD). The Department of National Defence funds some XR projects through the Innovation for Defence Excellence and Security (IDEaS) program, focusing on cognitive enhancement, navigation technology and PTSD research (Shared Services Canada 2019, 7).

Meanwhile, the Canadian government has funded the development of immersive content. In 2017, the government allocated $482,000 to create AR experiences that bring Canada's history and cultural heritage to life for city visitors (Public Services and Procurement Canada 2017). Subsequently, in 2019, the government extended its support by investing $350,000 in the Greater Vancouver International Film Festival (VIFF), with the goal of developing "VIFF Immersed: International Content Market." This market, comprising an XR display and conference, served as a platform connecting content creators with both local and international partners in the 2020 and 2021 VIFFs (Western Economic Diversification Canada 2019).[41]

In 2020, the Canada Media Fund, a public-private partnership dedicated to funding the development of original Canadian content, launched a joint program with Spcine, the media funding agency in São Paulo, Brazil. The funders hope to promote co-development of immersive media projects. The incentive package included $100,000, with each organization contributing an equal share (Canada Media Fund 2020). In 2023, the Canada Media Fund (2023) introduced a new incentive program — this time with two regional councils in France.

Conclusion

Although Canada has not ignored XR, Canadian officials need to "face reality" and do more to encourage XR. The Canadian government lacks a strategy and vision for XR and its place within the larger ecosystem of data-driven technologies. Specifically, Canadians have not focused on the growing import of the XR/AI relationship and the potential for these co-evolving technologies to become the next gateway to the internet.

XR is a particularly complex technology with many components, infrastructural elements and underlying technologies. The authors have shown that other nations have adopted strategies and invested significantly in XR research and infrastructure, and are developing the technologies that support and enable immersive experiences. In addition, some governments see XR and AI as complementary technologies, understanding that they will continue to evolve separately and in tandem. For these reasons, the authors make three recommendations.

Recommendations

Develop a strategy to nurture XR in Canada: Canadian government officials understand the importance of strategies to articulate a government's vision regarding a technology's contribution to the country's social and economic development. As noted earlier, Canada was the first nation in the world to enact a national AI strategy.[42] Canada has also established a national Advisory Council on Artificial Intelligence to build

40 See www.asc-csa.gc.ca/eng/sciences/vection.asp.

41 See https://creativebc.com/2021/02/viff-immersed-call-for-submissions/.

42 See https://cifar.ca/ai/.

upon Canada's strengths and global leadership in AI, identifying opportunities to create economic growth that benefits all Canadians and ensuring that AI advancements reflect Canadian values. The council has a public awareness working group and a commercialization working group.[43] The Canadian government has also drafted a strategy on critical public infrastructure, which never mentions XR or how the internet, and how individuals go online, might evolve.[44]

But technology is rapidly changing, and Canada's focus on AI may have led it to underinvest in other related data-driven technologies, such as XR, as well as in how AI and XR intersect. The Canadian government has already acknowledged the importance of XR.[45] The next step is to formalize this recognition in an official strategy.

Therefore, the government should call for, and Parliament should approve, legislation to establish a national advisory committee on the evolution of data-driven technologies, including AI and XR. The advisory committee should be tasked to develop a vision for government support of these technologies — including the components, the infrastructural elements and the underlying technologies. The committee should ensure that the vision includes clear goals, milestones and sectors for targeted investment. It should also focus on ways to multiply funding for XR research through public-private partnerships. The advisers should perform an analysis of the state of Canadian infrastructure, reporting on whether the nation's cloud, high-speed internet and semiconductor capacity are sufficient to sustain the continued evolution of XR. Finally, the advisory committee should examine whether current data and technology governance can evolve to meet the challenges of current platform business models and the scale and scope of data utilized by immersive platforms.

To inform this process, the advisory committee could look to efforts to draft similar strategies elsewhere. For example, in Finland, the government entity Business Finland released a draft Metaverse Strategy, which focused on immersive experiences, especially in the industrial, health-care and social interaction sectors. The Finnish strategy also emphasizes embedding values within the metaverse ecosystem.[46] Elsewhere in Europe, the European Commission's strategy on Web 4.0 and virtual worlds focuses on four key pillars: empowering people and reinforcing skills; supporting a European Web 4.0 industrial and business ecosystem; supporting societal progress and virtual public services; and shaping global standards for open and interoperable virtual worlds and Web 4.0 (European Commission 2023).

Focus on digital twins as a means of solving complex problems: Digital twins are an XR application that could significantly benefit the Canadian economy and human welfare. But their benefits are not widely understood. To build that understanding, Canada must fund applied and basic research in XR. Canada's defence ministry should join with Innovation, Science and Economic Development, and disaster relief organizations, including the Canadian Red Cross, to fund digital twin research and development.

Second, policy makers could combine IDEaS and the Strategic Innovation Fund to support a competition for digital twins to address major strategic and national problems.[47] Such competitions might be used to show the benefits (and potential governance challenges) of using digital twins (for example, to reduce health-care costs or to map the spread of wildfires).

But the Canadian government should begin by developing a strategy for digital twins. Policy makers could build on the work of the United Kingdom, which views digital twins as essential infrastructure for future economic growth and research, and of the South Korean government, which introduced a Digital Twin Activation Strategy (Aaronson et al. 2023).

Organize citizens' assemblies on the XR/AI relationship: The Department of Canadian Heritage could work with the Canadian people to develop a grassroots approach to the XR/AI nexus. For several

43 See https://ised-isde.canada.ca/site/advisory-council-artificial-intelligence/en.

44 See www.publicsafety.gc.ca/cnt/rsrcs/pblctns/srtg-crtcl-nfrstrctr/index-en.aspx.

45 See https://ised-isde.canada.ca/site/investment-canada-act/en/investment-canada-act/guidelines/guidelines-national-security-review-investments.

46 See www.digitalfinland.org/.

47 See www.canada.ca/en/department-national-defence/programs/defence-ideas.html; https://ised-isde.canada.ca/site/strategic-innovation-fund/en.

years, the Canadian Commission on Democratic Expression has organized citizens' assemblies to better understand, anticipate and respond to the effects of new digital technologies on public life and Canadian democracy.[48] Policy makers could ask the commission to further explore XR and XR/AI and their implications for democracy. Policy makers could learn from the European Citizens' Panel on Virtual Worlds, which informed the development of the EU strategy on Web 4.0 and virtual worlds.[49]

With these actions, Canada would be well-positioned to build on its AI achievements and nurture XR.

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48 See www.commissioncanada.ca/.

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