RESEARCH SERVICES FOR THE CANADIAN GEOSPATIAL DATA INFRASTRUCTURE (CGDI):

Trends in geospatial technologies and strategies relevant to the CGDI

Prepared for:

CANADA CENTRE FOR MAPPING AND EARTH OBSERVATION
NATURAL RESOURCES CANADA
OTTAWA, CANADA

Prepared by:

HATFIELD CONSULTANTS LLP
#200 - 850 HARBOURSIDE DRIVE
NORTH VANCOUVER, BC
CANADA V7P 0A3
TEL: 1.604.926.3261 • WWW.HATFIELDGROUP.COM

NOVEMBER 2024

NRCAN12496
VERSION 2.0

This document was prepared by Hatfield Consultants LLP (Hatfield) in their personal capacity. The opinions expressed in this article are the author's own and do not necessarily reflect the views and opinions of Natural Resources Canada.

Aussi disponible en français sous le titre : Services de recherche pour l'infrastructure canadienne de données géospatiales (ICDG) : tendances relatives aux technologies et aux stratégies géospatiales pertinentes pour l'ICDG

Cat. No. M104-22/2025E-PDF (Online) / ISBN 978-0-660-76473-3 2

TABLE OF CONTENTS

LIST OF TABLES ii
LIST OF FIGURES ii
LIST OF ACRONYMS ii

1.0 INTRODUCTION 1

2.0 METHODOLOGY 1
2.1 APPROACH 1

3.0 COMMENTARY ON GEOSPATIAL TRENDS 2
3.1 EVOLUTION OF SPATIAL DATA INFRASTRUCTURE 3
3.2 EVOLUTION OF NATIONAL MAPPING AGENCIES 6
3.3 EVOLUTION OF USER NEEDS 7

4.0 TRENDS IN GEOSPATIAL TECHNOLOGIES 8
4.1 INTEGRATION OF IOT WITH GEOSPATIAL TECHNOLOGY 8
4.2 ADVANCES IN REMOTE SENSING TECHNOLOGY 9
4.3 GEOSPATIAL BIG DATA AND CLOUD COMPUTING 11
4.4 AI AND MACHINE LEARNING IN GEOSPATIAL ANALYSIS 13
4.5 DIGITAL TWINS 14
4.6 INDIGENOUS DATA SOVEREIGNTY 15
4.7 IMPROVED CONNECTIVITY 16

5.0 EXTERNAL ISSUES: PESTEL 17
5.1 POLITICAL 18
5.2 ECONOMIC 20
5.3 SOCIAL 21
5.4 TECHNOLOGICAL 22
5.5 ENVIRONMENTAL 24
5.6 LEGAL 25
5.7 SUMMARY 25

6.0 EXPERIENCE IN OTHER COUNTRIES 26
6.1 UNITED KINGDOM 26
6.2 AUSTRALIA AND NEW ZEALAND 27
6.3 USA 28
6.4 EUROPE 30
6.5 INDIA 31
6.6 SINGAPORE 31
6.7 ARCTIC COUNTRIES 32

7.0 POTENTIAL AREAS OF ACTION FOR CGDI 33
7.1 GOVERNANCE AND INSTITUTIONS 34
7.2 POLICY AND LEGAL 35
7.3 FINANCIAL 36
7.4 DATA 37
7.5 INNOVATION 37
7.6 STANDARDS 38
7.7 PARTNERSHIPS 39
7.8 EDUCATION AND CAPACITY 40
7.9 COMMUNICATION AND AWARENESS 41
8.0 CONCLUSION 41
9.0 REFERENCES 42
10.0 ANNEX A – INTERNET SEARCH TERMS 48

LIST OF TABLES

Table 1 New and emerging conditions and their impacts on SDIs (Coetzee et al. 2021) 6
Table 2 Potential action areas for CGDI in relation to IGIF strategic pathways. 33

LIST OF FIGURES

Figure 1 Geospatial drivers and trends related to geospatial information management (UN-GGIM 2020). 4

LIST OF ACRONYMS

Acronym	Definition
AI	Artificial intelligence
ANZLIC	The Spatial Information Council [of Australia and New Zealand]
API	Application Programming Interface
ARD	Analysis ready data
AWS	Amazon Web Services
BC	British Columbia
C-DAS	Copernicus Data Access Service
CAP	Cooperative Agreements Program
CARE	Collective Benefit, Authority to Control, Responsibility, and Ethics

Acronym	Definition
CCMEO	Canada Centre for Mapping and Earth Observation
CCOG	Canadian Council on Geomatics
CEOS	Committee on Earth Observation Satellites
CGDI	Canadian Geospatial Data Infrastructure
CMR	Common Metadata Repository
CRCSI	Cooperative Research Centre for Spatial Information
CRIM	Computer Research Institute of Montreal
CRTC	Canadian Radio-television and Telecommunications Commission
CSA	Canadian Space Agency
DAACs	Distributed Active Archive Centers
DEA	Digital Earth Australia
DIAS	Data and Information Access Services
DTE	Digital Twin Earth
EO	Earth observation
EODMS	Earth Observation Data Management System
EOSDIS	Earth Observing System Data and Information System
ESA	European Space Agency
EU	European Union
EUROGI	European Umbrella Organisation for Geographic Information
FAIR	Findable, Accessible, Interoperable, and Reusable
FBP	Fire Behavior Prediction
FGDC	Federal Geographic Data Committee
FGP	Federal Geospatial Platform
FSDF	Foundation Spatial Data Framework
GDPR	General Data Protection Regulation
GIS	Geographic information system
GPS	Global positioning system
ICSM	Intergovernmental Committee on Surveying and Mapping
IPT	Innovation Platform Testbed
ISRO	Indian Space Research Organisation
IT	Information technology
IoT	Internet of things
ML	Machine learning
MPA	Maritime & Port Authority of Singapore
NASA	National Aeronautics and Space Administration
NGAC	National Geospatial Advisory Committee
NMA	National Mapping Agency
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council

Acronym	Definition
NRCan	Natural Resources Canada
NRSC	National Remote Sensing Centre
NSDI	National Spatial Data Infrastructure
OCAP	Ownership, control, access, and possession
OGC	Open Geospatial Consortium
OSDP	Open Science and Data Platform
PESTEL	Political, economic, social, technological, environmental, and legal
PIPEDA	Personal Information Protection and Electronic Documents Act
PaaS	Platform as a service
RCM	Radarsat Constellation Mission
RISAT	Radar Imaging Satellite
RSSSA	Remote Sensing Space Systems Act
SAR	Synthetic aperture radar
SDI	Spatial Data Infrastructure
SLA	Singapore land authority
SQL	Structured query language
STAC	SpatioTemporal Asset Catalog
UK	United Kingdom
UN	United Nations
UNA	User needs assessment
UN-GGIM	United Nations [Committee of Experts on] Global Geospatial Information Management
UNDRIP	United Nations Declaration on the Rights of Indigenous Peoples
UN-IGIF	United Nations Integrated Geospatial Information Framework
US	United States [of America]
USA	United States of America
USGS	United States Geological Survey
USMCA	United States-Mexico-Canada Agreement

ADVISORY STATEMENT

This environmental scan addresses relevant trends in geospatial technologies and strategies relevant to the Canadian Geospatial Data Infrastructure (CGDI). The objective is to review key literature to identify trends in geospatial technologies, identify emerging issues and opportunities for the CGDI, and future strategies for integrating geospatial technology trends into the CGDI.

The research was completed by Hatfield Consultants LLP (Hatfield), contracted to develop this report by Natural Resources Canada (NRCan). This work was informed by Hatfield's 30 years of activity providing geospatial services in Canada and internationally. The information presented was collected from publicly available records accessed between July date to October 2024. The geospatial landscape in Canada continues to evolve. As such, the research findings represent a moment in time and cannot represent a complete or up-to-date reflection of the full situation across Canada. Further, it does not encompass all public or private actions being taken by the Government of Canada in relation to the CGDI. For definitive, up to date information on any initiative or organization encompassed herein, please refer to original sources.

Editorial changes have been made by NRCan to the original version prepared by Hatfield for publication purposes.

1.0 INTRODUCTION

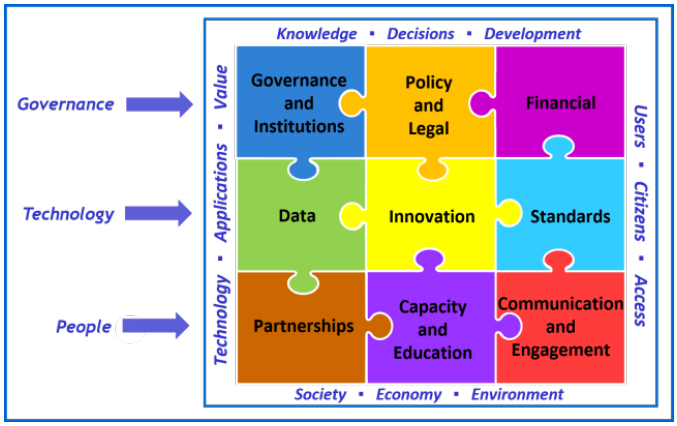
Canada's spatial data infrastructure, referred to as the Canadian Geospatial Data Infrastructure (CGDI), is the collection of geospatial data, standards, policies, applications, and governance that facilitate the access, use, and integration of spatial data (CCMEO 2024a). The process to establish the CGDI began in the late 1990s with the aim to help Canadians gain new perspectives into social, economic and environmental issues, by providing an online network of resources that improve the sharing, use, and integration of information tied to geographic locations in Canada. The CGDI is supported by GeoConnections, a national program led by the Canada Centre for Mapping and Earth Observation (CCMEO) as part of Natural Resources Canada (NRCan) that supports the integration and use of the CGDI (GeoConnections 2012).

This environmental scan addresses relevant trends in geospatial technologies and strategies relevant to the CGDI. The **objective** is to review key literature to identify trends in geospatial technologies, identify emerging issues and opportunities for the CGDI, and future strategies for integrating geospatial technology trends into the CGDI.

The environmental scan is conducted in the context of the United Nations (UN) Integrated Geospatial Information Framework (UN-IGIF), which is a strategic guide developed by the UN to assist countries in strengthening their national SDI. It provides a foundation for making sound decisions based on reliable, authoritative, interoperable, and maintained geospatial information.

The UN-IGIF consists of **nine strategic pathways**: governance, policy and legal, financial, data, innovation, standards, partnerships, capacity and education, and communication and engagement.

The UN-IGIF aims to improve the availability, accessibility, and application of geospatial information for sustainable development and for societal, economic, and environmental benefits.



2.0 METHODOLOGY

2.1 APPROACH

This document is one component of a larger stocktaking exercise led by NRCan's Canada Centre for Mapping and Earth Observation (CCMEO). The stock-take includes the following data collection methods: 1) individual/small group interviews with a sample of provincial/territorial and federal government organizations; 2) on-line geospatial data producer and user inventories (surveys) to collect more detailed information from interviewee organizations; 3) a third party desk study (desktop research); 4) in addition,

this third party environmental scan was undertaken (literature review) to provide an overview of trends in geospatial technologies and strategies relevant to the CGDI.[1]

To address the objective to identify trends in geospatial technologies, identify emerging issues and opportunities for the CGDI, and future strategies for integrating geospatial technology trends into the CGDI, Hatfield and CCMEO identified key research areas related to the UN-IGIF nine strategic pathways and tools, including a political, economic, social, technological, environmental, and legal (PESTEL) framework.

The focus of the scan is on trends, emerging issues, and future strategies, therefore the research focused on recent publications within the last five years; however, older publications are reviewed and referenced where they were considered to provided important foundational context relevant to the emerging issues and future strategy. For example, the 2005 Remote Sensing Space Systems Act (RSSSA) (Branch 2007a; Branch 2007b) remains relevant today given its impact on future strategies and opportunities for the CGDI.

Hatfield implemented the following methodology to generate this document:

1. **Identify information sources**: use internet search tools to identify institutional reports, research papers, industry reports, news articles, and other sources to identify relevant information. Key search terms are provided in Annex A. Use knowledge within the study team (sometimes based on un-published material and research experience) to identify relevant information.

2. **Review information sources**: review of information based on knowledge and expertise within the study team.

3. **Group discussion to develop report structure**: review information gathered and use study team knowledge and expertise to structure the trends for reporting. Consider the inter-relationships of trends when developing the structure.

4. **Report findings**: summarize the findings in the environmental scan document.

5. **Review**: review of the environmental scan by the study team and with NRCan to identify any gaps and to update information.

3.0 COMMENTARY ON GEOSPATIAL TRENDS

The importance and rapid development of the geospatial sector is reflected by the analysis and interest of international, government, and industry organizations. Most notably the UN Committee of Experts on Global Geospatial Information Management (UN-GGIM) and stakeholders have released several publications related to emerging technologies and the UN-IGIF. Industry literature on geospatial trends is also important, given the growth in private sector involvement in the geospatial sector. In addition, several publications related to the CGDI produced for NRCan are relevant to the analysis of trends in geospatial technologies, particularly observations from a user needs assessment (UNA) related to the CGDI and the Arctic SDI.

[1] In this document, SDI and CGDI are used interchangeably.

3.1 Evolution of Spatial Data Infrastructure

The most recent meeting of the UN-GGIM in August 2024 recognized the constantly evolving nature of the future geospatial information ecosystem (UN-GGIM 2024). Agility is required for adapting to the rapid changes to incorporate new ideas, principles and elements as the concept, technologies and roles evolve within the wider digital ecosystem. The expert team also recognized the importance of **purpose, particularly how geospatial data and technologies can contribute to overcoming global challenges and embracing emerging opportunities**. The report identifies that the purpose is informed by **three drivers**: 1) The need for solutions to global problems. (e.g. 2030 Agenda); 2) The need for equitable access to knowledge; and 3) The need to bridge the geospatial digital divide (UN-GGIM 2024).

UN-GGIM has published several forward-looking vision statements and documents, which are summarized in UN-GGIM (2022):

- Our future digital world will be increasingly interconnected through flows of information, resources, goods and services, people, and ideas.
- The 'single' direction supply of data and services is no longer the end point. The future geospatial information ecosystem must take direction out of the equation to locate, integrate and process disparate and diverse data.
- SDIs are designed as 'human accessible' libraries that are not machine friendly. The future ecosystem will be self-organized around the demand for geospatial information, technologies and services (EUROGI 2021) that will deliver solutions to global problems that cannot be addressed on a country-by-country basis.
- The Fourth Industrial Revolution (4IR), the ongoing transformation of traditional industries through the integration of advanced technologies (Schwab 2015), is bringing unprecedented advances in technologies that are providing the geospatial community with the capabilities to address major challenges and opportunities. The ecosystem must deliver the location-based knowledge, services and automation expected by economies, societies and citizens in the 4IR age (Geospatial World 2021). The interdependence between the digital (machine) world and human world will be total (EUROGI 2021) – requiring a new workforce ready, skills development framework.
- Enhanced governance, business models, policies, processes, and partnerships are needed to empower users, keep people safe and secure, and break through the participation barrier so that no person is left behind. The future ecosystem provides a momentous opportunity to raise awareness of the importance and significance of geospatial information, unify terminology, cement the geospatial brand globally, and launch geospatial as a career choice.

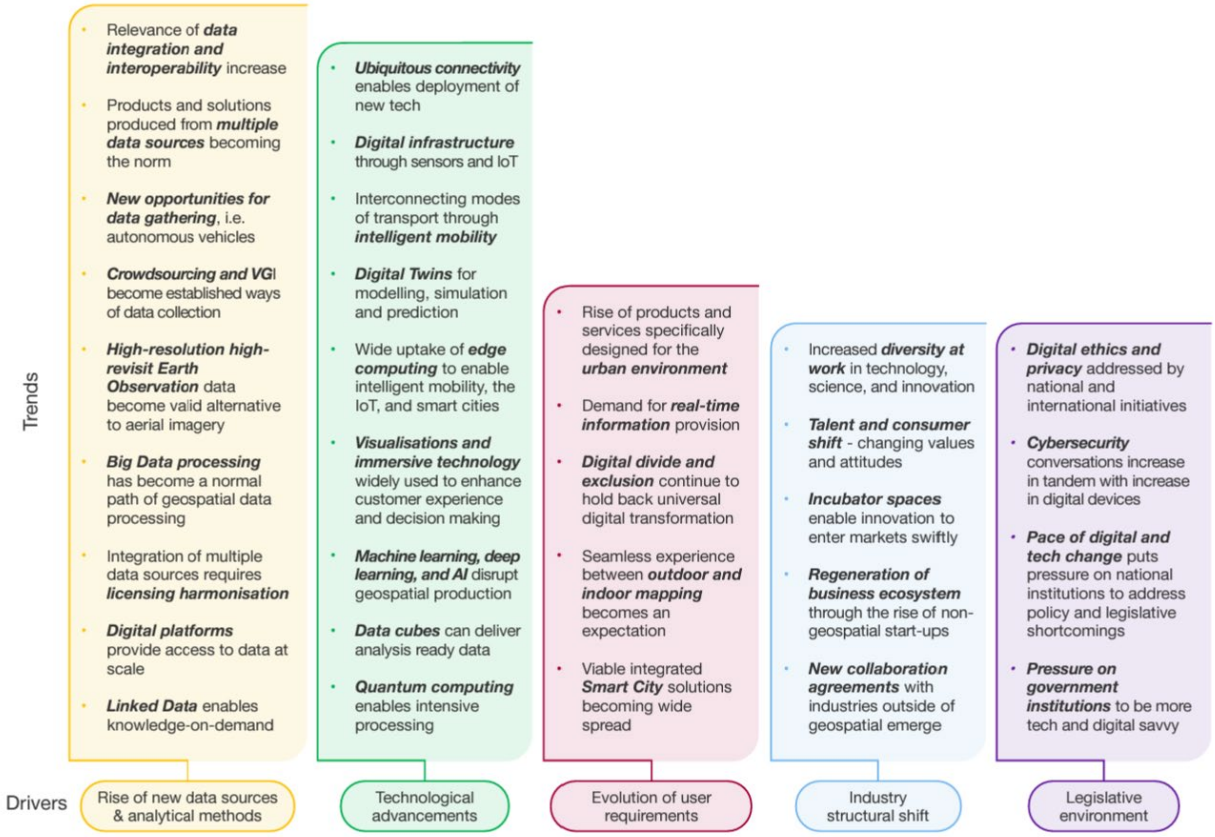
The UN-GGIM *Future trends in geospatial information management: the five to ten year vision* (UN-GGIM 2020) sets out five top forces:

- Technological advances;
- Rise of new data sources and analytics methods;
- Evolution of user requirements;

- Industry structural changes; and
- Regulatory and policy environment.

The report compares geospatial trends with relation to these drivers (Figure 1). It argues that many of the future trends are exposing the inherent limitations of a traditional SDI. **Firstly**, the emerging data ecosystem due to the growing availability of more diverse data and the continuous digital and technological disruption that is more dependent on location and integration. **Secondly**, the increasing requirement for data to be more flexible, readable, timely and integrated with other data. **Finally**, the focus of SDI has predominately been on geospatial data rather than developing geospatial capacity to support the diverse responsibilities of government. The UN-GGIF is based on a recognition that SDI is moving towards a "knowledge infrastructure".

Figure 1: Geospatial drivers and trends related to geospatial information management (UN-GGIM 2020).



In their paper *Towards a sustainable geospatial ecosystem beyond SDIs*, Coetzee et al. (2021) summarize the outcome of a series of discussions about a future vision beyond SDI initiated by the Policies Portfolio Group of the European Umbrella Organization for Geographic Information (EUROGI) in 2020 and 2021. They identify the geospatial ecosystem comprising billions of 'actors' (citizens, companies, governments, civil society organizations, IoT devices, and increasingly also 'intelligent' machines) producing and consuming geospatial information, mediated through ever changing platforms, an increasingly diverse set of geo-analytical tools, and dynamic, constantly evolving networks. This evolution includes:

- changes in technology;
- the volume and nature of geospatial information being generated;
- the increased importance of location, from government policymaking to an individual user's daily living experiences;
- the rise of large and well-resourced private companies providing geospatially based platforms and services;
- the skill sets needed to exploit the new opportunities, which have opened up;
- data management and governance, including the importance of protecting privacy and dealing with bias and cybersecurity issues;
- more advanced analytical tools, such as AI (Artificial Intelligence) and ML (Machine Learning);
- a widening digital divide between developed and developing nations; and
- the roles, relevance and capabilities of different organizations and institutions.

(Coetzee et al. 2021)

According to Coetzee et al. (2021) major components of the future geospatial ecosystem include:

- next generation e-governance processes;
- modern data licensing;
- user-centric technology platforms and services enabled in part by AI/ML;
- application programme interfaces (APIs);
- open data and open analytical software; and
- stakeholder collaboration mechanisms.

New rules of engagement and standards will be necessary to help manage growth and change. The use of consensus frameworks such as the UN-IGIF can help to bridge the digital divide between developed and developing nations (Coetzee et al. 2021). A summary of new and emerging conditions and their impacts on SDIs is provided in Table 1.

Table 1: New and emerging conditions and their impacts on SDIs (Coetzee et al. 2021)

New and emerging condition	Impact on SDIs
Location in decision-making will be commonplace	▪ The current catalogue and portal approach is not sufficient for decision making by a wider and more diverse user and provider community.
New geospatial data sources and services	▪ The SDI concept is not suitable for the emerging collection of new producers of geospatial data and services. ▪ Static metadata records and catalogues which relate mainly to historical data are not suitable for many of the new data providers, data types, and applications. ▪ Certain key data themes, such as Earth Observation (EO) imagery, are available from multiple commercial sources.
Technological advances	▪ SDIs driven by governments cannot keep up with today's technological advances or the massive amounts of location information being produced in real-time or near real-time. ▪ SDIs have focused mostly on data availability; geo-analytics availability is now also very important. ▪ IoT devices raise privacy concerns that were not present in 'traditional' SDIs. ▪ Developing countries need SDI good practice examples that are based on modern technologies and practices.
More automation, analytics, and intelligence	▪ Moral and legal issues arising from AI and automated decision making are beyond the scope of SDIs, and even the geospatial community. ▪ The way in which data is searched and accessed can be re-invented to be much more efficient and human friendly. ▪ Increasingly machines are autonomously undertaking much geospatial data processing and applying increasingly sophisticated geo-analytics, leading to an increasing number of cases where algorithms make final action-orientated decisions. Traditional SDIs are not at all suitable for dealing with this major emerging reality. ▪ Ad hoc analysis of real-time or near real-time data is fundamental for many automatization processes (e.g., in industry 4.0 applications). However, 'real-time' data streams have never been seriously addressed in traditional SDIs.
User expectations are changing	▪ The overwhelming bulk of users are not geospatial experts, and they expect much more than digital libraries (clearinghouses) provided by SDIs. A supply-driven SDI cannot provide the geospatial data and visualizations that they expect and increasingly demand.
Organizations are changing	▪ Organizational hierarchies, which were appropriate for national SDIs, will be replaced with more agile, multiparticipant team-based structures. ▪ Organizations must cater for users outside the 'traditional' user base of geospatial experts.

3.2 Evolution of National Mapping Agencies

In their report on the **evolving role of national mapping agencies** (NMAs), Geospatial World argues that as NMAs continue to adapt to changing societal needs and technological landscapes, their future role will focus on supporting policy priorities and enhancing their economic and social relevance through the continued development and implementation of Geospatial Knowledge Infrastructure (Geospatial World 2024).

Technological innovation is pivotal to the evolution of NMAs and Geospatial World identities technological and innovation drivers affecting NMAs:

- Digital twin technology;
- Use of AI and ML in geospatial data processing;
- Big data analytics and GeoAI; and
- Predictive modeling in forecasting trends and informing decision-making processes.

"The evolution of National Mapping Agencies is driven by a confluence of technological advancements, increasing demand for geospatial services, regulatory frameworks, strategic partnerships, data interoperability, advanced analytics, and societal impact. These factors collectively enhance the capabilities of NMAs, enabling them to meet the diverse and growing needs of modern societies. The ongoing adaptation to these driving forces ensures that NMAs remain relevant and effective in the evolving geospatial landscape." (Geospatial World 2024)

3.3 Evolution of User Needs

The most recent UNA related to the CGDI and the Arctic SDI was completed in 2019 (Hatfield Consultants 2019), which included specific assessments of the needs of Indigenous communities and organizations. The assessment aimed to address new opportunities and challenges for Canadians with recent developments in information and communications technology, geomatics technology, and availability of spatial data. The study was structured in two parts to enable the research team to provide sufficient attention to major stakeholder groups for the CGDI: Canadian stakeholders, including federal, provincial, territorial, and municipal governments, academia, private sector, and non-government organizations, and Indigenous (First Nations, Inuit, Métis) organizations in Canada, including Indigenous governments, Tribal Councils, Treaty Organizations, Indigenous NGOs/Non-profits, and Indigenous-owned private companies.

The findings were structured around Thematic Data Requirements, Technology, Applications, and Tools, Policy, Standards, and Governance, and Training and Capacity Building. Key findings included:

- Open data is a key requirement and provides many perceived benefits to users. Where data cannot be made available free of cost, users still want to be able to discover the data easily and understand its accessibility, license, and costs.
- Awareness of web services was growing. Users also show interest in programmatic access to data through Application Programming Interfaces (APIs).
- Awareness of use of cloud computing and the concept of Platform as a Service (PaaS) was growing, with users expressing interest in moving from geo-portals to geo-platforms. In this context, geo-portals are websites that provide users with access to search for and retrieve geospatial data and metadata and are aligned with traditional SDIs; geo-platforms provide tools for data integration, visualization, and analysis, and they support interoperability across various systems. Given the lack of progress on a Canadian big Earth data platform, collaboration with existing and proposed geo-platforms was recommended.

- There was some uncertainty about how different federal and provincial/territorial geospatial resources and initiatives contribute and co-exist within the same broad CGDI ecosystem. Since the study's publication (2019), GEO.ca was launched in 2022 as the definitive source for Canada's open geospatial information, a collaborative effort between federal and provincial/territorial stakeholders to bring together authoritative geospatial data, EO data, and applications (CCMEO 2024a).

The Indigenous assessment also identified the importance of Collaboration and Institutional Arrangements, in particular:

- Further engagement with Indigenous communities and organizations was considered imperative to validate the findings of the UNA to gain a more complete picture of Indigenous user needs and to explore alternative viewpoints.
- Connectivity challenges due to bandwidth limitations were especially a problem for Indigenous organizations, in the north, parts of rural British Columbia (BC) and other 'remote' locations. It was recommended to better understand priorities and to identify cost-effective ways to improve access to technology, applications, and tools.
- Equitable participation by Indigenous organizations must be understood in the context of community resources, as lack of funding was identified as a key barrier for Indigenous aspirations around the use of geospatial data.
- Indigenous communities and organizations require clear policies and standards around data ownership, storage, sharing, and access. This is especially important with respect to confidentiality and intellectual property concerns and how communities can protect sensitive information.
- Capacity building was a commonly expressed need amongst Indigenous organizations, regardless of their size, location, or existing geographic information system (GIS) capabilities.

4.0 TRENDS IN GEOSPATIAL TECHNOLOGIES

Based on the key literature in the introduction and additional research, this section summarizes key trends in geospatial technologies relevant to Canada and the CGDI. The aim is to explore the major trends for Canada, aligned with the UN-IGIF where appropriate, and is not intended to be exhaustive.

4.1 INTEGRATION OF IOT WITH GEOSPATIAL TECHNOLOGY

The IoT involves embedding sensors and connected devices throughout built and natural landscapes, collecting vast amounts of data about people, relationships, transactions, and the physical world. The number of IoT devices is hard to estimate, with the estimates in 2019 of 74 billion IoT devices by 2025 (Policy Horizons Canada 2019) already exceed almost threefold to 207 billion by 2024 (Marr 2023).

IoT devices are increasingly being used to collect geospatial data. These devices are often Global Positioning System (GPS) enabled and can provide real-time geospatial data on a variety of factors, from traffic patterns to environmental conditions.

Features of IoT technology that can create challenges and opportunities for CGDI governance include:

- **Real-Time Data Collection**: IoT devices, such as sensors and smart devices, can collect and transmit data in real-time. This provides up-to-date spatial data, which is crucial for many applications, such as traffic management, disaster response, and environmental monitoring. However, many CGDI users are not experienced in integration of real time data.
- **Increased Data Volume**: IoT devices generate a large volume of data, providing a more detailed and comprehensive view of the environment. This can enhance the accuracy and reliability of geospatial applications; however, it also presents big data management challenges.
- **Integration of Diverse Data Sources**: IoT devices can collect a wide variety of data types, from temperature to motion and light levels. This diverse data can be integrated to provide a more holistic view of the environment. However, many CGDI users are not experienced in integration of different data sources.
- **Cost-Effective Data Collection**: IoT devices can often collect data more cost-effectively than traditional methods, such as manual surveys. This can reduce data generation costs.
- **Automation and Efficiency**: IoT devices can automate data collection and transmission, reducing the need for manual intervention. This can reduce data generation costs.
- **Improved Decision-Making**: The real-time, detailed, and diverse data provided by IoT devices can support more informed decision-making. This can enhance the effectiveness of SDI in supporting various applications, from urban planning to environmental management.

IoT devices are considered an inherent component of **Digital Twins** (see section 4.5). **Edge computing**, a distributed computing framework that allows IoT devices to quickly process and act on data at the edge of the network (Microsoft 2024a), is another related technology.

An example of real-time environmental reporting is a CCMEO collaboration with Health Canada to publish the Canadian real-time environmental radiological monitoring dataset to GEO.ca (CCMEO 2024b), Canada.ca, Open Science and Data Platform. The application updates and displays radioactivity measures from sensors across the country every 15 min. CCMEO is exploring opportunities to apply a similar approach to other data sources that generate data regularly and replicate the near real-time mapping process.

While the legal and regulatory issues related to IoT data should be addressed broadly by federal and provincial data ownership, data protection, and privacy laws, CGDI governance may be impacted by issues around sharing of location data and interoperability standards.

4.2 ADVANCES IN REMOTE SENSING TECHNOLOGY

The use of drones and satellites for data collection is increasing. They provide high-resolution, real-time data for a variety of applications, from environmental monitoring to mapping and surveying.

Satellite remote sensing enables global coverage and can provide long time series of data, which is crucial for many applications, such as forest management and monitoring the impacts of climate change (Wulder et al. 2022). Satellite sensors can collect data on temperature, humidity, cloud cover, and other atmospheric

conditions, which is used for weather forecasting and climate research. Communication satellites support the sharing and dissemination of spatial data, making it accessible to users around the world. GPS satellites provide critical spatial data that enables precise navigation and location-based services.

Trends in satellite remote sensing technology include:

- **Increased Resolution**: commercial satellites collecting data at a much higher resolution (10 to 30 cm). This allows for more detailed observations and analysis.
- **Miniaturization of Satellites**: development of constellations of small satellites has made satellite technology more accessible and cost-effective, providing more frequent updates and wider coverage.
- **Hyperspectral Imaging**: satellites are capturing data across a wide range of the electromagnetic spectrum, providing more detailed information about the Earth's surface.
- **Real-time Data Transmission**: advancements in communication technology have made it possible to transmit data from satellites to Earth in real-time, allowing for quicker analysis and response.
- **Increased Use of AI and Machine Learning**: being used to analyze satellite data more efficiently and accurately.
- **Integration with IoT**: satellites' data are being used in conjunction with IoT devices to collect and analyze data for various applications, such as weather forecasting, disaster management, and environmental monitoring.
- **Big data:** remote sensing data is one of the key drivers of growth in geospatial big data.
- **Improved Accessibility of Satellite Data**: cloud-based platforms, open data policies, and open-source software mean that satellite data is becoming more accessible, which is fostering innovation and expanding the use of satellite data in various fields.

Canada has a long history as a global leader in satellite remote sensing technology. Canada's strategy for satellite Earth observation (Canadian Space Agency 2022) recognizes that satellite technologies are an integral part of Canadian lives, important for Canadian industry, and vital to support evidence-based decision making and planning. The four objectives of the strategy are:

1. Ensure that satellite Earth observation data is free, open, and accessible to maximize science, innovation, and economic development;
2. Harness satellite EO to address climate change and issues that matter to Canadians;
3. Strengthen delivery of critical services to keep Canadians healthy, safe and informed; and
4. Inspire skills and capacity development for the next generation.

The Government of Canada's Strategy for Satellite Earth Observation is an important driver for the CGDI related to policy, enabling services delivery, and ensuring capacity skills are available to support its

implementation. The Strategy seeks to enhance access to open data. However, open EO data licensing is not fully embraced, with a limited number of Radarsat-1 images released under an open license (Canadian Space Agency 2019a; AWS 2024) and restrictions on RCM data (Canadian Space Agency 2019b) in compliance with RSSSA (Branch 2007a; Branch 2007b). Many stakeholders in Canada identify the benefits of the European Union (EU) and United States (US) open data policies for Copernicus (European Commission 2015) and Landsat (Wulder et al. 2012), respectively, which can be contrasted with the challenges users find with access to RCM data. The Earth Observation Hub Report: 2024 Industry Trends and Analysis (up42 and GeoAwesome 2024) highlights that industry users of Earth observation data favour a mix of commercial and open data sources when possible. As the industry continues to evolve, these insights suggest that EO data providers and platform developers must continue to innovate, balancing cost with quality, while also enhancing user trust in cloud-based solutions (from both the data provider and user perspective).

Canada is a leader in satellite radar remote sensing. Canada's Radarsat Constellation Mission (RCM) has provided radar data to address numerous requirements of Canadian government users (Canadian Space Agency 2020). The Government of Canada recently allocated $1.012 billion to the Canadian Space Agency to support the development of RADARSAT+, which includes a replacement satellite for the RCM and to design a next-generation satellite system to succeed the RCM (Canadian Space Agency 2023).

Complementing satellite remote sensing, drone technology continues to advance and provide highly versatile platforms for data collection. Drones can be equipped with various sensors, including optical, thermal, multispectral, and LiDAR, to collect different types of data based on the requirements of the task. Drones often provide a more affordable alternative, making remote sensing technology more accessible for various applications.

In summary, evolution of remote sensing technology can create challenges and opportunities for CGDI governance, specifically:

- Supporting improvement in the accessibility of remote sensing data with open data policies. Balancing security concerns with open data in relation to the RSSSA; and
- Rapid evolution of the remote sensing and evolution of cloud infrastructure and data and interoperability standards to manage big data.

4.3 GEOSPATIAL BIG DATA AND CLOUD COMPUTING

Geospatial big data is a continuing trend because of the proliferation of IoT devices, remote sensing technology, and other forms of geospatial data generation such as mobile devices and social media.

The development of big data infrastructure is occurring within a context of rapid growth in the provision of remote sensing data and change in user expectations about access to and use of such data. The data available on the state of the planet is growing in precision, volume, velocity, variety, and value, increasing the complexity of scenarios for data exploitation, as well as the resources required by the communities using the data.

In response, cloud-based platforms are becoming more popular for managing and analyzing spatial data. They offer scalable storage, processing power, and access to advanced analytics tools. Cloud computing is playing a crucial role in supporting SDI globally:

1. **Scalable Storage**: Cloud platforms provide scalable storage solutions, allowing organizations to store large volumes of spatial data without worrying about physical storage limitations.
2. **Data Processing and Analysis**: Cloud computing offers powerful processing capabilities that can handle complex computations required for spatial data analysis. This allows for faster processing and real-time analysis of spatial data.
3. **Accessibility**: Cloud platforms enable easy access to spatial data and allow multiple users to work on the same data simultaneously, promoting collaboration.
4. **Cost-Effective**: Cloud computing eliminates the need for organizations to invest in expensive hardware and software for data storage and processing. Organizations can pay only for the resources they use.
5. **Integration and Interoperability**: Cloud platforms often support a wide range of applications and formats, making it easier to integrate different types of spatial data and use various geospatial analysis tools.
6. **Data Backup and Recovery**: Cloud services often include data backup and recovery options, ensuring that spatial data is protected against loss or damage.
7. **Advanced Analytics Tools**: Many cloud platforms offer advanced analytics tools and services, including AI and machine learning capabilities, which can be used to extract valuable insights from spatial data.
8. **Real-Time Data Sharing**: Cloud computing allows for real-time data sharing, which is crucial for many applications that rely on up-to-date spatial data, such as disaster management, navigation, and transportation planning.

Big geospatial data and the technologies developed to address its challenges and opportunities continue to evolve but are maturing. The most important issues and opportunities for CGDI governance are related to **standards for data and cloud platform interoperability**.

The evolution to cloud computing is illustrated by moving the Federal Geospatial Platform (FGP) from on-premises computing infrastructure to the cloud. In 2014, the Government of Canada initiated the FGP, and a public site known as Open Maps on the Government of Canada's Open Government Portal. Launched in 2017, these sites provided open geospatial data from Canadian federal departments/agencies, as well as those from the provinces and territories, and some Canadian municipalities. To support responsiveness and technology evolution, FGP was migrated to the cloud, enabling to streamline and modernize the way web content is deployed on Open Maps (AWS 2021). GEO.ca is a state of the art, cloud-based solution to manage, store and disseminate geospatial data and information. GEO.ca addresses many emerging trends listed – it advances geospatial data, information management and dissemination, as a high-performing, user-friendly, accessible platform that enables proper usage of the cloud, and microservices to ensure

system scalability to achieve cost savings, while securing all development, staging and production zones in using the latest security best practices. GEO.ca leverages Generative AI and ML for cataloguing technologies (similarity engine, semantic search engine) that improve search and discovery user experience significantly over traditional portals/platforms. It also uses a new, intuitive, open-source map viewer, GeoView, that prioritizes accessibility/performance. GEO.ca provides improved effectiveness at aggregating metadata from diverse data sources and in user-interface (CCMEO 2024a). Another notable initiative is the Open Science and Data Platform (OSDP), created to provide access to cumulative effects content collections of open science, data, and other information that is otherwise dispersed over the federal-provincial digital landscape. The OSDP accesses data from GEO.ca, demonstrating the value of standards-based interoperable systems.

As geospatial data proliferate, the concept of a **data lake** has emerged. A data lake captures both relational and non-relational data from a variety of sources—business applications, mobile apps, IoT devices, social media – without having to define the structure or schema of the data until it is read (Microsoft 2024b). This contrasts with the traditional geospatial data warehouse, which is relational in nature with the structure or schema modeled or predefined by product requirements that are curated, conformed, and optimized for structured query language (SQL) operations. Geo.ca has embraced a data lake as part of search and discovery through using geoCore, which transforms traditional metadata inputs into a metadata lake that permits faster, more flexible search functionality (CCMEO 2024a).

In the realm of big Earth observation data, leadership in addressing standards and interoperability is provided by the Open Geospatial Consortium (OGC). In 2021 the OGC completed its Testbed-16 Innovation Initiative, a collaborative effort involving 27 organizations, including NRCan, CSA, the Computer Research Institute of Montreal (CRIM), CubeWerx and Compusult. The initiative aimed to rapidly prototype, design, develop, and test solutions to problems related the **Earth Observation Cloud Architecture** – a standards-based software architecture that enables the deployment and execution of data processing applications close to the physical location of Big Data, such as EO data or outputs from models. Testbed-16 included activities on a Data Access and Processing API, Earth Observation Application Packages, and Data Access and Processing (OGC 2021a). These efforts contributed to the publication of the **OGC Best Practice for Earth Observation Application Package** (OGC 2021b).

NRCan and CSA leadership in the development of Canada's big Earth observation data platform – known as **Digital Earth Canada** – represents an opportunity for governments to support the adoption of modern geospatial cloud computing standards. In addition, continued development of Geo.ca represents an important example geospatial data infrastructure.

4.4 AI AND MACHINE LEARNING IN GEOSPATIAL ANALYSIS

Geospatial technologies are increasingly integrating AI and ML to automate data analysis, improve accuracy, and predict trends. This allows for more efficient processing and interpretation of large volumes of spatial data.

AI and ML are being used in several ways relevant to SDIs:

- **Automated Data Analysis**: AI and ML algorithms can be used to efficiently process and analyze large volumes of spatial data and to identify patterns, anomalies, and trends in the data, providing valuable insights for decision-making.
- **Predictive Modeling**: AI and ML can be used to create predictive models based on spatial data. These models can forecast future events or trends, such as traffic patterns or environmental changes, helping planners and policymakers make proactive decisions.
- **Image Recognition and Processing**: AI and ML are used in image recognition to identify and classify objects in remote sensing imagery. This can be used in various fields such as agriculture (identifying crop types, assessing health of crops), urban planning (identifying buildings, roads), and environmental monitoring (detecting changes in land use or vegetation).
- **Real-time Data Processing**: AI and ML can process and analyze data in real-time, providing immediate insights, which can support emergency response.
- **Data Quality Improvement**: AI and ML can help improve the quality of spatial data by identifying and correcting errors, filling in missing data, and validating data accuracy.
- **Integration of Diverse Data Sources**: AI and ML can help integrate and analyze data from diverse sources, providing a more comprehensive view of the spatial environment. This can include data related social media.

CCMEO's GeoAI initiative provides a compelling example of the potential for AI to is transform geospatial data generation. GeoAI provides up-to-date information on various geographical features across the country, including surface water, roads, buildings and forested areas, to support emergency preparedness and response (NRCan 2024a). GeoAI automatically extracts features such as roads, buildings, lakes, and rivers from aerial or satellite images using machine learning algorithms. The benefit of using GeoAI data series are its ability to generate updates faster than previous methods while maintaining high levels of precision.

In summary, AI and ML technology creates opportunities for CGDI governance, specifically helping NMAs to improve and update geospatial framework data. Challenges may be related to the skills and expertise required to utilize these technologies.

4.5 DIGITAL TWINS

In the context of SDIs, a digital twin is a virtual representation of an object or system designed to reflect a physical object accurately. It spans the object's lifecycle, is updated from real-time data and uses simulation, machine learning and reasoning to help make decisions (IBM 2024). This can include buildings, infrastructure, or even entire cities.

The digital twin integrates data from various sources, including existing geodata, sensors, drones, satellites, and other IoT devices, to create a comprehensive, 3D model of the physical world. This model can be used for various purposes, such as urban planning, disaster management, infrastructure maintenance, and

environmental monitoring. For example, a digital twin of a city could provide real-time information about traffic patterns, air quality, energy usage, and other key metrics. This data can be used to make more informed decisions, improve efficiency, and enhance the quality of life for residents.

Major information technology (IT) and business technology firms are developing and offering digital twin infrastructure, e.g. Microsoft's Azure Digital Twins (Microsoft 2024c) and SAP (Howells and Gibbons Paul 2024).

In 2021, Canada's National Research Council (NRC) completed a study on digital twins summarizing the social, policy, economic, environmental, and defense impacts (Jansen, Rebecca 2021). The full study is not publicly available, but the highlights indicate primary drivers are governments for security and defense as well as the private sector. Considerable interest in digital twins has emerged from major cities.

In 2020, the European Space Agency (ESA) launched its Digital Twin Earth (DTE) initiative, which aimed to demonstrate digital replicas of our planet leveraging AI, cloud computing, Earth science and modeling and Earth-scale environmental, societal, and economical data. ESA initiated activities that aim to prototype an example of Digital Twin Earth for a certain topic area using existing capabilities, science, and infrastructure.

An OGC Urban Digital Twins Interoperability Pilot is underway led by the Korea Land and Housing Corporation (OGC 2024). The pilot proposes implementing scenarios and supporting APIs for urban noise analysis and situational analysis of geo-referenced still and moving imagery for use cases in a Smart City.

Related to digital twins, 3D mapping is a significant advancement offering a more detailed and realistic representation of the physical world. This is particularly useful in fields like construction, architecture, urban planning, telecommunications, environmental management, archaeology, and heritage preservation. Arguably, the application of 3D mapping and visualization is most relevant to municipalities and industry, at more local scales.

In summary, digital twin technology development creates a role for CGDI governance focused on policy and standards and potentially helping to address data governance and privacy concerns.

4.6 INDIGENOUS DATA SOVEREIGNTY

Indigenous data sovereignty is a growing concern and an important issue in the realm of data governance and policy, and more broadly, reconciliation, and equity, diversity and inclusion. Indigenous data sovereignty refers to the right of Indigenous peoples to govern the collection, ownership, and application of their own data. The United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) Act (Government of Canada 2021) is expected to influence Indigenous data sovereignty by affirming the rights of Indigenous peoples to control their own data, promote culturally sensitive data practices, and support the development of Indigenous-led data governance frameworks. The 2023-2026 Data Strategy for the Federal Public Service Government of Canada identifies support for Indigenous data sovereignty as a priority intended to help support Indigenous self-determination (Government of Canada 2024).

The First Nations principles of OCAP® (ownership, control, access, and possession) establish how First Nations' data and information will be collected, protected, used, or shared[2]. OCAP® is a tool to support strong information governance on the path to First Nations data sovereignty. Given the diversity within and across Nations, the principles will be expressed and asserted in line with a Nation's respective world view, traditional knowledge, and protocols.

The Collective Benefit, Authority to Control, Responsibility, and Ethics (CARE) Principles for Indigenous Data Governance, first stated in 2018, emphasize the importance of data being used to benefit Indigenous Peoples (Global Indigenous Data Alliance 2024). These principles are people and purpose-oriented, aiming to advance Indigenous innovation and self-determination by ensuring that data practices respect Indigenous rights and interests. They complement the Findable, Accessible, Interoperable, and Reusable (FAIR) principles by integrating considerations of power dynamics and historical contexts. The CARE principles relate closely to the OCAP® principles which also emphasize Indigenous control over data. Both frameworks advocate for Indigenous sovereignty over data, ensuring that data governance aligns with Indigenous values and supports community empowerment. In British Columbia, the BC First Nations Regional Information Governance Centre[3] is pioneering on issues related to Indigenous data sovereignty.

In summary, Indigenous data sovereignty is an important consideration influencing CGDI governance. For example, Indigenous voices have been added to geospatial governance (e.g., appointment of Indigenous advisors to the Geographical Names Board of Canada), and release of the report on dissemination of open geospatial data under the Open Government Licence-Canada through OCAP principles (Hackett and Olson 2019). Indigenous data sovereignty may evolve into a role in foundation data generation and management for areas which overlap traditional territories.

4.7 IMPROVED CONNECTIVITY

Improving connectivity globally and to rural communities in Canada is an important trend that impacts the future of CGDI development and benefits. Connectivity was identified as a challenge in the CGDI user needs assessment (Hatfield Consultants 2019).

Megaconstellations like Starlink, a project by SpaceX, improve connectivity in remote communities in several ways:

- Global Coverage: traditional internet service providers often struggle to provide service in remote or rural areas due to the high cost and difficulty of infrastructure installation. Starlink, with its network of satellites, can provide global coverage, reaching areas that were previously unserved or underserved.
- High-Speed Internet: comparable to that in urban areas. This can significantly improve the quality of life and economic opportunities in remote communities.

[2] "OCAP® is a registered trademark of the First Nations Information Governance Centre (FNIGC)" – see https://fnigc.ca/ocap-training/.

[3] https://www.bcfndgi.com/

- Low Latency: satellites in low Earth orbit can provide lower latency than traditional satellite internet. This means faster response times when using the internet for connecting to SDIs.
- Scalability: as the demand for internet connectivity grows, more satellites can increase capacity. This scalability makes it a potentially sustainable solution for global internet coverage.

Applications such as disaster response can be improved in situations where the ground infrastructure might be damaged. The Government of Canada has made significant investments to improve internet connectivity across the country, including rural and remote areas. Key initiatives are:

1. Universal Broadband Fund: in November 2020, the government announced a $1.75 billion investment to help connect Canadians to high-speed internet across the country. The goal is to provide all Canadians with access to high-speed internet, no matter where they live. A rapid response stream aims to support projects that can be completed quickly and will benefit communities significantly.
2. Telesat Lightspeed Low Earth Orbit (LEO) broadband satellite constellation. With funding agreements with the Government of Canada and the Government of Quebec of $2.14 billion, Telesat LEO is expected to play a critical role in bridging the digital divide by expanding the reach of internet and 5G networks in unserved and underserved communities in Canada, with affordable, high-speed broadband connectivity. Plans to launch the first Telesat Lightspeed satellites are expected mid-2026 (Telesat, LEO).
3. Canada Infrastructure Bank's Growth Plan: as part of this plan, the Canada Infrastructure Bank has committed $2 billion to large-scale broadband projects across Canada.
4. Partnership with SpaceX: the Canadian Radio-television and Telecommunications Commission (CRTC) granted SpaceX a license to provide satellite internet connectivity in Canada. This aims to provide high-speed internet to rural and remote areas.

In summary, improved connectivity addresses a significant challenge and barrier for CGDI governance in terms of ensuring equitable access to geospatial services and the benefits of the CGDI, which is in line with IGIF objectives. There is an opportunity to assess the impact and benefits on CGDI engagement of improvement in connectivity in rural and northern regions and for specific communities.

5.0 EXTERNAL ISSUES: PESTEL

The rapid pace of technological, social, environmental, and economic change presents challenges to the development and strengthening of NSDI. Macro-environmental factors can affect collection, management, and use of geospatial data by governments, partners, and stakeholders. With strategic planning, investment, and collaboration, issues can be anticipated and proactively managed. The UN-IGIF is designed to provide strategic guidance that enables country-specific action plans to be prepared and implemented.

The following sections are structured around a PESTEL framework, which identifies the external factors that might affect all organizations, across jurisdictions, that participate in the management of the CGDI.

Key to impact, uncertainty, and priority ratings:

		Impact	Uncertainty	Priority
n	low	CGDI governance will be affected, but through planning or action the impact is expected to be low.	The key trends and issues are well known, enabling planning to manage the impact	Lower priority for resource allocation.
nn	medium	CGDI governance will be affected, but through planning or action the impact is expected to be moderate.	The key trends or issues are known but there is moderate uncertainty, affecting planning to manage the impact	Moderate priority for resource allocation.
nnn	high	CGDI governance will be affected, and despite planning or action this will have a significant positive or negative impact.	The key trends or issues are known but there is considerable uncertainty due to the pace of change, affecting planning to manage the impact	Highest priority for resource allocation.

5.1 POLITICAL

	Issue for the management of the CGDI	Impact on CGDI & Uncertainty
Evolution of federal, provincial & territorial responsibilities	▪ Framework geospatial data generation in Canada is largely driven by the provinces and territories, as well as municipal and regional government. ▪ The role of federal government is evolving towards consolidation and integration of data, e.g. efforts related to digital elevation (NRCan 2024b). ▪ A governance issue for Canada's national and provincial mapping agencies is defining their roles in developing and implementing strategies for geospatial data management, including data collection, sharing, and standardization at multiple levels. This is related to the role and mandate of the Canadian Council on Geomatics (CCOG) as the major federal-provincial-territorial consultative body for geomatics needs.	Impact: nn Uncertainty: n Priority: nn

	Issue for the management of the CGDI	Impact on CGDI & Uncertainty
Evolution of federal, provincial & territorial responsibilities (Cont'd.)	▪ The federal Standard on Geospatial Data (Government of Canada 2017) is managed by the Treasury Board with input from CCMEO and others: Any potential updates/revisions to this standard will impact geospatial ecosystem management in Canada.	
Importance of Indigenous reconciliation	▪ Indigenous reconciliation in Canada, particularly in the context of data and mapping, is a significant part of the country's efforts to address historical injustices and build a more equitable future. ▪ Engagement with Indigenous organizations on SDI issues must incorporate Indigenous data sovereignty as the right of Indigenous peoples to govern the collection, use, and sharing of their data. ▪ A governance issue for the CGDI is integrating Indigenous knowledge and perspectives into geographical data and mapping practices, incorporating Indigenous data governance systems, recognizing Indigenous place names, acknowledging traditional territories in official maps and geographical databases, and improving the quality and availability of data for Indigenous communities.	Impact: nnn Uncertainty: n Priority: nnn
Open data in relation to privacy and security	▪ The shift to open data policies in Canada reflects a global trend towards transparency and citizen engagement. It represents a cultural shift within the government towards openness and accountability. Key milestones included: 2011, Canada joining the Open Government Partnership; 2014, the Directive on Open Government (Government of Canada 2014), which mandates all federal departments/agencies to maximize the release of data and information; and 2016, launch of the Open Government Portal. ▪ Provincial, territorial, and municipal governments also embraced open data policies over a similar period. ▪ Government open data action plans and the Federal Data Strategy 2023-2026 (Government of Canada 2024) influence open data progress and it remains an important governance issue for the CGDI. Restrictions to remote sensing data access in relation to the RSSSA (Branch 2007a) remain an issue.	Impact: nnn Uncertainty: n Priority: nnn

5.2 ECONOMIC

	Issue	Impact & Uncertainty
Power of big technology firms	The big technology firms, particularly Google, Microsoft, Amazon, and Meta wield incredible power with their collection and use of geospatial data. Governments must address privacy, competition, and ethical concerns. ▪ Google has considerable power with its business model for Earth Engine. Google is updating this policy, and starting in September 2024 all Earth Engine usage must be linked to Cloud projects. In addition, non-commercial free usage is limited including for government agencies (Google 2024). ▪ Europe has made huge public investments to promote use of platforms as an alternative to Earth Engine and other big technology firms, e.g. thematic exploitation platforms, Copernicus Data and Information Access Services (DIAS), and Copernicus Data Access Service. ▪ Meta and IBM launched an AI Alliance in collaboration with over 50 Founding Members and Collaborators globally to promote open and transparent innovation in AI. While the initiative has been praised for its potential to drive innovation and economic growth, there are several concerns that have been raised related to Data Privacy, transparency, and monopoly and market dominance. Regulation of big technology firms is challenging. Collaboration and commercial arrangements with big tech firms are an issue that governments may help to address through standards and ensuring interoperability of systems.	Impact: nnn Uncertainty: nn Priority: nnn
Canada's investment in geospatial innovation	▪ Canada's population and market size are much smaller than those of the US or Europe. This can limit the scale of domestic demand and make it more challenging for Canadian businesses to grow and compete internationally. The geospatial technology sector is not unique in this regard and Canada is affected by its dependence of trade with the US. ▪ Funding has included CSA investments in organizations to advance innovative applications that focus on EO challenges and sustainable development priorities and GeoConnections contribution agreement funding. ▪ CCMEO through GeoConnections or other funding has an opportunity to stimulate growth in the geospatial sector, in particular Canadian SMEs.	Impact: nn Uncertainty: n Priority: nn
Government budget constraints	▪ Budget 2023 included more than $1 billion for RCM and Radarsat+ (Canadian Space Agency 2023), however, it also included spending reductions of $15.4 billion over 5 years.	Impact: nn Uncertainty: nn Priority: nn

	Issue	Impact & Uncertainty
Government budget constraints (Cont'd.)	▪ Budgets can affect the CGDI, including update of framework data, innovation, or international collaboration. Governments can support efficiencies, such as CCMEO's GeoAI initiative. ▪ Canada is modernizing the RSSSA, which will impact RCM and Radarsat+ data access. ▪ Globalisation and regulation of geospatial data and industries will be an issue for the CGDI, especially as remote sensing, AI/ML, IoT and digital twin technologies develop.	

5.3 SOCIAL

	Issue	Impact & Uncertainty
Changes in how geospatial data are created, e.g. use of social media	Social media has significantly impacted geospatial data generation and management, including: ▪ Data Volume: an explosion in the volume of geospatial data available for analysis. ▪ Real-Time Data: available to support disaster management, traffic management. ▪ Citizen Participation: users contribute data about their local environment. Issues for CGDI governance are related to regulations on data quality, privacy, and data integration and their impact on the future geospatial ecosystem envisioned by the UN-GGIM.	Impact: nnn Uncertainty: n Priority: nn
Equity diversity and inclusion; accessibility	Ensuring that data practices are equitable, diverse, and inclusive can help address systemic biases, promote fairness, and enhance the quality and relevance of data. This includes addressing Indigenous rights and communities, and people with disabilities. This includes equitable access, representation in the data, and ethics of data use.	Impact: nn Uncertainty: n Priority: nn
Use of mobile devices	Massive use of mobile devices impacts the CGDI like social media above, however, mobile devices also impact: ▪ Accessibility: geospatial data are more accessible to the public. Users have access maps, location-based services, and other geospatial information directly from their devices. ▪ User-generated content: citizens can easily generate geospatial data. Issues for the CGDI with mobiles devices include ensuring that geospatial data and services are accessible on these devices in the future geospatial ecosystem.	Impact: nnn Uncertainty: n Priority: nn
User expectations	▪ Users expect instant access to information, e.g. weather forecasts, traffic, and disaster information (floods, wildfire, air quality). ▪ An issue for CGDI governance is to maintain an understanding of user needs and expectations, which have evolved since the CGDI User Needs Assessment (Hatfield Consultants 2019).	Impact: nn Uncertainty: nn Priority: nn

	Issue	Impact & Uncertainty
Education and skills requirements	▪ The rapid pace of technology change means the geospatial field is becoming increasingly technical, requiring skills in data science, programming, statistics, machine learning, and big data analytics. This includes developments in areas like AI, IoT, cloud computing, and implementing OGC API standards. ▪ Simply "keeping up with technology" is an important issue, including for Canada's university and college education and training programs and government. The CGDI can address this issue through leadership for training and capacity building on geospatial standards and interoperability. ▪ The complexity of geospatial data, combined with a general lack of geospatial and data literacy in the public and other groups, limits the accessibility of this information, even when it is made fully open and available. Many people simply do not have the geomatics knowledge or experience to fully engage with and leverage these resources.	Impact: nnn Uncertainty: n Priority: nnn

5.4 TECHNOLOGICAL

	Issue	Impact & Uncertainty
Rapid Technological Change	▪ Keeping up with the rapid pace of technological change requires continual learning and adaptation, which is an issue for government programs, even those focused on technology and innovation such as GeoConnections. ▪ Governments can show leadership by building awareness among stakeholders of technology trends and their impacts on the CGDI.	Impact: nnn Uncertainty: nnn Priority: nn
Paradigm shift in geospatial data supply	▪ SDIs are moving from a 'single' direction supply of data and services to an on-demand paradigm focus based on machine-actionable data and automated analytics (UN-GGIM 2022). ▪ This transition is an issue for the CGDI as it impacts the role of Canada's national and provincial mapping agencies.	Impact: nn Uncertainty: n Priority: nn
Integration of IoT and geospatial technology	▪ IoT is growing and an issue for the traditional role of Canada's national and provincial mapping agencies and SDI governance. These issues may be addressed by government data and privacy policies and directives, with specific inputs for locational data from CCMEO and its federal/provincial/territorial partners.	Impact: nn Uncertainty: nn Priority: n
Advances in remote sensing technology	▪ Remote sensing advances are linked to AI and ML analytics and big geospatial data management. ▪ Governments have a role in supporting improvement in open data policies and balancing security with access. In addition, the development of Digital Earth Canada is an	Impact: nn Uncertainty: nn Priority: nn

	Issue	Impact & Uncertainty
Advances in remote sensing technology (Cont'd.)	opportunity to show leadership in the development of a multi-stakeholder EO data analytics platform built on modern geospatial cloud computing standards.	
Big geospatial data management and analytics	▪ Big geospatial data is a central part of technological change, especially the growth in satellite and airborne remote sensing data and IoT devices. ▪ The Canadian ecosystem of big EO data analytics platforms is heterogeneous and there has been a lack of coordination and standards between platforms. Digital Earth Canada is a much-needed initiative that can learn from other countries' experiences. Governments can play a leadership role in the adoption of modern geospatial cloud computing standards, such as OGC API standards.	Impact: nnn Uncertainty: n Priority: nnn
Disruptive AI and ML technologies	▪ AI and ML technologies create opportunities for Canada's national and provincial mapping agencies to improve and update geospatial framework data more efficiently, as with CCMEO's GeoAI initiative. Issues may be related to the skills and expertise required to utilize these technologies, which can be addressed, e.g. through training, capacity-building, use cases and knowledge sharing.	Impact: nnn Uncertainty: n Priority: nn
Digital twins development	▪ A digital twin integrates data from various sources and leverages standards for data interoperability. Digital twin technology development creates a role for CGDI governance focused on policy and standards and potentially privacy.	Impact: nn Uncertainty: n Priority: n
Data Integration standards	▪ Integrating different types of geospatial data from various sources can be complex. There can be issues with compatibility, standardization, and synchronization. ▪ Adoption of OGC API suite of standards is an issue for users and CCMEO/GeoConnections could play a capacity building role.	Impact: nn Uncertainty: n Priority: n
Internet access and connectivity	▪ Inequality of broadband internet access remains an issue, having been identified in the most recent CGDI User Needs Assessment (Hatfield Consultants 2019). Connectivity impacts groups that are already at a disadvantage for SDI adoption and modernization, such as Indigenous communities and organizations. ▪ The improved connectivity is an opportunity for CGDI to demonstrate improvements in equitable access to knowledge, which is an objective under UN-IGIF.	Impact: nn Uncertainty: n Priority: nn

5.5 ENVIRONMENTAL

	Issue	Impact & Uncertainty
Size of Canada for foundational data production	▪ Users want to have access to high quality foundational data at provincial/territorial and national extent. Data availability and standards often change across provincial/territorial boundaries. ▪ The ability to generate high quality, seamless data is an issue that the federal government has sought to address, e.g. National Elevation Data Strategy (NRCan 2024b). CCMEO/GeoConnections can continue to play a leadership role in CCOG and in efforts to develop standards for national datasets.	Impact: n Uncertainty: n Priority: nn
Energy consumption from big data analytics	▪ Growth in AI, ML, and data analytics has significant environmental and energy impacts, including energy intensive data centres, model training and inference, as well as water usage for cooling and resources for hardware.	Impact: nn Uncertainty: n Priority: n
Climate change, disaster risk management, sustainable development goals	▪ Climate change, natural and human disasters, and pandemics are challenging government agencies at all levels with preparedness, response, and recovery. This includes increased demand for real-time data, more detailed data: better predictive models: and public communication. Disasters are not restricted to national or sub-national jurisdictions. ▪ Monitoring progress in the United Nations sustainable development goals requires geospatial datasets. ▪ Meeting citizen's expectations will require investments including in capacity and skills to respond to the needs.	Impact: nnn Uncertainty: nn Priority: nnn
	▪ CCMEO's GeoAI initiative is an example of the CGDI and national mapping initiative benefiting disaster response information needs.	
Urban rural divide	▪ Data availability and capacity to engage with the CGDI is a challenge in rural regions(Hatfield Consultants 2019). As noted above, improvements in equitable access to geospatial knowledge helps Canada address IGIF requirements.	Impact: n Uncertainty: n Priority: nn

5.6 LEGAL

	Issue	Impact & Uncertainty
Data Privacy and Security	▪ As more spatial data is collected and stored, there is an increasing focus on ensuring data privacy and security. This includes developing strategies for anonymizing data and protecting it from cyber threats. ▪ With the introduction of data protection regulations like the EU General Data Protection Regulation (GDPR) and Personal Information Protection and Electronic Documents Act (PIPEDA) in Canada, there's a growing emphasis on ensuring that SDI complies with relevant laws and regulations. This includes obtaining necessary consents for data collection and providing transparency about how data is used. ▪ Governments can play a role in educating participants in the CGDI to respect data and privacy regulations	Impact: nnn Uncertainty: nnn Priority: nn
AI laws and regulations	▪ The development and deployment of AI technologies raises numerous legal and regulatory issues that governments, organizations, and societies must address, including ethics, privacy and data protection, liability/safety, intellectual property, and labour market impacts.	Impact: nn Uncertainty: nn Priority: nnn
First Nations principles of OCAP™ and CARE principles	▪ CGDI modernization needs to respect the First Nations principles of OCAP™ and CARE principles, which establish how First Nations' data and information will be collected, protected, used, or shared. Governments can support understanding of how to respect OCAP™ and CARE (Hackett and Olson 2019)	Impact: nn Uncertainty: n Priority: nnn
FAIR principles	▪ FAIR principles are an issue for data producers, given the data privacy, security, and related concerns. ▪ Governments can encourage adoption of FAIR principles.	Impact: n Uncertainty: n Priority: nnn
International privacy regulations	▪ Canadian organizations working internationally must be aware of international regulations that impact data custodianship, e.g. EU GDPR. CCMEO along with its federal government partners can support understanding of responsibilities for international activities.	Impact: n Uncertainty: n Priority: n

5.7 Summary

The PESTEL analysis identifies a large range of external issues faced by the CGDI, with a qualitative assessment made on their impact, uncertainty, and priority regarding the continued effective operation of the CGDI. The PESTEL analysis was conducted in the perspective of Hatfield and these external issues and potential actions should be taken in the context of other discussions and strategies.

Most of the influential issues for the SDI and geospatial sectors in the near/medium term relate to the **social, technological**, and **legal themes**. The highlights include:

- **Privacy and security** and the **rapid pace of technological change** are both high priority for CGDI but also highly uncertain. More work is needed to understand these areas, their impacts, and how to manage them effectively in the years to come.
- **AI/Machine Learning**, **Mobile phones** and **Social media** are all high impact, but medium priority because they are arguably better understood and more predictable. Work should be done in the coming years to better understand these areas, their impacts and how best to manage them, but this work may be balanced against other priorities.
- **Reconciliation with Indigenous Peoples** will have a high impact and is a key priority, including the component of data principles like **FAIR/OCAP/CARE**, and should be a focus for strategic planning in the coming years.
- Other topics which are both high impact and high priority and could therefore be a focus for strategic planning moving forwards include: **Climate change and disasters, Big data, Education and training, Influence of big tech firms,** and **Open data.**

With a number of high impact issues, a prioritization and planning process is required, which may serve as a useful focus for strategic actions, which is explored in Section 7.0.

6.0 EXPERIENCE IN OTHER COUNTRIES

To support the understanding of trends in geospatial and related technologies that can impact the CGDI, this section highlights the experience of other countries and strategies and actions undertaken, noting potential lessons that may be learned for the CGDI, where applicable.

6.1 UNITED KINGDOM

The United Kingdom (UK) has initiated several SDI initiatives to improve the accessibility, integration, and sharing of geospatial data across various sectors.

Key initiatives include:

1. **UK Geospatial Commission**: Established in 2018, the commission is responsible for developing a strategy to maximize the value of geospatial data and promote its use across the public and private sectors. The Commission published the UK's **Geospatial Strategy** (Geospatial Commission 2023), outlining how the UK plans to unlock the significant economic, social, and environmental opportunities offered by location data.
2. **UK Geospatial Data Standards Register** - agreed ways of sharing and accessing geographic information. They help ensure that the data is findable, accessible, interoperable, and re-usable adhering to the FAIR data principles. Using these standards will:
    - Ensure UK geospatial data is more consistent and coherent and usable across a wider range of systems;

- Empower the UK geospatial community to become more engaged with the relevant standards and standards bodies; and
- Advocate the understanding and use of geospatial data standards within other sectors of government.

3. **Geo6**: established in 2018, the Geo6 is a collaboration between six key UK public sector geospatial data providers: Ordnance Survey, British Geological Survey, Coal Authority, HM Land Registry, UK Hydrographic Office, and Valuation Office Agency. Five of the partner bodies are working together to improve user access to geospatial data.

The key issues or trends addressed by the UK and of relevance to Canada are:

1. Establishing a clear organizational structure for the development of the national SDI with an up-to-date and public, **Geospatial Strategy.**

1. Emphasis on standards and supporting engagement by SDI users with standards in support of FAIR principles.

2. Bringing together major government departments and agencies (i.e. Geo6) that produce important, foundational geospatial data. This analogous to Canada's CCOG membership.

6.2 AUSTRALIA AND NEW ZEALAND

Australia and New Zealand have been proactive in implementing spatial data infrastructure initiatives to enhance the availability, accessibility, and interoperability of geospatial data. Key initiatives include:

- ANZLIC – The Spatial Information Council – is the intergovernmental organization providing leadership in the collection, management, and use of spatial information in Australia and New Zealand. The Foundation Spatial Data Framework (FSDF) aims to provide consistent and accurate base-level geospatial data, with modernization a key initiative under the ANZLIC Strategic Plan 2020-24 (ANZLIC 2020), including the alignment with the UN-GGIM's 14 fundamental geospatial themes.
- Intergovernmental Committee on Surveying and Mapping (ICSM) – is a Standing Committee of ANZLIC. Several Working Groups come from key government, academic, and private organizations from within Australia and New Zealand. ICSM has a five-year strategic framework 2019-2024 (ICSM 2019) that addresses national drivers (ANZLIC Collaborative Framework, ANZLIC Foundation Spatial Data Framework, 2026 Spatial Industry Transformation & Growth Agenda) and international drivers (UN SDGs and standards for spatial data creation, collection and delivery). The three Strategic Challenges addressed by ICSM are 1) improve foundation spatial datasets, 2) address emerging spatial data challenges, and 3) communicate the value of ICSM work.
- Digital Earth Australia (DEA) is an initiative by Geoscience Australia focused on increasing the utilization of EO data across Australia and is one of seven priorities stated in the Australian Space Agency's 2019-2028 Space Strategy (Australian Space Agency 2019). It is a program covering access to data, along with outreach and education activities. DEA was funded under the Australia Technology and Science Growth Fund with a budget of AU$36.9 million over three years from 2019-

20 and AU$12.8 million ongoing (CRCSI 2018). DEA uses high performance computing provided by the Australian National Computational Infrastructure and commercial cloud computing platforms (a hybrid-cloud approach), DEA organizes and prepares analysis ready data to support a range of environmental monitoring applications and has been recognized for the innovation, stakeholder engagement, and best practice (Geoscience Australia 2017; Geoscience Australia 2024).

The key issues or trends addressed by Australia and New Zealand and of relevance to Canada.

1. Governance structures and institutions are established to support collaboration internationally between Australia and New Zealand and with national and state government departments/agencies. This is analogous to collaboration between Canada and the United States and within Canada between the federal government and provinces/territories under CCOG; however, communication of the governance structure is clear and public.

2. Importance of developing and publishing a multi-year strategy and making effort to communicate the benefits of ANZLIC and its committees and working groups.

3. Importance of long-term funding to DEA as a strategic initiative, which has provided Australia with a significant profile internationally for innovation in satellite EO big data management and analytics. Digital Earth Canada provides Canada an opportunity to demonstration leadership for a multi-stakeholder platform and embracing modern, open cloud geospatial standards.

6.3 USA

The United States has implemented several spatial data infrastructure initiatives to enhance the accessibility, integration, and sharing of geospatial data.

The National Spatial Data Infrastructure (NSDI) was established by the Federal Geographic Data Committee (FGDC). The four core themes of the goals in the National Spatial Data Infrastructure Strategic Plan 2021-2024 (FGDC 2020) – policy and governance, data assets, shared services and interoperability, and partnerships – are guided by the IGIF.

Notable initiatives by the US include Geospatial Platform (https://www.geoplatform.gov/), which provides shared and trusted geospatial data, services, and applications for use by government agencies and the public in support of the Geospatial Data Act of 2018. Innovative features include embracing of modern standards such as SpatioTemporal Asset Catalog (STAC) and availability of OGC GeoAPI Services. The National Geospatial Advisory Committee (NGAC) is a Federal Advisory Committee sponsored by the Department of the Interior, authorized under the Geospatial Data Act. This NGAC includes representatives of non-Federal interested parties involved in national geospatial activities, which includes the private sector. This is a notable difference to the CCOG including only federal, provincial, and territorial representatives in Canada.

The FGDC solicited public comments on a Draft NSDI Strategic Plan (2025 – 2035) through early August 2024 and endorsed in October, 2024 (FGDC 2024). The plan describes that what was envisioned in the 1990s as a top-down national infrastructure, led by the federal government, has transitioned to a ground-up implementation with Tribal, State, and local governments, nonprofit and private sector organizations developing and integrating disparate SDIs across the Nation. Significant advancements were made under

the previous plan with the distribution of cost-matching grants through the FGDC's Cooperative Agreements Program (CAP) which helped fund the implementation of data standards, training, strategic partnerships, and the development of geospatial data clearinghouse nodes across the Nation.

The 2025 – 2035 plan notes:

- Key challenges: national security, extreme weather, economic disparity, energy, immigration, infrastructure, community resilience, food, water and environmental security, and public health.
- New approach: "transitioning from monolithic systems to an integrated and interoperable geospatial ecosystem."
- Strategic partnerships: "this vision requires renewed commitment from all sectors, increased collaboration, new technologies, and adequate resources".
- The need to monitor and adapt to key trends, including Big data and analytics: address the deluge of data to analyze and understand.

The Strategy notes four goals:

Goal 1 – Governance: Implement National Governance.

Goal 2 – Data and Technology: Modernize the Infrastructure and Leverage Advanced Technology.

Goal 3 – People: Building a Skilled and Inclusive Geospatial Workforce for a Sustainable Future.

Goal 4 – Implementation of the plan involves Use Cases.

The United States has long been the world leader in EO systems due to its leadership in developing space-based systems. By 2030, the volume of data in the National Aeronautics and Space Administration (NASA) Earth Observing System Data and Information System (EOSDIS) archive is expected to surpass 320 PB (NASA 2023). The United States' approach is to increasingly develop these resources on large commercial public cloud operators such as Amazon Web Services (AWS), Google Cloud and Microsoft Azure. Cloud migration projects by NASA, United States Geological Survey (USGS) and National Oceanic and Atmospheric Administration (NOAA) are indicative of this approach. In 2016 NASA began a system evolution project called "Earthdata Cloud", which became operational in 2019 with key services, such as NASA's Common Metadata Repository (CMR) and Earthdata Search deployed. Additionally, NASA's Distributed Active Archive Centers (DAACs) are moving the data archives they manage into the cloud.

The key issues or trends addressed by the United States and of relevance to Canada are:

1. Developing a long-term strategic plan with opportunities for public consultation and input, to address key challenges, including a re-evaluation of the approach to geospatial data management;
2. Development of strategic partnerships with the CAP providing funding to support implementation of data standards, training, and SDI nodes across; and
3. Transformation of the approach to Earth Science Data dissemination, through embracing the publica cloud and modern, open cloud geospatial standards.

6.4 EUROPE

Europe has implemented several SDI initiatives to enhance the accessibility, integration, and sharing of geospatial data.

Key initiatives include:

1. INSPIRE Directive: The Infrastructure for Spatial Information in Europe (INSPIRE) is an EU directive that aims to create a unified SDI across Europe. It enables the sharing of environmental spatial information among public sector organizations and facilitates public access to spatial information across Europe.

2. Copernicus Programme: This is an EU programme aimed at developing European information services based on satellite EO and other data. It provides users with free, full, and open access to data in several themes.

3. Common European Data Space initiative (European Commission 2024a): This EU initiative aims to create a unified market for data within the EU, facilitating the secure sharing and reuse of data across various sectors while ensuring that individuals and companies retain control over their data, thereby enhancing Europe's global competitiveness and data sovereignty

The European Commission European Data Strategy aims to make the EU a leader in a data-driven society. Creating a single market for data will allow it to flow freely within the EU and across sectors for the benefit of businesses, researchers and public administrations (European Commission 2024b). The European Data Act, which entered into force in January 2024, aims to make more data available for use via new rules on who can use and access data and for which purposes across all economic sectors in the EU. A European Data Governance Act entered into force in June 2022 is related and addresses trust in data sharing, mechanisms to increase data availability, and technical obstacles to the reuse of data.

Big geospatial data management in Europe is largely funded by the public sector, but with substantial input and participation by the private and academic sectors. There is a great deal of emphasis put on capacity building within the private and academic sectors, and frequently projects will be duplicated across several initiatives. In 2016 ESA announced the EO Innovation Platform Testbed Poland (IPT-Poland) initiative to validate data distribution to a cloud-based infrastructure to exploit data from the Copernicus Sentinel satellites. In 2017 the creation of Copernicus Data and Information Access Services (DIAS) began, with the vision for a "cloud-based one-stop shop for all Copernicus satellite data and imagery as well as information from the six Copernicus services, that also give access to sophisticated processing tools and resources"[4]. Since then, a Copernicus Data Access Service (C-DAS) has evolved as the future target of EU investment (European Commission 2022).

The key issues or trends addressed and relevance to Canada:

1. Europe has invested in standardization of SDIs across the EU through the INSPIRE Directive, an ambitious effort given the diversity of member states.

[4] https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Accessing_Copernicus_data_made_easier

2. The Copernicus Programme truly embraced open EO data policies. In tandem the EU has invested in cloud-based EO data infrastructure to provide an alternative to reliance on the big technology firms public cloud infrastructure. These investments have had mixed success in terms of sustainability.

6.5 INDIA

India has made significant strides in geospatial technology, driven by advancements in satellite technology, remote sensing, GIS, and related technologies.

The Indian Space Research Organization (ISRO) has been at the forefront of launching and managing a series of EO satellites, including the Cartosat, Resourcesat, and Radar Imaging Satellite (RISAT) series, which provide high-resolution imagery and data for various applications. India's National Remote Sensing Centre (NRSC) (ISRO 2024) is responsible for data acquisition, processing, and dissemination. Data Products include imagery and products for various applications, including agriculture, forestry, water resources, and urban development.

India's NSDI is managed by the Department of Science and Technology. Part of the NSDI, India recently modernized its National GIS Portal, now called Bharatmaps to create a comprehensive GIS platform at the national level to support governance, development planning, and citizen services. This provides consistent State-Level GIS Portals to promote consistency across the country. In addition, the Government of India has launched platforms like data.gov.in to promote the sharing of geospatial data and other datasets, enhancing transparency, innovation, and research.

National security concerns have influenced regulation of geospatial information and impacted innovation. Introduction of the Geospatial Information Regulation Bill, 2016, placed restrictions on acquisition and dissemination of geospatial information. However, due to opposition to the Bill from the private sector, in 2021 the Government of India published new guidelines with the objective of creating a liberal geospatial data policy. Restrictions on the acquisition and dissemination of geospatial data were removed (Misra and Chacko 2021).

The key issues or trends addressed by India and of relevance to Canada are:

1. Adaption of regulation of geospatial information acquisition, dissemination, publication, and distribution to find a balance between national security concerns and provide the private sector with certainty in working with the regulatory framework.

6.6 SINGAPORE

Singapore is recognized as a leader in adopting and implementing geospatial technologies to enhance urban planning, governance, and public services. Key initiatives include:

- Geospatial Singapore (GeospatialSG) – Singapore's NSDI conceptualized to GeospatialSG, signifying the whole-of-nation approach to collectively maximize the use of geospatial information and technology for Singapore's social and economic development.

- OneMap – Singapore's national map portal, developed by the Singapore Land Authority (SLA), provides a wide range of geospatial data and services, including maps, location-based services, and APIs for developers.
- Smart Nation Initiative (Smart Nation and Digital Government Office 2024) – includes geospatial technologies for smart urban planning, infrastructure management, and service delivery bringing in mobility solutions, smart buildings, and real-time environmental monitoring. Includes various national strategies, e.g. Singapore National AI Strategy and Digital Connectivity Blueprint.
- Geospatial Master Plan (SLA and MPA 2024) – this strategic plan co-driven by the SLA and the Maritime and Port Authority of Singapore guides the development and use of geospatial information and technology in Singapore. The 2024-2033 plan include three strategies: mainstreaming, deepening capabilities, and going global.
- Public-Private Partnerships – Singapore has stimulated collaboration between the government, academia, and private sector to drive innovation in geospatial technologies. This includes joint projects, research initiatives, and technology development.
- Capacity Building and Training – efforts to build capacity in geospatial technologies through training programs, workshops, and academic courses offered by institutions like the Singapore University of Technology and Design and the National University of Singapore. These efforts aim to provide the skills and knowledge required.

The key issues or trends addressed by Singapore and of relevance to Canada are:

1. Establishing a long-term Geospatial Strategy based on geospatial technology trends and opportunities, involving key government agencies, private sector, and research institutions;
2. Importance of capacity building and training across government agencies and the private sector; and
3. Opportunities for Public-Private Partnerships.

6.7 ARCTIC COUNTRIES

NMAs from Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden, and the United States, along with partners and affiliates developed the Arctic SDI. A Strategic Plan (2020-2025) (Arctic SDI 2020) and associated Roadmap and Implementation Plan were developed, but status is unclear due to lack of public information on activity.

7.0 POTENTIAL AREAS OF ACTION FOR CGDI

This section summarizes potential actions to address the key issues identified in the PESTEL analysis, and the key opportunities and challenges presented by the technological trends. These actions are provided from the perspective of Hatfield, contracted to develop this report, noting that these perspectives are informed by Hatfield's 30 years of activity providing geospatial services in Canada and internationally. Formal recommendations related to the UN IGIF should be developed collaboratively as part of whole-of-community strategy development.

This analysis is presented in alignment with the nine strategic pathways of IGIF to inform actions and strategy development for the CGDI. The premise is that by addressing the issues, collaborative efforts can strengthen and mature the CGDI in the face of rapid technological change. In doing so, there are also opportunities for the CGDI to adapt to emerging technology trends and further benefit CGDI producers and users.

The key opportunities are generally aligned with the fundamental elements of the future geospatial information ecosystem identified for each IGIF strategic pathway in the most recent meeting of the Committee of Experts on Global Geospatial Information Management (Fourteenth session New York, 7–9 August 2024) (UN-GGIM 2024).

In addition, the opportunities are also aligned with the **2023–2026 Data Strategy for the Federal Public Service** (Government of Canada 2024), which is organized into four mission areas focused on concrete, achievable and high-impact opportunities:

1. Proactively considering **data by design** in all stages of government initiatives;
2. Effectively stewarding **data for decision-making;**
3. Improving user experience and maintaining trust by **enabling data-driven services** through data that flows securely where it is needed; and
4. **Empowering the public service** with the talent and tools it needs

The following sub-sections provide details of the potential areas of action identified from the perspective of Hatfield. A summary of these potential areas of action and their alignment with the IGIF strategic pathways provided in Table 2.

Table 2: Potential action areas for CGDI in relation to IGIF strategic pathways.

Opportunity (see Sections 7.1 to 7.9 below for details)	Governance & Institutions	Policy & Legal	Financial	Data	Innovation	Standards	Partnerships	Communication & engagement
Collaborative development of a "Future CGDI" strategy	■	□	□	□	□	□	■	□
Indigenous reconciliation and inclusivity	■						■	□
Leadership on open science and open data	□	■		■		□	□	
Leadership on data governance	■	□		■			□	
Leadership on analysis ready data (ARD)				■	□		□	
Address legal and regulatory issues that can impact innovation		■		□	□	□		
Digital Earth Canada & Geo.ca – development and use of geospatial platforms	□			■	□	□	□	
Leadership on adoption of standards and interoperability				□		■	□	
Capacity and skills development across CGDI stakeholders	□						■	■
Communication on flagship activities and innovative use cases				□			□	■

Key:

□ Opportunity relevant to IGIF strategic pathway

■ Opportunity highly relevant to IGIF strategic pathway

7.1 GOVERNANCE AND INSTITUTIONS

This strategic pathway establishes the leadership, governance model, institutional arrangements, and a clear value proposition to strengthen multi-disciplinary and multisectoral participation in, and a commitment to, achieving the UN-IGIF.

The objective is to build a community consensus on institutional mandates and build a cooperative data sharing environment through a shared vision and understanding of the value of the CGDI and the roles and responsibilities to achieve the vision.

Issues/risks Canada needs to address under the governance and institutions pathway:

- **Evolution of SDIs and role of NMAs:** the role of NMAs and SDIs is changing, as recognized by the UN-IGIF process. The evolution of NMAs is driven by technological advancements, increasing demand for geospatial services, regulatory frameworks, strategic partnerships, data interoperability, advanced analytics, and societal impact (Geospatial World 2024). While these factors can enhance the capabilities of NMAs, they are challenging and require strategic responses.

- **Uncertainty around CGDI governance:** the respective roles of CCMEO, GeoConnections, CCOG, and GNBC are unclear to many CGDI users outside of key federal and provincial departments/agencies.
- **Lack of a public strategic plan:** engaging stakeholders in the CGDI requires a strategic plan with clear goals and objectives, which is developed with inputs from all CGDI stakeholders.
- **Varying background of stakeholders:** the CGDI necessarily needs to support stakeholders with varying resources and capacity in geospatial technologies, which requires careful consideration of service development and delivery.

Key opportunities in the context of the issues related to the governance and institutions pathway are:

- **Collaborative development of a "Future CGDI" strategy**: Federal/provincial/territorial mapping agencies can lead the development of a strategy as a means of consensus-building among partners and stakeholders. This strategy could guide the development and direction of the CGDI and its evolution into a geospatial information ecosystem. This strategy could contribute to the effective stewardship of **data for decision-making** under the 2023–2026 Data Strategy for the Federal Public Service.
- **Indigenous reconciliation and inclusivity**: Governments can foster opportunities for Indigenous organizations and under-represented groups to engage, influence, and participate in and benefit from the CGDI.

7.2 POLICY AND LEGAL

This strategic pathway establishes a robust policy and legal framework that is essential for instituting effective, efficient, and secure management and exchange of geospatial information - nationally and sub-nationally.

The objective is to improve the policies and laws associated with, and having an impact on, geospatial information management. This requires keeping abreast of issues arising from the evolving, innovative, and creative use of geospatial information and emerging technologies.

Issues/risks Canada needs to address under the policy and legal pathway are:

- **Open science:** data sharing is greatly supported by the Federal Open Government Licence - Canada (Government of Canada 2022) and similar Provincial/Territorial licences, e.g. BC Open Government Licence (Government of British Columbia 2024), but policy and legal restrictions apply to Radarsat and RCM data due to the RSSSA and its regulations. Canadian licensing of RCM and RADARSAT-2 data have greatly impacted the availability and utility of Canadian EO data resources. In particular, the requirement of the RCM data policy to restrict data to 'vetted users' is a significant impediment to data interoperability, data fusion, and data collaboration.
- **Ethics related to use of AI and social media data**: developing policies, regulations and laws that ensure the ethical use of data and AI in geospatial information management is challenging and requires international cooperation.

Key opportunities in the context of the issues related to the policy and legal pathway are:

- **Leadership on open science and open data**: Cross-government engagement to align key SDI related activities with "open science", where open science is characterized by "openness, transparency, scrutiny and traceability of results, access to large volume of complex data, and the availability of community open tools" (ESA 2024). Digital Earth Canada is a good example opportunity, for example enabling access to open EO data and ARD.
- **Leadership on data governance**: Governments to continue to advance frameworks and roles for the management, use, and sharing of geospatial data, including with Indigenous organizations in relation to OCAP™ and CARE. Effective data governance policy and legal frameworks help to maintain trust, an opportunity under the 2023–2026 Data Strategy for the Federal Public Service.

7.3 FINANCIAL

This strategic pathway establishes the business model, develops financial partnerships, and identifies the investment needs and means of financing for delivering the UN-IGIF, as well as recognizing the milestones that will achieve and maintain momentum to realize benefits.

The objective is to achieve an understanding of the financial plans required to establish and maintain the UN-IGIF, as well as the longer-term investment program that enables government to respond to evolving societal, environmental, and economic demands for geospatial data.

Issues/risks Canada needs to address under the financial pathway are:

- **Sustainable funding model challenge**: the effective evolution of the CGDI requires long-term strategies, which require continuous financial support. For example, Australia or the EU's long-term commitments to big geospatial data platforms.
- **Investment required in innovative technologies:** given the rapid pace of technological change, financial incentives may be needed to encourage investments in new and emerging technologies that enhance the geospatial ecosystem.
- **Participation of the Canadian private sector in the future CGDI**: many advances in geospatial technologies are dominated by international big technology firms, including cloud computing, AI, IoT, and remote sensing. Mechanisms to support and stimulate the Canadian private sector are required, particularly SMEs.

Opportunities in the context of the issues related to the financial pathway are:

- **Collaborative development of a "Future CGDI" strategy**: the needed strategy should include financial strategy. In the context of government spending/budget constraints, there is an opportunity to identify geospatial technologies and the CGDI as key cross-cutting technologies related to innovation in AI and IoT, as well as critical services to Canadians to address climate change and disaster response and risk reduction. Improved and coordination of efforts among the federal departments/agencies and provinces/territories can maximize efficiency of investments in

geospatial data collection and management. Implementation of a strategy would empower the public service aligned with the 2023–2026 Data Strategy for the Federal Public Service.

7.4 DATA

This strategic pathway establishes a geospatial data framework and custodianship guidelines for best practice collection and management of integrated geospatial information that is appropriate to cross sector and multidisciplinary collaboration.

The objective is to enable data custodians to meet their data management, sharing and reuse obligations to government and the user community through the execution of well-defined data supply chains for organizing, planning, acquiring, analyzing, integrating, aggregating, curating, publishing and archiving geospatial information.

Issues/risks Canada needs to address under the data pathway are:

- **Open data**: Canadian government policy is to make geospatial data widely and freely available and accessible to all users. However, there is a need to address restrictions for Radarsat, RCM, and other remote sensing data due to the RSSSA and its regulations.
- **Data integration and management**: Integrating data from various sources and managing it effectively to provide comprehensive and accurate information.

Opportunities in the context of the issues related to the data pathway are:

- **Leadership on open science and open data**. Examples of recent leadership include GeoAI (NRCan 2024a) and National Elevation Data Strategy (NRCan 2024b).
- **Leadership on analysis ready data (ARD)**: Example is the ARD specification for Canadian synthetic aperture radar (SAR) data (Short et al. 2019) following the Committee on Earth Observation Satellites (CEOS) Analysis Ready Data for Land (CARD4L) initiative. The ARD SAR collection is available for federal government users within the Earth Observation Data Management System (EODMS). Development of ARD contributes to Effectively stewarding **data for decision-making** under the 2023–2026 Data Strategy for the Federal Public Service.

7.5 INNOVATION

This strategic pathway recognizes that innovation has the potential to stimulate, trigger and respond to rapid change, leapfrog outdated technologies and processes, and to bridge the geospatial digital divide. Technology is continually evolving, creating new opportunities for innovation and creativity.

The objective is to leverage the latest cost-effective technologies, innovations and process improvements so that governments, businesses and academia, no matter their current situation, may leapfrog to modern geospatial information management systems and practices.

Issues/risks Canada needs to address under the innovation pathway are:

- **Emerging technologies integration**: it is important for the CGDI to embrace new technologies and to evolve towards a geospatial information ecosystem. However, adapting to rapid

technological change is an issue for all levels of government, but essential to maintain the ecosystem's relevance and effectiveness.

Opportunities in the context of the issues related to the innovation pathway are:

1. **Collaborative development of a "Future CGDI" strategy:** Federal/provincial/territorial governments can lead the development of a geospatial strategy, engaging external CGDI partners and stakeholders, and ensure linkages to government innovation and policy priorities and further promote inter-agency and federal / provincial collaboration. A transformational innovation strategy requires the synchronization of priorities, systems, and processes.

2. **Address legal and regulatory issues that can impact innovation**: Examples are the reform of the RSSSA and providing guidance around privacy and ethics for use of AI in geospatial initiatives.

3. **Digital Earth Canada & Geo.ca**: **Big data analytics tools for innovation in predictive analytics** champion key use cases, e.g. Public Health Agency of Canada disease modelling, next generation of the Canadian Forest Fire Behavior Prediction (FBP) System.

7.6 STANDARDS

This strategic pathway establishes and ensures the adoption of best practice standards and compliance mechanisms for enabling data and technology interoperability to deliver integrated geospatial information and location-based knowledge creation.

The objective is to enable an efficient and consistent approach for different information systems to be able to discover, manage, communicate, exchange and apply geospatial information for a multitude of uses, improved understanding and decision-making.

Issues/risks Canada needs to address under the standards pathway are:

- **Interoperable protocols**: Establishing standards that ensure data can be easily shared and used across different systems and platforms. The current Canadian ecosystem of big EO data analytics platforms is heterogeneous and there has been a lack of coordination and standards between platforms.

- **FAIR and CARE data principles**: while generally supported by all levels of government in Canada, adopting and implementing policies and standards that make data widely available, accessible, and applicable is challenging and requires resources.

Opportunities in the context of the issues related to the standards pathway are:

- **Leadership on adoption of standards and interoperability:** CCMEO can play a role on standards, licencing, and interoperability, particularly the use of OGC API Standards for SDI modernization.

- **Digital Earth Canada & Geo.ca:** standards play a critical role in enabling users to find, analyze and interpret large volumes of EO data. Digital Earth Canada is intended to address issues and adopt standards for data and interoperability. Digital Earth Canada presents and opportunity to

allow EO datasets in remote disparate data centers to be analyzed together. There is an opportunity for Canada to lead in this area by researching and providing common open tools to allow scalable, performant distributed EO data processing capability to take place. An example activity using the OGC EO Application Package and OGC API – Processes was completed by OGC, NRCan and CRIM (OGC 2021a; OGC 2021b).

The OGC API family of standards enables organizations to provide interoperable geospatial data via the web. This may aid in more effective discovery and distribution of geospatial information. They are built on RESTful principles, which make them more modular, scalable, and easier to implement than previous OGC standards. The OGC API standards include:

1. OGC API - Features: This standard provides access to collections of geospatial data, known as 'features'. It allows users to query and retrieve feature data in various formats.
2. OGC API - Maps: This standard provides a way to create, change, and query maps.
3. OGC API - Tiles: This standard provides access to pre-rendered geospatial data tiles, which can be used to build up a map or scene.
4. OGC API - Coverages: This standard provides access to 'coverage' data, such as satellite imagery or digital elevation models, which cover a particular geographic area.
5. OGC API - Processes: This standard provides a way to run geospatial processes on a server, allowing users to perform complex analyses without needing to download and process the data locally.

7.7 PARTNERSHIPS

This strategic pathway establishes cross-sector and interdisciplinary cooperation, coordination and collaboration with all levels of government, the geospatial industry, private sector, academia, and the international community, as an important premise to developing and sustaining an enduring nationally integrated geospatial information framework.

The objective is to create and sustain the value of geospatial information through a culture based on inclusion, trusted partnerships and strategic alliances that recognize common needs, aspirations and goals, towards achieving national priorities and outcomes.

Issues/risks Canada needs to address related to the partnerships pathway are:

- **Multi-stakeholder collaboration**: Engaging a diverse range of stakeholders is required to advance the ecosystem in Canada, otherwise there is a risk of duplication of effort, redundancy, and lack of impact.
- **Public-private partnership**: Forming partnerships between public institutions and private companies is required to drive innovation and investment, which challenges existing business models and approaches.

Opportunities in the context of the issues related to the partnerships pathway are:

- **Collaborative development of a "Future CGDI" strategy**: the development of the needed strategy is an opportunity to build partnerships. As noted under the governance strategic pathway, partner with Indigenous organizations is required to foster inclusion and reconciliation.
- **Digital Earth Canada & Geo.ca:** while some Canadian EO data analytics platforms bring together either academia and government, or academia and private enterprises, bringing all three actors (government, industry, and academia) is challenging. Innovation and collaboration can be supported through funding mechanisms related to Digital Earth Canada or initiatives such as CSA smartEarth. Further developments leveraging GEO.ca can also stimulate partnerships between CCMEO and other government departments/agencies.

7.8 EDUCATION AND CAPACITY

This strategic pathway establishes enduring capacity development and education programs so that the value and benefits of integrated geospatial information management is sustained for the longer term.

The objective is to raise awareness, build and strengthen knowledge, competencies, skills, instincts, processes, resources, and innovative entrepreneurship that organizations, communities and individuals require to utilize geospatial information for evidence based decision-making and effective service delivery.

Issues/risks Canada needs to address related to the education and capacity pathway are:

- **Professional training**: Providing education, training, and continuing professional development that enhances competency of geospatial professionals to address new technological developments. Fostering continuous learning and development of new competencies and skills to keep pace with technological advancements.
- **Developing talent within the public service:** to lead on the development of a future CGDI, governments needs to attract, retain, and develop talent to develop policies, applications, and systems, often competing with the private sector.

Opportunities in the context of the issues related to the education and capacity pathway are:

- **Capacity and skills development across CGDI stakeholders**. CCMEO works with partners to develop geospatial capacity and skills needs across government agencies and other stakeholders to effectively collect, manage, and use geospatial data, particularly those involving big geospatial data and accessing and exploiting data via web services. Capacity building can contribute to proactively considering **data by design** in all stages of government initiatives, aligned with the 2023–2026 Data Strategy for the Federal Public Service.
- **Digital Earth Canada & Geo.ca:** Digital Earth Canada is a shift towards cloud-based data science, which will require a large capacity building and support component but represents a unifying initiative for education and capacity building.

7.9 COMMUNICATION AND AWARENESS

This strategic pathway recognizes that stakeholder identification, user engagement and strategic communication are essential to successfully deliver UN-IGIF arrangements nationally and sub-nationally for sustainable social, economic and environmental development.

The objective is to ensure effective communication and engagement to enhance and deepen participation and contributions from all stakeholders and at all levels. Commitment, mutual understanding, cooperation and communication are essential among organizations and stakeholders.

Issues/risks Canada needs to address related to the innovation communication and awareness pathway are:

- **Strategic communication**: Implementing communication strategies that raise awareness of the ecosystem's value and benefits.
- **Stakeholder engagement**: Actively involving stakeholders in the ecosystem's development and activities.

Opportunities in the context of the issues related to the communication and awareness pathway are:

- **Collaborative development of a "Future CGDI" strategy**: the development of the needed strategy is opportunity for communication and engagement with stakeholders.
- **Communication on flagship activities and innovative use cases**: communication on geospatial initiatives can be consistently linked to the overall geospatial strategy. For example, powerful communications on Radarsat+, Digital Earth Canada, GeoAI, and Geo.ca can be linked to their contribution to Canada's SDI.

8.0 CONCLUSION

The objective of this environmental scan is to review key literature to identify trends in geospatial technologies, identify emerging issues and opportunities for the CGDI, and future strategies for integrating geospatial technology trends into the CGDI. The outputs of the scan are also intended to support NRCan/CCMEO's planning, in collaboration with federal/provincial/territorial partners, informed by the nine strategic pathways of the UN IGIF.

The literature search conducted by Hatfield identifies numerous key trends in geospatial technologies relevant to Canada and the CGDI. The major themes explored are integration of IoT with geospatial technology, advances in remote sensing technology, geospatial big data and cloud computing, AI and machine learning in geospatial analysis, digital twins, Indigenous data sovereignty, and improved connectivity.

External macro-environmental factors affect the collection, management, and use of geospatial data by government agencies, particularly the rapid pace of technological, social, environmental, and economic change. To identify and assess these external factors, the scan includes a PESTEL analysis to identify the most influential issues for the CGDI and geospatial sectors. In the near/medium term, the highest impact and priority issues were related to the social, technological, and legal themes.

The experience of other countries, in the context of similar external factors and technology trends, can be informative for Canada's strategic action plan. The scan includes a review of experience in the United Kingdom, Australia and New Zealand, USA, Europe, India, Singapore, and Arctic countries related to the Arctic SDI. Common themes across several countries include the importance of a public geospatial strategy, an advisory committee that includes representatives of non-Federal interested parties involved in national geospatial activities, which includes the private sector, long term commitment in areas such as capacity building and training, and public-private partnership business models.

Finally, Hatfield identifies potential actions to address the key issues identified in the PESTEL analysis and the key opportunities and challenges presented by the technological trends. These actions are aligned with the nine strategic pathways of UN-IGIF to inform collaborative CGDI actions and whole-of-community strategy development. This scan provides one of several expected inputs to the process.

9.0 REFERENCES

ANZLIC. 2020. ANZLIC Strategic Plan 2020-24. [accessed 2024 Jul 8]. https://www.anzlic.gov.au/sites/default/files/files/ANZLIC%20Strategic%20Plan%202020-24_3.pdf.

Arctic SDI. 2020. Arctic SDI Strategic Plan 2020 – 2025. [accessed 2024 Sep 17]. https://arctic-sdi.org/.

Australian Space Agency. 2019. Australian Civil Space Strategy 2019–2028. [accessed 2024 Jul 8]. https://www.industry.gov.au/publications/australian-civil-space-strategy-2019-2028.

AWS. 2021. Canada's Federal Geospatial Platform supports decision-making using AWS. [accessed 2024 Nov 20]. https://aws.amazon.com/blogs/publicsector/canadas-federal-geospatial-platform-supports-decision-making-using-aws/.

AWS. 2024. Registry of Open Data on AWS: RADARSAT-1. [accessed 2024 Jul 31]. https://registry.opendata.aws/radarsat-1/.

Branch LS. 2007a. Remote Sensing Space Systems Act (RSSSA). [accessed 2020 Dec 10]. https://laws-lois.justice.gc.ca/eng/acts/R-5.4/.

Branch LS. 2007b. Remote Sensing Space Systems Regulations. [accessed 2020 Dec 17]. https://laws-lois.justice.gc.ca/eng/regulations/SOR-2007-66/page-1.html.

Canadian Space Agency. 2019a. Open data: over 36,000 historical RADARSAT-1 satellite images of the Earth now available to the public. [accessed 2024 Jul 31]. https://www.canada.ca/en/space-agency/news/2019/03/open-data-over-36000-historical-radarsat-1-satellite-images-of-the-earth-now-available-to-the-public.html.

Canadian Space Agency. 2019b. RADARSAT Constellation Mission Synthetic Aperture Radar Data Policy. https://www.asc-csa.gc.ca/pdf/eng/publications/rcm-sar-data-policy.pdf.

Canadian Space Agency. 2020. Earth Observation Service Continuity Harmonized User Needs Document. Rev E, September 11, 2020.

Canadian Space Agency. 2022. Resourceful, resilient, ready: Canada's strategy for satellite earth observation. Saint-Hubert, QC: Canadian Space Agency.

Canadian Space Agency. 2023. RADARSAT+: over $1 billion for the future of satellite Earth observation. [accessed 2024 Jul 31]. https://www.asc-csa.gc.ca/eng/news/articles/2023/2023-10-18-radarsat-plus-over-1-billion-dollars-for-the-future-satellite-earth-observation.asp.

CCMEO. 2024a. GEO.ca. [accessed 2024 Aug 16]. https://geo.ca/home/.

CCMEO. 2024b. The Canadian Radiological Monitoring Network. geo.ca. [accessed 2024 Sep 17]. https://geo.ca/science/the-canadian-radiological-monitoring-network/.

Coetzee S, Gould M, McCormack B, Mohamed-Ghouse Z, Scott G, Kmoch A, Alameh N, Strobl J, Wytzisk A, Devarajan T. 2021. Towards a Sustainable Geospatial Ecosystem beyond SDIs 1. EUROGI: Druento, Italy.:1–33.

CRCSI. 2018. Digital Earth Australia funded under Australia Technology and Science Growth Plan. https://www.crcsi.com.au/news/dea-2018-budget-funding/.

ESA. 2024. Open Science. [accessed 2024 Jul 8]. https://www.esa.int/About_Us/Digital_Agenda/Open_Science.

EUROGI. 2021. Towards a sustainable geospatial ecosystem beyond SDI. [accessed 2024 Jul 31]. https://ggim.un.org/meetings/GGIM-committee/11th-Session/.

European Commission. 2015. Legal notice on the use of Copernicus Sentinel Data and Service Information. [accessed 2024 Jul 31]. https://sentinel.esa.int/documents/247904/690755/Sentinel_Data_Legal_Notice.

European Commission. 2022. Commission welcomes a new service to better access and exploit the EU's Copernicus satellites data. [accessed 2024 Jul 8]. https://ec.europa.eu/commission/presscorner/detail/en/ip_22_7374.

European Commission. 2024a. Common European Data Spaces. https://digital-strategy.ec.europa.eu/en/policies/data-spaces.

European Commission. 2024b. European data strategy. [accessed 2024 Jul 8]. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-data-strategy_en.

FGDC. 2020. National Spatial Data Infrastructure Strategic Plan 2021-2024. [accessed 2024 Jul 8]. https://www.fgdc.gov/nsdi-plan/nsdi-strategic-plan-2021-2024.pdf.

FGDC. 2024. NDSI Strategic Plan. [accessed 2024 Jun 9 and 2025 Feb 18]. https://www.fgdc.gov/nsdi-plan.

GeoConnections. 2012. Canadian Geospatial Data Infrastructure vision, mission and roadmap - The way forward. Report No.: 28e. [accessed 2024 Aug 22]. https://ostrnrcan-dostrncan.canada.ca/handle/1845/159054.

Geoscience Australia. 2017. Australian Geoscience Data Cube innovation recognised on world stage. https://www.ga.gov.au/news-events/news/latest-news-archive/australian-geoscience-data-cube-innovation-recognised-on-world-stage.

Geoscience Australia. 2024. Digital Earth Australia recognised for excellence. The DEA Open Data Cube receives Outstanding Digital Platform of the Year. [accessed 2024 Jul 8]. https://www.ga.gov.au/scientific-topics/dea/news/digital-earth-australia-recognised-for-excellence.

Geospatial Commission. 2023. UK Geospatial Strategy 2030: Unlocking the power of location. [accessed 2024 Jul 31]. https://assets.publishing.service.gov.uk/media/6489b1fb103ca6000c039ea2/2023-06-15_UK_Geospatial_Strategy_2023_.pdf.

Geospatial World. 2021. The Power of Where: A Geospatial Knowledge Infrastructure to Enhance the World Economy, Society and Environment, jointly organized by Geospatial World, United Nations Statistic Division and Strategic Partners. [accessed 2024 Jul 31]. https://geospatialmedia.net/pdf/GKI-White-Paper.pdf.

Geospatial World. 2024. Evolving Role of National Mapping Agencies: Transitioning to Geospatial Knowledge Infrastructure. [accessed 2024 Aug 28]. https://www.geospatialworld.net/consulting/reports/evolving-role-of-national-mapping-agencies/2024/pdf/evolving-role-of-national-mapping-agencies-new.pdf.

Global Indigenous Data Alliance. 2024. CARE Principles for Indigenous Data Governance. [accessed 2024 Aug 29]. https://www.gida-global.org/care.

Google. 2024. Earth Engine for Noncommercial and Research Use. [accessed 2024 Jun 8]. https://earthengine.google.com/noncommercial/#certain-government-agencies.

Government of British Columbia. 2024. Open Government Licence - British Columbia. [accessed 2024 Aug 21]. https://www2.gov.bc.ca/gov/content/data/policy-standards/open-data/open-government-licence-bc.

Government of Canada. 2014. Directive on Open Government. [accessed 2024 Aug 21]. https://www.tbs-sct.canada.ca/pol/doc-eng.aspx?id=28108.

Government of Canada. 2017. Standard on Geospatial Data. [accessed 2024 Sep 17]. https://www.tbs-sct.canada.ca/pol/doc-eng.aspx?id=16553.

Government of Canada. 2021. United Nations Declaration on the Rights of Indigenous Peoples Act. [accessed 2024 Nov 20]. https://laws-lois.justice.gc.ca/eng/acts/u-2.2/page-1.html.

Government of Canada. 2022. Open Government Licence - Canada. [accessed 2024 Aug 21]. https://open.canada.ca/en/open-government-licence-canada.

Government of Canada. 2024. 2023–2026 Data Strategy for the Federal Public Service. [accessed 2024 Aug 16]. https://www.canada.ca/en/treasury-board-secretariat/corporate/reports/2023-2026-data-strategy.html.

Hackett J, Olson R. 2019. Dissemination of open geospatial data under the Open Government Licence-Canada through OCAP principles. Report No.: 57e. [accessed 2024 Aug 12]. https://ostrnrcan-dostrncan.canada.ca/handle/1845/144005.

Hatfield Consultants. 2019. Canadian Geospatial Data Infrastructure (CGDI) user needs assessments. Report No.: 55e. [accessed 2020 Mar 17]. https://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/fulle.web&search1=R=314606.

Howells R, Gibbons Paul L. 2024. How Twins Are Driving the Future of Business. [accessed 2024 Jul 31]. https://www.sap.com/canada/insights/viewpoints/how-digital-twins-are-driving-the-future-of-business.html.

IBM. 2024. What is a digital twin? [accessed 2024 Aug 28]. https://www.ibm.com/topics/what-is-a-digital-twin.

ICSM. 2019. ICSM Strategic Framework 2019-2024. [accessed 2024 Jul 8]. https://www.icsm.gov.au/about/strategic-plan.

ISRO. 2024. Government of India National Remote Sensing Centre. [accessed 2024 Sep 17]. https://www.nrsc.gov.in/.

Jansen, Rebecca. 2021. Scientometric Study on Digital Twins. [accessed 2024 Jul 31]. https://publications.gc.ca/collections/collection_2021/cnrc-nrc/NR16-367-2021-eng.pdf.

Marr B. 2023. IoT and smart device trends: What you need to know for the future. Forbes. [accessed 2024 Nov 20]. https://www.forbes.com/sites/bernardmarr/2023/10/19/2024-iot-and-smart-device-trends-what-you-need-to-know-for-the-future/.

Microsoft. 2024a. What is edge computing? [accessed 2024 Aug 28]. https://azure.microsoft.com/en-ca/resources/cloud-computing-dictionary/what-is-edge-computing.

Microsoft. 2024b. What is a Data Lake? [accessed 2024 Sep 17]. https://azure.microsoft.com/en-ca/resources/cloud-computing-dictionary/what-is-a-data-lake.

Microsoft. 2024c. Azure Digital Twins. [accessed 2024 Jul 31]. https://azure.microsoft.com/en-us/products/digital-twins.

Misra A, Chacko M. 2021. Key Changes Announced In The Regulation Of Geospatial Data & Data Services. Mondaq. [accessed 2024 Sep 17]. https://www.mondaq.com/india/fiscal-monetary-policy/1124090/key-changes-announced-in-the-regulation-of-geospatial-data-data-services.

NASA. 2023. Earthdata Cloud Evolution. [accessed 2024 Jul 8]. https://www.earthdata.nasa.gov/eosdis/cloud-evolution.

NRCan. 2024a. Revolutionizing emergency preparedness with on-demand mapping. [accessed 2024 Jul 31]. https://natural-resources.canada.ca/simply-science/revolutionizing-emergency-preparedness-on-demand-mapping/26092.

NRCan. 2024b. National Elevation Data Strategy. [accessed 2024 Jun 8]. https://natural-resources.canada.ca/maps-tools-and-publications/satellite-imagery-elevation-data-and-air-photos/national-elevation-data-strategy/24977.

OGC. 2021a. OGC Earth Observation Applications Pilot: CRIM Engineering Report. [accessed 2020 Dec 15]. http://docs.opengeospatial.org/per/20-045.html.

OGC. 2021b. OGC Best Practice for Earth Observation Application Package. Report No.: 20-089r1. https://docs.ogc.org/bp/20-089r1.html#toc0.

OGC. 2024. OGC Urban Digital Twins Interoperability Pilot. [accessed 2024 Jun 8]. https://www.ogc.org/initiatives/ogc-urban-digital-twin-interoperability/.

Policy Horizons Canada. 2019. The Next Digital Economy. [accessed 2024 Aug 22]. https://horizons.service.canada.ca/en/2019/06/20/the-next-digital-economy/index.shtml.

Schwab K. 2015. The fourth industrial revolution. What it means and how to respond/Schwab Klaus. Foreign Affairs, December. 12.

Short NH, Charbonneau F, Peiman R, DeAbreu R. 2019. Analysis ready data specification for Canadian SAR data. Report No.: 51. [accessed 2024 Sep 11]. https://ostrnrcan-dostrncan.canada.ca/handle/1845/143885.

SLA, MPA. 2024. Singapore Geospatial Master Plan 2024-2033. [accessed 2024 Sep 17]. https://file.go.gov.sg/singapore-geospatial-master-plan-2024.pdf.

Smart Nation and Digital Government Office. 2024. Smart Nation Signapore. [accessed 2027 Sep 17]. https://www.smartnation.gov.sg/.

Telesat, LEO. Telesat Completes $2.54 Billion Funding Agreements for Telesat Lightspeed Satellite Constellation with Strong Government Backing. [accessed 2024 Oct 4]. https://www.telesat.com/press/press-releases/telesat-completes-2-54-billion-funding-agreements-for-telesat-lightspeed-satellite-constellation-with-strong-government-backing/.

UN-GGIM. 2020. Future trends in geospatial information management: the five to ten year vision – Third Edition, August 2020. Academic Press.

UN-GGIM. 2022. Future Geospatial Information Ecosystem: From SDI to SoS and on to the Geoverse. Making the Step Change Using the Integrated Geospatial Information Framework. Discussion Paper.

UN-GGIM. 2024. The future geospatial information ecosystem: Note by the Secretariat. Committee of Experts on Global Geospatial Information Management Fourteenth session. New York, 7–9 August 2024. https://ggim.un.org/meetings/GGIM-committee/14th-Session/documents/E-C.20-2024-8-Add_1-Future_Geospatial_Information_Ecosystem_05Jul2024.pdf.

up42, GeoAwesome. 2024. Earth Observation Hub Report: 2024 Industry Trends and Analysis. [accessed 2024 Aug 29]. https://geoawesome.com/the-earth-observation-hub-report-2024-industry-trends-and-analysis/.

Wulder M, Masek J, Cohen W, Loveland T, Woodcock C. 2012. Opening the archive: How free data has enabled the science and monitoring promise of Landsat. Remote Sensing of Environment. 122:2–10. doi:10.1016/j.rse.2012.01.010.

Wulder MA, Roy DP, Radeloff VC, Loveland TR, Anderson MC, Johnson DM, Healey S, Zhu Z, Scambos TA, Pahlevan N. 2022. Fifty years of Landsat science and impacts. Remote Sensing of Environment. 280:113195.

10.0 ANNEX A – INTERNET SEARCH TERMS

Arctic SDI initiative
Big tech firms and geospatial data
Canadian data privacy legislation
Data and metadata standards adopted by the government of Canada
Digital Earth Canada initiative
EU GDPR
Indigenous reconciliation in Canada and data and mapping
Internet connectivity investments in Canada
OGC API standards
OGC innovation projects involving Canada
OGC testbed projects involving Canada
Open data policies in Canada
Open Government Licence - Canada
PIPEDA and geospatial data
Spatial Data Infrastructure and 3D mapping
Spatial Data Infrastructure and AI or machine learning
Spatial Data Infrastructure and big data analytics
Spatial Data Infrastructure and cloud computing
Spatial Data Infrastructure and data privacy and security
Spatial Data Infrastructure and Digital twins
Spatial Data Infrastructure and drones
Spatial Data Infrastructure and Internet of things
Spatial Data Infrastructure and Interoperability
Spatial Data Infrastructure and Realtime data analysis
Spatial Data Infrastructure and satellites
Spatial Data Infrastructure business models
Trends in satellite remote sensing technology
UN Integrated Geospatial Information Framework
USA / UK / Europe / Australia / India / Singapore and UN IGIF