

Evaluation of CANARIE

Final Report

July 2014



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Executive Summary

Introduction and Background

In order for Canada to continue to produce world-class research, to innovate ground-breaking technologies, and to remain connected to some of the planet's leading edge scientific developments, the nation requires access to the necessary digital infrastructure. To that end, Nordicity and Bytown Consulting have been engaged to evaluate the extent to which CANARIE, Inc. (CANARIE) is helping Canada attain those goals.

Based on CANARIE's records and primary research data obtained between March and May 2014 (via a series of interviews and an online survey), the project team evaluated CANARIE in light of five key issue areas typical to reviews of federally funded programs and organizations:

- Achievement of Expected Outcomes: the extent to which CANARIE is meeting the goals outlined in its contribution agreement (e.g., regarding network operations, technology innovation and private sector innovation);
- Relevance and Continued Need: the extent to which CANARIE remains helpful for current users and will continue to be a critical resource as users' needs evolve in the future;
- Alignment with Government Priorities: the extent to which CANARIE remains aligned with specific directions outlined by Canada's federal government (e.g., Digital Canada 150, the Federal Budget 2014, and the 2007 Science and Technology [S&T] Strategy);
- Alignment with Federal Roles and Responsibilities: the degree to which CANARIE is a necessary and critical function for the federal government to provide;
- Demonstration of Efficiency and Economy: the extent to which CANARIE has been efficiently operating and managing the CANARIE Network, contributing to technology innovation and leveraging the Network to assist firms and Canadian universities to advance innovation and commercialization of products and services.

Summary of Findings

Based on the five above key issues areas, the findings of the project team can be summarized as follows:

Achievement of Expected Outcomes

CANARIE has met – or is in the process of meeting – its stated objectives:

- During the five-year evaluation period (i.e., April 1, 2010 to present), CANARIE has made significant progress against its objectives for evolving and extending the network and its services, leading the development of research software tools, and stimulating ICT innovation and commercialization.
- CANARIE continued to build on previous mandate successes by further developing high speed backbone connectivity across the country, reaching out with its Optical Regional Advanced Network (ORAN) partners to some 1,965 connected institutions.

- The CANARIE Network serves all the provinces and territories of Canada, and during the current mandate, CANARIE's completion of a dedicated ultra-high speed (100G, or 100 billion bits per second) network from coast to coast, from Victoria to Halifax, is on schedule.
- CANARIE traffic has increased by 385 percent during the five-year evaluation period, and users have indicated that CANARIE has provided reliable and sufficient capacity to meet their evolving needs, especially but not exclusively in applications involving very large datasets.
- CANARIE continues to be an essential component of Canada's digital infrastructure and is deemed by those consulted in academia and industry to be fundamental to research and education, and to achieving a successful innovation eco-system by facilitating collaboration and data transfers between researchers and educators, in Canada and across the globe, and by making digital content readily accessible.
- CANARIE is well-recognized by its peers in other countries as being one of the leading advanced networks in the world. CANARIE works closely with its international National Research and Education Network (NREN) peers in advancing the state of the art in high speed networking across the globe.

Relevance and Continued Need

CANARIE is highly relevant to users, and will continue to remain so in the coming years, including in the following ways:

- Data-intensive research activities are highly dependent on the CANARIE Network to transmit large volumes of data globally in a reliable, efficient and secure manner across a broad spectrum of academic disciplines including the natural, health, and social sciences; engineering; and the humanities.
- Services such as those of the Canadian Access Federation (CAF) and the Content Delivery Service (CDS) allow educators to provide access to a wide range of resources and content with minimal administrative and financial burden.
- The need for CANARIE programs and services will grow over the next three years, as researchers, educators and entrepreneurs engage in activities that require the collection and transmission of increasingly large volumes of data.
- The discontinuation of CANARIE programs and services would have a highly negative impact on users, as well as Canada's ability to maintain leadership in research and development.
- There will be an increased need for CANARIE programs and services to facilitate research and education both with international partners and within Canada.
- Digital Accelerator for Innovation and Research (DAIR) program users predict an increase in the use of that program, with particular interest paid to the use of cloud computing tools.

Alignment with Government Priorities

CANARIE and its programs and services both directly and indirectly support the objectives of several relevant policy documents. For example:

- CANARIE supports the objectives of Digital Canada 150 (DC 150), particularly the creation of “economic opportunities” and “connecting Canadians” – two key pillars of the plan – in the following ways:
 - By providing cloud infrastructure to Canadian entrepreneurs and emerging businesses, CANARIE’s DAIR program directly aligns with the creation of “economic opportunities,” and
 - By connecting research institutions (and researchers) across Canada CANARIE has contributed to “connecting Canadians,” and also has helped to address the “Open Science” element of DC 150.
- CANARIE contributes to the goals of the 2014 Federal Budget, by promoting “research excellence” and acting in parallel to planned investments to be made through the Canada First Research Excellence Fund (CFREF), in particular through its support of post-secondary institutions and facilitation of Canada’s participation in world-leading research projects (e.g., the ATLAS Experiment).
- CANARIE has led to the development of new knowledge, attracted (and retained) highly qualified persons, and led to the commercialization of new products and services – thereby directly contributing to three pillars of Canada’s S&T strategy.

Alignment with Federal Roles and Responsibilities

CANARIE provides, and likely will continue to provide, a service that Canadian researchers and entrepreneurs need – one that cannot readily be provided by the private sector. To that end:

- Stakeholders and users of CANARIE mostly agree that CANARIE provides programs and network services that are appropriate for federal government support and aligned with its roles and responsibilities – ensuring that Canadian researchers and educators from coast to coast have an accessible and reliable leading edge, advanced high-speed network available to them.
- Without CANARIE, research institutions would have to form some other organized effort to enable collaboration, communication and access to Canadian and international research – likely at greater expense than the cost of CANARIE.
- If institutions were forced to pursue private sector solutions, the costs incurred would likely render many research activities cost-prohibitive.
- Helping SMEs grow via programs like DAIR is generally supported by the research community as a legitimate mission for CANARIE.
- Vice Presidents of Research at academic institutions, researchers, partner ORANs, and incubators/accelerators all have a clear understanding of the purpose and role of CANARIE, though that understanding seems somewhat less clear among Chief Information Officers (CIOs) of academic institutions.

Demonstration of Efficiency and Economy

As in its previous mandate, CANARIE is living within its means and delivering its programs efficiently:

- CANARIE is well-focused on its mandate and related initiatives and funds are distributed proportionately and sufficiently commensurate with expected outcomes.
- For the duration of its current mandate, from April 1, 2012 to March 31, 2015, CANARIE is forecast to have achieved cost-recovery of \$11.4 million, just \$0.3 million shy of its \$11.7 million cost-recovery target.
- With its ORAN partners, CANARIE has leveraged its network and services efficiently, assisting Research and Education (R&E) institutions and the private sector to innovate and commercialize products and services, while realizing cost-savings for users and participants in its programs.
- CANARIE has demonstrated best practices in managing and operating the network. These include its co-delivery model with the ORANs, regularly analyzing key performance metrics, delivering a best-effort service, scalable and flexible network operations (garnering low legacy costs when upgrades are needed), and operating a hybrid system to serve the needs of large and small users.

1. Introduction

In August 2012, the Government of Canada announced a three-year, \$62 million investment in CANARIE Inc. (CANARIE), the organization responsible for advancing Canada's knowledge and innovation infrastructure. As part of the resulting Contribution Agreement, CANARIE was required to establish a performance measurement system within one year. In consultation with Industry Canada, CANARIE developed a Performance, Audit and Evaluation Strategy (PAES), intended to guide the measurement and evaluation of CANARIE's overall performance.

This report presents an evaluation of CANARIE, primarily guided by the objectives outlined in the Contribution Agreement, the expected outcomes presented in the PAES, and Treasury Board Secretariat (TBS) evaluation policies and guidelines.

1.1 Objectives and Scope of the Evaluation

The objective of this report is to present an accurate, evidence-based evaluation of CANARIE's effectiveness in achieving program objectives and expected outcomes, as well as the continued need for and relevance of CANARIE, its alignment with government priorities and with federal roles and responsibilities, and the efficiency and economy of its programs and services.

The scope of this evaluation encompasses the following periods:

- April 1 2010 to March 31 2012, which involved the evaluation of programs against the objectives of CANARIE's previous mandate and covers the period of time not included in the previous evaluation of the CANARIE program; and
- April 1 2012 to the present, which involved the evaluation of programs against CANARIE's new mandate.

1.2 CANARIE Objectives and Program Profile

CANARIE's core purpose is to ensure the advancement of Canada's knowledge and innovation infrastructure, with a mission to design and deliver digital infrastructure, and drive its adoption among Canada's research, education and innovation communities.

The Contribution Agreement between CANARIE and Industry Canada sets out the following objectives for CANARIE over the course of the current mandate:

- **Network Operations:** To continue to operate the CANARIE Network as an essential research infrastructure;
- **Technology Innovation:** To develop, demonstrate, and implement next-generation technologies to advance the CANARIE Network as a leading-edge research network;
- **Private Sector Innovation:** To leverage the CANARIE Network to assist firms operating in Canada and Canadian universities to advance innovation and commercialization of products and services to bolster Canada's technology innovation capabilities; and,

- **Management and Administration of the Agreement:** To manage and administer the Agreement for supporting and delivering projects selected by CANARIE to deliver and manage the CANARIE Network, to support technology innovation, and to stimulate private sector innovation.

Achievement of the above objectives is pursued through CANARIE's provision of a wide range of programs and services. The following CANARIE programs are included as part of the current mandate and this evaluation:

- **Research Middleware Program:** Subsequent to completing its mandate for 2007-12, CANARIE moved forward with a program supporting the development of research software. As part of this program, CANARIE funds the development of Research Platform Interfaces (RPIs), reusable software components that can be reused in any research software platform, and Network-Enabled Platforms (NEPs), complete research software platforms that include RPIs.
- **Network Alliance Programs:** Network Alliance Programs benefit regional high-speed networks (ORANs) that have partnered with CANARIE to provide integrated services. The Network Alliance Programs encompass support for the ORANs through the Network Alliance Development (NAD) and Network Alliance Infrastructure (NAI) funding streams. NAD supports the operations of network partners, while NAI assists in the maintenance and expansion of high quality infrastructure and capacity. The NAD program was phased out in the 2014-15 fiscal year.
- **Legacy Programs:** The legacy programs are extensions of support through programs introduced in previous mandates, including the Lightpaths and Infrastructure Extension programs.

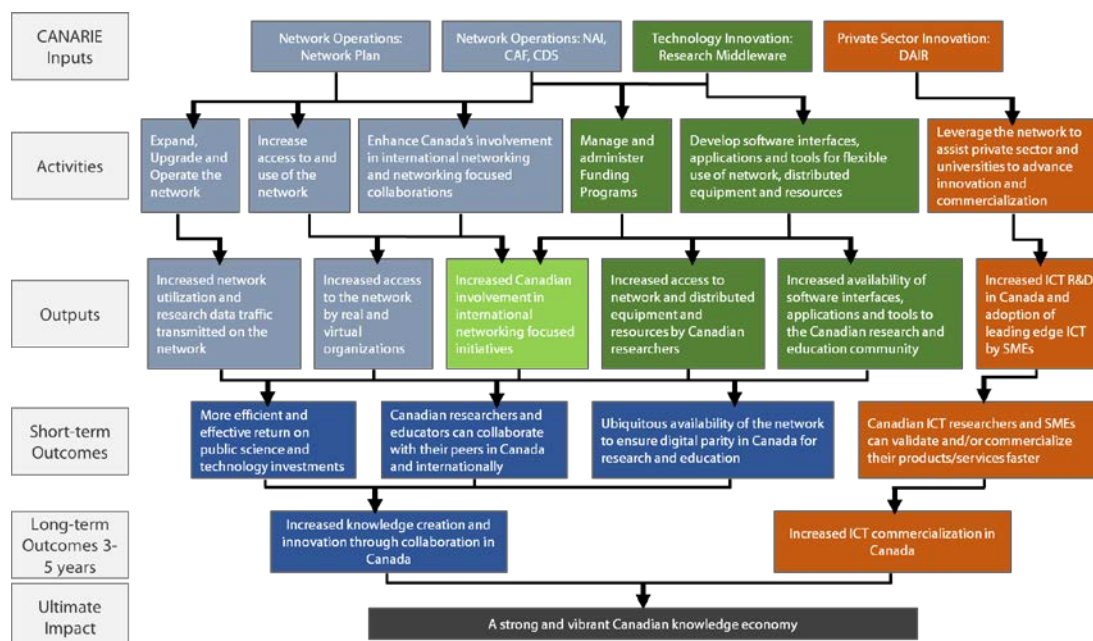
CANARIE also provides a range of services to support researchers, educators and entrepreneurs, including:

- **Canadian Access Federation (CAF):** CAF provides members with access to eduroam, (a service that provides students, staff and faculty with access to wireless campus networks they are visiting using only their home credentials) and to federated single sign-on (FSSO). FSSO provides secure remote access to distributed web resources at participating institutions.
- **Content Delivery Service (CDS):** This newly-launched program provides access to Internet content from approved providers for research and educational institutions. The service is delivered on a dedicated portion of the CANARIE Network and leverages peering relationships with content providers.
- **Digital Accelerator for Innovation and Research (DAIR):** DAIR provides researchers and entrepreneurs with access to free cloud-based computing and storage resources to help them accelerate product commercialization and gain a competitive edge in the global market.

1.2.1 Logic Model

The logic model (below) reflects CANARIE's mandate, as defined in the Industry Canada Contribution Agreement. This chart provides a representation of what can reasonably be expected to result in terms of outcomes from various CANARIE activities. Results of CANARIE activities (i.e., the expected outcomes) will be addressed as part of the evaluation study. Please note that the reference in the Logic Model to "Ubiquitous availability of the network to ensure digital parity in Canada for research and education" was not a specific goal or expected outcome referred to in the CANARIE Contribution Agreement, and therefore is not addressed as such in the evaluation. Instead, and in this respect, the evaluation focuses simply on assessing the extent to which CANARIE has made the network available across Canada.

Exhibit 1.1: CANARIE Logic Model



1.2.2 Program Financing

Funding from Industry Canada accounts for the vast majority of CANARIE revenues, while expenses are spread across network infrastructure and other programs and services. Exhibit 1.2 (next page) presents CANARIE's revenue streams and program spending over the course of the current mandate. As seen below, operating expenses and overhead are below the limit set by the Contribution Agreement (17.4%) in each year of the mandate.

Exhibit 1.2: CANARIE Revenues and Expenditures
PROGRAM REVENUES & EXPENSES
Forecast vs. Budget
April 1, 2012 to March 31, 2015
(in 000's)
Prepared April 2014
For the fiscal years

	2012-13	2013-14	2014-15	2015-16	Total
	<i>Actual</i>	<i>Actual (Draft)</i>	<i>Forecast</i>		
REVENUES					
FUNDING					
Industry Canada Funding	12,600	23,000	26,400		62,000
TOTAL FUNDING	12,600	23,000	26,400		62,000
PROGRAM REVENUES					
Interest Income	30	190	178		398
CAF Participation Fees	133	167	183		483
IEP End User Fees		74	242		316
DAIR User Fees	5	7	5		17
TOTAL PROGRAM REVENUES	168	438	608		1,214
TOTAL REVENUES	12,768	23,438	27,008		63,214
PROGRAM EXPENSES					
Network Infrastructure & Services	5,326	12,243	7,510	838	25,918
Network Alliance Programs	1,232	2,608	4,515	1,624	9,979
Legacy IEP	1,953	1,453	1,268		4,674
NEP-RPI	326	2,267	6,062	467	9,122
DAIR	736	732	817	243	2,528
Future Program Fund	28	152	1,029		1,209
TOTAL PROGRAM EXPENSES	9,601	19,455	21,202	3,171	53,429
Operating Expenses & General Overhead	2,861	3,447	3,477		9,785
TOTAL EXPENSES	12,462	22,902	24,679	3,171	63,214
EXCESS OF REVENUES OVER EXPENSES	306	536	2,330	(3,171)	

Note: Due to rounding, some figures may not sum.

The 2012-2015 funding agreement additionally entailed the exploration and implementation by CANARIE of a cost-recovery strategy. After extensive stakeholder consultation, CANARIE developed and submitted to Industry Canada a business plan outlining a range of cost-recovery initiatives, including cost-sharing with provincial and territorial partners (ORANs) and the collection of user fees for selected services. The plan projected a total cost-recovery of \$11.72 million over the remainder of the mandate and was approved by the Minister of Industry in March 2013.

In reviewing the efficiency and economy of CANARIE operations, this evaluation also presents CANARIE's progress in achieving the goals of this cost-recovery plan.

1.3 Study Approach and Key Issues

The approach adopted in this evaluation began with an identification of the issues and specific indicators based on the CANARIE Contribution Agreement, the elements of the CANARIE Logic Model, and the issues and metrics described in CANARIE's current Performance, Audit and Evaluation Strategy.

The following five key issues were addressed as part of this evaluation, which are typical of evaluations of federally funded programs and organizations:

- Achievement of Expected Outcomes: Has CANARIE effectively achieved its objectives and expected outcomes?
- Continued Need for the Program: Is CANARIE relevant and is there a continued need for the program?
- Alignment with Government Priorities: To what extent has CANARIE contributed to government Science and Technology (S&T) policy priorities and Research and Development (R&D) goals?
- Alignment with Federal Roles and Responsibilities: Does CANARIE play a necessary and legitimate role as a type of program requiring federal government support?
- Demonstration of Efficiency and Economy: How cost-effective has CANARIE Inc. been in operating and managing the CANARIE Network, in contributing to technology innovation and in leveraging the Network to assist firms and Canadian universities to advance innovation and commercialization of products and services?

1.4 Methodology – Multiple Lines of Evidence

The methodology for this program evaluation consisted of a combination of several primary and secondary research approaches designed to mutually reinforce one another when applied to the five key issues identified above. These approaches included a review of documents both obtained through secondary research and provided by CANARIE, an online survey, the examination of a series of case studies, and interviews with key stakeholders and users. Additionally, CANARIE provided the research team with access to a summary of stakeholder consultation findings from the research surrounding the development of CANARIE's 5-year strategic plan (as conducted by Monitor Deloitte). Nearly all findings in this report combine evidence from two or more of these research approaches.

The following table outlines the over 150 stakeholders whose input, in one form or another, has been integrated into this report.

Exhibit 1.3: Overview of Consultations

	Survey Respondents	Evaluation Interviews	Monitor Deloitte Consultations*	Total Represented
University and College Leaders (TOTAL)	14	7	12	33
CIOs	13		9	22
VPRs	1	1	3	5
Funded software developers		3		3
CAF partners		3		3
DAIR users and partners	19	7		26
Researchers and developers	21	2	7	30
CANARIE Network Partner Representatives and International Partners		8	15	23
Industry and Private Sector Partners/Associations		2	13	15
Government departments and agencies (users, researchers, and others)		6	6	12
CANARIE Staff & Management		5		5
Others (research funders and innovation ecosystem partners)			7	7
TOTAL CONSULTED	54	37	60	151

* A summary document of these consultations was provided to the project team.

Notably, of the universities consulted by the research team as part of this study, six are members of the U15 Group of Canadian Research Universities – specifically, the University of Toronto, Dalhousie and the University of Saskatchewan (which responded to the survey), as well as McGill University and the University of British Columbia (which were interviewed), and the University of Manitoba (which was consulted by Monitor Deloitte). As such, through one line of evidence or another, the findings contained in this report include the views of CANARIE-experienced researchers and administrators at some of Canada’s largest research institutions. Having some representation from one-third of the U15 universities in the evaluation study sample is significant, because the U15 undertake 80 percent of all competitive university research in Canada, produce more than 75 percent of all doctorates awarded in Canada, and represent a research enterprise that attracts more than \$5 billion annually.¹

In examining evidence collected from the above-mentioned consultations, combined with a document and file review (i.e., the multiple lines of evidence), the project team observed that this evidence tended to converge on common findings. The remainder of this sub-section outlines how these lines of evidence were approached in more detail.

¹ See www.U15.ca/who-we-are for more information on the U15 Group of Canadian Research Universities.

1.4.1 Document and File Review

Documents provided by CANARIE included previous evaluations and performance audits, annual reports, and customized reports on the CANARIE organization and its role in Canada's science and technology community. CANARIE also supplied copies of reports submitted by funding recipients.

In addition, where relevant, government documents (strategies, budgets, policies) were reviewed to determine CANARIE's alignment with the broader objectives of the Canadian government. In a similar vein, the research team was provided a summary of the findings of stakeholder consultations conducted as part of the development of CANARIE's 5-year strategic plan (2015-2020), henceforth referred to as "mandate renewal stakeholder consultations."

Many of the findings of that strategic study, which was based on extensive consultations with over 100 stakeholders, converge with several findings from this evaluation – especially in the context of feedback in interviews and survey responses concerning achievements of CANARIE. Where there is converging evidence of this kind, it has been pointed out in this report.

Finally, documents relating to other National Research and Education Networks (NRENs) were reviewed in order to ascertain CANARIE's position among its peers on the international research and education stage.

For a complete list of documents reviewed, see Appendix A (Sources).

1.4.2 Primary Data Collection

To supplement the data collected from secondary sources, the research team undertook three mutually supportive primary data collection approaches:

- An online survey,
- A series of stakeholder interviews, and
- An examination of indicative case studies.

The methodologies associated with these approaches are explained below.

Online Survey

The research team worked with CANARIE to administer an online survey. The survey invitation was distributed by CANARIE to a total of 335 contacts, including chief information officers (CIOs) at Canadian universities, vice-presidents of research (VPRs) at Canadian universities, researchers and developers, and small- and medium-sized businesses using DAIR. It should be noted that the survey was only distributed to DAIR users that had one or more years of experience with the DAIR program (at the time of the survey).

The online survey was launched on March 26, 2014 and closed on May 16, 2014.

A total of 54 individuals responded to the online survey. The highest response rate was in the researcher category: 33% of invited researchers completed the survey (Table 1). The DAIR user category also received a high level of responses, with 29% of invited users completing the survey. While only 11% of CIOs responded, those CIOs represent 196,254 full-time and part-time enrolled students (graduates and undergraduates), or 15.4 percent of all enrolled students in the Association

of Universities and Colleges of Canada (AUCC) member institutions; and represent 8,177 faculty members, or 14 percent of all faculty in AUCC member institutions.² As such, while figures containing survey results from CIOs should be treated with some caution, they remain broadly indicative of the overall environment.

However, only one VPR from the 92 invitees responded to the survey. Due to the extremely low response rate in that category, the results were omitted from the analysis included in this report.

A full list of the number of responses collected for each Exhibit derived from survey results is available in Appendix G (Survey Responses by Question).

Exhibit 1.4: Breakdown of Survey Respondents

Stakeholder Group	Number of Respondents	Survey Target List	Response Rate (%)
Chief Information Officers (CIOs)	13	114	11
Vice-Presidents Research (VPRs)	1	92	1
Researchers and developers	21	63	33
DAIR users	19	66	29
TOTAL	54	335	16

While some of the response rates listed in the above table may seem low, it is important to remember that participation in this exercise was completely voluntary—and no incentive was offered to either CIOs or VPRs to participate. Furthermore, not all stakeholders engage directly with CANARIE, so some potential respondents may not have felt adequately informed to participate in the survey. At the same time, two other consultation exercises have recently been undertaken regarding CANARIE: a cost recovery consultation in late 2012-early 2013 and the consultations regarding CANARIE's 5-year strategic plan (consulted by Monitor Deloitte).

The survey questionnaire, developed in close collaboration with CANARIE, inquired about respondents' experiences with and perceptions of CANARIE programs and services, including:

- Current and anticipated future use of the CANARIE Network, and its programs and services;
- CANARIE's sufficiency in meeting current and anticipated future demand;
- Outcomes of CANARIE-supported research, education and innovation activities;
- Projected impact if CANARIE ceased to exist;
- Cost-savings resulting from use of the CANARIE Network, and participation in programs and services; and,
- Role of CANARIE in establishing and maintaining Canada's leadership position in research networking.

² Figures derived from <http://www.aucc.ca/canadian-universities/facts-and-stats/enrolment-by-university/> (assuming a student:faculty ratio of 24:1).

The complete questionnaire is presented in Appendix D (Survey Questionnaire), and the survey results are presented throughout the report.

Interviews

In total, 37 stakeholders were interviewed by phone and in person, including CANARIE staff and management, partner networks, current users, and representatives from Industry, research centres, government departments and international peer networks.

Interviewees for this study were selected by CANARIE, with input from the research team. Some key stakeholders were not included as interviewees for this study as they had already been consulted regarding the development of CANARIE's 5-year strategic plan. As mentioned above, some of the results of that consultation process have been incorporated into this document.

The breakdown of interviewees according to stakeholder groups was presented in Exhibit 1.3.

The interviews were designed to corroborate and complement the findings of the online survey and document review. Each stakeholder group was asked a different set of questions, addressing evaluation issues most relevant to their relationship with CANARIE.

The interview questionnaires are presented in Appendix E (Interview Questionnaire), while a list of those interviewed can be found in Appendix F (List of Interviewees).

Case Studies

Four case studies were completed as part of the evaluation, in an effort to take a closer look at the evaluation issues through specific examples. The following is a list of case studies completed:

- TRIUMF;
- Project Whitecard;
- Metafor Software; and,
- The Canadian Brain Imaging Research Network (CBRAIN)/Global Brain Imaging Research Network (GBRAIN).

The outcomes and findings of these case studies are presented in Appendix B (Case Studies). The case studies were developed primarily through interviews, supplemented with a review of relevant websites and documentation (e.g., funding reports obtained from CANARIE).

1.4.3 International Peer Organizations/Networks

In order to provide some comparative perspectives on CANARIE operations, several international partners and peer networks were examined as a part of this evaluation. In addition to two interviews, which were conducted with representatives from Internet2 and the International Center for Advanced Internet Research (ICAIR), document reviews provided additional details on international research-based networks, including:

- AARNet (Australia),
- SURFnet (Netherlands),
- Janet (UK),

- REANNZ (New Zealand),
- NORDUnet (Scandinavia), and
- ESnet (US).

Examination of NRENs included a review of publicly available information on their respective official websites, other online information about the initiatives and activities of these organizations, and a review of the *TERENA Compendium of National Research and Education Networks*, 2013 Edition (www.terena.org/compendium). The review of the *TERENA Compendium* in particular was an important source of information to help the evaluation team to identify CANARIE best practices. This *Compendium* has grown over the more than ten years since its inception and has become a recognized authoritative reference source for researchers and organizations that are interested in the development of research and education networking.

1.5 Steering Committee

As part of the approach to evaluating CANARIE's programs and services, CANARIE appointed a Steering Committee to review and provide feedback on the findings presented in this report by Nordicity and Bytown. The Steering Committee was composed of 11 members, representing research and funding bodies, universities, international research networks and government.

The Committee approved the evaluation work plan, as well as the final evaluation findings presented in this report.

A complete list of Steering Committee members is presented in Appendix C (Steering Committee).

1.6 Organization of the Report

The remainder of this report addresses each of the five key issues outlined in Section 1.3. In turn, each of those sections begins with a summary of the conclusions made regarding a given key issue area, followed by a more in-depth assessment of CANARIE performance in each area.

2. Achievement of Expected Outcomes

CANARIE's objectives are achieved through the organization's three main initiative areas: network operations, technology innovation (research software program), and private sector innovation (DAIR).

Success of CANARIE is assessed to the extent that it has achieved its intended objectives and obtained its expected outcomes. To that end, this section of the report concludes that:

- During the five-year evaluation period (i.e., April 1, 2010 to present), CANARIE has made significant progress against its objectives for evolving and extending the Network and its services, leading the development of research software tools, and stimulating ICT innovation and commercialization.
- CANARIE continued to build on previous mandate successes by further developing high speed backbone connectivity across the country, reaching out with its ORAN partners to some 1,965 connected institutions.
- The CANARIE Network serves all the provinces and territories of Canada, and during the current mandate, CANARIE's completion of a dedicated ultra-high speed (100G, or 100 billion bits per second) network from coast to coast, from Victoria to Halifax, is on schedule.
- CANARIE traffic has increased by 385 percent during the five-year evaluation period, and users have indicated that CANARIE has provided reliable and sufficient capacity to meet their evolving needs, especially but not exclusively in applications involving very large datasets.
- CANARIE continues to be an essential component of Canada's digital infrastructure and is deemed by those consulted in academia and industry to be fundamental to research and education, and to achieving a successful innovation eco-system by facilitating collaboration and data transfers between researchers and educators, in Canada and across the globe, and by making digital content readily accessible.
- CANARIE is well-recognized by its peers in other countries as being one of the leading advanced networks in the world. CANARIE works well with its international NREN peers in advancing the state of the art in high speed networking across the globe.

The programs that enable CANARIE to achieve its objectives were described in Section 1.2. They include the Research Software Program, the Network Alliance Program, the Legacy Programs, and DAIR. These programs help CANARIE to expand the reach and capacity of the Network and to foster technology innovations in the Canadian research and academic community and the private sector, and to enable ease of access to research data and tools.

2.1 Network Operations

Evaluation Issue: To what extent has CANARIE achieved its current objective and related expected outcomes for operating the CANARIE Network as an essential research infrastructure?

CANARIE's achievements in operating Canada's advanced national research and education network can be assessed in terms of how it has grown and improved the Network, and how it has positioned itself as an essential component of Canada's digital R&D infrastructure.

Converging Evidence on Network Operations from the Mandate Renewal Stakeholder Consultations

A parallel consultation to the evaluation of the CANARIE program was undertaken on behalf of CANARIE by Monitor Deloitte. This initiative involved consultations with over 100 internal and external stakeholders – consisting of individuals and focus groups including researchers, university leaders, private sector partners, industry groups, federal and provincial governments, and national and international partners and peers. The purpose of the consultation was to develop the framework for CANARIE's next mandate.

CANARIE's achievements with respect to "Network Operations", according to the results of this consultation, are as follows:

- Built a reliable, high-speed optical network.
- Infrastructure has extensive geographic reach to connect researchers nationally and globally.
- Delivered network support and maintenance for over 20 years.
- Committed to continual infrastructure upgrades to adapt to emerging trends.
- Provided specialized networking services directly to some research organizations at no cost when needed.

The mandate renewal stakeholder consultations also reported on international perceptions of CANARIE, making the following observations on the organization:

- Highly talented staff with strong technical skills.
- Well respected in the international community.
- Effective operators of a state-of-the-art national network.
- Early adopter of emerging trends.
- Innovative programs tailored to serve R&E needs.
- Proactive at establishing international connections to support global collaborations.

All the above findings converge with the findings of this evaluation, as discussed below.

2.1.1 Growth of the Network

Growth of the Network is measured in terms of the extent of its reach, traffic increases, accessibility, and the capacity at which it is able to provide services.

CANARIE's Reach

CANARIE is mandated to provide a dedicated very high speed, high bandwidth network for researchers and educators across the country. Exhibit 2.1 demonstrates the extent of its reach and the success it has had in achieving this reach during the past two decades or more of its existence. Based on the information in Exhibit 2.1, altogether in 2014 CANARIE is accessible by some 1,965 research and education organizations across Canada. CANARIE enables these organizations to connect to each

other and to other organizations across the world with high capacity for data transfers at very high speeds.

Exhibit 2.1: Reach of CANARIE through its Regional ORAN Partners

CANARIE & ORAN	Institutions connected 2014	CANARIE & ORAN	Institutions connected 2014
British Columbia through BCNET	62 K-12 school districts	Alberta through Cybera	604 K-12 schools/19 school boards
	47 Colleges and universities		17 Colleges and universities
	14 Federal labs and cultural institutions		1 Federal lab
	13 Provincial health institutions		1 Consortium
	2 Consortia		3 Provincial institutions
Saskatchewan through SRNet	2 Municipal institutions (libraries)	Manitoba through MRnet	4 Industry connections
			1 Municipal institution (library)
	16 Colleges and universities		596 K-12 Schools/38 school boards
	9 Federal departments and labs		12 Colleges and universities
	13 Consortia		5 Federal labs
Ontario through ORION	7 Provincial labs and health centres	Quebec through RISQ	2 Consortia
	3 Industry connections		1 Provincial health centre
	2 Research parks		2 Industry connections
			1 Research park
	22 K-12 school boards		72 CÉGEPs and universities
New Brunswick through Univ. of New Brunswick	48 Colleges and universities	Nova Scotia through ACORN-NS	16 Federal institutions
	14 Federal institutions		1 Consortium
	3 Consortia		9 Provincial institutions
	19 Provincial institutions		2 Industry connections
	4 Industry connections		
Prince Edward Island through Univ. of PEI	1 Municipal (library)	Newfoundland & Labrador through ACORN-NL	33 Colleges and universities
	8 K-12 school districts		5 Federal institutions
	25 Colleges and universities		2 Industry connections
	3 Federal institutions		15 Provincial institutions, including Dept. of Education (K-12 schools)
	1 Provincial institution		4 Colleges and universities
Northwest Territories through Aurora College	15 Colleges and universities	Yukon through Yukon College	1 Consortium
	1 Federal institution		1 Federal institution
	1 Department of Education (K-12 schools)		2 Provincial connections
			2 K-12 schools
	57 K-12 schools		31 K-12 schools 2)
	32 Colleges		13 Colleges
	22 Provincial institutions		40 Provincial institutions

Source: As reported on CANARIE's official website at www.canarie.ca/en/network/connected_institutions.

CANARIE is accessible to K-12 schools, colleges and universities, laboratories, health institutions, private and public sector consortia, libraries, and federal and provincial public establishments. CANARIE was started in 1993 and many of these institutions came on board during past mandates. Nonetheless, during the five-year evaluation period of this study, CANARIE has become more accessible, particularly to private industry connections and consortia, and to the education sector, research centres and parks, libraries, and cultural institutions.

Generally, based on interviewee and survey responses, the success of CANARIE working with its ORAN partners in reaching all potential users varies across provinces. Larger regions and provinces are typically very well served, while smaller regions and provinces tend to lag behind their larger counterparts. This discrepancy is perhaps because smaller and more remote areas require more resources. Reaching that last mile of connection is sometimes not possible or too expensive. There is a continuing need to work on getting that final link between more remote institutions to connect with the CANARIE backbone.

In terms of the DAIR program, CANARIE recently signed a Memorandum of Understanding (MOU) to partner with the Association of University Research Parks (AURP) Canada, a consortium of 26 Canadian research parks. Though this MOU does not represent a network extension agreement (it only provides for DAIR-related services), through this partnership AURP Canada will provide a white-label offering of CANARIE's DAIR program to strengthen commercialization opportunities for the nearly 1,400 knowledge-based businesses located in research and technology parks. Free basic access to cloud-based compute, network and storage resources for small businesses will be accessible to the members of AURP's 26 research parks, to develop, test, prototype and demonstrate next-generation products.³

Furthermore, at least one interviewee felt that CANARIE should extend its reach in terms of DAIR-related services (distinct from its network services per se) to work more closely with local level organizations in Canada, such as Invest Ottawa, that have technology innovation and commercialization initiatives underway. The DAIR program is one of CANARIE's initiatives that is most relevant for this kind of outreach. It should be noted, however, that CANARIE has indeed a growing list of existing relationships with local Canadian technology incubators and accelerators, including the City of Fredericton's goFrednetwork, Startup Calgary, TEC Edmonton, Accelerator YYC, and the ICT Association of Manitoba (ICTAM). DAIR is also being deployed in support of colleges' applied research initiatives. Algonquin College, New Brunswick Community College, Centennial College, George Brown College, Humber College, and Red River College are the first among several colleges that are taking advantage of DAIR's free, state-of-the-art cloud resources to support applied research alliances between colleges and local business.

Increase in Traffic

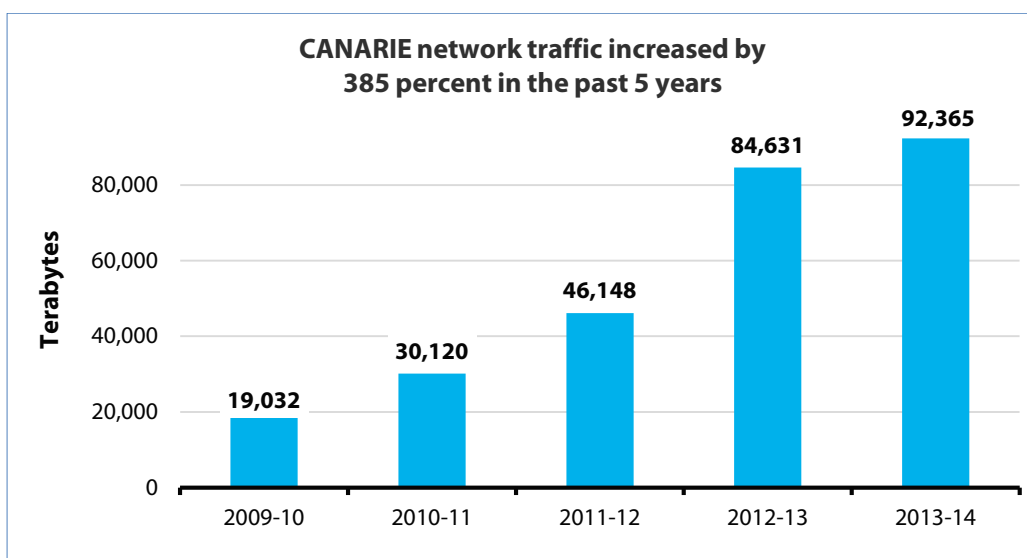
A further testament to CANARIE's growth is the increase in network traffic over the evaluation period. During the past five years CANARIE traffic has grown by 385 percent. According to CANARIE traffic reports, this averages to approximately 77 percent growth a year from 2009-10 to 2013-14. The key informants interviewed for this study and the survey respondents mostly agree that the demand for high speed transmission of data is growing exponentially for scientific and engineering research projects and for the development of new innovative technology applications. So it is not surprising to see this kind of rise in CANARIE traffic statistics. The growth trend in Exhibit 2.2 shows a particular

³ Two initiatives contemplated under the MOU between AURP and CANARIE involve addressing the technology innovation objective of CANARIE. The first is to develop a search engine to link data between the 26 member parks of the AURP, and the second is an Internet Protocol cataloguing system which AURP wishes to pursue.

surge by an additional 38,483 terabytes, during 2011-12 to 2012-13, but the increases in other years are also very significant.

The growth in traffic during the past five years is evidence of CANARIE's ability to serve the research and innovation community, offering unfettered speed and capacity that accelerates discovery and enables rapid sharing of critical data and toolsets.

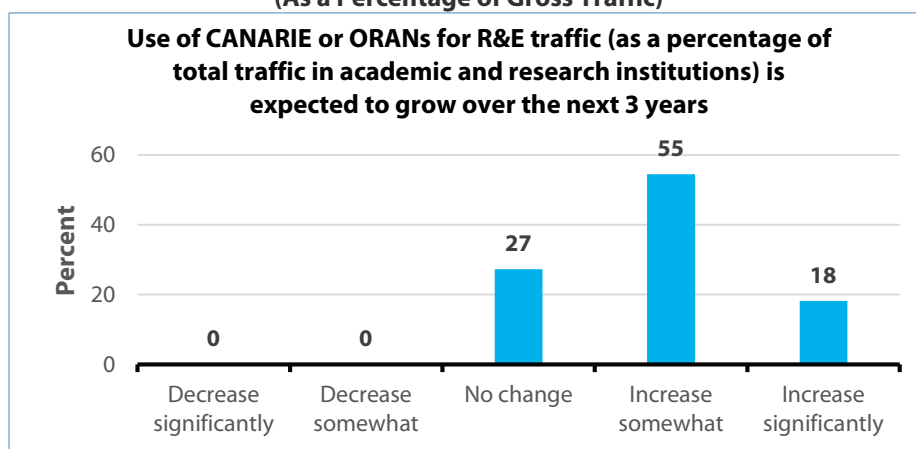
Exhibit 2.2: CANARIE Network Traffic – Terabytes (2009-10 to 2013-14)



Source: CANARIE quarterly traffic reports.

The CIOs who responded to the CANARIE 2014 Survey estimated that on average 56 percent of their institutions' total research and education traffic (as a percentage of monthly gross traffic) is carried by the CANARIE Network or by regional ORANs. This level of traffic is an absolute increase of 10 percent of gross traffic identified by the previous CANARIE users' survey (March 2011), conducted for the previous *Evaluation of CANARIE – June 2011*. In addition, 73 percent of CIO survey respondents estimated that this growth of CANARIE usage as a percentage of gross traffic will increase during the next three years (Exhibit 2.3).

**Exhibit 2.3: CIOs Expectations of CANARIE Traffic Increases for Research and Education
(As a Percentage of Gross Traffic)**



Source: CANARIE 2014 Survey.

Note: Responding CIOs in the survey represent 196,254 full-time and part-time enrolled students (graduates and undergraduates), or 15.4 percent of all enrolled students in AUCC member institutions, and represent 8,177 faculty members, or 14 percent of all faculty in AUCC member institutions.

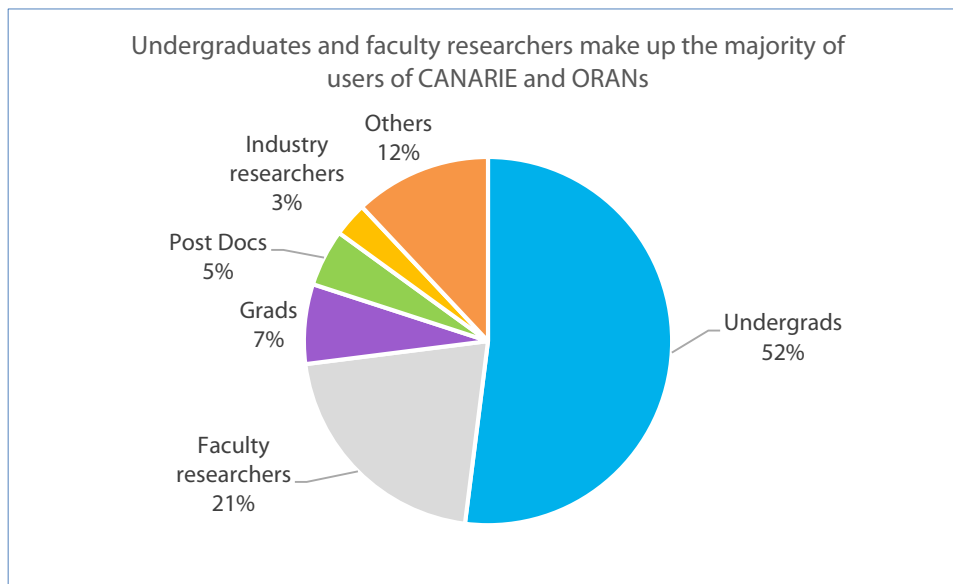
Feedback from interviewees and survey respondents indicates that R&E users are satisfied that CANARIE has been well able to meet the rise in demand for its services, and they mostly agree that CANARIE is well-positioned to meet further increases in future traffic demand. At the same time, some do caution that CANARIE will be chasing an exponential growth in demand, so new capacity additions must be continuous.

Access and Capacity

Based on the results of the CANARIE 2014 Survey, and according to CIO respondents, an average of 93 percent of university populations (including students and faculty) currently have access to CANARIE and the ORANs. This figure ranges from a low of 30 percent reported for one institution to a more common high of 100 percent of students.

Exhibit 2.4 shows that the largest group of users are undergraduate students. Undergraduate users account for approximately 52 percent of all users in the responding institutions. Faculty and Post Doctorate students account for 26 percent and graduate students 7 percent. A relatively smaller proportion of users as reported by CIOs are industry researchers. The explanation for the high usage of CANARIE and ORAN connectivity by undergraduates is largely due to their access to various online services including educational content (e.g., via the Content Delivery Service), to innovative learning management systems (including, for example, access to online testing and lecture materials), Internet based research, distance learning programs, CAF services (eduroam and FSSO), and day-to-day communications.

Exhibit 2.4: Users of CANARIE and ORAN Networks

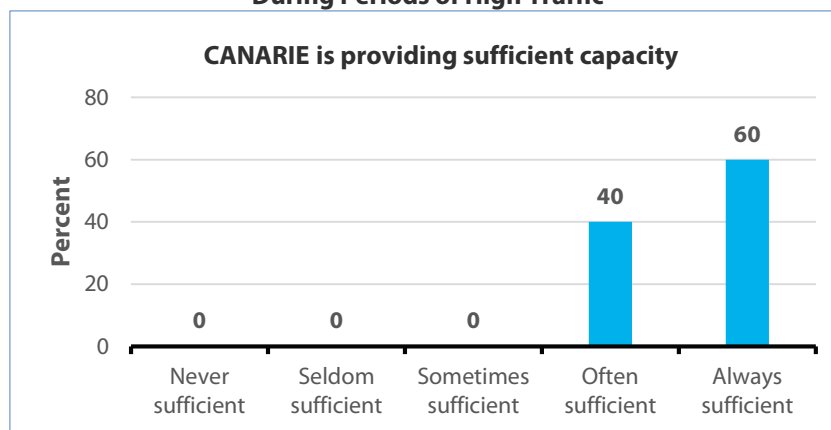


Source: CANARIE 2014 Survey.

Note: Responding CIOs in the survey represent 196,254 full-time and part-time enrolled students (graduates and undergraduates), or 15.4 percent of all enrolled students in AUCC member institutions, and represent 8,177 faculty members, or 14 percent of all faculty in AUCC member institutions.

Interviewees and survey respondents generally agree that CANARIE has provided sufficient capacity during the five year evaluation period of this study. Exhibit 2.5 provides the responses of CIOs to the capacity question, particularly during periods of high traffic. In addition, Exhibit 2.6 provides the expectations of CIOs that CANARIE can continue to fulfill network and related services into its next mandate. The expectations regarding fulfillment of future requirements, as shown in Exhibit 2.6, are a little more conservative than actual performance shows in Exhibit 2.5. This difference is mostly due to the uncertainties that several interviewees have expressed regarding government commitment to ongoing and stable support for CANARIE as an essential component of Canada's digital infrastructure, rather than being a comment on CANARIE's delivery of their services. Almost all interviewees agree that CANARIE has excelled in delivering its mandate and achieving expected outcomes with regards to network operations.

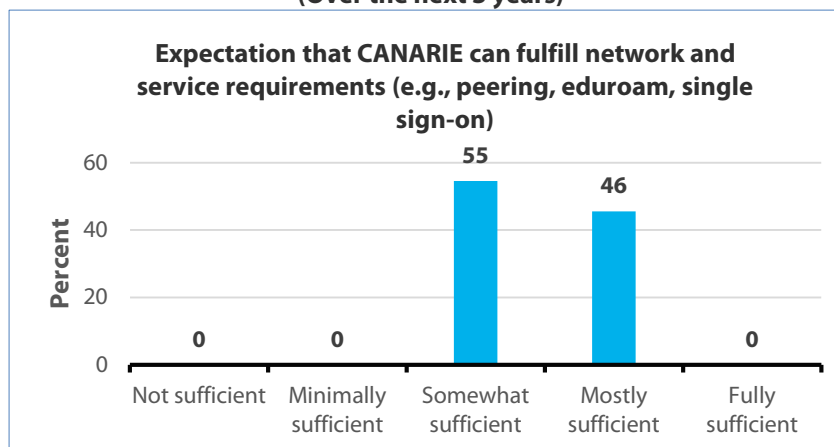
Exhibit 2.5: CIOs Assessment of CANARIE's Capacity During Periods of High Traffic



Source: CANARIE 2014 Survey.

Note: Responding CIOs in the survey represent 196,254 full-time and part-time enrolled students (graduates and undergraduates), or 15.4 percent of all enrolled students in AUCC member institutions, and represent 8,177 faculty members, or 14 percent of all faculty in AUCC member institutions.

Exhibit 2.6: Expectation that CANARIE Can Fulfill Future Requirements (Over the next 3 years)



Source: CANARIE 2014 Survey.

Note: Responding CIOs in the survey represent 196,254 full-time and part-time enrolled students (graduates and undergraduates), or 15.4 percent of all enrolled students in AUCC member institutions, and represent 8,177 faculty members, or 14 percent of all faculty in AUCC member institutions.

2.1.2 Improvement of the Network

During the five-year period of evaluation, CANARIE has made significant progress against its objectives for evolving and extending the Network and its services, leading the development of research software tools, and stimulating ICT innovation and commercialization.

Extending the Network and its Services

CANARIE has continued to invest in the core network, completing the conversion from leased circuits to higher capacity CANARIE-managed fibre for the segments between Thunder Bay and Winnipeg, and between Rimouski and Halifax.

CANARIE also continued to supply connectivity to the North. This was achieved by extending its network over satellite. Over the period, satellite support for this initiative migrated from the Canadian Space Agency to Telesat, with no interruption to service to the North during that transition. CANARIE is also working with authorities of the Northwest Territories' government, assessing the feasibility for developing a Mackenzie Valley Fibre project to link Inuvik to CANARIE's fibre in Edmonton, Alberta.

During its current mandate, CANARIE launched the Network Alliance Infrastructure program to facilitate the co-delivery approach it has with the ORANs. This program helps cover partial operational costs borne by the ORANs to support their role in providing regional network services. Cost-sharing between CANARIE and the ORANs is a new approach introduced in this program and one that was successfully implemented (see Section 6 on economy and efficiency of CANARIE for more details). Twenty-seven NAI upgrade initiatives with the ORANs were initiated during the evaluation period covered by this study, of which eight have been completed as of March 2014, and the balance are in completion phases or in progress. These upgrade projects typically range from increasing reliability and resiliency of regional networks, to improving or installing new optical switching gear, to extending network branching and services, to increasing capacity.

In addition to NAI, CANARIE introduced and continues to deliver the Legacy Infrastructure Extension Program as a follow-up program to the Infrastructure Extension Program (IEP) of the previous CANARIE mandate. IEP has extended the Network by bringing online and connecting additional research institutions. During the current mandate, under the legacy program, CANARIE continues to review the use of these connections for optimum cost-recovery.

During the evaluation period, the CAF, a service operated by CANARIE to streamline identity management in Canada, increased in membership. Participation grew steadily from 38 participants in April 2012, when CANARIE took over the program, to 103 participating colleges and universities in all Canadian provinces – a growth of 171 percent in just 3 years. Ongoing growth in CAF is being supported by reducing the barriers to adoption of the key technology to support identity management, and by partnerships between CANARIE and some fourteen service and content providers in Canada.

CAF provides three services to students, staff and faculty at participating Canadian institutions as they travel throughout Canada and all over the world. Eduroam, or "education roaming," provides roaming wireless network access to enable users to authenticate using the same credentials as they would at their home institution or office at affiliated institutions. Likewise, other institution members in Canada and all over the world can access the eduroam service using their home institution credentials.

According to CANARIE, the eduroam service within CAF has skyrocketed, with 3 million logins to the service in March 2014.

Federated single sign-on (FSSO) is another CAF service added during the evaluation period which provides integrated access to protected, distributed web-based resources at participating institutions and allows students, educators and researchers to access many remote resources and services over the Internet using a web browser. With FSSO, the user is granted access to a remote application based on verification of their credentials at their home institution. The biggest advantage of FSSO is that users can now access numerous resources and services across the country with a single sign-on – i.e., they need only login once to access a myriad of applications.

The third service added for CANARIE users via CAF is eduGAIN. This service gives Canadian users a “digital passport” which enables them to access a wide range of content and applications at eduGAIN’s participating global institutions. Similarly, member institutions of eduGAIN can offer their users an opportunity to access the resources of CAF’s participating institutions across Canada.

Interviewees have completely endorsed CANARIE’s initiative in getting CAF up and running, and in providing the services described above. Researchers, faculty, CIOs and VPRs have all given high marks to CANARIE with respect to their CAF initiative and services. This level of agreement is confirmation that these improvements of CANARIE services via the CAF initiative strengthens Canadians’ prospects for global collaboration and opens up new opportunities for innovation and discovery.

In February 2012, CANARIE added a CDS, to provide Research and Education (R&E) institutions with faster access to Internet-based content, like learning-delivery systems and cloud-computing services. The CDS is enabled through settlement-free peering, in which organizations choose to make their Internet content available at no charge. Among the content providers participating in CDS are Amazon.com, Facebook, Google, Limelight, Microsoft, and Yahoo! In all there are ten content providers participating in CANARIE’s CDS. Such peering enables users of CANARIE to not only have superior access for collaboration amongst their community, but also provides users with superior access to public domain information in support of their work.

Finally, during the period of evaluation CANARIE has joined and become a member of a blue ribbon international initiative comprising the CEOs of the top twenty NRENs in the world, whose vision is to drive towards a common international approach to global network architecture, above-the-net services, video conferencing and identity management. Interviews have confirmed that CANARIE is an active, leading member of this initiative, and has garnered respect and recognition as a leading-edge contributor by its peers.

Deploying Research Software

CANARIE has leveraged existing investments from its previous mandate in the NEP program to develop a broader toolkit of reusable research software components, and to reduce duplication in software development for research. During the evaluation period, CANARIE has further evolved the research software program to enable increased access to data and tools and to accelerate research outcomes.

It is expected that over time, the use of common research software components will become the norm. One illustrative example of what this initiative can achieve is the ExPLORE Complex Oceanographic Data service, which was designed by Oceans Networks Canada to extend the

interoperability and exchange of multi-dimensional and mobile marine data for use by a multidisciplinary community of sciences, the public, governments and other parties.

During the current mandate, 48 reusable software components and 12 network enabled platforms have been funded by CANARIE. Private sector partners have been part of many of software development teams. Additionally, to better support and guide this software initiative, CANARIE increased its internal expertise in the software development area by staffing a small team to build the infrastructure to manage the services being developed and offered by the community, and to work with the community to oversee the architectural evolution of the research software program.

The Network Enabled Platforms program during the previous mandate funded 20 successful research platforms across the country. These range from deep sea to deep space exploration projects, and cover a broad spectrum of science and technology endeavors, including applications in bioinformatics, brain imaging, space science, cloud-enabled weather modelling, disaster response and management, environmental sensing, health services, and intelligent transportation systems..⁴ A notable example of these platforms is the BigBrain mapping project, evolved from the CANARIE-funded CBRAIN and GBRAIN platforms. BigBrain was chosen by Massachusetts Institute of Technology (MIT) as one of 10 breakthrough technologies for 2014.⁵ The BigBrain project is a collaboration between researchers in Canada and Germany, connected by advanced high speed networks in Canada (CANARIE) and Germany and the research software and computing tools that enable them to access the BigBrain database developed by the Montreal Neurological Institute (MNI) at McGill University.

Stimulating ICT Innovation and Commercialization

In order to leverage CANARIE resources to stimulate private sector innovation, CANARIE offers the DAIR program, which provides powerful cloud resources for product development and testing that give entrepreneurs the opportunity to accelerate time-to-market. During the evaluation period, CANARIE launched a successful pilot DAIR project which has evolved into a full-fledged program and service during the current mandate. This program essentially provides cloud computing infrastructure as a service for development of ICT applications by Canadian SMEs for a one-year period. Since the pilot initiative, CANARIE has made the service easier to use by SMEs with the addition of a more advanced configuration portal. A wider range of operating systems are supported and the system has been modified to increase uptime of the service based on lessons learned from the pilot.

More evaluation findings on DAIR are presented in Section 2.3 of this report.

2.1.3 CANARIE as an Essential Research Infrastructure

CANARIE appears to be an essential component of Canada's digital infrastructure and is deemed by those consulted in academia and industry both to be fundamental to research and education, and to achieving a successful innovation eco-system. It achieves these objectives by facilitating collaboration

⁴ View summaries of NEP initiatives at: www.canarie.ca/en/network-programs/network-platforms/nep/projects.

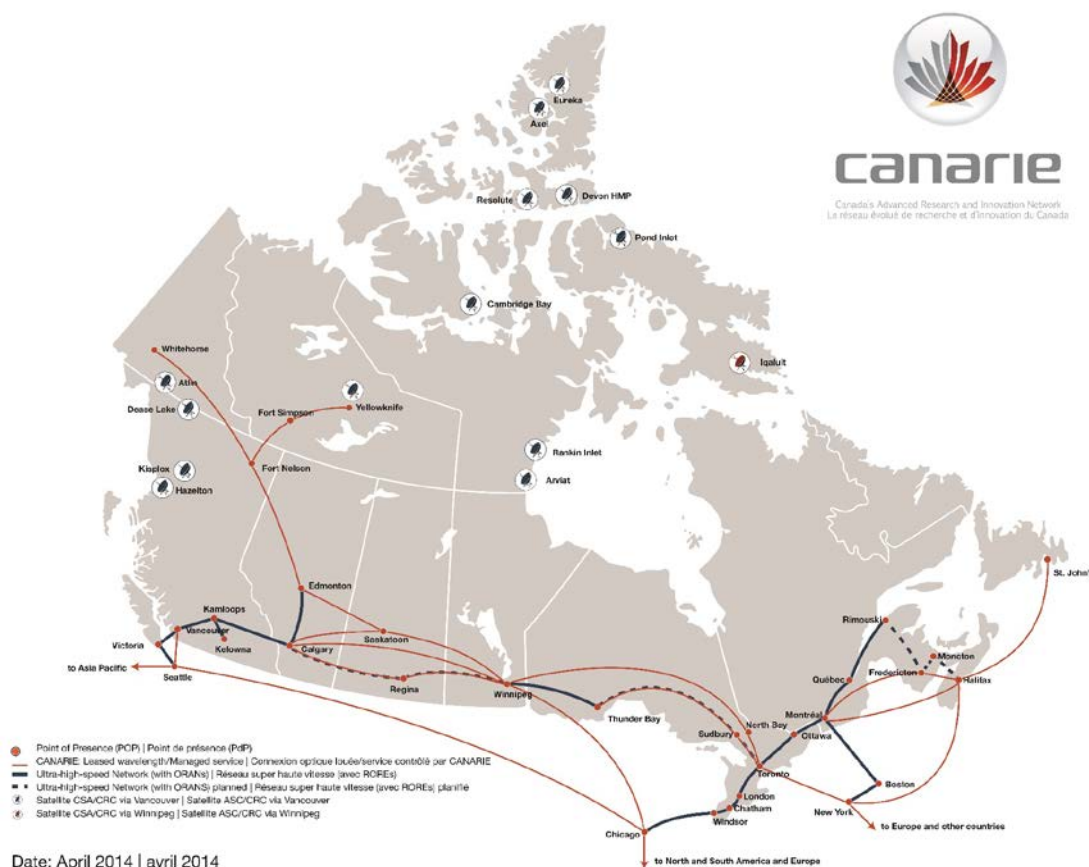
⁵ See www.technologyreview.com/featuredstory/526501/brain-mapping/.

and data transfers between researchers and educators, both in Canada and across the globe, and by making digital content readily accessible.

CANARIE as a Backbone for Canada's Digital Infrastructure Eco-system

CANARIE is part of a global alliance of high-speed networks for research and education comprising more than 100 NRENs, serving more than one million users in Canada (as estimated by the populations using the Network in 1,965 organizations – see Exhibit 2.1), and connecting them to each other and to research data, colleagues and instruments in more than 100 countries.

Exhibit 2.7: CANARIE Network Map



Source: CANARIE

As the above map illustrates, CANARIE is a core component of Canada's digital infrastructure and is fundamental to research and education, and to achieving a thriving innovation eco-system. The current network map of CANARIE (Exhibit 2.7) shows that all the provinces and territories of Canada are being served by the network. International access is also routed through Seattle to Asia and

Pacific regions and through New York and Chicago to Europe and other countries. And, according to the map, North and South America is routed through Chicago. Satellites also extend services to Northern Canada via Vancouver and Winnipeg.

During the current mandate, CANARIE's completion of a dedicated ultra-high-speed (100G, or 100 billion bits per second) network from coast to coast is on schedule, in response to increasing data traffic and expectation that this traffic will continue to increase. It will link Canada from Victoria to Halifax, via Vancouver, Kamloops and Kelowna, Calgary and Edmonton, Regina, Winnipeg, Toronto, Ottawa, Montreal, Quebec City, Rimouski, and Fredericton. The Rimouski to Halifax component essentially completes the planned core ultra-high speed backbone of the system during this mandate. Canada will enjoy a pan-Canadian backbone for its advanced research and education network, as a CANARIE managed and operated system in partnership with the ORANs, only leasing branch-offs from carriers to extend the system to other locations in Canada.

Leadership and Recognition

It is quite clear from the interviews and survey responses that the CANARIE Network has a reputation as one of the world's most advanced NRENs. It is a hybrid network, equipped with leading-edge optical and routing equipment, enabling CANARIE to offer traditional IP network services and Lightpath services (dedicated end-to-end connections) while continuing to develop new network service offerings based on the most advanced technology available.

CANARIE's network is built on a scalable model comprising acquired fibre to build ROADM (Reconfigurable Optical Add Drop Multiplexer) network connections. These ROADM network connections give CANARIE an ability to cost-effectively expand to 100 gigabits per second as the need for this capacity requirement continues to grow now and in the future. In addition to ROADM, a Synchronous Optical Network (SONET) network layer is built into the system using a mixture of CANARIE-lit wavelengths, carrier-leased wavelengths and wavelengths swapped with like-minded organizations.

With this hybrid infrastructure, CANARIE offers greater flexibility in service offerings in order to meet the changing needs of users, scaling up from users with smaller data exchange needs up to very-intensive data applications, such as high energy physics applications.

Just recently, for example, CANARIE and its global partners enabled Canadian physicists to achieve a 100 gigabit per second transatlantic transmission. On May 16, 2014, CANARIE announced that together with its global network partners Internet2, NORDUnet, ESnet, SURFnet, and GÉANT, the first transatlantic transmission at 100 gigabits per second between Canadian physicists and the Large Hadron Collider at the CERN Laboratory in Geneva, Switzerland was achieved. The Canadian High Energy Physics network organization, HEPnet/Canada at the University of Victoria, proved that data could be transferred from Geneva to Ottawa at 94 gigabits per second. At this speed, users could transmit 1 petabyte (1 million gigabytes) of data in one day.

To put this into perspective, 1 petabyte of data is equivalent to the entire printed collection of the U.S. Library of Congress being transferred 100 times. In recognizing the significance of this achievement, Dr. Randall Sobie from the University of Victoria, the director of the transatlantic transmission initiative, remarked that: "This unprecedented speed of data transfer to Canada would not be possible

without the next-generation digital infrastructure that CANARIE and its provincial, territorial and global research and education network partners manage and evolve.”⁶

Another example of CANARIE’s recognition and leadership was at the SuperComputing conference in Seattle, Washington, in November 2011. CANARIE participated in the transfer of 1 petabyte of data between the California Institute of Technology and the University of Victoria at a combined rate of 186 gigabits per second, setting a world record at the time. Such accomplishments by CANARIE and its partners have stood well for Canada and given this country a global reputation for excellence in networking technology.⁷

Having achieved a record breaking speed in 2011, CANARIE and its partners did not rest on their laurels. At the SuperComputing Conference in Salt Lake City, Utah, November 2012, a team of high energy physicists led by the California Institute of Technology (Caltech), University of Victoria and University of Michigan brought a powerful combination of intelligence and technology together and succeeded in almost doubling the record for data transfer, which had been set at 186 Gbps the year before on November 2011. As with the previous record-breaking data transfer, CANARIE provided the backbone ultra-high-speed fibre-optic network connection between Canada and the U.S., while BCNET provided the connection from the University of Victoria to CANARIE.⁸

CANARIE is well-recognized now, as in the past, as being in the forefront in national network operations compared to other international peers and in working with its counterparts in developing the world’s top high speed connectivity between various other national research and education networks. As one representative from a CANARIE regional partner put it in an interview: “CANARIE is one of the most highly respected national networks on the planet.”

CANARIE’s as a Component of Canada’s Digital Infrastructure

Based on responses from interviewees and open-ended comments from survey respondents in the CANARIE 2014 Survey, there is agreement that CANARIE is an important component of Canada’s research infrastructure and will continue to be needed for a future of new and innovative data-intensive applications emerging in fields such as genomics, astronomy, and bioinformatics. As such, it plays an important role in Canada’s overall digital infrastructure. The recent report prepared by the Leadership Council for Digital Infrastructure (DI) concluded that “Canada has some distance to go to achieve [an integrated and connected DI ecosystem], despite some excellent foundational elements being in place.”⁹ Interviewees and survey respondents consulted for this evaluation study recognize that one of these “foundational elements” is CANARIE. As one respondent put it: “Without the [CANARIE] Network, we are nothing.”

⁶ “Canadian physicists achieve 100 gigabit/second transatlantic transmission, enabled by CANARIE and its global partners”, CANARIE press release, Ottawa, Ontario, May 16, 2014.

⁷ “Supercomputer network blasts torrent of data”, CNET article, December 14, 2011.

www.cnet.com/news/supercomputer-network-blasts-torrent-of-data

⁸ “Déjà vu all over again? CANARIE and BCNet help break another global record for data transfer”, December 13, 2012. www.canarie.ca/templates/news/releases/PressReleaseSC12.pdf.

⁹ “Summary Report – Digital Infrastructure Summit 2014”, Conclusions of Summit 2014, held in Ottawa on January 28-29, in Ottawa, Ontario.

With the recent announcement by the federal Minister of Industry (on April 4, 2014) of the Digital Canada 150 plan, CANARIE is now set as an important component of Canada's digital future. CANARIE is very relevant to the general digital infrastructure plan, but it is particularly important for the third of the five pillars in the plan. The third pillar emphasizes economic opportunities and focuses on accelerating innovation across the economy, use of digital tools to boost productivity and develop businesses to capture growing markets, and "big data" applications in health care, research and development, as well as the myriad activities of business and government. However, CANARIE is entering its last year of its current and short three-year mandate, with no specific direction articulated towards it in government's long term plans and commitments. This lack of specific continuing mandate limits CANARIE's ability to initiate longer term, strategic projects.

Though the CANARIE team is small and its current mandate from Industry Canada is short-term, it provides first-rate 24-7 services, both for local providers and users, and for regional networks, expanding and augmenting the network by adding capacity and empowering technologies. Over the past 15 years CANARIE has introduced major improvements through at least three significant upgrades, and during every upgrade they have been deemed excellent, by those consulted for this evaluation, in working with their partners to facilitate the changes.

The Network has continued to expand during the current mandate with recent milestones including the signing of a western contract to develop 100 gigabit connectivity and a brand new fibre connection introduced from Rimouski to Halifax. The announcement of this new fibre build was made in April 2014. Other CANARIE improvement projects were cited earlier in Section 2.1.2.

To conclude this section, CANARIE has indeed demonstrated leadership in fulfilling its essential role in operating the Network and providing an advanced digital communications backbone. This achievement is not just in terms of addressing capacity needs and managing the flow of traffic, but also in terms of ensuring that Canada has the most advanced networking technology applications and related services.

2.2 Technology Innovation

Evaluation Issue: To what extent has CANARIE achieved its objectives and related expected outcomes for technology innovation – i.e., "to develop, demonstrate and implement next-generation technologies to advance the CANARIE Network as a leading edge research network"?

CANARIE facilitates technology innovation by expanding the reach of Canadian researchers to collaborate amongst themselves in Canada and with researchers across the world. An important part of CANARIE's agenda for supporting technology innovation is the support it provides to the R&E community through its Research Software Program. This program is a continuation of the successful Network-Enabled Platforms program of CANARIE's previous mandate (see *Evaluation of CANARIE – June 2011*), aimed at empowering researchers by helping them to use the Network to seamlessly access distributed data, tools and research instruments.

Converging Evidence on Technology Innovation from the Mandate Renewal Stakeholder Consultations

CANARIE's achievements with respect to "Technology Innovation", according to the mandate renewal stakeholder consultations, are as follows:

- Facilitated development of middleware tailored to meet research needs.
- RFP-based funding ensures projects are needs-based.
- CANARIE successfully provides its users with world-class infrastructure to drive research advancement and enable collaboration.
- CANARIE effectively promotes collaboration between academia and industry, nationally and internationally and has strong relationships with many key ecosystem players.

These findings converge with the evaluation findings discussed below.

2.2.1 Research Collaboration and Technology Innovation

CANARIE enables research collaboration and technology innovation in at least two ways: (i) by providing access to high bandwidth; and (ii) by supporting the development of applications and interface tools and software platforms that allow researchers to access globally distributed research data, tools and colleagues.

Enabling Collaboration and Innovation through High Bandwidth

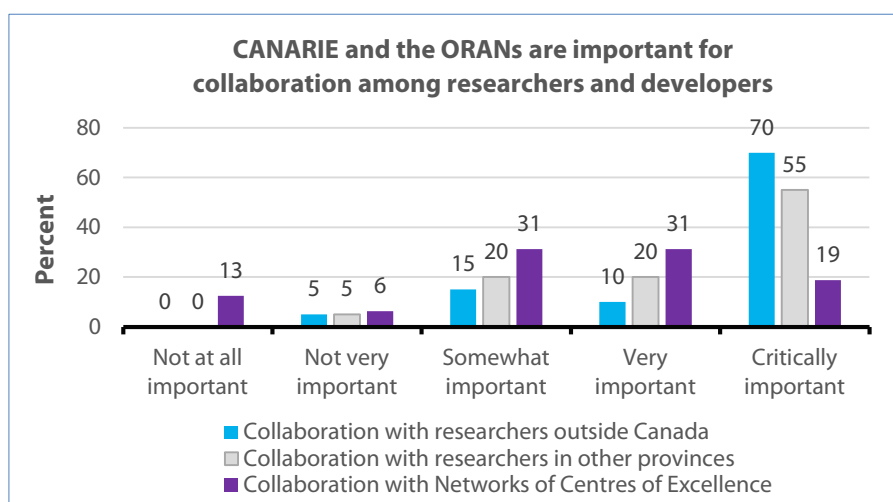
Access to the Network provides an opportunity to communicate and collaborate, certainly on a researcher-to-researcher level, but also to broadcast research results, exchange very large datasets, transmit learning programs, replicate experiments, conduct online conferences, organize technical committees, and run live workshops or teaching seminars. There are many other ways that researchers collaborate with the use of CANARIE, but the main point is that the high bandwidth network has become critical for them in realizing the collaborations needed to advance their work and contribute to Canada's technology innovation progress. The BigBrain project was already cited earlier as one example of this collaboration at an international level which benefited from CANARIE support, and is recognized as one of 10 breakthrough technologies for 2014 by MIT.¹⁰

Exhibit 2.8 provides the CANARIE 2014 Survey responses of researchers and technology developers regarding the importance of CANARIE's role in facilitating their capabilities for technology innovation through collaboration. Clearly the overwhelming response is that CANARIE is important. Eighty percent of respondents reported that CANARIE is "very" or "critically" important for collaboration with researchers outside Canada; 75 percent reported that it is "very" or "critically" important for collaboration with other researchers in Canada; and 50 percent indicated that it is "very" or "critically" important for collaboration with other researchers in Networks of Centres of Excellence (but noting that in this latter category an additional 31 percent said it is "somewhat" important). Generally, only 5

¹⁰ See www.technologyreview.com/featuredstory/526501/brain-mapping/

to 19 percent considered CANARIE not important for collaboration within the range of these researcher response categories.

Exhibit 2.8: Researcher Responses on the Importance of the CANARIE Network for Collaboration



Source: CANARIE 2014 Survey.

The responses of researchers shown in Exhibit 2.8 about collaboration are further confirmed in that they also reported in the Survey that since 2010 they individually undertook via CANARIE, an average of 5 joint innovation projects involving remote collaboration with Canadian partners within their respective provinces; an average of 5 joint innovation projects with Canadian researchers outside their provinces; and an average of 6 joint innovation projects with researchers outside Canada. Furthermore, since 2010, researchers individually published an average of 9 scientific articles co-authored with their collaborators outside Canada. Researchers also indicated that their use of CANARIE funds enabled them to author, on average, the following:

- 4 scientific articles in peer-reviewed academic journals;
- 7 technical reports; and,
- 7 invited presentations given at conferences, workshops and meetings.

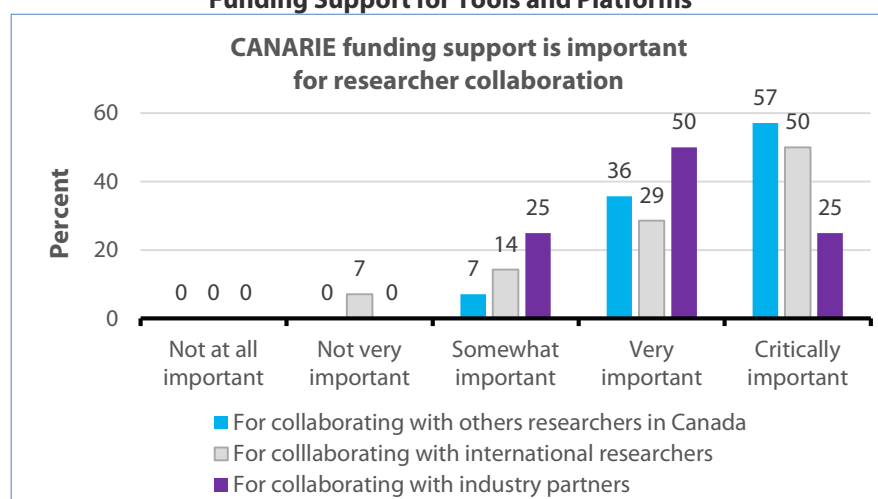
The role of CANARIE in research and technology innovation as reported by researchers is clearly in their view significant and impactful.

Enabling Collaboration and Innovation by Developing Applications and Interface Tools

Researchers were also asked if they considered CANARIE funding support to develop the software, tools, and research platforms that empower them to access globally distributed data, tools and instruments, to be important for collaboration. Exhibit 2.9 shows that indeed researchers consider the research software program and other funding support as a relevant contribution by CANARIE. The

chart shows quite dramatically that the response by researchers, while not unanimous about “how important”, is almost unanimous in considering CANARIE funding an important factor for successful collaboration and innovation with other researchers in Canada, with international researchers, and with counterparts in private industry. Only 7 percent of researchers consider CANARIE “not very important” for collaborating and innovation with international researchers.

Exhibit 2.9: Researcher Responses on the Importance of CANARIE Funding Support for Tools and Platforms



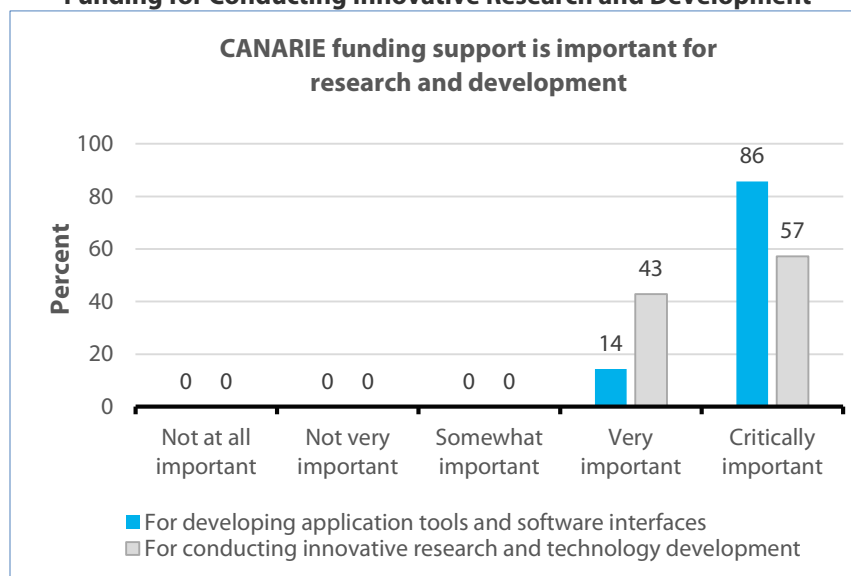
Source: CANARIE 2014 Survey.

Researcher respondents to the survey are also unanimous about the importance of CANARIE funding for the development of tools and platforms for conducting innovative research (Exhibit 2.10). All respondents indicated they consider CANARIE funding “very” or “critically” important for developing application tools and software interfaces, and generally for conducting innovative research and technology development.

While interviewees and survey respondents generally agreed that CANARIE has led to increased collaborative partnerships for the development of research platforms, they have also indicated that more partnerships are likely coming on board in the future, citing some already ongoing successful examples in Ocean Networks Canada, Canadian Light Source, SNOLAB in Ontario, and TRIUMF.

As noted earlier, RPIs that some researchers have developed for their own needs are transferable to other users. The legacy of NEP program projects from the previous mandate have allowed researchers to create platforms and interfaces that make CANARIE available to a large cross-section of researchers and technology developers. CANARIE is currently facilitating the transfer of such services and platforms.

Exhibit 2.10: Researcher Responses on the Importance of CANARIE Funding for Conducting Innovative Research and Development



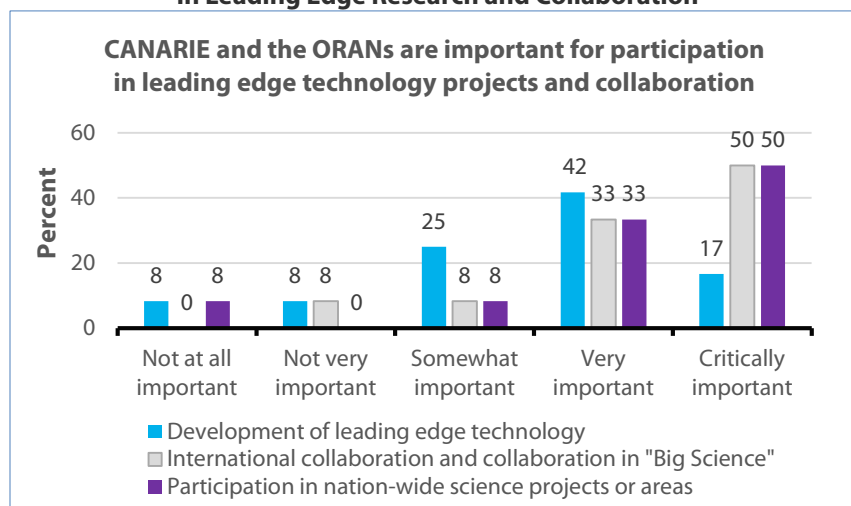
Source: CANARIE 2014 Survey.

Seventeen such services and new platforms have been created by CANARIE. Overall, 60 such services and platforms are being developed during the current mandate. By the end of this mandate, these services and platforms will be released for common work among R&D users. These new services and platforms provide value-added unique applications that encourage collaboration and technology innovation.

CIOs' Views on CANARIE's Importance for Collaboration and Innovation

CIOs were also asked about the importance of CANARIE with respect to participation in leading edge research and collaboration (Exhibit 2.11). CIO responses are more mixed than researcher responses, but nonetheless similarly significant importance is attributed to CANARIE with respect to its role and contribution. Fifty-nine percent of CIOs indicated that CANARIE is "very" or "critically" important for development of leading edge technology; 88 percent reported that it is "very" or "critically" important for international collaboration in "Big Science" projects; and 88 percent indicated it is "very" or "critically" important for participation in nation-wide science projects or areas.

Exhibit 2.11: CIO Responses on the Importance of CANARIE for Participation in Leading Edge Research and Collaboration

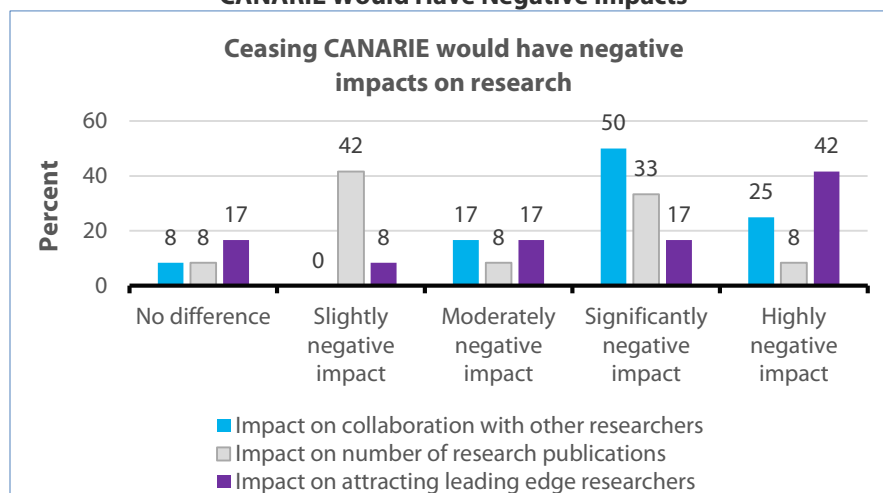


Source: CANARIE 2014 Survey.

Note: Responding CIOs in the survey represent 196,254 full-time and part-time enrolled students (graduates and undergraduates), or 15.4 percent of all enrolled students in AUCC member institutions, and represent 8,177 faculty members, or 14 percent of all faculty in AUCC member institutions.

The CANARIE 2014 Survey also asked CIO respondents to provide their assessment of impacts if CANARIE was no longer providing its services (Exhibit 2.12). Seventy-five percent indicated that this would result in a "significantly" or "highly" negative impact on collaboration between researchers; 41 percent reported that this would result in a "significantly" or "highly" negative impact on research publications; and 59 percent indicated this would result in a "significantly" or "highly" negative impact on attracting leading edge researchers.

Exhibit 2.12: CIO Responses on Whether Cessation of CANARIE Would Have Negative Impacts

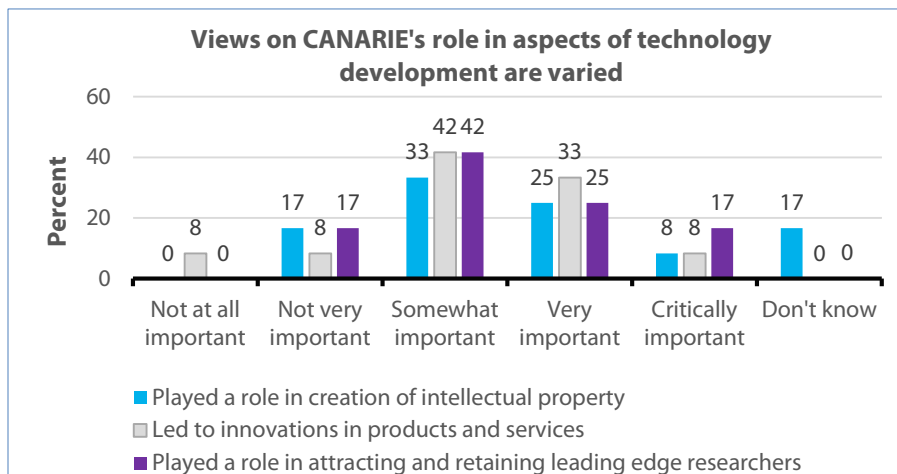


Source: CANARIE 2014 Survey.

Note: Responding CIOs in the survey represent 196,254 full-time and part-time enrolled students (graduates and undergraduates), or 15.4 percent of all enrolled students in AUCC member institutions, and represent 8,177 faculty members, or 14 percent of all faculty in AUCC member institutions.

Finally, CIOs were asked about the role of CANARIE in other aspects of technology development and innovation. The responses by CIOs to questions about intellectual property, innovations in products and services, and attraction and retention of researchers is generally more mixed and conservative than what the researchers indicated, judging by other responses to other questions in the survey and by the feedback obtained from interviews. Exhibit 2.13 shows that a proportion of CIOs responded “don’t know”, but 66 percent considered CANARIE of some importance for the creation of intellectual property; 83 percent considered CANARIE of some importance for innovations in products and services; and 84 percent considered CANARIE of some importance for attracting and retaining leading edge researchers.

Exhibit 2.13: CIO Responses on CANARIE's Role in Aspects of Technology Development



Source: CANARIE 2014 Survey.

Note: Responding CIOs in the survey represent 196,254 full-time and part-time enrolled students (graduates and undergraduates), or 15.4 percent of all enrolled students in AUCC member institutions, and represent 8,177 faculty members, or 14 percent of all faculty in AUCC member institutions.

2.2.2 Positioning CANARIE as a Leading Edge Research Network

CANARIE has a track record of being seen by many in the NREN community, both in Canada and internationally, as a leader and innovator in operating and delivering an advanced communications and data transmission network. However, as the previous CANARIE Evaluation (2011) concluded, many of the interviewees and survey respondents for that study at the time indicated that CANARIE had lost some of the leadership position it had built up over its two decades of operation. In 2011 there was generally a somewhat dim view of CANARIE's leadership position, but mainly because other NREs had caught up with CANARIE and implemented their own state-of-the-art networks – i.e., not that CANARIE had slipped. This time around, however, in the current evaluation consultations with key informant interviewees (see list in Appendix F), and in the survey responses to open-ended questions, there was some agreement that CANARIE is now on the right path to regaining a leadership position, and is indeed recognized among its peers as one of the leaders.

2.3 Private Sector Innovation

Evaluation Issue: Has CANARIE succeeded in leveraging the CANARIE Network to assist firms operating in Canada and Canadian universities to advance innovation and commercialization of products and services to bolster Canada's technology innovation capabilities?

The current mandate of CANARIE supports the private sector in advancing innovation and commercialization through the DAIR program. This program was piloted in 2011, and launched as a full program in November 2012, as a response to the federal government's Digital Economy Strategy

consultation. Many of the pilot users applied to the new full service, which includes a fee for use when they request resources over a specific threshold. The new program retains the same basic service structure: essentially including cloud computing infrastructure as a service for development of ICT applications by Canadian SMEs. The service was made easier to use for SMEs with the addition of a more advanced configuration portal.

The extent to which this program has succeeded is difficult to gauge at this time, considering that it is at an early stage and many of the users are still in transition between product development and commercialization. Nevertheless, some assessments can be made based on the interviews done with DAIR users, and from related survey responses.

Converging Evidence on Private Sector Innovation from the Mandate Renewal Stakeholder Consultations

CANARIE's achievement with respect to "Private Sector Innovation", according to the mandate renewal stakeholder consultations, is as follows:

- Provided SMEs with access to cost-effective cloud services.

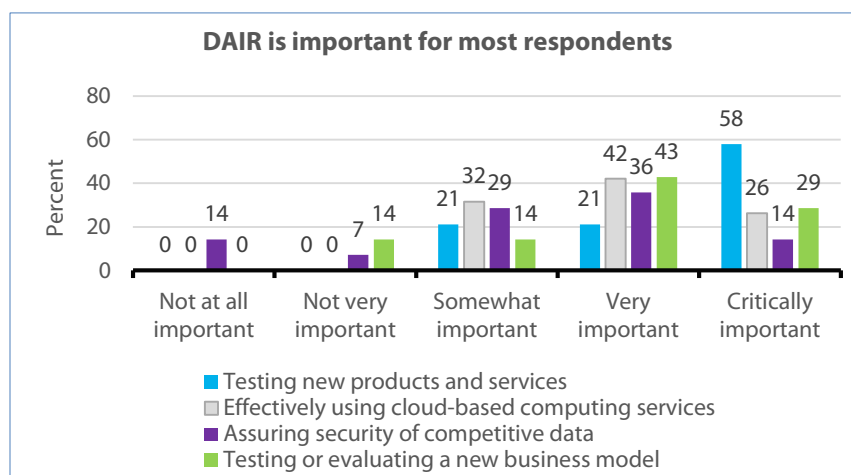
This finding converges with the evaluation findings discussed below.

Development of Products and Services and Accelerating Commercialization

DAIR has served 230 users during CANARIE's current mandate. These users are small and mid-sized companies that DAIR helped to understand how cloud computing can make a difference for them, reducing barriers to entry in the competitive market, and providing a test-bed for confirmation of the workability of their products and service offerings before they go to market.

Exhibit 2.14 shows the assessments by DAIR users of how the program has helped them with regards to some key indicators of acceleration and commercialization – in terms of the importance of testing products and services, using cloud-based computing, assuring security of their data, and evaluating their business models. Seventy-nine percent of DAIR users said that DAIR was "very" or "critically" important to them for testing their new products or services; 68 percent for effectively using cloud-based computing services; and 72 percent for testing or evaluating a new model for rolling out their businesses. Only 50 percent of DAIR users indicated that the program was "very" or "critically" important for assuring the security of their competitive data. Only a very small percentage of users are at the other end of the scale indicating that DAIR was "not at all" or "not very" important, with the balance in the mid-point indicating "somewhat important".

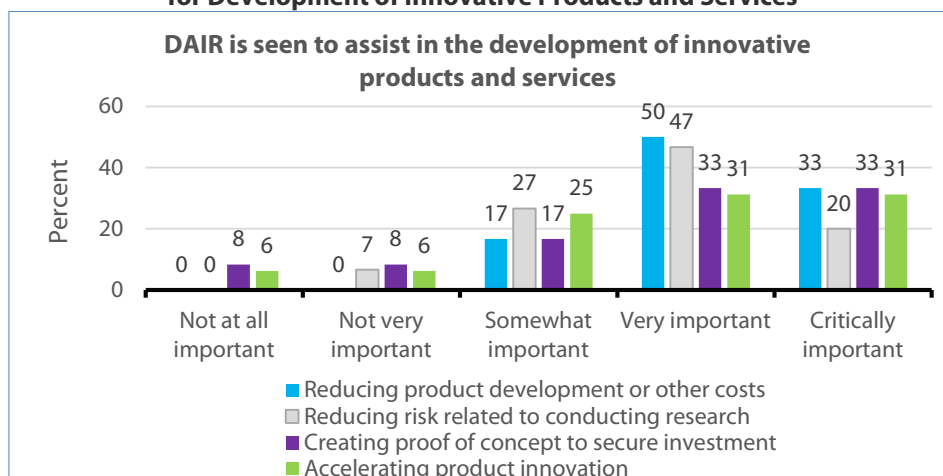
Exhibit 2.14: DAIR Users Responses on the Importance of DAIR for Accelerating Commercialization



Source: CANARIE 2014 Survey.

Exhibit 2.15 shows DAIR users' assessments of importance with respect to indicators of how the program helped them in developing innovative products and services – in terms of reducing development costs, reducing risks related to conducting research, creating proof of concept to secure investment, and accelerating product innovation. Eighty-eight percent of DAIR users reported that the program was “very” or “critically” important to them for reducing their development costs; 67 percent for reducing the risk associated with conducting research; 66 percent for helping them to create proof of concept; and 62 percent for accelerating innovation.

Exhibit 2.15: DAIR Users Responses on the Importance of DAIR for Development of Innovative Products and Services



Source: CANARIE 2014 Survey.

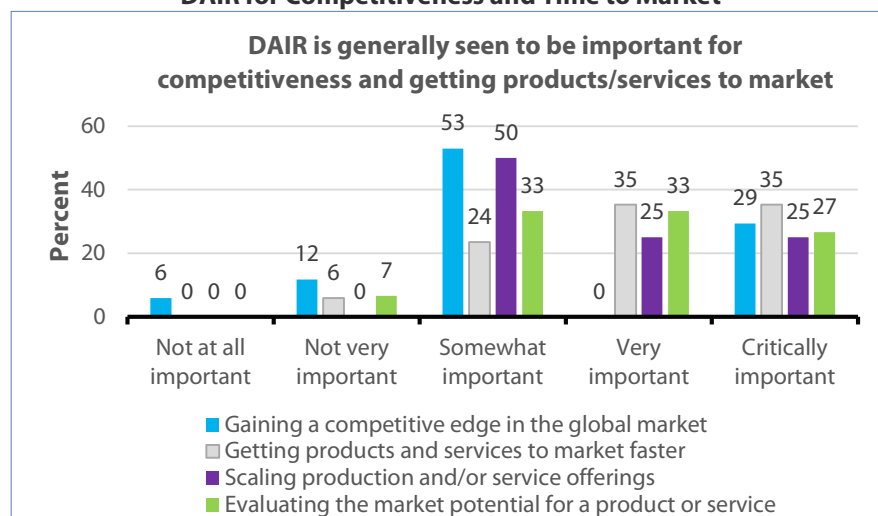
The significance of cost-savings to DAIR survey respondents (i.e., to 88 percent of them) is confirmed from interviews with some of the users. DAIR users generally indicated in the interviews that DAIR is a cost-saving opportunity for them, more so than a time-saving one (see Exhibit 2.16 showing the comparable percentage figure for DAIR as a time-saver as 72 percent of survey respondents).

Competitiveness and Time-to-Market

It is perhaps too early to assess the impact of DAIR on current and recent users of the program because it is too early to assess the impacts on many of the companies benefiting from its services. Exhibit 2.16, however, does provide some insight where DAIR users are finding the program most useful for their success at this stage. Of high importance is getting their products and services to market faster. Seventy percent of users assess this indicator of DAIR performance as “very” or “critically” important. Similarly 60 percent of users assess that DAIR helping them to evaluate the market potential of their products or services is “very” or “critically” important.

On the other hand, scaling production and/or service offerings is of lesser importance, and least important is gaining a competitive edge in the global market. These latter observations are perhaps not surprising given the stage of development at which DAIR companies are deemed. Moreover, the DAIR program is not necessarily geared to directly provide global marketing services or guide companies on how to scale-up their businesses.

Exhibit 2.16: DAIR Users’ Responses on the Importance of DAIR for Competitiveness and Time to Market



Source: CANARIE 2014 Survey.

A notable result from the survey of DAIR users is that on average they estimated that DAIR helped them get to market 20 weeks sooner. In addition, based on their assessments, they estimated on average that they saved 24 percent on development costs on an average base investment per project of \$147,235. Their estimated savings for using DAIR as opposed to a commercial vendor is, on average, \$7,047 per company. Interviews with users of DAIR indicate that the most important benefit

of DAIR is that it is a predictable cost-saving model for them, important in the crucial early days of developing their products or services.

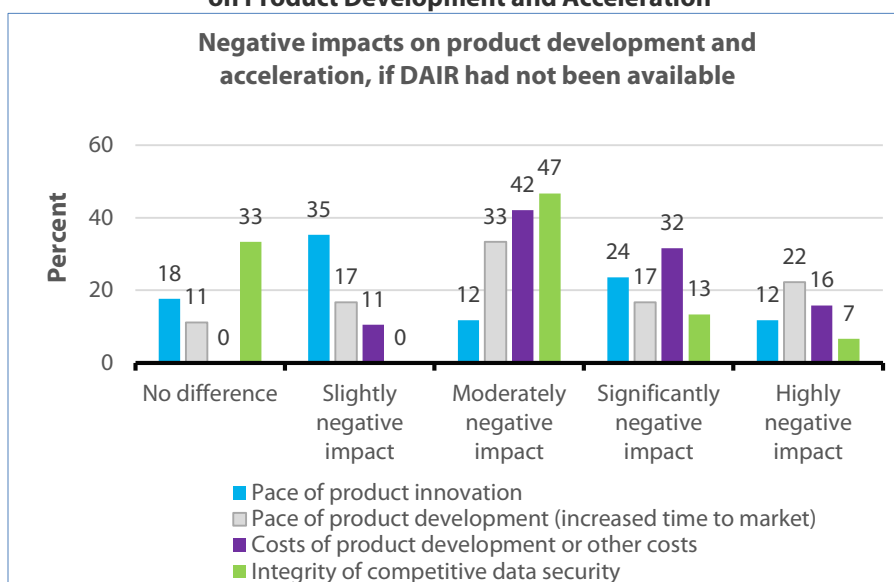
Another indicator of the effectiveness of DAIR support to users of the program services is whether DAIR in some way enabled the companies to hire new employees. Fifty-three percent of respondents indicated that they hired new employees, an average of 3 new employees; and 37 percent reported they hired students (on average 2 students per respondent).

If DAIR was not Available

Counterfactual measures are sometimes used in evaluations to assess what would have happened if beneficiaries of a program had not had a particular service offering. The CANARIE 2014 Survey asked DAIR users what the impact would have been on their work if DAIR had not existed. The results of this question are shown in Exhibits 2.17 and 2.18.

Exhibit 2.17 shows that 90 percent of DAIR users deemed the impact on their costs of product development, or other costs, would be from “moderately” to “highly” negative; 72 percent of users deemed the impact similarly negative on increased time to market; 67 percent on the integrity of competitive data security; and 48 percent on the pace of product innovation. The survey responses on this question clearly suggest that DAIR users value savings in costs as a most important factor for them, with time-to-market also important but secondary to cost savings.

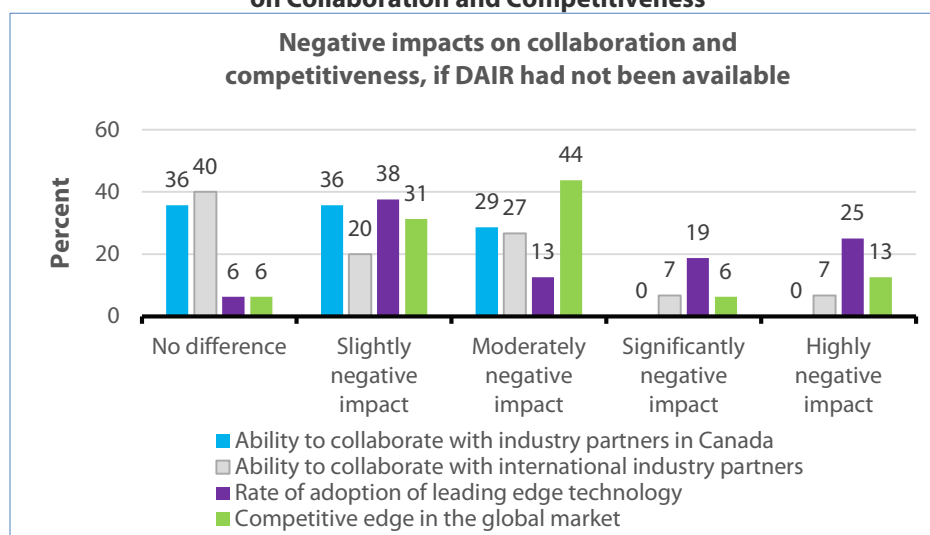
Exhibit 2.17: DAIR Users’ Responses Regarding Negative Impacts on Product Development and Acceleration



Source: CANARIE 2014 Survey.

Exhibit 2.18 on the other hand generally shows that DAIR users do not deem that the absence of DAIR would have had as negative an impact on other commercialization indicators – i.e., ability to collaborate, rate of adoption of leading edge technology, and competitive edge globally.

Exhibit 2.18: DAIR Users' Responses Regarding Negative Impacts on Collaboration and Competitiveness



Source: CANARIE 2014 Survey.

Perhaps the explanation of this result is that it is premature to ask about these latter counterfactual indicators to companies who are at an early pre-commercialization stage of developing their products and services.

Reach and Benefits of DAIR

Some of the interviewees, including DAIR users, suggest that DAIR is not reaching its full potential in terms of reaching out to possible other users. To this end, CANARIE is now marketing DAIR more than it had initially – for example, CANARIE is reaching out to new users through its partnerships with organizations such as the AURP Canada and the Industrial Research Assistance Program (IRAP) of the National Research Council. The AURP initiative is expected to accelerate the number of new users seeking to commercialize new innovative products and services emanating from the activities and projects at the research parks. The IRAP initiative is expected to have similar results.

A good example of DAIR benefits to SMEs is the service it provided to Galdos Systems Inc. The DAIR program enabled them to test their product to the extent that they were able to enter into an agreement with Expedia, the world's largest travel company, an agreement to use Galdos INdicio, a product which enables a whole range of location-enabled applications. Expedia will use INdicio to better organize and present all of its geographic data including points of interest, tourist regions, and entertainment districts. Galdos sold the license for INdicio to Expedia. The impact of DAIR in this case is that it allowed Galdos to demonstrate the commercial viability and performance of its product.

Without DAIR this would not have been possible because, as cited by Galdos, they did not have the resources at the early stages of development.¹¹

¹¹ There are several other such success stories posted on the CANARIE website: see, for example, the stories of Project Whitecard Inc., gnowit, and ZEROSPAM Security Inc. at www.canarie.ca/en/dair-program/about.

3. Relevance and Continued Need

In addition to CANARIE's achievement of its objectives, this evaluation considers CANARIE's ability to address the needs of the Canadian research, education and innovation communities, as well as the degree to which CANARIE's Network, programs and services will continue to be necessary and relevant to stakeholders.

Indeed, the evaluation indicates that CANARIE is highly relevant to users, and will continue to remain so in the coming years, including in the following ways:

- Data-intensive research activities are highly dependent on the CANARIE network to transmit large volumes of data globally in a reliable, efficient and secure manner.
- Services such as CAF and CDS allow educators to provide access to a wide range of resources and content with minimal administrative and financial burden.
- The need for CANARIE programs and services will grow over the next three years, as researchers, educators and entrepreneurs engage in activities that require the collection and transmission of increasingly large volumes of data.
- The discontinuation of CANARIE programs and services would have a highly negative impact on users, as well as Canada's ability to maintain leadership in research and development.
- There will be an increased need for CANARIE programs and services to facilitate research and education both with international partners and within Canada.
- DAIR users predict an increase in the use of that program, with particular interest paid to cloud computing tools. Survey respondents also saw the need for marketing/promotional assistance, though such services are not currently part of DAIR's (or CANARIE's) mandate

This section examines the different ways in which CANARIE meets the needs of users, anticipated changes in the way CANARIE programs and services are utilized, and the consequences of a CANARIE-managed research and education network ceasing to exist.

3.1 Relevance

Evaluation Issue: Has CANARIE addressed relevant contemporary needs of the Canadian research and education community and of the private sector?

The relevance of CANARIE as an essential component of Canada's digital infrastructure can be measured in terms of its contribution to addressing contemporary needs by meeting the demand of researchers and technology developers for high-intensity and high-volume data for R&D innovations and applications; providing the technology that enables researchers to broaden their reach across Canada and the globe; serving educators and those they teach with an advanced digital network to achieve the highest possible standards in their professions; and helping to accelerate and commercialize new products and services.

Meeting the demand

Interviewees and survey respondents have indicated that there is an increasing demand for data-intensive applications in their research. They therefore considered ramping up the communications and networking infrastructure to have been an important and relevant priority for R&D that CANARIE has been addressing during its current and previous mandates. Various reasons for this demand for data-intensive capabilities have been cited by interviewees and survey respondents:

- growth in the number of researchers who use cloud processing systems;
- new satellite applications for transmission of more than 1 terabytes per day – including new remote sensing device needs and pending launches and use of new satellites with multispectral and hyperspectral imaging capabilities;
- growth in data volumes produced by observatories and new telescopic instrumentation for space research;
- changes in the use of advanced models for energy management and analyses in urban systems and buildings;
- increase in density and volume of transportation, traffic, and navigation systems;
- Big Science project data requirements;
- increases in throughputs due to sequencing and genomics instruments;
- new digital and graphic instrumentations in a variety of fields producing higher resolution data by a factor of 10 or more;
- increases in the number of research platform users;
- more collaboration across the globe on cross-border issues (e.g., weather and health);
- new methods in physical and social sciences for data integration and analysis;
- new data analytics and virtual teaching venues and paradigms in education; and
- national safety and security needs.

This increase in the complexity of information requirements cited above, and the fact that high volume, high intensity data is being distributed globally now more than ever, is a clear demonstration that CANARIE has been and is addressing contemporary needs in a relevant manner by extending and upgrading its advanced network.

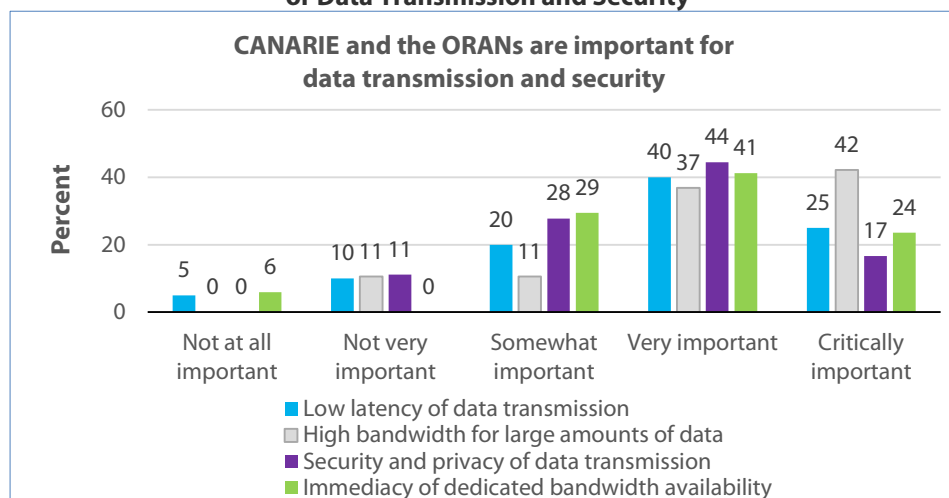
Broadening Researchers' Reach

How relevant is CANARIE in broadening researchers' reach? Exhibits 3.1 and 3.2 show the responses of researchers on some key indicators of relevance regarding the technology provided by CANARIE to achieve higher researcher reach.

Exhibit 3.1 shows that 79 percent of researcher respondents indicated that providing high bandwidth for large amounts of data is "very" to "critically" important for them; 65 percent indicated low latency of data transmission and immediacy of dedicated bandwidth availability are similarly important; and 61 percent indicated that security and privacy of data transmission is similarly important. It should

also be noted that for all these categories, many of the balance of researchers indicated that these measures of relevance are “somewhat important.”

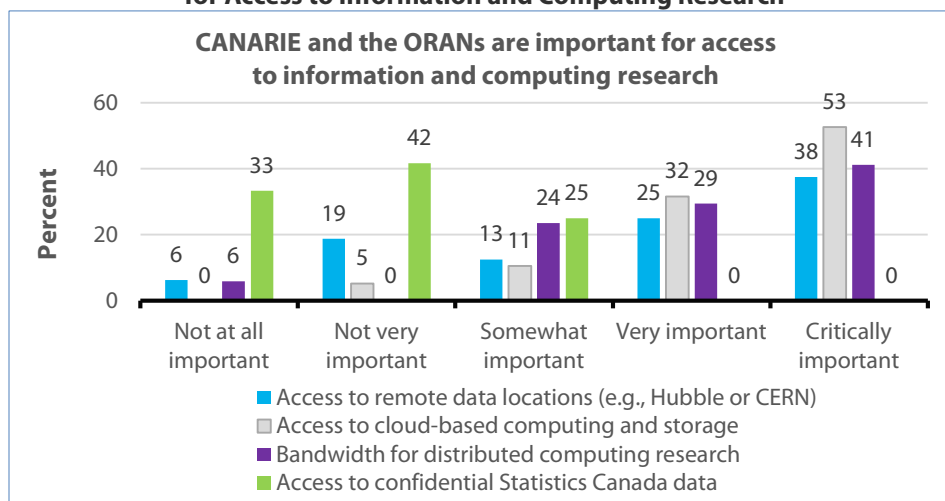
Exhibit 3.1: Researcher Responses on the Relevance of CANARIE or Data Transmission and Security



Source: CANARIE 2014 Survey.

Exhibit 3.2 shows that 85 percent of researcher respondents indicated that providing access to cloud-based computing and storage is “very” to “critically” important for them; 70 percent indicated bandwidth for distributed computing is similarly important; 63 percent indicated that access to remote data locations is similarly important; and 0 percent indicated that access to confidential Statistics Canada data is similarly important – the latter result probably being due to no users of Statistics Canada data having responded to the survey.

Exhibit 3.2: Researcher Responses on the Relevance of CANARIE for Access to Information and Computing Research



Source: CANARIE 2014 Survey.

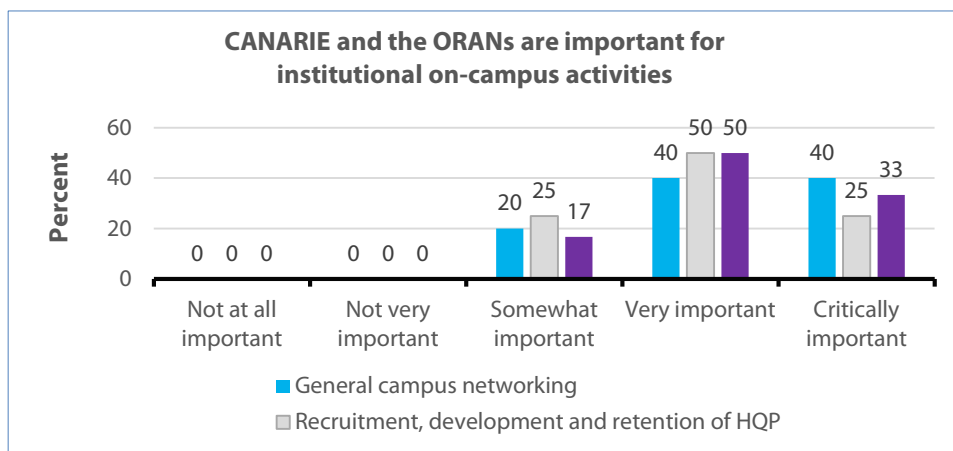
From these survey responses of researchers, it can be concluded that CANARIE has indeed been addressing relevant and contemporary needs in providing the kind of advanced networking technology required to deliver the services that R&D researchers and other users want.

Serving Educators and Students

CANARIE is not only about serving the needs of researchers and private sector users. CANARIE is also relevant as an advanced vehicle facilitating new virtual teaching venues and paradigms in education. CIOs were asked about other uses and relevance of CANARIE for educators and those they teach. Previously, in Section 2.1.1, Exhibit 2.4, it was shown that the largest percentage of users of CANARIE on college and university campuses are undergraduates.

Exhibit 3.3 provides responses of CIOs on the relevance of CANARIE for other on-campus activities, such as student and faculty day-to-day networking (not including R&D related communications), recruitment of Highly-Qualified Personnel (HQP), and networking as an educational tool. Eighty percent of CIOs indicated that CANARIE is “very” or “critically” important for general campus networking and 83 percent indicated use of the network as an educational tool is similarly important. Seventy-five percent of CIOs indicated CANARIE is “very” or “critically” important for recruitment, development and retention of HQP.

Exhibit 3.3: CIO Responses on the Relevance of CANARIE for On-Campus Activities

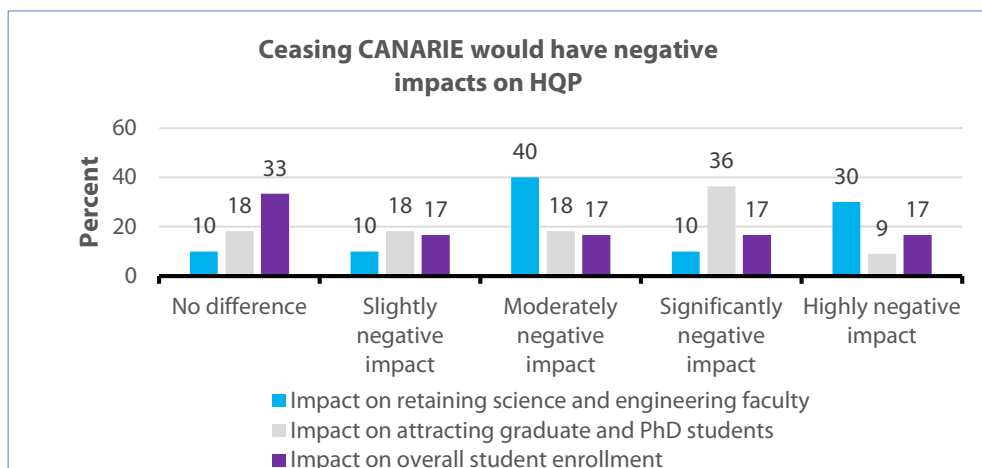


Source: CANARIE 2014 Survey.

Note: Responding CIOs in the survey represent 196,254 full-time and part-time enrolled students (graduates and undergraduates), or 15.4 percent of all enrolled students in AUCC member institutions, and represent 8,177 faculty members, or 14 percent of all faculty in AUCC member institutions.

A counterfactual question was also asked of CIOs, to indicate what the impact would be on HQP if CANARIE ceased to exist. Exhibit 3.4 shows the responses of CIOs to this question. Eighty percent of CIOs indicated that cessation of CANARIE would have a “moderately” to “highly” negative impact on retaining science and engineering faculty; 63 percent indicated a similar negative impact on attracting graduate and PhD students; and 51 percent indicated a similar negative impact on overall student enrollment.

Exhibit 3.4: CIO Responses on Negative Impacts on HQP if CANARIE Ceased



Source: CANARIE 2014 Survey.

Note: Responding CIOs in the survey represent 196,254 full-time and part-time enrolled students (graduates and undergraduates), or 15.4 percent of all enrolled students in AUCC member institutions, and represent 8,177 faculty members, or 14 percent of all faculty in AUCC member institutions.

Based on the feedback from interviews and survey respondents, CANARIE has also been serving educators and those they teach with relevant offerings based on the Canadian Access Federation's suite of services – eduroam, eduGAIN, and FSSO. These services seem to be very well received by educators and students alike, and the secure single sign-on is a key feature that is liked and deemed relevant to their needs.

The relevance of CANARIE to the R&E community also applies to non-research colleges and schools across Canada, including those in rural and remote areas. For example, thirteen campuses of Yukon College have benefitted by being connected to CANARIE as they are heavily involved in distance education, whether within the territory or connecting to other institutions in the rest of Canada.

Another similar example is in Manitoba, where CANARIE connects K-12 and post-secondary schools in the province. CANARIE funded the capital for MRNet to set up dark fibre that connects schools in Manitoba. By doing so CANARIE encouraged networking at that level which enables educators to improve access to learning materials and resources and benefits students by virtually expanding their horizon of knowledge.

Acceleration and Commercialization of New Products and Services

During its current mandate CANARIE has evolved from its role in providing networking for relevant innovative R&D and education activities at Canadian institutions, to also being involved in industry focused initiatives (the DAIR program). DAIR has broadened its user base and relevance.

DAIR is a relevant contribution to the federal government's science and technology agenda, encouraging innovation and commercialization of Canadian technology products and services. It is

one of many government programs (such as the Centres of Excellence for Commercialization and Research program) aimed at helping small and medium-sized enterprises in Canada to grow from pre-market stages of development to successful commercialization of their salable offerings.

DAIR provides relevant services to Canadian high-tech entrepreneurs, as confirmed in interviews and survey responses, enabling them to access free cloud-based computing and storage resources, to help them gear up product development and gain access to markets. Compared to commercial cloud services, DAIR offers high-performance resources, with no hidden costs and the assurance that their data stays in Canada. Users of DAIR leverage the program to develop, test, and demonstrate a range of products, including offerings in mobile applications, multimedia offerings, IT security systems, and many other similar and relevant applications for today's digital market.

Contributing to Achieving Digital Parity

CANARIE has contributed to achieving digital parity across regions, provinces and territories, and across institutions of different sizes and locations within provinces. The network map in Exhibit 2.7 shows the extent of CANARIE's reach across the country. While the coverage is not ubiquitous, it nonetheless covers an increasingly larger geographic share of Canada's terrain and population agglomerations than in previous mandates. CANARIE is deemed to have done a very good job during the past five years, with limited resources, expanding and improving the network, in partnership with the ORANs, and ensuring within its budget that there is network access to all regions and as many institutions and individual users as possible in Canada. The evaluation consultations with key informants and survey respondents confirm this observation.

Other Indicators of CANARIE's Relevance

As a national organization, CANARIE is able to facilitate and bring together activities and initiatives to take advantage of opportunities that individual organizations cannot or would not do by themselves. In this respect it acts as an "aggregator", making it easier for those needing a service to acquire it from vendors at a more reasonable price while enabling vendors to service a greater demand base that makes the venture feasible and fruitful.

An example of this kind would be the potential collaboration of CANARIE with Internet2 in their Net+ program, to deliver services to Canadian higher education institutions. CANARIE is investigating this option, and working with community stakeholders to provide Net+ services which would deliver complementary network offerings as a result of aggregation economically.

Finally, the relevance of CANARIE can be measured in exponential terms if one considers that the \$62 million *three-year* budget with which it is operating is only a very small fraction of the total *annual* R&D budget of the Canadian government. With a relatively small budget CANARIE is providing essential communications services to significant Canadian R&D work – including government research labs and R&D centres; large-scale initiatives in a cross-section of science and technology priorities and big-data projects that are themselves recipients of major funding from federal and provincial governments; and the private sector. Statistics Canada estimated in 2013 that "... for R&D

funding, the business enterprise sector is expected to finance \$14.4 billion ..., followed by the federal government sector at \$6.0 billion and the higher education sector at \$5.3 billion."¹²

3.2 Continued Need for CANARIE

Evaluation question: Is there a continued need for CANARIE?

In the section above, the relevance of CANARIE to researchers, educators, and the private sector was established, leading to the question of whether CANARIE programs and services will *continue* to remain relevant and necessary in the foreseeable future. As it stands, CANARIE's funding agreement with Industry Canada spans a three-year mandate. Given the rapid rate of technological advancement, coupled with the practical implications of the exponential growth of technological capacity and data generation, the needs of CANARIE beneficiaries will continue to change and evolve over the near- and medium-terms. This change will, in turn, impact the long-term planning, and funding requirement, of CANARIE.

Interviews and survey responses have pointed to the fact that the need for CANARIE's Network, and many of its programs and services will continue to be strong, and furthermore, will likely grow in the coming years. The continued dependence of Canada's research, education and innovation communities on the digital infrastructure, managed and operated by CANARIE, can be measured in terms of:

- the anticipated future needs of stakeholders for such infrastructure and the sufficiency of CANARIE resources to meet those needs; and,
- the impact of the discontinuation of CANARIE programs and services on stakeholders.

These factors are further elaborated on in the following sections.

3.2.1 Evolving Future Needs

Future needs in terms of a CANARIE-managed network and CANARIE programs and services requires an examination of the organization's international presence, as well as the evolving requirements of researchers, educators, and the private sector in Canada.

Continued Need for an International Presence

A scan of the global landscape of digital infrastructure makes evident the important role played by national organizations in ensuring connectivity and adequate infrastructure for research and education communities worldwide. CANARIE is one of over 100 National Research and Education Networks (NRENs) that manages network infrastructure for academic and research institutions.

Interviewees indicated that there is a continued need for CANARIE to serve as Canada's representative on the international stage, collaborating with other NRENs to continue to develop congruent network infrastructure, in order to facilitate collaboration and networking among the global research and education community. CANARIE's participation in the Global R&E Network CEO Forum demonstrates

¹² See Statistics Canada link: <http://www.statcan.gc.ca/daily-quotidien/131128/dq131128c-eng.htm>.

the key role it plays in the advancement of a global R&E community,¹³ focused on advancing research networking and collaboration worldwide. CANARIE's leadership position on the global research and education networking front will continue to allow Canada to participate in research with international partners.

Maintaining CANARIE's global leadership position requires continued commitment to and involvement in international initiatives, including (but not necessarily limited to):

- Global Lambda Integrated Facility (GLIF), an international consortium of NRENs and other institutions working toward advancing international lightpath networks.
- Starlight Consortium, a collaboration between iCAIR, the University of Illinois at Chicago, Argonne National Laboratory, SURFnet and CANARIE on the design of advanced, application-focused network resources; and
- Global Ring Network for Advanced Applications Development (GLORIAD), a network serving over 4,000 partnerships and enabling research networking across the world.

The fundamental role played by CANARIE in such international collaborations and partnerships is evidence of the continued need for the organization's international presence. According to one interviewee, the necessity for a nationally-managed research and education network arises out of the "economies of scale, both intellectually and financially" that are afforded to such an organization, and that cannot be readily replicated at the sub-national level. CANARIE allows Canada to participate on the international stage within the contemporary context of borderless research activities, which will only continue to increase in prevalence.

Continued Need within Canada

Within Canada, the need for an advanced high speed network for researchers and educators will continue to grow over the next three years, necessitating the programs and services of CANARIE. As one interviewee stated, "the deluge of data coming out of new research developments increasingly necessitates a national super high-speed network that is constantly evolving." However, although CANARIE, as it currently exists, is perceived to be mostly sufficient to continue addressing these needs, according to interview and survey results, there is room for improvement. One interviewee, for instance, foresaw the need for a 100 Gbit/s connection for his institution within three years – a capacity that is currently not available to his institution, though as previously presented in Section 2, CANARIE is evolving such a core capability within the backbone of its network.

Many interviewees commended CANARIE on its ability to remain attuned and responsive to the changing needs of its user base. To aid the justification of future funding and strategic directions for CANARIE, this section presents the evolving needs that came out of the survey and interview responses.

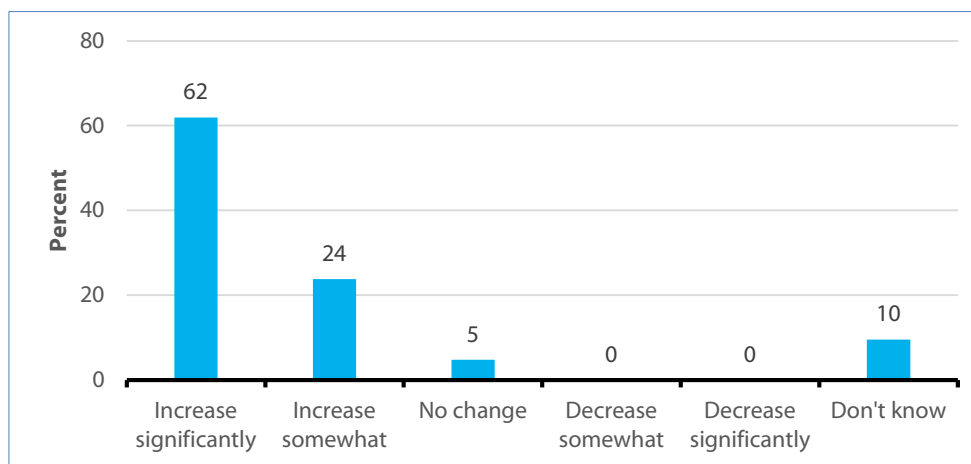
¹³ The Global R&E Network CEO Forum consists of the Chief Executive Officers of CANARIE and NRENs in Australia, China, Mexico, Europe (DANTE), Germany, USA, UK, European Nordics (NORDUnet), New Zealand, Latin America, France, Brazil, The Netherlands, and Southern and Eastern Africa (UbuntuNet Alliance).

Evolving Needs of Researchers and Educators

One only needs to look to a few examples of ‘big data’ research projects being conducted on the CANARIE Network to see that network and computing needs among researchers are growing at lightning-speed.

Given the significant research projects supported by the CANARIE Network, many of which require large amounts of bandwidth and computing capacity, the Canadian research community’s network needs are likely to multiply over the coming years. Researchers and developers who responded to the CANARIE survey were asked to estimate the change in their usage of a high-bandwidth network in the next three years. Exhibit 3.5, below, presents the range of their responses.

Exhibit 3.5: Anticipated Change in Usage of High-bandwidth Network by Researchers



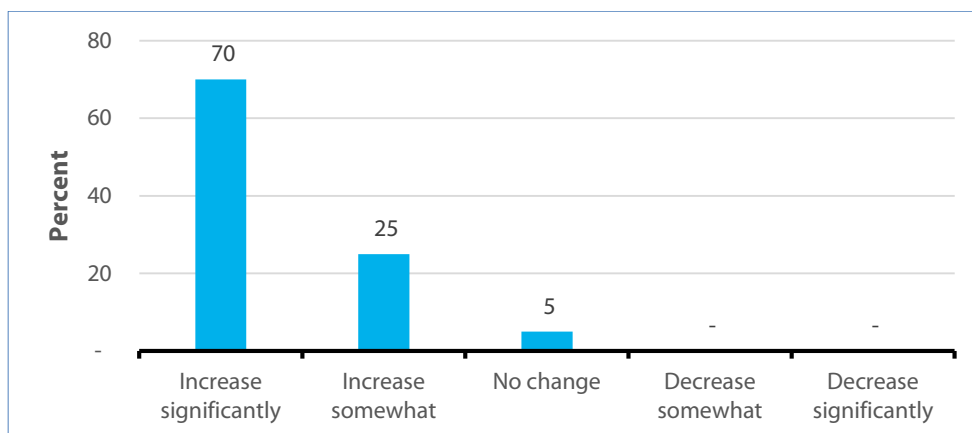
Source: CANARIE 2014 Survey.

As shown in the figure above, 86 percent of researchers and developers reported that they expect bandwidth usage levels to increase “somewhat” or “significantly” over the next three years. Though a small number of respondents (5 percent) anticipated no change in network use, and some (10 percent) were not able to estimate anticipated change, none of the researchers and developers who responded to the survey reported any expected decrease in their bandwidth usage. At the same time, when asked if CANARIE should continue offering network operations, 100% of the 93 stakeholders consulted as part of the development of CANARIE’s 5-year Strategic Plan agreed that CANARIE’s network operations should continue and/or be expanded/improved.

Indeed, as the amount of data and the ways in which data is used continue to increase, so will the need for the CANARIE Network. The factors contributing to an increase in network use by researchers are discussed in Section 3.1, above. One interviewee estimated that some projects have new satellites that are expected to generate at least twice the amount of data currently produced within the next six months. In addition, new initiatives in remote locations (e.g., new communications infrastructure in Inuvik) will add to the amount of data that is expected to be generated and transmitted over the CANARIE Network in the near future.

Interview and survey responses also revealed researchers' evolving needs in terms of digital infrastructure, including components such as a digital network, digital storage, computing, and remote sensors. Exhibit 3.6 presents the expected change in researchers' use of digital infrastructure over the next three years.

Exhibit 3.6: Anticipated Change in Usage of Digital Infrastructure by Researchers

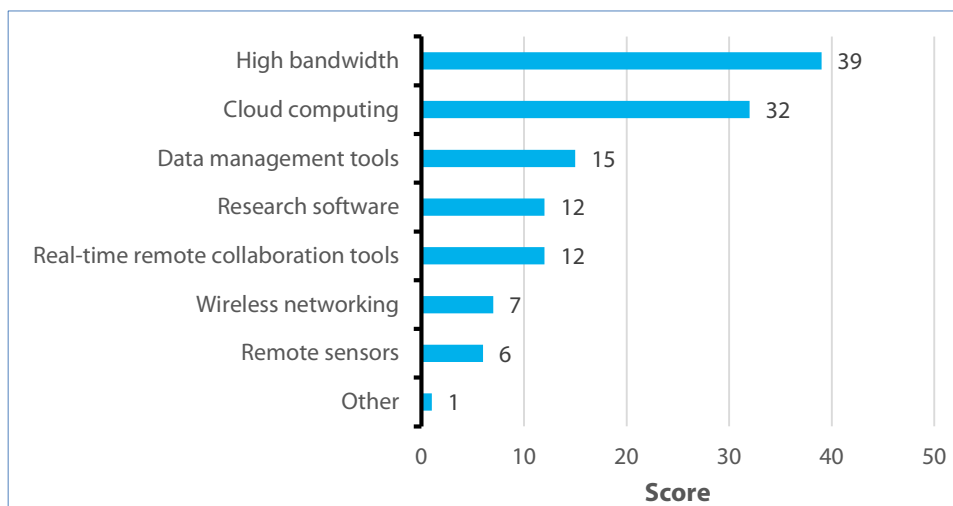


Source: CANARIE 2014 Survey.

In terms of researchers' use of digital infrastructure over the next three years, the majority (70 percent) reported anticipating a 'significant' increase in their use of digital infrastructure, with an additional 25 percent responding that their use of digital infrastructure will "increase somewhat." Once again, only a small proportion (5 percent) projected no change in their use of digital infrastructure, while none anticipate that their use will decrease over the next three years.

CANARIE offers researchers an array of digital infrastructure tools. Interviews pointed to the importance of network virtualization and wireless network to upcoming projects. Survey respondents were asked to indicate the top three tools they will need for their research during the next three years. The results are shown in Exhibit 3.7, below.

Exhibit 3.7: Top Digital Infrastructure Tools over the Next Three Years¹⁴



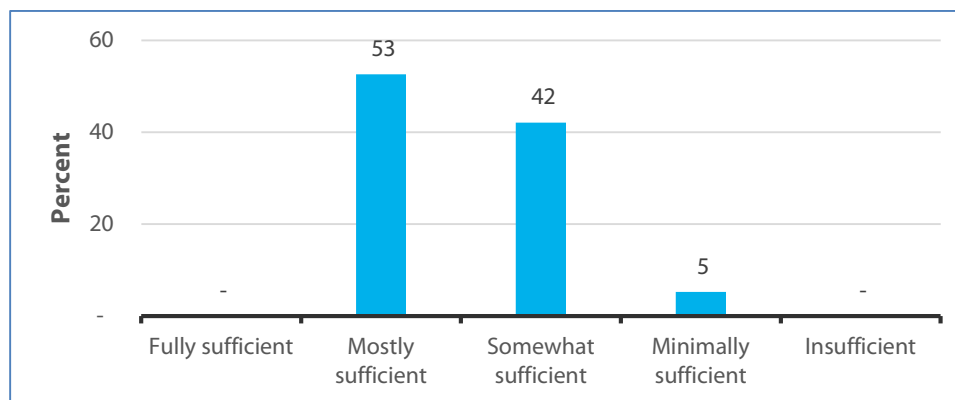
Source: CANARIE 2014 Survey.

According to the researchers and developers who responded to the survey, the top three digital infrastructure tools that will be required in three years are high bandwidth, cloud computing and data management tools.

How sufficient are CANARIE's resources to meet the future needs of the Canadian research community? Nearly all (95 percent) researchers and developers who responded to the survey perceived current CANARIE resources to be "mostly" or "somewhat" sufficient to meet their future requirements, although 5 percent did note that CANARIE is 'minimally' sufficient to meet future needs. Researchers' responses to this question are shown in Exhibit 3.8, below.

¹⁴ Score is a sum value. Three points were allocated to the most important tool selected by each respondent, followed by two points for second most important and one point for third most. The average value is not taken in order to preserve the weighting accrued through multiple responses.

Exhibit 3.8: Researchers' Perceptions of CANARIE Sufficiency in Meeting Future Needs



Source: CANARIE 2014 Survey.

Though none of the researchers or developers who responded to the survey felt that current CANARIE resources are “insufficient” for meeting their evolving research needs, none felt that the CANARIE is “fully sufficient” either. With nearly all respondents reporting that CANARIE resources are mostly or somewhat sufficient, there is indication that CANARIE may need to increase its resources in some respects to fully meet the needs of the research and education community which it serves.

One interviewee from a partner network estimated that over the past few years, traffic over the CANARIE Network had increased, on average, by 50 percent per year and estimated that it will continue to grow at a similar rate over the next three years. As noted in Section 2, the growth across all networks was even higher than this estimate, with an average of 77 percent in year-over-year growth from 2009-10 to 2013-14. In addition, as shown in Exhibit 2.3 in Section 2, a majority of CIOs expect that their R&E traffic (as a percent of gross traffic) over the CANARIE network will “somewhat” or “significantly” increase over the next three years. Given these indications, it can be estimated that the need for the CANARIE Network will not only continue, but can be expected to increase quite rapidly.

Similarly, an increase in use of peering and federated access services, can be expected in the education community. To that end, some interviewees highlighted the lack of alternatives for educational institutions that both will require access to higher speed connections, but do not have the resources to procure such services from commercial providers.

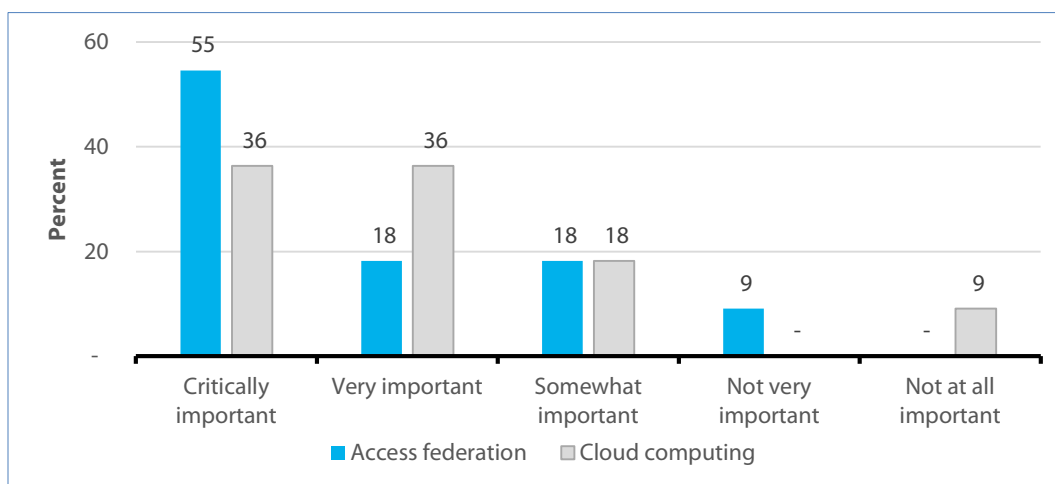
As outlined in Section 2, on average, 93 percent of the population of the institutions responding to the survey have access to CANARIE and the ORANs. Federated authentication of institutional affiliation has simplified and reduced the costs of access to resources from other institutions. CAF has been under CANARIE management for just over two years and interview responses suggested that the program will continue to attract more participants. There are currently 103 participants in the CAF program, which represents a 171% increase from the 38 participants in the program when CANARIE took it over in April 2012. In addition to this growth, the use of eduroam (a service within the CAF program) has grown significantly, totalling more than 3 million logins in March 2014.

Interview results highlighted the high level of dependence of library services on CAF. As one interviewee noted, CANARIE should “expect to see more and more of this happening in the coming years.” Given how essential CAF has been to institutions already participating, it is likely that CAF usage will continue to grow. One interviewee predicted that CAF usage will grow at an even steeper curve than network usage, driven by new institutions signing up for the program.

Similarly, CDS is in the nascent stages of forming partnerships with content providers and providing users settlement-free access to content. In particular, interviewees suggested an increased need for cloud computing services in the education sector, indicating a growing demand for CDS in the coming years.

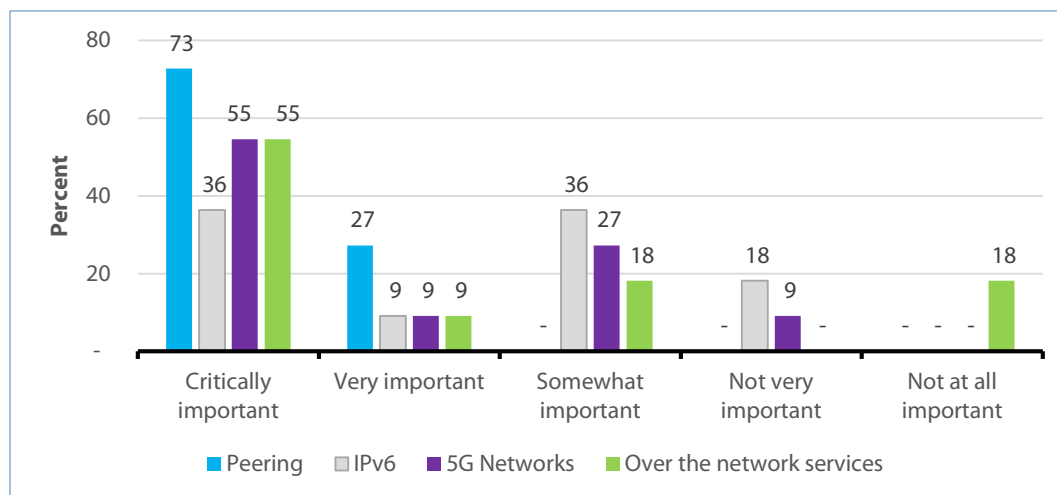
According to survey results, 91 percent of CIOs attributed some level of importance to access federation services, and 90 percent indicated that cloud computing services were “somewhat” to “critically” important.

Exhibit 3.9: Importance of Access Federation and Cloud Services to CIOs



Source: CANARIE 2014 Survey.

Exhibit 3.10: Importance of Peering, IPv6, 5G Network and Over the Network Services to CIOs



Source: CANARIE 2014 Survey.

All of the CIOs who responded to the survey agreed that CANARIE is “somewhat” to “mostly” sufficient to fulfil network requirements in terms of peering and CAF services over the next three years. The ability of CANARIE to maintain an excellent level of service in terms of CDS is unpredictable, and highly dependent on user demand for specific content, which may fluctuate according to new partnerships with content providers. One interviewee noted that CANARIE must be prepared to deal with surges in demand: “The trouble is, if a killer application or service comes on board, [CANARIE] may face the short-term problem of providing the service.”

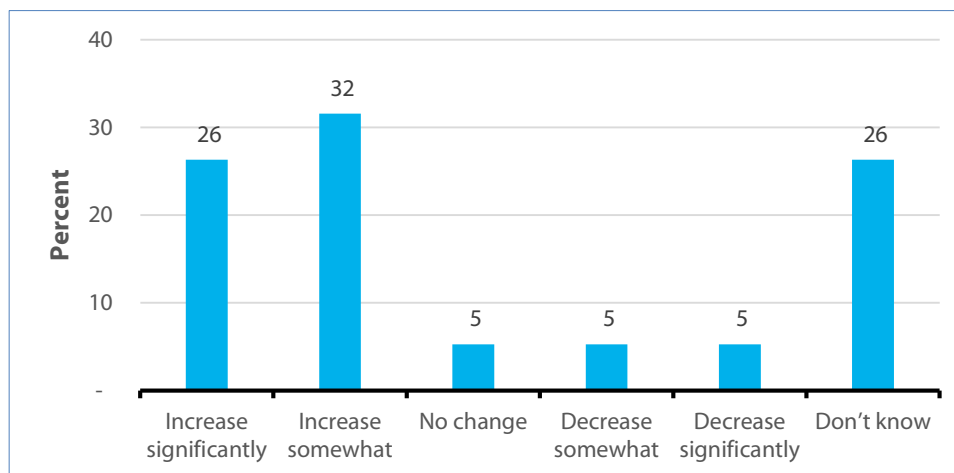
Evolving Needs of SMEs and Entrepreneurs

Less than two years after its launch as a full program, DAIR has had a significant impact on its users (as illustrated in Section 2.3), and many users anticipate an increase in demand for the program over the next three years. Interviews suggested, however, that future take-up of the DAIR program by startups and entrepreneurs is highly dependent on the program’s promotional efforts, and the extent to which awareness of the program is raised among the entrepreneurial community. One interviewee anticipated that the increase in usage will be modest if the program continues to be promoted through word-of-mouth.

That said, there are several factors for CANARIE to consider to ensure that DAIR remains effective in stimulating private sector innovation. For example, some interviewees noted that the need for DAIR (as it is currently offered) might be tempered by the development of comparable offerings (in terms of both the availability of appropriate bandwidth/speed and online resources – and the pricing of those services) by commercial providers. In addition, some interviewees noted the inconvenience caused by the limited length of time in which companies could remain as DAIR users. The transition from the DAIR program to commercial services (at the conclusion of their participation in DAIR) can incur costs and some disruption. In combination, these concerns could conceivably lessen the appeal of DAIR in the future, at least as the program is currently structured.

These concerns aside, the majority (58 percent) of current DAIR users who responded to the survey (which includes only of DAIR users with more than one year of experience with the program), anticipate that usage of the program will somewhat or significantly increase. This finding is supported by the conclusions of consultations surrounding CANARIE's 5-year Strategic Plan, which noted that 77% of the 48 interviewees contacted supported the continued operation and/or expansion of DAIR. It does appear, however, that DAIR is more difficult to foresee than other, more predictable areas such as research and education network usage. Indeed, over one quarter (26 percent) of respondents were not able to estimate the change in usage.

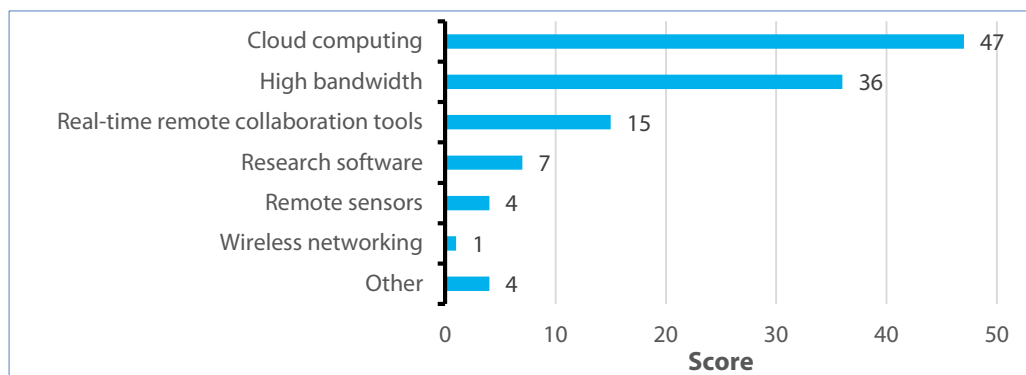
Exhibit 3.11: Anticipated Change in Usage of DAIR Program over the Next Three Years



Source: CANARIE 2014 Survey.

When asked about the digital infrastructure tools that will be most important to them during the next three years, DAIR users ranked cloud computing, high bandwidth and real-time remote collaboration tools as the top three tools.

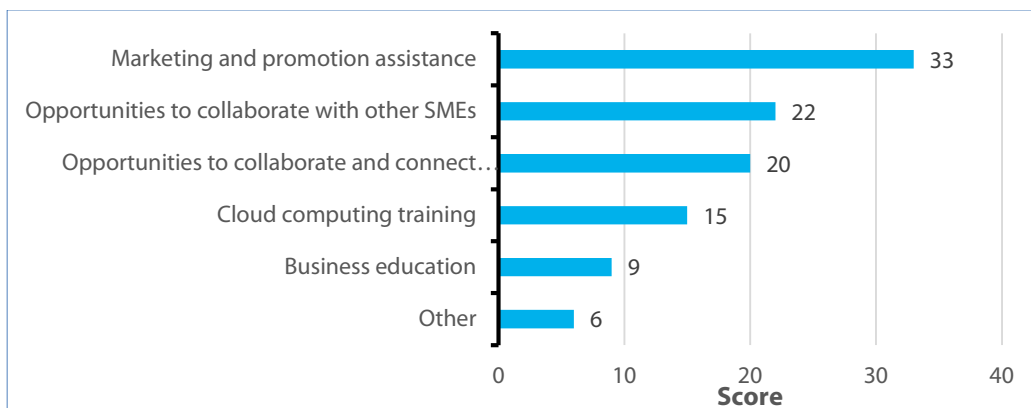
Exhibit 3.12 - Top Digital Infrastructure Tools for DAIR Users over the Next Three Years¹⁵



Source: CANARIE 2014 Survey.

Whereas business education and technical training were reported to be lower priority assistance programs during the next three years for DAIR users, the survey pointed to marketing and promotion and collaboration assistance as emerging needs among the DAIR user base. However, it should be noted that marketing and promotional assistance is not currently part of DAIR's (or CANARIE's) mandate.

Exhibit 3.13 - Top Assistance Programs for DAIR Users over the Next Three Years¹⁶



Source: CANARIE 2014 Survey.

¹⁵ Score is a sum value. Three points were allocated to the most important tool selected by each respondent, followed by two points for second most important and one point for third most. The average value is not taken in order to preserve the weighting accrued through multiple responses.

¹⁶ Score is a sum value. Three points were allocated to the most important tool selected by each respondent, followed by two points for second most important and one point for third most. The average value is not taken in order to preserve the weighting accrued through multiple responses.

Increased Relevance as a Result of New Initiatives

Overall, stakeholders believe that new programs introduced by CANARIE have increased CANARIE's relevance to the needs it is trying to address.

The DAIR program is generally aligned with industry needs, although a few interviewees questioned the alignment of the program with CANARIE's core mandate. Though it has resulted in participants hiring students, several interviewees noted that CANARIE's mandate calls for further initiatives to bridge the gap between academia and business.

CDS has addressed the increased need of the research and education community to access content and cloud services, and provides another way in which institutions can reduce costs while still leveraging technologies to enhance learning opportunities.

The Research Software Program, in particular, seems to have effectively responded to the need for software solutions and knowledge sharing among some developers. The program has been successful in creating efficiencies in development and research, allowing developers to build on the work of their peers to create adaptive, efficient and practical software solutions. These solutions have allowed researchers to more easily access and use available resources. For example, in February 2014, CANARIE announced the funding of nine new software projects, which were poised to not only contribute 21 new software components, but also to re-use 12 existing software components.

3.2.2 Negative Impacts of Discontinuation of Services

If funding for CANARIE were to be discontinued, the high level of dependency of the research, education and innovation communities on the network would require a transition to a comparable alternative – likely from the private sector. Several interviewees stated that although possible, the costs of such a transition would be much higher than continued funding of CANARIE. As well, this transition would take time and interrupt the research and education community's ability to participate meaningfully in their activities.

Alternatives to achieving an equivalent level of connectivity, if even possible, would be cost-prohibitive. If the gap were to be filled by industry, there would be additional costs to both providers and users. In addition, the inclusion of profits in the equation may impact priorities at the expense of leading-edge research. Another alternative, as noted by many interviewees, would be for researchers and institutions to achieve international connectivity through US channels (e.g., Internet2), which would not only be more expensive, but also create external dependencies (e.g., regarding the Patriot Act and/or net neutrality regulations in the US). Collaborative research efforts would be likely to continue in such a scenario, but in a much more costly, perhaps less secure, and much less efficient manner.

Overall, interview and survey respondents agreed that if CANARIE ceased to exist, the consequences would be dire. Below are highlights of some interview responses:

- The R&E community would "suffer dramatically;"
- "Without CANARIE, interprovincial and international linkages for Canadian researchers and educators would be seriously jeopardized and the Canadian position on the international arena, fragmented;"

- “Without CANARIE and its community of resources, research would become more isolated and happen in silos. It would become much less creative and a whole lot less productive.”
- “It would put Canada at a significant disadvantage, nationally and internationally.”

Furthermore, multiple interviewees indicated that the results would be “catastrophic” and “disastrous,” and that some research and educational activities would “come to a halt.”

The impact would be far greater on the smaller provinces, as they are dependent to a higher degree on the connectivity afforded by the CANARIE Network, and many institutions would be hard-pressed to find alternatives to current levels of connectivity through CANARIE, as equivalent services are not available over commercial channels.

In the absence of the CAF service, Canadian institutions would lose the advantage of federated identity and access management and the meaningful cost and service benefits it delivers. Though it would be possible to set up the same level of access to research resources from other institutions, the process would be time consuming as individual bilateral agreements, as well as operational and policy arrangements, would need to be put into place with each institution.

In the absence of DAIR, current users suggested that they may face cash flow problems and experience an increased time to market (e.g., a longer prototyping period). The cost-prohibitive nature of alternative commercial cloud services may result in innovative ideas being “shelved” rather than tested and commercialized. However, as noted above, these commercial costs are decreasing over time.

In all, the absence of CANARIE would have a profoundly negative effect on research, education and innovation in Canada.

4. Alignment with Government Priorities

Evaluation Question: To what extent has CANARIE contributed to government S&T policy priorities and R&D goals?

In determining CANARIE's alignment with, and contribution to, government S&T policies, priorities and goals, the three policy documents included in this section are considered most relevant to CANARIE programs and services. The first and most recent is Digital Canada 150, the federal government's digital plan moving towards 2017, which provides a contemporary context for CANARIE's activities. The second is the Federal Budget for 2014, which illustrates CANARIE's alignment with government R&D-related investments and expenditures. Lastly, and perhaps the most directly related, is Canada's 2007 S&T Strategy.

CANARIE and its programs and services both directly and indirectly support the objectives of these policy documents. For example:

- CANARIE supports the objectives of Digital Canada 150, particularly the creation of "economic opportunities" and "connecting Canadians" – two key pillars of the plan –, in the following ways:
 - By providing cloud infrastructure to Canadian entrepreneurs and emerging businesses, CANARIE's DAIR program directly aligns with the creation of "economic opportunities," and
 - By connecting research institutions (and researchers), across Canada, CANARIE has contributed to "connecting Canadians," and also has helped to address the "Open Science" elements of DC 150.
- CANARIE contributes to the goals of the 2014 Federal Budget, by promoting "research excellence" and acting in parallel to planned investments to be made through the Canada First Research Excellence Fund (CFREF), in particular through its support of post-secondary institutions and facilitation of Canada's participation in world-leading research projects (e.g., the ATLAS program).
- CANARIE has led to the development of new knowledge, attracted (and retained) highly qualified persons, and led to the commercialization of new products and services – thereby directly contributing to three pillars of Canada's S&T strategy.

4.1 Alignment with Digital Canada 150

Announced in April 2014, Digital Canada 150 aims to support Canada in the digital age through five pillars:

- Connecting Canadians;
- Protecting Canadians;
- Economic Opportunities;
- Digital Government; and,
- Canadian Content.

In particular, CANARIE is aligned with the "Economic Opportunities" pillar of Digital Canada 150, as it has helped Canada "rank among the world leaders in adopting digital technologies," and allowed Canada to become a global leader in leveraging technology to achieve economic benefits.

More specifically, through programs such as DAIR, CANARIE has facilitated the acceleration of innovation and commercialization, and allowed "Canadian companies large and small [to] use digital tools to boost productivity, develop their businesses, and capture growing markets at home and abroad." Digital Canada 150 highlights the DAIR program as a notable investment in this area, further illustrating CANARIE's direct alignment with the national digital strategy.

In addition, CANARIE is aligned with the Digital Canada 150's first pillar, "Connecting Canadians," which aims to increase and improve connectivity across Canada to enable "e-commerce, high-resolution video, employment opportunities and distance education—providing rural and remote communities with faster, more reliable online services." Through partnership with the ORANs, CANARIE has significantly contributed to parallel advancements in the Canadian research and education landscape, and its mandate is complementary to this digital strategy. Potential synergies also exist between CANARIE programs and the Provincial and Territorial Infrastructure Component of the Building Canada Fund, as CANARIE-supported projects may be eligible for leveraged support for connectivity expansion initiatives.

CANARIE activities are also aligned with the "Digital Government" pillar, as the Network is among the resources used by government R&D centres. Additionally, CANARIE contributed to the "Open Science" initiative by providing the network (via FSSO), by enabling connections to Compute Canada (for data storage and computation) and by funding research software that can make it easy to archive, tag, and retrieve data. As CANARIE continues to develop the CDS program, government-led Open Data initiatives may also be able to leverage existing CANARIE platforms to disseminate data to the research and education community.

4.2 Alignment with Federal Budget 2014

Tabled in February 2014, the Federal Budget includes investments in support of advanced research and innovation. A significant portion of these investments will flow through the newly-created CFREF, which will provide \$1.5 billion in funding over 10 years to post-secondary institutions for the advancement of research in areas that create economic advantages for Canada. CANARIE is aligned with this direction as it provides the backbone digital infrastructure, services and software tools that support and accelerate Canadian research excellence and innovation, and promote accessibility and mobility of knowledge.

In addition, CANARIE has provided leadership and enabled world recognition for Canadian researchers through its leading-edge model for supporting many of Canada's big investments in science – e.g., TRIUMF, Institute of Quantum Computing, and other similar initiatives receiving significant funding from government and other programs.

CANARIE has established a long tradition (two decades) of working hand in hand with the research, education and innovation communities and the Government of Canada to deploy the digital infrastructure and services that optimize government investments and expenditures. In doing so,

CANARIE has contributed to the achievement of the Government's S&T and R&D directions, as expressed in the 2014 Budget.

4.3 Creation of Competitive Advantages for Canada

CANARIE has played a significant role in advancing Canada's overall strategy to mobilize science and technology, through the creation of competitive advantages for the Canadian research, education and innovation communities. Broadly speaking, CANARIE has helped advance science and technology in Canada through minimizing inequalities in terms of access to connectivity and resources across the country. Thus, the competitive advantages created by CANARIE programs and services span all regions of Canada. One interviewee commended CANARIE's advancement of science and technology across Canada: "CANARIE provides the same access for users in St. John's as that expected by users in Toronto or Vancouver. This helps even the playing field for addressing entrepreneurial, knowledge and people advantages in all parts of the country."

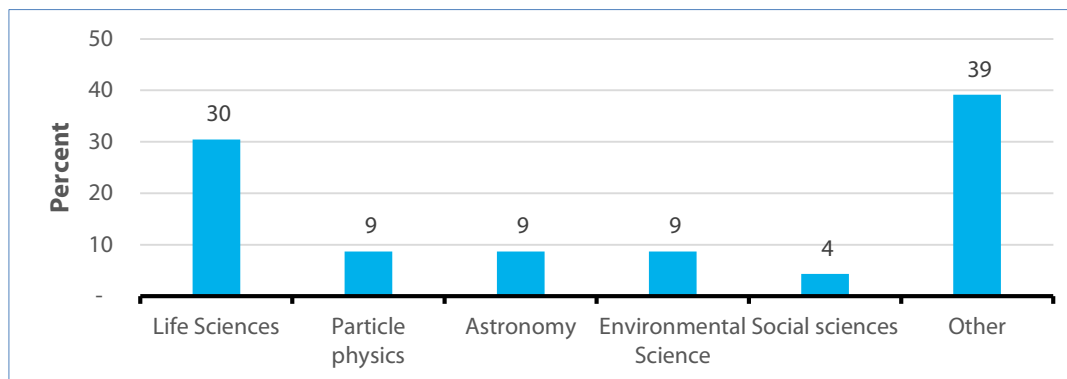
Canada's 2007 S&T strategy sets out a framework for building "a sustainable national competitive advantage based on science and technology and the skilled workers whose aspirations, ambitions, and talents bring innovations to life." The framework for implementing the strategy consists of three categories of competitive advantage – knowledge, people and entrepreneurial. CANARIE's contributions toward creating advantages in each of these categories are outlined below.

4.3.1 Knowledge Advantages

Canada's 2007 S&T strategy sets out to focus strategically on research that promotes national interests and to maintain Canada's leadership position in terms of global public research and development performance. In particular, the strategy highlights four priority research areas: Environmental Science and Technologies; Natural Resources and Energy; Health and related Life Sciences and Technologies; and Information and Communications Technologies.

Among researchers who responded to the CANARIE survey, 30 percent reported that their research was most closely associated with Life Sciences, as seen in Exhibit 4.1, below.

Exhibit 4.1 – Researchers' Scientific Discipline



Source: CANARIE 2014 Survey.

However, as shown in Exhibit 4.1, nearly 40 percent of respondents reported that their research activities fell outside of the category choices provided in the survey. Research disciplines listed by those who selected “Other” included, computer science and information technology, transportation systems, mechatronics, remote sensing, and urban systems engineering.

In February 2014, CANARIE announced the recipients of a new round of funding through the Research Software Program (NEP/RPI). Building on previous investment in 20 new research platforms, the newly funded projects directly contribute to the four priority research areas listed in Canada’s S&T strategy. Exhibit 4.2, below, highlights some of these platforms and their respective priority research disciplines.

Exhibit 4.2 – Selection of NEP-RPI Projects, by S&T Research Priority Area

Project Name	Leading Research Institution	Project Description + Highlights	Priority S&T Area
Web-Enabled Awareness Research Network (WARN)	Ocean Networks Canada (ONC)	<ul style="list-style-type: none"> Development of software platforms for earthquake and tsunami detection. Collaboration between ONC, University of British Columbia, and University of Victoria. Leveraging existing platforms and previous investments. Upon completion, will allow users to access and use data in innovating ways, and has the potential to be applied in other jurisdictions. 	Environmental Science and Technologies
High Energy Physics (HEP) Data: Intensive Distributed Cloud Computing	Department of Physics and Astronomy, University of Victoria	<ul style="list-style-type: none"> Development of a distributed cloud computing system. Research applications include CANFAR (Canada), ATLAS (int'l), NECTAR (Australia) and Belle-II (Japan), with international collaboration between more than 4,000 researchers. Leveraging private-sector investments (Amazon EC2 in-kind grant for US\$15,000 for use of cloud computing resources for the Belle-II project). 	Natural Resources and Energy
CBRAIN for High Performance Computing (CHPC)	Montreal Neurological Institute, McGill University	<ul style="list-style-type: none"> Development of platform for automating CBRAIN activities from remote scripts or platforms. Aims to allow authentication, data cataloguing, registration and movement of brain-imaging data. Aims to facilitate data gathering across Compute Canada resources and/or between research institutions. 	Health and related Life Sciences and Technologies
M+M: Movement + Meaning Middleware	School of Interactive Arts and Technology, Simon Fraser University	<ul style="list-style-type: none"> Development of middleware to enable construction of semantic models for movement analytics. The platform will allow visualization of sensor-based movement, with applications in gaming, animation and robotics. A collaboration between Simon Fraser University and H+ Technologies, M+M leverages public-private partnership to advance leading-edge technologies. 	Information and Communications Technologies

Inherently, all projects supported by the Research Middleware Program relate in some way to the Information and Communications Technology category. However, the wide array of research disciplines involved in the program and the extent to which the software developed enables collaboration and advancement in those fields indicate the breadth and depth of CANARIE's impact on Canada's S&T community.

Other projects that received Research Software Program funding in this round include:

- **SKA Global Science Data Delivery Platform**, led by the Department of Physics and Astronomy, University of Calgary;
- **Genetics and Genomics Analysis Platform (GenAP)**, led by the Department of Human Genetics, McGill University; and,
- **Map-updating Web Service for the Update of the National Hydrographic Network using Landsat-8 Imagery**, led by Centre de Recherche Informatique de Montreal (CRIM).
- **Software-as-a-Service (SaaS) for Big Data Analytics**, led by the Department of Physics and Astronomy, University of Victoria

In addition to the projects supported through the Research Middleware Program, CANARIE creates knowledge advantages for Canada through contribution to better learning opportunities for students. Educational institutions throughout Canada benefit from advanced connectivity and network solutions through ORANs and the CANARIE network. In particular, distance learning and inter-provincial and international networking and collaboration are facilitated by the CANARIE Network, creating knowledge acquisition and sharing opportunities that would otherwise not exist for the Canadian education community. CANARIE also continues to improve research and education digital infrastructure across Canada through the NAI program.

In addition, CAF allows streamlined access to international repositories of knowledge resources, creating a gateway for Canadian students and researchers to the wealth of information available through institutions across Canada and the world. CAF also allows student mobility – intra-provincially, across Canada, and internationally – to occur with ease and minimal administrative burden to host institutions.

Furthermore, CDS allows institutions to access a growing pool of content and applications. The introduction of this program has minimized application and content costs through settlement-free access to content carried on the CANARIE network.

Overall, CANARIE has contributed immensely to both improved infrastructure and streamlined access at universities, colleges and research institutions across Canada, in effect, maximizing the impact of Federal education investments by decreasing costs to institutions.

4.3.2 People Advantages

Canada's S&T strategy also prioritizes the enhancement of opportunities for S&T graduates and an increase in the supply of highly-qualified personnel (HQP) and globally-connected S&T graduates across Canada.

CANARIE's programs and services have contributed to the creation of people advantages through facilitating the training of HQP, attracting leading researchers to Canadian institutions, and connecting the Canadian and global research and education communities.

Exhibit 4.3, below, presents the total number of HQPs trained as a result of CANARIE, as reported by researchers and developers who responded to the survey.

Exhibit 4.3 – Breakdown of Trained HQP as a Result of CANARIE

HQP Category	% of total HQP	Average per Researcher
Post-doctoral fellows	15	3
PhDs	15	3
Technicians	16	3
Masters students	18	4
Undergraduates	36	7

Source: CANARIE 2014 Survey.

As shown in the figure above, undergraduate students made up the largest proportion of trained HQPs, accounting for more than double the amount of HQPs reported overall by researchers in each of the other categories. However, due to the small sample size, it is not possible to extrapolate the figures to reflect the aggregate research disciplines. Survey results also revealed the importance of CANARIE to HQP attraction and retention:

- All CIO respondents attributed a degree of importance (ranging from “somewhat” to “critically” important) to CANARIE in terms of HQP recruitment, development and retention;
- A majority (84 percent) of CIOs indicated that CANARIE played an important role (“somewhat” to “critical”) in attracting and retaining leading-edge researchers to their institutions;
- CIOs indicated that if CANARIE ceased to exist, there would be negative impacts on retaining science and engineering faculty, attracting graduate and PhD students; and, overall student enrollment (see Exhibit 3.4 in Section 3.1 for breakdown of responses).

In addition, as noted in Section 2.3, more than half of DAIR users who responded to the survey reported having hired new employees as a result of participation in the program.

Finally, CANARIE's contribution to the creation of people advantages in Canada can be measured by the degree to which the CANARIE Network facilitates international research collaboration, which leads to a globally-connected Canadian research and education community. An overwhelming majority of researchers and developers who responded to the survey indicated that CANARIE is “somewhat” to “critically” important for collaborating with international researchers. Interviews also indicated that CANARIE has been essential to international networking, and Canada's participation in world-class research.

4.3.3 Entrepreneurial Advantage

As part of the national S&T strategy, the Government also prioritizes the commercialization of innovative products and services by fostering a competitive and dynamic business environment; pursuing public-private research and commercialization partnerships, and increasing the impact of federal business R&D assistance programs. CANARIE's introduction of the DAIR program during its previous mandate has increased its strategic alignment with the Government's prioritization of entrepreneurship and commercialization.

To date, the DAIR program has allowed hundreds of researchers, entrepreneurs and small- and medium-sized enterprises to accelerate the time-to-market of their products and services. As noted in Section 2.3, a survey of DAIR users revealed an average 20 week reduction in time-to-market and 24 percent savings on development costs, increasing competitiveness and reducing financial strain for emerging companies.

The case studies in Appendix B provide additional examples of CANARIE's creation of entrepreneurial advantage, including Metafor Software, a Canadian startup that has leveraged the DAIR program to remain innovative and competitive in the ICT market.

Another indicator of CANARIE's contribution to entrepreneurial advantages is the creation of intellectual property enabled by the network, programs and services. As shown in Exhibit 2.13 in Section 2.2.1, a majority of CIOs (66 percent) attributed some importance to CANARIE for the creation of intellectual property, while an even larger proportion (83 percent) considered CANARIE important to innovations in products and services.

Publications and presentations serve as additional indicators of entrepreneurial activity spurred by CANARIE. Exhibit 4.4 presents indicators of productivity among the researchers and developers who responded to the survey, in terms of the number of articles and reports published and presentations given at conferences, workshops and meetings. The average level of activity per researcher is calculated by dividing the total number reported in each category by the number of researchers that responded to this particular question.

Exhibit 4.4 – Entrepreneurial Research Activities since 2010 Related to CANARIE Funding

Activities	Total Number Reported by Survey Respondents	Average per Researcher
Number of scientific articles (in peer-reviewed academic journals)	286	24
Number of invited presentations given at conferences, workshops and meetings	164	14
Number of technical reports	85	7

Source: CANARIE 2014 Survey.

Proportionally, the largest output from research activities is in the form of scientific articles, followed by invited presentations. While Exhibit 4.4 represents the average breakdown of these activities among survey respondents, the small sample size does not allow extrapolation of results to reflect the aggregate research disciplines.

Finally, several interviewees suggested that CANARIE is well-positioned to strengthen connections between industry and academia. This opinion was echoed in mandate renewal stakeholder consultations, which identified an opportunity for CANARIE to serve “as a key convener of collaborations between academic researchers and the private sector and incenting commercialization.”¹⁷ Seizing such an opportunity would allow CANARIE to further contribute to creating entrepreneurial advantages (and in many cases, people and knowledge advantages) for Canada.

¹⁷ Monitor Deloitte, “CANARIE 5-Year Strategic Plan (2015-2020): BOD Pre-Read Material: Summary of Stakeholder Consultation Findings,” February 2014.

5. Alignment with Federal Roles and Responsibilities

As with any program funded through government support, it is critical to periodically consider whether CANARIE continues to play a necessary, legitimate role. More specifically, should Canada's federal government be in the business of facilitating interconnections between Canadian-based research institutions (via ORANs), and between those institutions and leading international research sites? One might also question whether CANARIE's role in facilitating private sector innovation (e.g., through the DAIR program) is an appropriate role for a federally funded organization. Furthermore, it is important that parties in the research and education field in Canada have a clear understanding of CANARIE's mandate as a federally funded organization.

There is a compelling case to conclude that CANARIE provides, and likely will continue to provide, a service that Canadian researchers and entrepreneurs need – one that cannot readily be provided as effectively by the private sector or some new cooperative vehicle organized by provincial ORANs. To that end:

- Stakeholders and users of CANARIE mostly agree that CANARIE provides programs and network services that are appropriate for federal government support and aligned with its roles and responsibilities – ensuring that Canadian researchers and educators from coast to coast have an accessible and reliable leading edge, advanced high-speed network available to them.
- Without CANARIE, research institutions would have to form some other organized effort to enable collaboration, communication, and access to Canadian and international research. Such a collaboration could be dominated by the larger provinces, and the collective expense could be greater than the cost of CANARIE.
- If institutions were forced to pursue private sector solutions, the costs for doing so by these institutions would likely render many research activities cost-prohibitive.
- Helping SMEs grow via programs like DAIR is generally supported by the research community as a legitimate mission of CANARIE. While some research stakeholders would like to revise DAIR's orientation, they recognized why helping SMEs is a legitimate role for CANARIE.
- Vice Presidents of Research at academic institutions, researchers, partner ORANs, and incubators/accelerators all have a clear understanding of the purpose and role of CANARIE. CANARIE's role seems somewhat less clear among CIOs of academic institutions, but that is likely because they deal directly with the ORANs, not CANARIE.

5.1 Necessary and Legitimate Role for a Federal Government Supported Program

Evaluation question: Does CANARIE play a necessary and legitimate role as a type of program requiring federal government support?

The consensus among interviewees was that Canada needs the kind of service that CANARIE provides to fully leverage the billions of federal dollars spent on academic and government research – medicine, science, and the humanities and social sciences.

Respondents speculated that without CANARIE, some other organized effort would need to be arranged to fulfill that role of enabling collaboration, communication, and access among Canadian and international researchers.

If not CANARIE, the most commonly mentioned arrangement was a process whereby the provincial ORANs would form a common buying group and broker commercial telecommunications providers. However, it was felt that would be inefficient, and require more staff to be hired by the provinces to develop the relationships and knowledge to orchestrate national high speed networks. Moreover, with different mandates and funding capacity, a buying group would not provide the specialized services nor conduct the R&D that further leverages the investment in research.

It is believed that if the private sector were given the mandate to connect university and government research, it would be more expensive, less seamless, and services would not be as geographically complete. Even if the provinces brokered the private sector, the smaller research centres and provinces would not be as well served. Interviewees seemed to agree that it takes federal investment to ensure that there is equivalent service and stimulus to leverage Canada's investment in research and R&D.

In sum, CANARIE's role is a necessary one for a modern society whereby collaborative research on a national and global scale is crucial to be part of the developed world. While it could be done through another form of organization, it is believed that a national organization should be the leader, and there is no obvious alternative organization which would be more efficient and effective. As a national responsibility, it was difficult for stakeholders to conceive of support emanating from anywhere other than the federal government – especially given its stake in scientific research.

There was less unanimous support for the federal government's role, via CANARIE at least, to support industrial development and SMEs. However, most of the interviewees who worked with entrepreneurs or who fostered commercialization of research and export promotion applauded the rationale for CANARIE to step into the role of economic development in ways that were relevant to its assets and mandate.

5.2 Understanding the Mandate and Objectives of CANARIE

While CANARIE has developed its brand over the years, different stakeholders have different perceptions as to what CANARIE's most important roles are. The VPs of research at government labs and academic research institutions interviewed fully comprehend the important role of CANARIE. As well, established research scientists, who are regular users of CANARIE's services, recognize the essential backbone network role of CANARIE.

However, post-secondary institutions' CIOs appear to have less of an understanding of the role of CANARIE. They may not be as aware of CANARIE's multiple roles, and seem unaware of the cost-sharing and co-delivery funding models adhered to by CANARIE and its ORAN partners, and the efficiency benefits of this system (see Section 6 for more details on the efficiency and economy of

CANARIE). One interviewee advocates that CANARIE should do more outreach to this part of the user community.

Some economic development and trade promotion agencies, incubators, accelerators, and industry associations applaud CANARIE's outreach to the SME community, and would encourage more contact with research parks to help Canadian firms go global. In principle, more programs like DAIR should be initiated. While not everyone interviewed was perfectly satisfied by the DAIR program, they believed that the SME landscape could be negatively affected without CANARIE's active participation in it.

CANARIE's provincial peers, the ORANs, understand the mandate of CANARIE well. One interviewee commented that the software development and the R&D aspect of CANARIE was particularly important, as most ORANs were not mandated to allocate funds for such purposes. However, in another case, a provincial peer thought that the "commercialization direction" taken by CANARIE has been a misdirection – off topic, as it were – and doesn't fit with CANARIE.

CANARIE's provincial peers also recognize that the role of CANARIE can be quite invisible to users (many only know about CANARIE when something goes wrong, as CANARIE's services are quite behind the scenes). In fact, one provincial peer interviewee commented that CANARIE is handicapped from this lack of visibility and that it must keep explaining the role of CANARIE to government policy makers. However, some interviewees believed CANARIE has built its brand over 20 years, and its reputation helps communicate how essential it is.

Stakeholders interviewed in this evaluation were virtually unanimous in agreeing that CANARIE was needed on a national basis, and that support from the federal government was thought to be a natural consequence of that view. Most interviewees expressed concern that any alternative governance concept involving some form of provincial cooperation would be a poor substitute for CANARIE. One barrier is that the provincial ORANs operate under different funding mandates from each other. In big data research, only a government supported CANARIE can provide the required services and nation-wide accessibility for Canadian and foreign researchers. While not unanimous in terms of acceptance of the role, the support for promoting SME's competitive edge was believed to be a role that should be supported by the federal government.

6. Demonstration of Efficiency and Economy

CANARIE is a non-profit, arms-length, organization funded by the Canadian government. Under its current three-year mandate ending in April 2015, it operates under an Industry Canada Contribution Agreement which allocated \$62 million of federal funds for operating, extending, and improving the Network; providing support to partners and users to access the network; and enabling researchers, educators, and the private sector (SMEs) to benefit from its services. As such CANARIE is expected to deliver its services efficiently with an appropriate distribution of program funds to achieve the expected outcomes and objectives identified in the Contribution Agreement. It is also expected to operate the Network and its complementary program activities economically.

This section of the report will demonstrate that:

- As in its previous mandate, CANARIE is living within its means and delivering its programs efficiently.
- CANARIE is well focused on its mandate and related initiatives and funds are distributed proportionately and sufficiently commensurate with expected outcomes.
- For the duration of its current mandate, from April 1, 2012 to March 31, 2015, CANARIE is forecast to achieve cost-recovery of \$11.4 million, just \$0.3 million shy of its \$11.7 million cost-recovery target.
- With its ORAN partners, CANARIE has leveraged the Network and services efficiently, assisting R&E institutions and the private sector to innovate and commercialize products and services, while realizing cost-savings for users and participants in its programs.
- CANARIE has demonstrated best practices in managing and operating the Network. These include its co-delivery model with the ORANs, regularly analyzing key performance metrics, delivering a best-effort service, scalable and flexible network operations (garnering low legacy costs when upgrades are needed), and operating a hybrid system to serve the needs of large and small users.

As a result, the analysis in this section shows that CANARIE has indeed demonstrated efficiency and economy in operating and managing the Network, in delivering on its mandate to contribute to technology innovation and in leveraging the Network to assist R&E institutions and the private sector with regards to innovation and commercialization of products and services.

6.1 Consistency of Funds Allocation with Business Plans and Priorities

Evaluation Issue: Is the distribution of CANARIE funds approved and committed during its current mandate consistent with CANARIE business plans and priorities?

The CANARIE Contribution Agreement with Industry Canada states that CANARIE should address the objectives of the Agreement “to the extent resources permit”. This means that appropriate priorities and decisions for allocating and distributing limited funds across Canada are required. In the previous Evaluation of CANARIE (2011) it was determined that: “CANARIE has indeed lived within its means and balanced its resources well between operating the Network and supporting technology innovation.” Interviews and survey responses at the time confirmed this conclusion, and the analysis of

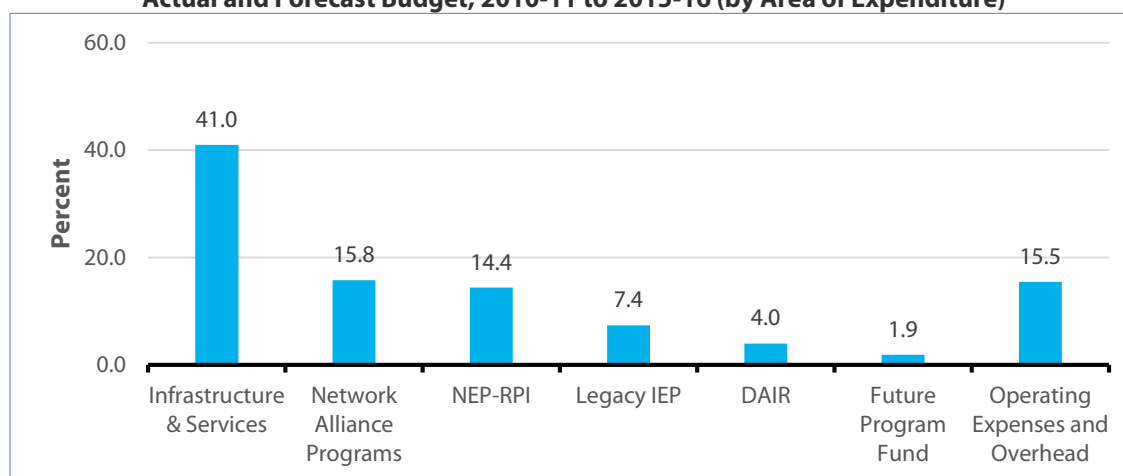
disbursements, financial planning and priorities, and operating costs further reinforced this evaluation conclusion in 2011.

Distribution of Funds

As in the previous evaluation, there is a consensus from the current round of consultations, including interviewee feedback and survey responses, that the choices that CANARIE made with its partners to invest funds over the current three-year mandate have been well made, focusing on relevant needs of the research and education community – including infrastructure build-up and improvement in all provinces and territories and funding for network platforms that enable world-class research which breaks new grounds in a broad spectrum of disciplines and priority fields of endeavor. In addition, the current mandate broadens CANARIE's role, extending it to supporting Canadian entrepreneurs in small and mid-sized firms across Canada, to help them accelerate their work and bring their products and services to market sooner than they would have otherwise been able to. As in its previous mandate, CANARIE's various initiatives and projects picked and prioritized during its current term have been effective and have addressed the balance of needs as defined by the objectives and intended outcomes of the organization. One interviewee responded with the remark: "CANARIE does the optimum possible with the resources allocated."

The distribution of CANARIE expenses (and revenues) was presented previously in Section 1.2.2. This distribution of expenses is shown again in Exhibit 6.1 to illustrate how actual and planned funds have been allocated to each of CANARIE's programs for the period from 2012-13 to 2015-16. As expected, network infrastructure and related services gets the biggest share of the CANARIE budget, since this is the core business of CANARIE. The operating and general overhead expenses total just over 15 percent of the total budget, which is the accepted norm in running government funded programs and organizations.

**Exhibit 6.1: Percentage Distribution of CANARIE Program Expenses –
Actual and Forecast Budget, 2010-11 to 2015-16 (by Area of Expenditure)**



Source: CANARIE, revenues & expenses table prepared January 2014.

While users and partners of CANARIE have provided their opinions (in interviews, the CANARIE 2014 Survey, and documents reviewed) that CANARIE has used government funds wisely for relevant and needed programs and services, there is also the view amongst a few of those consulted that CANARIE could address further opportunities enabled by linking the Network with high capacity computing services (e.g., Compute Canada).

CANARIE Financial Model – Leveraging Federal Funds

The overall funding model of the Canadian alliance or partnership that delivers advanced high-speed networking across Canada includes the ORANs, CANARIE, Industry Canada, and provincial government sources. CANARIE is one amongst its 12 delivery partners in the system. CANARIE represents only a portion of the funding that goes into the system. Partnership members share the costs of developing, upgrading, extending, and running the system. Funds flow from CANARIE to the ORANs to support the operation and to upgrade the system. Funding also flows from CANARIE to support projects initiated within the R&E community (e.g., research software programs). Provincial governments and memberships and service fees also provide sources of revenue for the ORANs.

CANARIE is only one, albeit a key, player in the overall financial model of Canada's advanced research and education network. The Industry Canada investment of \$62 million for the current mandate is leveraged by CANARIE to include ORAN funding from the provinces, membership and service fees. The next section also shows the extent to which CANARIE has demonstrated cost-recovery, by leveraging its expenditures and by collecting participation and user fees.

6.2 Cost Recovery

Evaluation Issue: How successful has CANARIE been in implementing its cost reduction and recovery goals?

Under the terms of its agreement with Industry Canada, which provides the program and operating funding for CANARIE, the organization was required to explore opportunities to complement the Government's investment and investigate cost recovery options. At the outset of its current mandate, CANARIE began a thorough analysis of alternatives and organized a wide-ranging consultation with members of its stakeholder community.

A *CANARIE Connection Fees Discussion Paper* was prepared and distributed to stakeholders to seek input on cost-recovery options for the organization. CANARIE organized conference calls and hosted face-to-face meetings to discuss and collect feedback on detailed proposals for addressing this issue. CANARIE also conducted, with the assistance of its ORAN partners, a detailed analysis of a usage-based fee model, involving traffic flows, institutional connectivity and peering statistics, and provincial population-based and research performance-based fee models.

The cost-recovery options outlined in the *CANARIE Cost-Recovery Business Plan* and the stakeholder *Discussion Paper* included cost sharing, cost avoidance initiatives, and fees for advanced network services. Overall, CANARIE's cost avoidance and cost recovery objective was to achieve \$11.7 million in total cost savings over the course of CANARIE's mandate.

The result of the consultations with stakeholders was that to maximize the impact and effectiveness of the government investment in CANARIE, the organization would continue to implement fees for its

CAF service, implement cost-sharing with provincial and territorial network partners on network infrastructure upgrades and extensions, and charge fees to private sector users of its cloud services, among other initiatives.

While CANARIE had investigated the option of charging a fee-for-service to research and education institutions (primarily universities and colleges), information gathered through the consultations demonstrated that these institutions are already paying for access to the network through fees to their provincial and territorial networks, and the balance between institutional, provincial and federal investments in CANARIE is reasonable. It was decided that levying additional connection fees would not happen.¹⁸

CANARIE's forecast cost-recovery revenues for the period from April 1, 2012 to March 31, 2015 are expected to total \$11.4 million, just \$0.3 million shy of the \$11.7 million targeted in its Cost-Recovery Business Plan. Exhibit 6.2 shows the cost-recovery amounts by source. CANARIE cost-recovery, as indicated, is due to revenues from membership and user fees, matching funds, in-kind contributions, and cost avoidance measures associated with the IEP (for example by "rightsizing" the network – i.e., configuring services optimally matched to user needs).

¹⁸ See "Minister of Industry Approves CANARIE Plan – Cost-recovery business plan outlines recommendations to complement government investments in research network infrastructure and services", CANARIE Press Release, Ottawa, ON, April 4, 2013.

**Exhibit 6.2: CANARIE Cost-Recovery Revenue by Source–
Forecast for April 1, 2012 to March 31, 2015 (\$ 000's)**

	FORECAST	COST-RECOVERY BUSINESS PLAN	VARIANCE
PROGRAM REVENUES			
Legacy – IEP	316	1,107	(791)
CAF Participation Fees	483	440	43
DAIR User Fees	17	195	(178)
Interest	398	383	15
TOTAL PROGRAM REVENUES	1,214	2,124	(911)
MATCHING FUNDS			
DAIR	175	232	(57)
NAI	5,116	4,846	269
TOTAL MATCHING FUNDS	5,291	5,078	213
IN-KIND CONTRIBUTIONS			
DAIR		300	(300)
NEP-RPI	887	769	118
TOTAL IN-KIND CONTRIBUTIONS	887	1,069	(182)
COST AVOIDANCE			
IEP	4,033	3,450	583
TOTAL COST AVOIDANCE	4,033	3,450	583
TOTAL	11,425	11,722	(297)

Source: CANARIE cost recovery table provided June 2014.

Note: The "Forecast" column includes "actuals" for the first two fiscal years of the period shown. Due to rounding, some figures may not sum.

6.3 Efficiency

Evaluation Issue: How cost-effective are CANARIE operations and activities compared to other Canadian S&T programs and initiatives? And how cost-effective is CANARIE compared to similar advanced network operations in other countries – e.g., USA, UK, Netherlands – recognizing the differences in mandates and scopes of activities?

The investment in CANARIE by the federal government is a crucial one that impacts on a very broad spectrum of users. It supports world-class, Canadian-based research that enables many private and public applications beneficial to Canadians in many areas of their daily life, including health, education, science and innovation, environment, security, and safety. Because of the broad implications and the importance of having such an advanced R&E network operating and serving Canadians, it is necessary to examine how efficient it is in delivering its mandate.

Converging Evidence on Efficiency from the Mandate Renewal Stakeholder Consultation

A key finding on “Efficiency”, according to the CANARIE stakeholder consultation, is as follows:

- Short-term funding hinders CANARIE’s ability to plan for infrastructure upgrades and attract top talent; it also results in instability and detracting of effort during mandate renewals.

This finding converges with the evaluation findings discussed below (see the last segment on “Efficiency Constraint”).

CANARIE Operates the Network Efficiently

CANARIE Inc., a non-profit organization, is made up of some thirty employees, including management and staff. This represents a 50 percent increase from 20 CANARIE employees at the start of the five-year evaluation period (i.e., since April 2010). The CANARIE operation is delivered with 15.5 percent of its budget spent on operations and overhead. This level of expenditure, as mentioned earlier, is within the norm for Canadian federal government program operations and delivery, particularly as these relate to various science and technology and R&D initiatives funded by the federal government. This is also below the 17.4 percent allowed for operations and overhead under the Industry Canada CANARIE Contribution Agreement.

In 2013, the federal government targeted \$6 billion for R&D funding and \$5.3 billion for higher education. Compared to this combined annual budget of \$11.3 billion, CANARIE’s annual funding as a public investment is a very small fraction (0.18 percent of total R&D and education spending), ensuring that the larger R&E community, and private sector participants in DAIR, are well served with an essential, advanced backbone communications, data transmission, cloud, and content provider network.

Though the CANARIE team is relatively small, users and partners have confirmed through interviews and survey responses that it provides excellent 24-7 services, with a quick turn-around and appropriate attention to ongoing day-to-day tasks related to network operations. CANARIE staff and management have also confirmed that though the budget for the current mandate has been relatively small, compared to previous mandates, it is sufficient to deliver an efficient network operation, upgrades, and set of contemporary and leading-edge services to users.

CANARIE has a reputation of being an efficiently run operation in the research and education community, and among its partners.

CANARIE Provides Cost-savings for Users

CANARIE is an aggregator and as such introduces efficiencies as a pan-Canadian high speed network service. It is an aggregator of demand which helps users become more of a market entity, able to negotiate deals for fibre usage and related data transmission and content services at more economical rates. As such CANARIE is also an aggregator of supply in that some carriers and service providers would not likely service any one of several users, institutions and provinces, without this aggregation of demand. Again, interviews and survey responses confirm this view and this realized role of CANARIE as an aggregator.

Survey respondents (CIOs) were asked what they estimate the total costs of network services would be if they had to resort to commercial services similar to that provided by CANARIE and the ORANs, if these did not exist. The total savings identified by eight CIOs for having CANARIE and the ORANs services was estimated at \$1.315 million, for an average savings of \$164,375 per institution. The maximum savings reported by one institution was \$520,000, and the minimum for another institution was \$35,000. Extrapolating these averages to the full complement of CANARIE institutional users is difficult without a broader sample base. However, it seems clear that the order of magnitude of savings would be significant for the research and education community at large, which itself is publically funded.

Researchers themselves have also responded to savings questions in the CANARIE 2014 Survey. Respondents indicated that on average they each saved \$19,169 by having used online CANARIE tools instead of travelling (e.g., for collaborative forums and conferences, attendance on technical and planning committees, meetings with research teams, and demonstrations of technology applications in trade shows and other venues). Researchers also estimated they saved an average of \$90,393 on data transfers, compared to if they had used commercial services; and saved an average of \$37,654 on research software, as compared prices on the open market. Again, it is difficult to extrapolate these average cost savings to the broader CANARIE user base, given the survey sample base. However, again, there does appear to be an order of magnitude that is not dismissible in savings to individual researchers and educators, who are also publically funded for the R&D work that they do.

Interviewees and survey respondents have also cited other various examples of cost-savings they realized by using CANARIE as their network and online service provider, including:

- DAIR enabled Galdos Systems Inc. to save on costs by working with three virtual machines with roughly 24 CPUs. Asking for 24 CPUs at the commercial level would have resulted in a significant cost to the firm. DAIR only charged about \$2,000 for this service and the savings to Galdos was in the order of 5 to 10 times that cost.
- CANARIE provided Communication Research Centre Canada with significant savings by enabling visual communications around the world with other researchers. This brought real presence to collaborative meetings, providing face-to-face videoconferencing contact while enabling huge travel cost savings.
- The videoconferencing cost-savings feature is particularly beneficial to other institutions in remote and rural areas such as Yukon College and others. They estimate that videoconferencing using CANARIE realizes 8 to 10 percent in savings compared to doing videoconferencing on a commercial carrier.
- Metafor Software was able to use 10 servers in the DAIR program for their tests, for a fee of \$1,000. This compares to an estimated \$12,000 for the same service on the commercial market. Having these resources at such a low cost allowed Metafor to be more innovative and bold.
- Eduroam provides researchers and students with seamless connectivity while they travel, realizing significant savings compared to using commercial suppliers for the same services. Similarly, it also provides significant savings for Canadian institutions hosting visitors from abroad. It simplifies provision of network services to visitors and locals by eliminating the need to set up connectivity requirements for individualized logins and access.

- There are also savings for students and researchers in accessing organized data from institutions such as Statistics Canada. CANARIE makes statistical data available for social science education applications and research, realizing significant access savings.

To conclude, the examples cited above demonstrate the extent and variety of cost-savings that CANARIE is able to achieve for network users, researchers, educators, and private sector innovators and SMEs.

Best Practices and Comparisons to Other NREns

To identify best practices that CANARIE deploys in delivering its network and related services, the evaluation team examined some of the comparative practices, mandates, and scope of operations described in several other advanced NREns across the world.

It should be noted, however, that comparing NREns in terms of efficiency is very difficult, because not all NREns have the same mandate, infrastructure, size, and suite of programs and services – nor do they have the same population bases or national geographic coverage. Compared to other advanced NREns, CANARIE, with its ORAN partners, is expected to serve one of the largest national land masses, with a population spread out across approximately 10 million square kilometres, larger than the U.S.A. and China, respectively.

The funding model for CANARIE is also different. Though most other advanced NREns get some form of government funding, their funding sources are often more diversified, and their public and/or private budgets relatively larger. They generally also have a better or more defined fit of their networks in their own national digital infrastructure strategies. Although in Canada we now have the Digital Canada 150 digital infrastructure plan, it is yet to be assessed how exactly CANARIE as an organization fits into this plan.

Notwithstanding all the above, the following best practices exercised by CANARIE in delivering its services were identified in the evaluation team's analysis:

- Co-delivery – The co-delivery model of CANARIE and its ORAN partners is indeed itself a best practice, and a good example of federal-provincial collaboration. This collaborative system was put in place early in CANARIE's history, and has worked well for approximately two-decades, serving local and national needs on an equal footing – helping Canadians achieve digital access, whether in heavily populated urban areas, or in remote and rural parts of the country.
- Scalability and flexibility – CANARIE as a national network is modular and scalable. It has evolved as such through several mandates and renewed Contribution Agreements with Industry Canada. It is deemed efficient because it garners low legacy costs as the needs for improvements and upgrades progress in step with technology innovation and change. Furthermore, the flexible nature of the management model, combining technical expertise and managerial acumen, with the necessary breadth and depth of experience, has served it well during this current and past mandates.
- Performance measurement and analysis of key metrics – CANARIE monitors its operations and services on a consistent and regular basis. Metrics on traffic flow, capacity, and accessibility are regularly compiled, and maintenance and upgrade needs are regularly

assessed against a guided strategic path to ensure that CANARIE continues to serve as the backbone network for R&E in Canada. Needs for improvements and advancing the Network are also regularly assessed based on dialogue with its user base, whether this involves concerted efforts from time to time to address specific issues, or involves broader consultation initiatives through its annual Users' Forum.

- Best-effort service – The CANARIE Network is a “best-effort” service, which is universally recognized as a means of delivering digital capabilities at a non-commercial low cost basis. Redundancies are built into the system to carry peak traffic with a minimum of disruption in the network. Interviewees were generally in agreement that this approach has worked well for them during the current mandate and in past years of CANARIE services.
- Hybrid system – The CANARIE Network is a hybrid system, combining the leasing or purchase of dark fibre and working with carriers and provinces for branch-offs from the main backbone network, and combining ROADM with SONET network connections. With this hybrid infrastructure, CANARIE offers greater flexibility in service offerings in order to meet the changing needs of users, scaling up from users with smaller data exchange needs to very-intensive data applications, such as high energy physics applications.
- Maintaining a leadership position – As far as keeping up with international peers as a best practice, interviewee feedback indicates that CANARIE has done this well and it is often a puzzle to others how well it does with limited resources. While CANARIE may be only one among other leading networks in the world, it is competitive and keeping up with the latest and evolving technologies. One respondent speculated that “... it may be one of the most efficient networks in the world, nimble and upgradable with modular scalability at multiple levels”. Another quote from a representative of a large NREN confirms this view: “From what I know about CANARIE, it seems like a very well-organized and guided, best practice oriented organization. Overall, [our organization] has had very positive experiences partnering with and working with our CANARIE colleagues. It is important for us to have a single point of national presence and organization of people to interact with. That is when you think about best practices and efficiency that are very helpful at the international stage.”

Leveraging Programs and Services

CANARIE has leveraged its programs and delivery of services through other initiatives of the federal government and others. The examples of IRAP and the AURP MOU with CANARIE have already been mentioned in earlier sections of this report. Furthermore, leveraging at the local and provincial institutional levels have also been identified in Section 2.1.1 (under CANARIE's Reach).

Interviewees, including individual researchers and representatives of SMEs, cited examples of their leveraging their use CANARIE in their applications for funding, though they could not estimate how much of a role CANARIE played in their receiving approval for those funds. One example is Galdos Systems Inc., which mentioned its use of the DAIR program as a test-bed in a recent submission to Tecterra (the Alberta-based Centre of Excellence for Commercialization). They received the funding they requested, and they credit CANARIE for at least providing Galdos with a level of credibility in that their products were successfully tested using DAIR.

CANARIE also provides complementary support for other funding programs. For example, the TRIUMF project cited that as part of its proposals for funding it often mentions the CANARIE high-speed infrastructure as a benefit which if not present would otherwise make their requests for support too large. IRAP is another example which provides thousands of firms with funding support, and some of these have engaged with the DAIR program.

Efficiency Constraint

Notwithstanding best practices and efficiency in operations, management and staff at CANARIE have expressed the view that the relatively short three-year mandate creates strategic inefficiencies in long-term commitment requirements for delivering ongoing network and related services. Stakeholders and ORAN partners have similarly expressed this view, particularly in terms of how it affects their own contributions and decisions about commitments to the overall system. During a short three-year mandate, for example, the CANARIE team and its partners may actually only have 18 months of real time program delivery – the balance being, at the front end, in planning, preparing and evaluating program initiatives and project proposals; and, towards the end, with intensive use of executive time in consultation, strategy development, and negotiating mandate renewal terms. The mandate renewal process itself poses challenges in making long-term deals for building infrastructure, and timelines of projects are said to be compromised. According to some interviewees, there may be, for example, several projects that researchers were not able to do, or even propose, as a result of the short timeframe for CANARIE funded initiatives.

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Appendix B: Case Studies

TRIUMF

1. About the Initiative

- TRIUMF is Canada's National Laboratory for particle and nuclear physics, and one of the world's leading subatomic physics labs. Located in Vancouver, it is owned and operated as a joint venture by a consortium of Canadian universities through a contribution from the National Research Council.
- TRIUMF is part of the world's most advanced network and computing grid and represents one of eleven global centres on the network. TRIUMF is connected directly to one of the major particle detectors (i.e., ATLAS) as part of the Large Hadron Collider (LHC) particle physics experiments at the European Centre for Nuclear Research (CERN) in Geneva, Switzerland. This facility is an example of a 'big science' project.
- TRIUMF hosts one of the ten Tier 1 Computing Centres around the world which process the petabytes of data taken every year by the ATLAS detector and store and distribute them for analysis.
- ATLAS is one of the two general-purpose detectors at the CERN Large Hadron Collider, and involves several thousand researchers including over a hundred scientists at Canadian universities and at TRIUMF.
- If all the data from ATLAS, were it to be recorded, would fill 100,000 CDs per second. This would create a stack of CDs 450 feet high every second, which would reach to the moon and back twice each year. The data rate is also equivalent to 50 billion telephone calls at the same time.
- International collaboration has been essential to ATLAS' success. Participating physicists come from more than 177 universities and laboratories and include 1000 students

2. Relevance of CANARIE (to the Initiative)

- TRIUMF in partnership with CANARIE established 'light path' connectivity across the 12,000 km distance between Vancouver and Geneva for the purpose of transferring massive data sets from LHC experiments to the TRIUMF computing centre (Tier-1) that serves as a primary processing and distribution node for the global community involved in ATLAS and related experiments.
- A number of ORANs, namely BCNET, Cybera, ORION, and RISQ also play important roles in connecting Tier-2 computing centres at McGill University, Simon Fraser University, the University of Alberta, the University of Toronto, and the University of Victoria to the Tier-1 centre at TRIUMF. All of this connectivity depends on the CANARIE backbone and CANARIE relationships with the various ORANs.
- Other projects at TRIUMF make extensive use of the ORAN infrastructure for information exchanges across the country and internationally, including a theory group that performs

most of its simulation and calculations on remote computer farms and transfers their datasets back to TRIUMF.

3. Achievement of Outcomes

- When CANARIE was last evaluated, ATLAS was just being initiated, but now creates huge sums of data in the management of the LHC data sets.
- So far, CANARIE, in partnership with BCNET, has managed to meet TRIUMF's needs and thus has enabled Canada's participation as a Tier 1 data centre. Over this period, TRIUMF has become known as one of the most consistently reliable Tier 1 sites contributing to ATLAS (in terms of peak availability, performance, up time, etc.), if not the fastest.
- The presence of the ATLAS program at UBC has also contributed to the attraction of HQPs to Canada (to then work on the world's largest cyclotron).
- CANARIE has also enabled TRIUMF to participate in the T2K experiment, a research collaboration with facilities in Japan and the UK focused on how neutrino particles change from one "flavour" to another as they travel (i.e., neutrino oscillations).
- For the T2K experiment the data is generated in Japan and analyzed at TRIUMF (and the UK's Rutherford Appleton Laboratory).

4. Alignment with Government Priorities

- TRIUMF's activities are most closely aligned with the Knowledge Advantage and People Advantage elements of Canada's S&T priorities.
- In developing linkages with leading research sites around the world, TRIUMF has used CANAIRE infrastructure to position Canada at the leading edge of particle physics research. As one of only 10 Tier 1 centres, TRIUMF places Canada in august company.
- In terms of the People Advantage, TRIUMF's participation in leading experiments (not only limited to ATLAS) has not only attracted HQPs to UBC and other participating Canadian universities, but has also held the attention of those HQPs already so employed. Furthermore, it allows Canadian graduates and researchers to collaborate with – and learn from – some of the world's leading minds in ones of sciences most publicized fields.

5. New Directions

- While TRIUMF is currently running at 5-10 Gbit/s per circuit, this need will rise to 100 Gbit/s over the next three years. The bandwidth will have to increase on a similar scale.
- This is a predictable need that has already been shared with CANARIE, but is required if TRIUMF is to continue to be a Tier 1 data centre.
- It will need to (continue to) be a dedicated lightpath to CERN.
- That said, the dedicated lightpath will need to be balanced with the general business network needs, which are more sporadic.

Project Whitecard

1. About the Initiative

- Project Whitecard (PWC) is an interactive digital media company founded in 2008, which has developed virtual and interactive learning programs in partnership with the Canadian Space Agency and now with NASA.

2. Relevance of CANARIE

- For several years, PWC has used CANARIE in a number of ways, particularly through the DAIR program. For example, it hosted learning software for NASA in order to make it a 24/7 “always-on” service.
- This proof of concept has allowed PWC to show that it is capable of hosting an immersive learning environment – and has thus enabled them to strike good relationships with software partners.

3. Achievement of Outcomes

- By enabling the hosting of NASA content, DAIR has helped to increase the stature of a Canadian company in the international marketplace (for hosting of SaaS).
- DAIR has enabled roughly \$1 million in savings for PWC, and has allowed them to parley the DAIR experience to other public funders (e.g., the Canada Media Fund). It has also allowed PWC to gain access to partnerships, including with the Bill & Melinda Gates Foundation and the MacArthur Foundation.

4. Alignment with Government Priorities

- Entrepreneurship: PWC’s initiative with NASA allowed them to prove their worth in the marketplace (e.g., to potential investors), thereby increasing their ability to commercialize their services and strike up new partnerships. This has had immediate returns to the firm, while also providing likely future benefits.
- Knowledge: DAIR has allowed PWC to develop and test new sales models and a thorough knowledge of how to host more than 2 million people on a given server. Hosting NASA content has proven impressive and has led to PWC (and thus Canada) being known as a leader in this domain.
- People: By participating in DAIR, PWC has created (or enabled the creation of) approximately 15 FTEs to date. Further employment growth is likely to depend on further growth in sales

5. New Directions

- PWC is looking to do more of the same.

Metafor Software

1. About the Initiative

- Metafor Software was founded in 2010 by Jenny Yang and Toufic Boubez, who now serve as the company's CEO and CTO, respectively.
- Metafor Software offers innovative anomaly detection Software-as-a-Service (SaaS) for web-based and data centre applications. The software developed by the company alerts users of irregular application activity through predictive analytics, minimizing manual troubleshooting time and allowing for the automation of internal software testing.
- In 2014, Metafor Software was selected as one of five "Cool Vendors" by Gartner, Inc. in the Application Performance Monitoring (APM) and IT Operations Analytics (ITOA) category.
- In 2013, Metafor Software was recognized as an ICT Emerging Rocket by the BC-based Ready to Rocket program. Each year, the Ready to Rocket program identifies technology companies in the province with high revenue growth and investment attraction potential.
- In 2010, Metafor Software was one of the inaugural winners of the Vancouver-based Generator Challenge and was awarded workspace at Discovery Parks.

2. Relevance of CANARIE (to the initiative)

- For its customer-facing production environment, Metafor Software uses third-party commercial cloud services. The high costs associated with these services prevent Metafor Software from testing highly innovative and risky ideas on commercial platforms.
- For its testing environment, Metafor Software uses the cloud infrastructure offered by CANARIE through the DAIR program, using 7 to 10 virtual servers.
- Metafor Software conducts all product testing on DAIR servers, and has been a DAIR participant since the launch of the program.

3. Achievement of Outcomes

- Metafor's R&D activities have been impacted by DAIR in a positive way. Without the DAIR program, product testing would require lengthy cost-benefit analysis and discussion prior to execution. In the absence of the DAIR program, many of Metafor Software's most successful ideas may not have made it to the testing phase.
- DAIR has allowed Metafor Software to run its testing environment in a highly cost-effective manner, reducing the risk, financial strain and time consumed by the transition from idea generation to testing.
- DAIR has enhanced the scalability of the Metafor Software's testing environment, and allowed the company to test a wider range of innovative ideas more quickly.
- According to Metafor Software CEO Jenny Yang, "The DAIR program has allowed us to be less constrained by cost in innovating and making our products better. It has given us the flexibility to test riskier ideas." "It's a small amount of money," she adds, "that has given us so much freedom."

- Essentially, the impact of DAIR on this startup has been financial. It would be much more costly to conduct the same testing on commercial infrastructure. Without DAIR, the company would be more limited and test fewer ideas.
- Through DAIR, the company paid fees of \$100 per virtual server for a whole year of access. Comparable services would cost an estimated \$100 per month from a commercial provider.
- Participation in the DAIR program has allowed Metafor Software to be more innovative and bold – “With DAIR, we’re able to easily say: ‘Go ahead and do it, test the idea.’”
- While the costs and time saved are positive outcomes of Metafor Software’s participation in the program, there have been some shortcomings. The infrastructure is not as mature or stable as its commercial counterparts, and the company does not use it at all for production.
- In addition, it is not easy to migrate from the testing environment to production, as there are significant differences between DAIR and the commercial platforms used by the company. These differences, however, are likely to exist between any two platforms; migration from one environment to another is never easy.
- Although frequent maintenance and lack of stability of the system have been noticed by the user, they have not had a huge impact on testing, as only highly tolerant workflows are housed on the DAIR platform.
- DAIR has worked for Metafor Software, but only in conjunction with complementary commercial solutions.

4. Alignment with Government Priorities

- The impact of the DAIR program on emerging technology companies such as Metafor Software reflects CANARIE’s shift in focus to commercialization and contribution to “entrepreneurial advantages” for Canada.
- The way that DAIR is used by Metafor Software as a testing platform allows the company to harden the product and continually make it better. Access to cost-effective infrastructure facilitates the development of more innovative ideas, and gives the freedom to push innovation into the realm of commercialization.
- Although DAIR does not have a direct impact on the company’s ability to compete at a global level, it has indirectly allowed the company to have more testing flexibility, which allows it to scale products more effectively and thus, be more competitive globally.
- Access to computing power has quickly become a basic requirement for technology startups, if they want to compete in today’s market. A vast majority of product development is taking place in the cloud and every startup will need to have infrastructure to support its product development. The ability of technology entrepreneurs to commercialize innovative ideas depends largely on the extent to which they can afford this infrastructure.

5. New Directions

- Access to computing power has become increasingly important to emerging technology entrepreneurs, startups and small businesses. As more companies deal with bigger amounts

of data, DAIR will continue to level the playing field and decrease barriers to commercialization.

- According to Jenny Yang, who commends CANARIE’s focus on supporting entrepreneurship, much more can be done to support early-stage startups and encourage commercialization.
- In particular, CANARIE has the potential to contribute to creating “knowledge advantages” for Canada by promoting and leveraging collaboration between academia and the private sector and by increasing the relevance of other CANARIE programs to entrepreneurs. Academia is very important to commercialization, and increasing linkages between the startup community and academics can be very beneficial.

Canadian Brain Imaging Research Network (CBRAIN)/Global Brain Imaging Research Network (GBRAIN)

1. About the Initiative

- CBRAIN is a research platform that provides scientists with immediate access to vast volumes of three- and four-dimensional brain-imaging data that is stored or created across the country. These data are available to a broad range of researchers via CANARIE's high-speed network.
- CBRAIN allows researchers to access brain-related information and to visualize, manipulate, and exchange images of the human brain throughout various stages of development, and during progression of neurological disorders such as autism, Parkinson's and Alzheimer's disease.
- The project lead for CBRAIN is the Montreal Neurological Institute, McGill University. Other participants include Rotman Research Institute, Baycrest Hospital Toronto, University of Western Ontario, University of Waterloo, Université de Montréal, Université Laval, Université de Sherbrooke, University of British Columbia, and University of Calgary.
- GBRAIN is the international extension (Canada, Germany, USA, and South Korea) of CBRAIN. The GBRAIN platform enables Canadian institutions connected to CBRAIN to connect to the international sites that are part of the GBRAIN scientific collaboration.
- CBRAIN and GBRAIN subsequently evolved into BigBrain, which was chosen by Massachusetts Institute of Technology (MIT) as one of 10 breakthrough technologies for 2014.¹⁹

2. Relevance of CANARIE (to the Initiative)

- The CBRAIN/GBRAIN platform utilizes the CANARIE network services to provide researchers and practitioners access to multi-dimensional and very data-intensive images and brain-related information.
 - CANARIE Network is hugely important, as dataset sizes keep increasing – by a factor of 10; project needs 175 terabytes, which means 1 gig for many operations, and special projects can require 10 gig links.
- In addition to providing network connectivity, CANARIE's NEP contribution to CBRAIN was \$2.4 million.
- CANARIE enables CBRAIN to access eight high performance computing centres and labs in Canada and one in Germany. These centres and labs can repeat each other's experiments and compare results directly; readily share raw image data and process maps; and place data repositories for access by the global scientific community. All this enables new questions to

¹⁹ See www.technologyreview.com/featuredstory/526501/brain-mapping/.

be asked of mapped data, after primary research is complete, and new or improved algorithms can easily be applied to old questions.

- Without CANARIE there would not have been a CBRAIN/GBRAIN project. The initial contact of the team leads with CANARIE was in 2007. By 2008 they already had global connectivity. CANARIE helped and coordinated the necessary steps to connect CBRAIN internationally and across Canada.
- CANARIE actively helped the CBRAIN/GBRAIN lead researchers to coordinate requests and usage justifications across various ORANs, other NRENs and target institutions in the USA, Europe and Asia.
 - CANARIE is a major player for creating new platforms, as it builds completely generic tools. The Montreal Neurologic Institute (MNI) uses a RPI platform, and is very much a participant. CANARIE's NEP and RPI service the research team, and thus builds the building blocks to support all other teams
- Because of CANARIE, Canadian researchers and users of CBRAIN/GBRAIN are able to connect to their collaborators and counterparts in Germany and other European sites through GEANT (the European network), to South Korea through Kreonet, and to the USA (UCLA) through Internet 2.
 - CBRAIN now connects to 19 countries, with some strong, and some weaker collaboration. Now, about 35% of CBRAIN traffic is connected by CANARIE is international (while 65% is national). Thus, CANARIE has helped increase Canadian participation in world-leading research globally.

3. Achievement of Outcomes

- International partners perceive GBRAIN as a unique opportunity to experiment with tools and data processing pipelines that they have never successfully installed themselves locally. This opened the doors for much productive scientific and technical collaboration. For example, CBRAIN/GBRAIN's international collaborative partners include LONI – USA, OutGrid – European Union, Julich – Germany, and CAN – South Korea.
- Having access through CANARIE has enabled the CBRAIN team to collaborate with the Julich supercomputer in Germany, and has facilitated biomedical researchers in Germany to interface with CBRAIN. CBRAIN has also connected to researchers throughout Europe via a high speed network hub in Amsterdam. CBRAIN team members have made site visits to Julich and Amsterdam, to set up ongoing research partnerships and collaborative project work.
- CANARIE has also enabled CBRAIN researchers to connect with UCLA's Lab of NeuroImaging, which is a top international site for brain imaging research and a natural partner for the CBRAIN team.
- Beyond that, CBRAIN also has a Lightpath connection with University of California Santa Barbara, to manipulate and explore 1 terabyte of 3-D image data. This represents a whole human brain sliced into 10,000 slices. These data were collected at Julich (Germany) and CBRAIN took the raw information and created a robust 3-D dataset for research. They

integrated the Julich data and made it useful for researchers. They also developed the web-based visualization software, and 3-D software processing tools.

- Because CANARIE has supported the development of CBRAIN/GBRAIN, the researchers have been able to leverage their work for additional funding from one of the Networks of Centres of Excellence applications on neuro-degenerative diseases. This is an ongoing initiative which involves research workshops that include some 75 leading investigators in Canada.
- The lead researchers are also finding that they are able to use the CANARIE-enabled work to leverage their funding requests from other sources, and to secure commitment to their research work by their home campus at McGill University.

4. Alignment with Government Priorities

- CBRAIN fits within the context of government sector priorities – specifically in the area of health and health services.
- The work on CBRAIN/GBRAIN has resulted in a spin-off company that does large scale brain image analysis for pharmaceutical companies (see www.biospective.com). Biospective does pre-clinical and clinical analysis, including MRI imaging studies, pathology studies, oncology models, autoradiography, immunohistochemistry, and other studies. Their work, for example, involves brain imaging data to study Alzheimer's disease and to do clinical trial simulations and analysis. This spin-off company also does "databasing" for organizations like Oracle.
- The technology and CBRAIN research platform enabled by CANARIE, the network plus the computing capacity, are seen by the university lead investigators in this initiative to have been a major draw for many of the HQP students involved in this field of work at their institutions.
- Furthermore, says Dr. Alan Evans, the Director of CBRAIN: "Without CANARIE our research community cannot compete with the rest of the world, and our own top researchers would move elsewhere."
- CANARIE handles the huge load of data coming out of CBRAIN's lab. With its German partner, CBRAIN has achieved the highest resolution model ever made. Germany chose Canada as a partner because CANARIE was involved. Because of this high profile work, foreign companies approach Canadian suppliers to CANARIE, e.g., Huron technologies (microscopes) convinced Germans to buy scanners from them as a result of their use in CBRAIN. So there is an informal partnership between the MNI and its suppliers – which CANARIE helped facilitate in its network role.
- CANARIE has enabled the MNI to leverage university and private-sector collaboration. CANARIE funding programs and activities led to the development and increased availability of software interfaces, applications and tools that facilitate easier, flexible use of distributed research equipment and resources for the CBRAIN project – although 90% of researchers don't know they are using CANARIE, Compute Canada, and storage sites.
- Now, CANARIE shares technical exchanges on how they do on platforms, e.g., genomics group (a new NEP) because of plans to do more research on the brain.

5. New Directions

- Brain mapping involves an intersection of imaging and computational analysis. High Performance Computing (HPC) plus advanced high speed networking (NRENs) are necessary for the analysis of 3D and 4D image levels of the brain. Increasingly the labs involved in brain research are operating in common coordinated multi-dimensional image spaces. They share results and co-lab activities. Without CANARIE this could not happen.
- The lead researchers at CBRAIN emphasize the importance of linking the HPC functionalities with the high speed connectivity enabled by CANARIE – namely, linking the services provided by Compute Canada and CANARIE. According to them, there are numerous projects in Canada, not just brain research, that co-depend on HPC and high speed networking. Linking the two organizations in one framework would have its benefits both for efficiencies in research activities and for education/training of HQP.
- Another suggestion resulting from the experience of the CBRAIN researchers is that Canada should consider CANARIE as an essential infrastructure that simply cannot be turned off. The challenge is how to continue to grow the CANARIE services as the demand (as they see it) grows for more data, more computing power, and faster/larger transfers of information across provinces and international borders.
- As such Canada needs to define a growth strategy while supporting the community of researchers and practitioners building the platforms that host and retrieve scientific information. These distributed platforms and the management of big databases are in their infancy, according to Dr. Alan Evans, the Director of CBRAIN. Better tools and techniques will continue to emerge, taking fuller advantage of the advanced high speed networks capabilities and HPC.
- CANARIE has helped the formation of larger, multi-disciplinary teams, e.g., a team with computer scientists and bio-sciences, which had not previously been assembled. Visiting scientists notice the interdisciplinary composition of the teams, and innovation and cutting edge will emerge. While CANARIE did not plan such an outcome it has had an impact on the insertion of computer scientists. That is important as other funding orgs don't fund computer science. CANARIE is very unique in landscape
- CANARIE funding has helped leverage additional funding that the MNI receives from other government programs and industry, e.g., CCNA funding was raised for Alzheimer and autism because of the C-BRAIN platform, so the leverage is clear and obvious.

Appendix C: Steering Committee

Bob Cook, University of Toronto (Chair)

Martha Crago, Dalhousie University

Martin Taylor, University of Victoria

Ann Doyle, Internet2

Erwin Bleumink, SURFnet

Rob Davidson, CFI

James Fulcher, Industry Canada

Catherine Dion, Industry Canada

Daniel Fairbairn, Industry Canada

Alan Winter, Genome BC (not present at inaugural meeting)

Janet Walden, NSERC (not present at inaugural meeting)

Appendix D: Survey Questionnaire

Introduction

As required by its Contribution Agreement with Industry Canada, CANARIE is undertaking an evaluation of its programs and services to demonstrate their benefit to Canadian taxpayers, and in particular to Canada's research and education (R&E) and innovation communities. To administer this evaluation, CANARIE has engaged an independent, third-party firm to manage a short, confidential online survey for you to complete. It should take less than 15 minutes of your time.

Confidentiality: Please note that all of the information you provide to CANARIE through this survey will be held in strict confidence. Your responses will only be reported in aggregate form and without attribution. Many thanks for your time and consideration. If you have any questions, please contact us at 613-943-5372 or harry.sharma@canarie.ca.

A. Contact information

A1. Your responses will be held in confidence by Nordicity. However, we would appreciate it if you provided your contact information should Nordicity need further clarification to some of your responses.

Name:	<input type="text"/>
Institution/Organization:	<input type="text"/>
Email:	<input type="text"/>

A2. Please identify your role at the institution that you are representing for this survey.

- ☐ Chief Information Officer (CIO) at an academic/research institution (Go to Section B)
- ☐ Vice-President, Research (VPR) at an academic/research institution (Go to Section C)
- ☐ Researcher or developer at an academic/research institution (Go to Section D)
- ☐ DAIR user at a small or medium-sized enterprise or academic/research institution (Go to Section E)
- ☐ None of the above (Survey ends)

B. CIO Questionnaire

In order to accurately complete this survey, you will need access to information on your institution's Internet usage and infrastructure, including its use of the CANARIE network.

B1. Please estimate the percentage of your institution's total research and education (R&E) traffic (as a percentage of monthly gross traffic) that is carried by the CANARIE network or by your regional ORAN network (e.g., ORION, BCNET, RISQ, etc.)

B2. In the next 3 years, how do you expect the percentage reported in Question B1 to change?

- ☐ Increase significantly
- ☐ Increase somewhat
- ☐ No change
- ☐ Decrease somewhat
- ☐ Decrease significantly
- ☐ Don't know

B3. In your opinion, how sufficient are CANARIE network and related services (i.e, peering, eduroam, and federated single sign-on) to fulfill your institution's needs as they evolve over the next 3 years?

- ☐ Fully sufficient
- ☐ Mostly sufficient
- ☐ Somewhat sufficient
- ☐ Minimally sufficient
- ☐ Not sufficient

B4. Please estimate the percentage of your university's population (incl. students and faculty) who currently have access to the research and education network.

B5. Approximately what percentage of people who have access to the research and education network are:

Faculty researchers	<input type="text"/>
Post Doctorate students	<input type="text"/>
Graduate students	<input type="text"/>
Undergraduate students	<input type="text"/>
Industry researchers	<input type="text"/>
Other	<input type="text"/>

B6. In your opinion, how important is the research and education network to increasing or improving the following activities at your institution:

	Critically important	Very important	Somewhat important	Not very important	Not at all important	Not applicable
Participation in National Science projects or areas (e.g., National science projects and areas include: NEPTUNE, Canadian Light Source, High Energy Physics, Astronomy, High Performance Computing, etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
International collaboration and participation in "Big Science" projects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Recruitment, retention and development of highly qualified personnel (HQP) (e.g. Graduate students, Ph.D students and academic staff)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
General campus networking	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Development of leading-edge technologies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Use of network as an educational tool	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

B7. If the national research and education network ceased operation on April 1, 2015, what impact would it have on the following?

	Highly negative impact	Significant negative impact	Moderately negative impact	Slightly negative impact	No difference	Not applicable
Ability to retain faculty	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ability to retain science and engineering faculty	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Annual number research publications published	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ability to collaborate with other professionals – both in Canada and internationally	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Overall student enrollment	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ability to attract graduate and Ph.D students to your institution	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ability to attract leading-edge researchers to your institution	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

B8. If your institution had to obtain services similar to those it receives from the national research and education network from a commercial carrier, please estimate total costs that your institutions would have incurred.

\$/year

B9. How important do you believe the following network services will be for your institution in the next 3 years?

Critically important	Very important	Somewhat important	Not very important	Not at all important	Not applicable
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Peering (Transiting IP traffic)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
IPv6	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Cloud computing for research and innovation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Access Federation (e.g., eduroam and federated single sign-on)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Over the network services (e.g., cloud-based services such as data storage, video collaboration, etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5G networks (combined wireless service with research and education networks)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

B10. To what extent has the CANARIE network provided sufficient capacity during periods of high traffic?

- ☐ Always sufficient
- ☐ Often sufficient
- ☐ Sometimes sufficient
- ☐ Seldom sufficient
- ☐ Never sufficient

B11. In your opinion, has CANARIE helped or hindered the establishment of Canada as a recognized leader in research networking? If so, how?

How it helped or hindered:

B12. Does your institution make use of CANARIE's Lightpath connections?

Lightpath is an on-going program allowing researchers to request and obtain dedicated CANARIE network infrastructure resources to build their own networks. Lightpath provides a dedicated high bandwidth communication channel, providing effective bandwidth over great geographical distances.

- ☐ Yes
- ☐ No

If you had to obtain the same level of service as a CANARIE Lightpath connection from a commercial vendor, what do you estimate the annual cost would be for the commercial connection?

Please indicate how important the Lightpath connection is to your institution (your researchers and educators) for the following activities:

	Critically important	Very important	Somewhat important	Not very important	Not at all important	Not applicable
Secured and dedicated end-to-end network connections	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Participation in collaborative national science projects (e.g., TRIUMF, NEPTUNE, SNOLAB, Compute Canada, etc.)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Participation in international collaborative research project (e.g., ATLAS, International Cancer Genome Consortia, Square Kilometre Array)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

B13. What percentage of research projects at your institution include collaborative research with other institutions located within your province?

% of projects

B14. What percentage of research projects at your institution include collaborative research with institutions located in other provinces?

% of projects

B15. What percentage of research projects at your institution include collaborative research with institutions outside of Canada?

% of projects

B16. In your opinion, does the availability of an advanced network (i.e., the CANARIE network) play a role in attracting and retaining researchers (Canadian and international) to your institution?

- ☐ Critically important
- ☐ Very important
- ☐ Somewhat important
- ☐ Not very important
- ☐ Not at all important
- ☐ Don't know

B17. In your opinion, to what extent has the availability of an advanced network (i.e., the CANARIE network) led to innovations in products and services at your institution?

- ☐ Critically important
- ☐ Very important
- ☐ Somewhat important
- ☐ Not very important
- ☐ Not at all important
- ☐ Don't know

B18. In your opinion, how important a role has the research and education network played in the creation of intellectual property at your institution?

- ☐ Critically important
- ☐ Very important
- ☐ Somewhat important

- ☐ Not very important
- ☐ Not at all important
- ☐ Don't know

C. VPR Questionnaire

C1. What percentage of your institution's research spending supports projects that require external collaboration?

C2. In the next 3 years, how do you expect the percentage reported in Question C1 to change?

- ☐ Increase significantly
- ☐ Increase somewhat
- ☐ No change
- ☐ Decrease somewhat
- ☐ Decrease significantly
- ☐ Don't know

C3. In your opinion, how sufficient are CANARIE's programs, services and funding to fulfill your organization's needs as they evolve over the next 3 years?

- ☐ Fully sufficient
- ☐ Mostly sufficient
- ☐ Somewhat sufficient
- ☐ Minimally sufficient
- ☐ Not sufficient

C4. How important is a national advanced research and education network, (i.e., CANARIE) to your institution for the following activities:

	Critically important	Very important	Somewhat important	Not very important	Not at all important	Not applicable
To participate in National Science projects or areas (e.g., NEPTUNE, Canadian Light Source, High Energy Physics, Astronomy, High	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Performance
Computing, etc.)

International
collaboration and
participation in "Big
Science" projects

Recruitment,
retention and
development of
highly qualified
personnel (HQP)
(e.g., Graduate
students, Ph.D
students and
academic staff)

Attracting high-
quality faculty,
post-doctoral and
doctoral students
to your institution

C5. In your opinion, how important is the availability of an advanced network (i.e., CANARIE network) to the attraction and retention of Canadian researchers to your institution?

- ☐ Critically important
- ☐ Very important
- ☐ Somewhat important
- ☐ Not very important
- ☐ Not at all important
- ☐ Don't know

C6. In your opinion, how important is the availability of an advanced network (i.e., CANARIE network) to the attraction and retention of international researchers to your institution?

- ☐ Critically important
- ☐ Very important
- ☐ Somewhat important
- ☐ Not very important
- ☐ Not at all important
- ☐ Don't know

C7. In your opinion, how important is the availability of an advanced network (i.e., CANARIE network) to the development of intellectual property by researchers at your institution?

- ☐ Critically important
- ☐ Very important
- ☐ Somewhat important
- ☐ Not very important
- ☐ Not at all important
- ☐ Don't know

C8. In your opinion, how important is access to an advanced network (i.e., the CANARIE network) to your institution's ability to develop and commercialize new products/services?

- ☐ Critically important
- ☐ Very important
- ☐ Somewhat important
- ☐ Not very important
- ☐ Not at all important
- ☐ Don't know

C9. In your opinion, how important is access to an advanced network (i.e., the CANARIE network) to your institution's ability to spin-off new companies from R&D activities?

- ☐ Critically important
- ☐ Very important
- ☐ Somewhat important
- ☐ Not very important
- ☐ Not at all important
- ☐ Don't know

C10. In your opinion, how important is access to an advanced network (i.e., the CANARIE network) to achieving your institution's overall research objectives?

- ☐ Critically important
- ☐ Very important
- ☐ Somewhat important
- ☐ Not very important
- ☐ Not at all important

☐ Don't know

C11. In which of the following four Science and Technology priority areas has your institution performed research between April 2010 and the present?

	Top research priority	2nd research priority	3rd research priority	4th research priority	5th research priority
Environmental science and technologies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Natural resources and energy	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Health and related life sciences and technologies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Information and communications technologies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other research	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

C12. If CANARIE ceased operation on April 1, 2015, what impact would it have on the following?

	Highly negative impact	Significant negative impact	Moderately negative impact	Slightly negative impact	No difference	Not applicable
Ability to attract researchers to your institution	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ability to attract research funding	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Annual number of research publications	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ability to collaborate with professionals in other institutions – both in Canada and international	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Number of innovative products	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

developed and commercialized as a result of your institution's research

Number of spin-off companies facilitated by your institution's research activities

☐ ☐ ☐ ☐ ☐ ☐

Intellectual property developed as a result of your institution's research activities

☐ ☐ ☐ ☐ ☐ ☐

Number of national research collaborations

☐ ☐ ☐ ☐ ☐ ☐

Number of international research collaborations

☐ ☐ ☐ ☐ ☐ ☐

C13. In your opinion, how important were the following factors to research conducted at your institution between 2010 and the present:

	Critically important	Very important	Somewhat important	Not very important	Not at all important	Not applicable
Collaboration with researchers outside of Canada	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Collaboration with researchers at institutions in other provinces	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Collaboration with Network Centres of Excellence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Secure user-controlled dedicated point-	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

to-point
bandwidth

Low latency of data transmission ☐ ☐ ☐ ☐ ☐ ☐

High bandwidth to accommodate large amounts of data generated by experiments ☐ ☐ ☐ ☐ ☐ ☐

Bandwidth for distributed-computing research required by scientific research ☐ ☐ ☐ ☐ ☐ ☐

Access to remote data locations (e.g. Hubble or CERN) ☐ ☐ ☐ ☐ ☐ ☐

Access to confidential Statistics Canada data ☐ ☐ ☐ ☐ ☐ ☐

Immediacy of availability of dedicated bandwidth ☐ ☐ ☐ ☐ ☐ ☐

Security and privacy of data transmission ☐ ☐ ☐ ☐ ☐ ☐

C14. In your opinion, has CANARIE helped or hindered the establishment of Canada as a recognized leader in research networking? If so, how?

How it helped or hindered:

D. Researcher/Developer Questionnaire

Note: This survey is about measuring the impacts of the CANARIE network. You may not be readily aware that you are using the CANARIE network as it is usually connected to the backend of your institution's Internet connection. So when answering the following questions, please consider the CANARIE network to be your institution's network that you access for research purposes.

Remember: As a small token of CANARIE's appreciation for your valuable time and input, the first 100 DAIR or Researcher/Developer respondents will be invited to select an iTunes, Google Play or Starbucks gift card.

D1. Which of the following scientific discipline(s) would you most closely associate with your academic research work?

- ☐ Particle physics
- ☐ Astronomy
- ☐ Social sciences
- ☐ Environmental Science
- ☐ Life Sciences
- ☐ Other, please specify: _____

D2. How data intensive do you consider your academic research to be?

- ☐ Extremely data intensive (daily data transfer of 1Terra Byte (TB) or more)
- ☐ Very data intensive (daily data transfer between 100Giga Bytes (GB) – 1TB)
- ☐ Somewhat data intensive (daily data transfer between 10GB – 100GB)
- ☐ Not very data intensive (daily data transfer between 1GB – 10GB)
- ☐ Not at all data intensive (daily data transfer of
- ☐ Not applicable

D3. Please quantify each of the following that pertain to your research between 2010 and the present:

Number of joint research projects involving local partners (within your institution)

Number of joint research projects involving remote collaboration with partners within your province

Number of joint research projects involving remote collaboration with partners outside your province (but within Canada)

Number of joint research projects involving remote collaboration with partners outside Canada

Number of scientific articles (in peer-reviewed academic journals) authored by you

Number of scientific articles (in peer-reviewed academic journals) co-authored by you with researchers at other institutions in Canada

Number of scientific articles (in peer-reviewed academic journals) co-authored by you with researchers at institutions outside of Canada

Number of patents filed in Canada due to your research

Number of triadic patents (i.e. patents registered in the US, EU, and Japan) due to your research

Number of new spin-off companies facilitated by your research

D4. Please rate the following factors in terms of their importance to the completion of the research projects you conducted over your institution's data-communications network between 2010 and the present:

	Critically important	Very important	Somewhat important	Not very important	Not at all important	Not applicable
Collaboration with researchers outside of Canada	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Collaboration with researchers at institutions in other provinces	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Collaboration with Network Centres of Excellence	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Secure user-controlled dedicated point-to-point bandwidth	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Low latency of data transmission	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
High bandwidth to accommodate large amounts of data generated by experiments	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Bandwidth for distributed-	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

computing
research required
by scientific
research

Access to remote data locations (e.g. Hubble or CERN) ☐ ☐ ☐ ☐ ☐ ☐

Access to confidential Statistics Canada data ☐ ☐ ☐ ☐ ☐ ☐

Immediacy of availability of dedicated bandwidth ☐ ☐ ☐ ☐ ☐ ☐

Security and privacy of data transmission ☐ ☐ ☐ ☐ ☐ ☐

Access to cloud-based computing and storage resources ☐ ☐ ☐ ☐ ☐ ☐

D5. In the next 3 years, how do you anticipate your usage of the high-bandwidth network will change?

- ☐ Increase significantly
- ☐ Increase somewhat
- ☐ No change
- ☐ Decrease somewhat
- ☐ Decrease significantly
- ☐ Don't know

D6. To what factors do you attribute this change?

D7. How do you believe your use of digital infrastructure in your research will change over the next 3 years (digital infrastructure includes components such as digital network, digital storage, computing, remote sensors, etc.)?

- ☐ Increase significantly

- ☐ Increase somewhat
- ☐ No change
- ☐ Decrease somewhat
- ☐ Decrease significantly
- ☐ Don't know

D8. Looking out 3 years from now, what are the top three digital infrastructure tools that you will need to use for your research?

	Most important tool	2nd most important tool	3rd most important tool
High bandwidth	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Cloud computing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Remote sensors	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Wireless networking	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Real-time remote collaboration tools	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Research software	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Data management tools	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

D9. In your opinion, how sufficient are CANARIE's programs, services and funding to fulfill your research needs as they evolve over the next 3 years?

- ☐ Fully sufficient
- ☐ Mostly sufficient
- ☐ Somewhat sufficient
- ☐ Minimally sufficient
- ☐ Not sufficient

D10. Please estimate the cost savings you realized on an annualized basis as a result of your use of the following services:

Use of online collaboration tools to reduce travel requirements

Data transfers over the network (e.g., instead of using a courier to send and receive storage devices with data)

Use of research software

Other services

D11. Please indicate the CANARIE programs from which you have received funding since 2010.

- ☐ NEP (any round)
- ☐ IEP
- ☐ Other, please specify _____
- ☐ Have not received any funding from CANARIE since 2010

D12. Please estimate the total amount of funding you received from each of the following CANARIE programs between 2010 and the present.

NEP (any round)

IEP

Other, please specify

Have not received any funding from CANARIE since 2010

D13. For each of the following, please quantify the amount that pertains to your use of CANARIE funds.

Number of scientific articles (in peer-reviewed academic journals)

Number of technical reports

Number of invited presentations given at conferences, workshops and meetings

Number of post-doctoral fellows trained as highly qualified personnel (HQP)

Number of technicians trained as highly qualified personnel (HQP)

Number of PhDs trained as highly qualified personnel (HQP)

Number of Masters students trained as highly qualified personnel (HQP)

Number of Undergraduates trained as highly qualified personnel (HQP)

D14. How important was the funding support you received from CANARIE to the following activities:

	Critically important	Very important	Somewhat important	Not very important	Not at all important	Not applicable
Conducting research	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Collaborating with other researchers in Canada	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Collaborating with international researchers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Collaborating with Industry partners	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Developing application tools or software interfaces	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

E. DAIR User Questionnaire

Remember: As a small token of CANARIE's appreciation for your valuable time and input, the first 100 DAIR or Researcher/Developer respondents will be invited to select an iTunes, Google Play or Starbucks gift card.

E1. How important has the DAIR program been to your organization's ability to commercialize its products and/or services in the following ways?

	Critically important	Very important	Somewhat important	Not very important	Not at all important	Not applicable
Getting your product/service to market faster	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reducing product development or other costs	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Reducing of risk related to conducting research	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Gaining a competitive edge in the global market	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Testing new products/services	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Scaling production and/or service offering	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Evaluating the market potential for a product/service	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Creating a proof of concept to secure investment	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Testing or evaluating a new business model	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Accelerating product innovation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Assuring security of competitive data	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Effectively using cloud-based computing services	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Collaborating with other Industry partners across Canada	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Collaborating with the academic and public sectors	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Collaborating with international Industry partners	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Adopting leading edge technologies	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

How many weeks faster were you able to get your product and/or service to market as a result of your use of DAIR services?

E2. Please indicate the amount of time and money your organization has invested in those projects that have been developed using DAIR -- and the percentage of saved by using DAIR.

	Amount invested	Percentage saved
Time (in weeks spent)	<input type="text"/>	<input type="text"/>
Money (in \$)	<input type="text"/>	<input type="text"/>

E3. If you had to obtain the same level of service as provided by the CANARIE DAIR program from a commercial vendor, what do you estimate the annual cost would be for the commercial connection?

\$/year

E4. Does your organization access funding from other government programs?

- ☐ Yes
☐ No

Which ones?

- ☐ BDC
☐ MITACS
☐ IRAP
☐ NSERC
☐ Other, please specify... _____

E5. Has your organization accessed funding from industry and private sector partners as a result of using DAIR?

- ☐ Yes
☐ No

Which types?

- ☐ Angel investors
☐ Venture capitalists
☐ Other, please specify... _____

E6. Over your organization's time using DAIR, have you expanded to employ more people?

Hired new employees? ☐ Yes

☐ No

How many?

E7. While using DAIR has your organization hired any students? (e.g. through a co-op program)

☐ Yes

☐ No

How many students did your organization hire?

E8. If CANARIE had not made DAIR available, what impact would it have on your organization in terms of the following?

	Highly negative impact	Significant negative impact	Moderately negative impact	Slightly negative impact	No difference	Not applicable
Pace of product commercialization (increased time to market)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Cost of product development or other costs	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Competitive edge in the global market	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Pace of product innovation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Integrity of competitive data security	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ability to collaborate with Industry partners in Canada	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ability to collaborate with international Industry partners	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Rate of adoption of leading-edge technology

○ ○ ○ ○ ○ ○

E9. In the next 3 years, how do you anticipate your usage of CANARIE's DAIR program will change?

- ☐ Increase significantly
- ☐ Increase somewhat
- ☐ No change
- ☐ Decrease somewhat
- ☐ Decrease significantly
- ☐ Don't know

E10. Looking out 3 years from now, what are the top three digital infrastructure tools that you will need to use?

	Most important tool	2nd most important tool	3rd most important tool
High bandwidth	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Cloud computing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Remote sensors	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Wireless networking	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Real-time remote collaboration tools	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Research software	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

E11. Looking out 3 years from now, what are the top three assistance programs from CANARIE that you will need to use?

	Most important program	2nd most important program	3rd most important program
Business education	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Cloud computing training	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Marketing and promotion assistance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Opportunities to collaborate and connect with the R&D community	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

- | | | | |
|--|-----------------------|-----------------------|-----------------------|
| Opportunities to collaborate with other SMEs | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Other | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

E12. Once you transition from DAIR, what will you want from a commercial cloud provider?

- | | |
|--|--|
| Setup and configuration services? | <input type="checkbox"/> |
| Access to GPUs? | <input type="checkbox"/> |
| Access to virtual load balancers? | <input type="checkbox"/> |
| Access to virtual firewalls? | <input type="checkbox"/> |
| Access to email services? | <input type="checkbox"/> |
| Access to storage and backup services? | <input type="checkbox"/> |
| How often would you like to be billed? | <input type="radio"/> Hourly
<input type="radio"/> Monthly
<input type="radio"/> Annually |
| How much do you expect to pay (per month)? | <input type="radio"/> Less than \$100
<input type="radio"/> \$101 to \$150
<input type="radio"/> \$151 to \$200
<input type="radio"/> \$201 to \$250
<input type="radio"/> \$251 to \$300
<input type="radio"/> More than \$300 |

E13. In your opinion, has CANARIE (via DAIR) helped or hindered the establishment of Canada as a recognized leader in private sector-based innovation? If so, how?

How it helped or hindered:

E14. Are there any other comments or feedback that you would like to add?

Please describe additional impacts or any unexpected outcomes (positive or negative) that you have experienced between 2010 and the present, as a result of CANARIE programs and services.

Thank you for completing the survey.

Appendix E: Interview Questionnaire

Interviews with CANARIE staff and management

Relevance and continued need for the program

1. To what extent has CANARIE led to increased research collaboration and networking nationally and internationally for Canadian institutions and private entrepreneurs? How do you see the needs for a CANARIE managed and operated network evolving over the next 3 years? Are the current CANARIE programs, services and funding necessary and sufficient to fulfill these needs as they evolve?
2. Have new initiatives that CANARIE has introduced (e.g., DAIR) increased its relevance to the needs that it is trying to address? What has been the response to these new initiatives in the research, education and innovation communities?
3. What do you think would be the effect on the Canadian research and education community if CANARIE ceased to exist?

Alignment with government priorities

4. To what extent has CANARIE contributed to the government's priorities in "entrepreneurial advantages," "knowledge advantages," and "people advantages" for Canadians?
5. What have been the impacts of CANARIE (network and program activities) on each of Canada's priority S&T research and development areas (i.e., ICT, health, environment, natural resources and energy)?
6. Have there been any unexpected outcomes (positive or negative) due to CANARIE?

Alignment with federal roles and responsibilities

7. To what extent do you feel that stakeholders, partners, and contributors to CANARIE understand its mandate and believe that this is a relevant, necessary and legitimate role for a Federal Government supported program?

Achievement of expected outcomes

8. Has CANARIE achieved the following outcomes from April 2010 to the present:
 - a. Expanded and upgraded advanced network capabilities and infrastructure
 - b. Enhanced Canada's involvement in international networking and network-focused collaborations for research
 - c. Led to the development and increased availability of software interfaces and tools that facilitate easier, more flexible use of network resources and/or distributed research equipment and resources
 - d. Led to increased collaborative partnerships for the development of research platforms

- e. Helped Canadian ICT researchers and SMEs accelerate validation and/or commercialization of products and services
- f. Helped to increase ICT R&D in Canada and helped adoption of leading edge ICT by small and medium-sized enterprises (SMEs)?

Demonstration of efficiency and economy

- 9. Does the allocation of funds across CANARIE programs and projects appropriately reflect priorities as established by program objectives and sufficiently support the achievement of expected outcomes?
- 10. To what extent has CANARIE successfully introduced cost recovery, cost sharing and cost reduction measures during its current mandate? What have been the results of these measures to date?
- 11. To what extent has CANARIE funding leveraged other funding from other government programs and industry?
- 12. In your opinion, how does CANARIE as a federally funded organization compare in terms of efficiency and economy in delivering S&T support to the research, development and education community (i.e., compared to other R&D and commercialization programs of, for example, NSERC, CIHR, CFI, NRC)?
- 13. How does CANARIE compare to international peers in terms of usage rates and efficiently managing and operating advanced network support programs?

Interviews with Government departments and agencies

Relevance and continued need

- 1. How do you anticipate the needs for a CANARIE managed and operated network to evolve over the next 3 years? Do you believe that current CANARIE programs, services and funding are necessary and sufficient to fulfill these evolving needs?
- 2. What do you think the effect would be on the Canadian research, education and innovation communities if CANARIE ceased to exist?

Alignment with government priorities

- 3. To what extent do you think CANARIE programs and services have contributed to creating “entrepreneurial advantages” for Canadians that help translate knowledge into commercial applications that generate wealth?
- 4. To what extent do you think CANARIE programs and services have contributed to developing “knowledge advantages” for Canadians that help in positioning Canada as a leader in generating health, environmental, societal and economic benefits?
- 5. To what extent do you think CANARIE programs and services contributed to facilitating “people advantages” for Canadians (i.e., contributed to developing or attracting and

retaining highly qualified personnel (HQP) in S&T fields in Canadian education and research institutions)?

6. How has CANARIE strengthened innovation capacity in Canada (e.g., encouraged R&D partnerships between business, academic and public sectors)?
7. Have there been any unexpected outcomes (positive or negative) due to CANARIE?

Alignment with federal roles and responsibilities

8. To what extent do you believe that CANARIE plays a necessary and legitimate role as a Federal Government supported program?
9. What do you understand the mandate and objectives of CANARIE to be?
10. Is the mandate and focus of CANARIE relevant as evidenced by support for continued involvement by the government in this type of program?

Demonstration of efficiency and economy

11. In your opinion, how does CANARIE as a federally funded organization compare in terms of efficiency and economy in delivering S&T support to the research, development and education community (i.e., compared to other R&D and commercialization programs of, for example, NSERC, CIHR, CFI, NRC)?

Interviews with partners and peer networks

Continued need and relevance

1. In your opinion, have CANARIE programs and services contributed to increased research and education innovation, and national and international networking at Canadian institutions/organizations?
2. How do you anticipate the needs for a CANARIE managed and operated network to evolve over the next 3 years? Do you believe that current CANARIE programs, services and funding are necessary and sufficient to fulfill these needs? To your knowledge, has CANARIE introduced new initiatives that have increased its relevance to the needs that it is trying to address?
3. What would be the effect on your organization, and the Canadian research and education community, if CANARIE ceased to exist?

Alignment with government priorities

4. Have there been any unexpected outcomes (positive or negative) due to CANARIE?

Alignment with federal roles and responsibilities

5. What do you understand CANARIE's mandate and objective as a Federal Government supported program to be? In your opinion, is this a legitimate role for Federal Government involvement and funding?

6. Is the mandate and focus of CANARIE relevant as evidenced by support for continued involvement by the government in this type of program?

Achievement of expected outcomes

7. How, if at all, has CANARIE helped your organization achieve the following:
- expanded and upgraded advanced network capabilities and infrastructure
 - increased and improved access to and use of the network by real and virtual organizations
 - led to the development and increased availability of software interfaces, applications and tools that facilitate easier, flexible use of distributed research equipment and resources?
 - led to increased collaborative partnerships for the development of research platforms
 - helped Canadian ICT researchers and SMEs accelerate the validation and/or commercialization of products and services
8. During the past three years or so, has the capacity of the CANARIE network kept up with demand? Does CANARIE provide sufficient capacity for periods of peak traffic?
9. Has CANARIE helped reinforce Canada's position as a recognized leader in the development and use of advanced research networks? If so, how?

Demonstration of efficiency and economy

10. Has CANARIE successfully established cost sharing agreements with your organization? If so, what have been the results of these agreements?
11. What, if any, cost-savings or gains have been realized by connected Canadian institutions and users due to CANARIE managed and operated resources?

Interviews with current CANARIE users**Continued need and relevance**

- In your opinion, have CANARIE programs and services led to a more innovative research and education activities at Canadian institutions/organizations? What has been the impact on your research and development activities?
- How will your needs in terms of a CANARIE managed and operated network, programs and services evolve over the next 3 years?
- Have new initiatives that CANARIE has introduced (e.g., DAIR) increased its relevance to the needs that it is trying to address? How have these initiatives met your own research needs?
- What would be the effect on your research activities, and the Canadian research and education community, if CANARIE ceased to exist?

Alignment with Government priorities

5. Has CANARIE helped you or your organization accelerate development and commercialization of innovative products and services? If so, how?
6. Has CANARIE facilitated your increased engagement in partnerships, research collaborations and/or networking (e.g., with other businesses, academic institutions or the public sector, nationally and internationally, to develop research platforms) ?
7. What has been CANARIE's impact on your ability to compete on a global level?
8. Have you experienced any unexpected outcomes (positive or negative) due to CANARIE?

Achievement of expected outcomes

9. Has the capacity of the CANARIE network kept up with the demands of your research activities? Does CANARIE provide sufficient capacity for periods of peak traffic?
10. Has CANARIE provided increased and improved access to and use of the network by your organization?
11. Have the CANARIE Inc. funding programs and activities led to you developing or having increased access to software interfaces and tools that facilitate easier, flexible use of network or distributed research resources? If so, what are these aids, who developed them and how have you benefited?

Demonstration of efficiency and economy

12. To what extent has CANARIE funding allowed you to leverage funding from other government programs and industry?
13. What, if any, cost-savings or gains have you realized through your use of CANARIE managed and operated resources?

Interviews with Industry**Continued need and relevance**

1. How do you anticipate that the needs for a CANARIE managed and operated network, programs and services will evolve over the next 3 years?
2. Have new initiatives that CANARIE has introduced (e.g., DAIR) increased its relevance to the needs that it is trying to address?
3. What would be the effect on the Canadian research, education and innovation communities if CANARIE ceased to exist?

Alignment with Government priorities

4. To what extent do you believe CANARIE has contributed to "knowledge advantages" for Canadians that help in positioning Canada as a leader in generating health, environmental, societal and economic benefits

- a. Has it fostered research excellence?
 - b. Has it leveraged university and private-sector collaboration?
 - c. Has it increased the impacts of federal R&D investments?
5. How has CANARIE strengthened innovation capacity in Canada (i.e., encouraged R&D partnerships between business, academic and public sectors)?
6. Have there been any unexpected outcomes (positive or negative) due to CANARIE?
7. To what extent does CANARIE contribute to the broader Canadian innovation and digital infrastructure landscape? For example, does CANARIE complement and enhance the roles and initiatives of other organizations such as Compute Canada?

Alignment with federal roles and responsibilities

8. What do you believe the mandate, objectives and role of CANARIE to be? Does it play a relevant, necessary and legitimate role as a Federal Government supported program?

Achievement of expected outcomes

9. Have the CANARIE Inc. funding programs and activities led to increased collaborative partnerships for the development of research platforms? If so, what collaborations are you aware of and what has been developed through those collaborations?
10. How effective has CANARIE been in helping Canadian ICT researchers and SMEs to validate and/or commercialize their products and services faster?

Demonstration of Efficiency and economy

11. To your knowledge, to what extent has CANARIE or your own organization leveraged additional funding from other government programs or industry to complement CANARIE funded initiatives?

Interviews with R&D Institutions, research centres and laboratories

Continued need and relevance

1. How will your institution's needs for a CANARIE managed and operated network, programs and services evolve over the next 3 years?
2. Have new initiatives that CANARIE has introduced (e.g., DAIR) increased its relevance to your organization's needs? If so, how?
3. What would be the effect on your organization, and the broader Canadian research and education community if CANARIE ceased to exist?

Alignment with Government priorities

4. Has CANARIE contributed to developing "knowledge advantages" for Canadians that help in positioning Canada as a leader in generating health, environmental, societal and economic benefits?

- a. Has it fostered research excellence at your organization?
 - b. Has it allowed your organization to leverage university and private-sector collaboration?
 - c. Has it increased the impacts of federal R&D investments?
5. Has CANARIE strengthened innovation capacity in Canada (i.e., Encouraged R&D partnerships between your organization and other businesses, academic institutions and the public sectors)? If so, what has been the outcome of these partnerships?
6. Has CANARIE helped increase Canadian participation in world-leading research globally? If so, how?
7. What have been the impacts of CANARIE on your organization's involvement in each of Canada's priority S&T research and development areas (i.e., R&D initiatives involving ICT, health, environment, natural resources and energy)?
8. Has your organization experienced any unexpected outcomes (positive or negative) due to CANARIE?

Alignment with federal roles and responsibilities

9. What do you understand the mandate and objectives of CANARIE to be? Does CANARIE play a relevant, necessary and legitimate role for a Federal Government supported program?

Achievement of expected outcomes

10. Have the CANARIE Inc. funding programs and activities led to the development and increased availability of software interfaces, applications and tools that facilitate easier, flexible use of distributed research equipment and resources for your organization? If so, what are these aids and how have they improved the network?
11. Have the CANARIE Inc. funding programs and activities allowed your organization to engage in increased collaborative partnerships for the development of research platforms? If so, what collaborations and what has been developed through those collaborations?
12. To what extent have CANARIE initiatives (such as DAIR) helped to increase ICT R&D in Canada and helped adoption of leading edge ICT by small and medium-sized enterprises (SMEs)?

Demonstration of efficiency and economy

13. To what extent has CANARIE funding leveraged other funding that your organization receives from other government programs and industry?
14. In your opinion, how does CANARIE as a federally funded organization compare in terms of efficiency and economy in delivering S&T support to the research, development and education community (i.e., compared to other R&D and commercialization programs of, for example, NSERC, CIHR, CFI, NRC)?

Interviews with International research-based networks

Continued need and relevance

1. Is there a continued need for national organizations such as CANARIE and its peers, to manage and operate advanced research and education networks, and to support national R&D communities in facilitating collaboration and accelerating technology development and commercialization?
2. In your opinion, has CANARIE established Canada as a recognized leader in research networking?

Alignment with Government priorities

3. To what extent has CANARIE advanced Canada's position on the international innovation and digital infrastructure landscape? (For example, what is CANARIE's position in relation to its international peers?)
4. Has CANARIE helped increase Canadian participation in world-leading research globally? If so, how?

Achievement of expected outcomes

5. Has CANARIE enhanced Canada's involvement in international networking and networking-focused collaborations for scientific and other research?

Demonstration of efficiency and economy

6. What are the number of users, extent of user traffic, and number and type of connected institutions in your network? In your opinion, and in this respect, how does CANARIE's performance compare to its international peers and to your organization?
7. What would you consider to be best practices for efficiently managing and operating advanced network support programs? To your knowledge, how would you rank CANARIE in terms of those best practices?

Appendix F: List of Interviewees

Jim Ghadbane, President and CEO, CANARIE

Peter Wilenius, Vice President Business Development, CANARIE

Nancy Carter, Chief Financial Officer, CANARIE

Thomas Tam, Chief Engineer, CANARIE

Mark Wolff, Chief Technology Officer, CANARIE

Howard Brunt, Vice President Research, University of Victoria

Pierre Menard, Senior Analyst, Shared Services Canada (formerly with Environment Canada)

David Schade, Scientist and Group Leader, Canadian Astronomy Data Centre, National Science Infrastructure

Debbie Kemp, Manager, Innovation Outreach, Department of Foreign Affairs, Trade and Development

Peter Jacobs, Director, Research Support Services Information Technology Services, University of New Brunswick

Michel Vanier, Chief Executive Office, RISQ

Terry Dalton, Executive Director, ACORN-Nova Scotia

Rick Steele, Technology Innovation Officer, Yukon Research Centre, Yukon College

Gerry Miller, Executive Director, MRnet

Mathieu Lemay, President and Chief Executive Officer, Inocybe Technologies Inc.

Jose Marti, Professor, Electrical Engineering, University of British Columbia

Randy Rowsell, Director Computing and Communications, Grenfell Campus, Memorial University of Newfoundland

Kristian Desjardins, Information Technology Specialist, Systems Technology Section, Natural Resources Canada (NRCan)

Eddie Yep, Vice President Engineering, Galdos Systems Inc.

Bobby Ho, Research Engineer, Canadian Research Centre

Mike Wiseman, Manager, Information Security, University of Toronto

Jenny Lang, Co-founder and Chief Executive Officer, Metafor Software

Randall Sobie, Adjunct Professor, University of Victoria

Marc-Etienne Rousseau, McGill University, Montreal Neurological Institute

Keir Novick, Staff IT Services, IT Manager, Simon Fraser University, BCNET

Bradley Goodyear, Regional Director - Maritime Region, IRAP/NRC



Don Fraser, Business Manager, Project Whitecard

Tom Rivington, President and Chief Executive Officer, F6 Networks

Barry Gander, EVP, CATA and iCanada

Andrew Browne, Development Director, Startup Calgary

Mike Richard, Vice President Operations, ComNet (NB)

Ron Van Holst, Director, Research Development, High Performance Computing, Ontario Centres of Excellence

Laura O'Brien, Founding Director and Project Manager, Association of University Research Parks Canada (AURP)

Steve MacDonald, Manager of IT Services, TRIUMF

Ann Doyle, Director, Global Programs, Internet2

Joe J. Mambretti, Director International Center for Advanced Internet Research (ICAIR), Northwestern University

Appendix G: Survey Responses by Question

The following table presents the number of survey responses used for each survey-related Exhibit:

Exhibit Number	Caption	Responses
2.3	CIOs Expectations of CANARIE Traffic Increases for Research and Education (As a Percentage of Gross Traffic)	11
2.4	Users of CANARIE and ORAN Networks	11
2.5	CIOs Assessment of CANARIE's Capacity During Periods of High Traffic	10
2.6	Expectation that CANARIE Can Fulfill Future Requirements (Over the next 3 years)	11
2.8	Researcher Responses on the Importance of the CANARIE Network for Collaboration	21
2.9	Researcher Responses on the Importance of CANARIE Funding Support for Tools and Platforms	14
2.10	Researcher Responses on the Importance of CANARIE Funding for Conducting Innovative Research and Development	14
2.11	CIO Responses on the Importance of CANARIE for Participation in Leading Edge Research and Collaboration	12
2.12	CIO Responses on Whether Cessation of CANARIE Would Have Negative Impacts	12
2.13	CIO Responses on CANARIE's Role in Aspects of Technology Development	12
2.14	DAIR Users Responses on the Importance of DAIR for Accelerating Commercialization	17
2.15	DAIR Users Responses on the Importance of DAIR for Development of Innovative Products and Services	17
2.16	DAIR Users Responses on the Importance of DAIR for Competitiveness and Time to Market	17
2.17	DAIR Users Responses Regarding Negative Impacts on Product Development and Acceleration	17
2.18	DAIR Users Responses Regarding Negative Impacts on Collaboration and Competitiveness	17
3.1	Researcher Responses on the Relevance of CANARIE on Data Transmission and Security	21
3.2	Researcher Responses on the Relevance of CANARIE for Access to Information and Computing Research	21
3.3	CIO Responses on the Relevance of CANARIE for On-Campus Activities	12
3.4	CIO Responses on Negative Impacts on HQP if CANARIE Ceased	12
3.5	Anticipated Change in Usage of High-bandwidth Network by Researchers	21
3.6	Anticipated Change in Usage of Digital Infrastructure by Researchers	20
3.7	Top Digital Infrastructure Tools	20
3.8	Researchers' Perceptions of CANARIE Sufficiency in Meeting Future Needs	19
3.9	Importance of Access Federation and Cloud Services to CIOs	11
3.10	Importance of Peering, IPv6, 5G Network and Over the Network Services to CIOs	11
3.11	Anticipated Change in Usage of DAIR Program	19
3.12	Top Digital Infrastructure Tools for DAIR Users	19
3.13	Top Assistance Programs for DAIR Users	18
4.1	Researchers' Scientific Discipline	21
4.3	Breakdown of Trained HQP as a Result of CANARIE	11
4.4	Entrepreneurial Research Activities since 2010 Related to CANARIE Funding	12