Canada Foundation for Innovation
Fondation canadienne pour l'innovation

Project Progress and Institutional Reports 2005:

An Analysis of Investments and Outcomes

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Planning and Outcome Assessment

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Canada Foundation for Innovation

Project Progress and Institutional Reports 2005: An Analysis of Investments and Outcomes

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Executive Summary

Canada's future prosperity is dependent on knowledge-based economic growth and improved productivity that will maintain a high quality of life and that of the environment. The source of this productivity is an expanding pool of scientific, analytical and technical knowledge and expertise embodied in people, capital, organizational and other resources. The Canada Foundation for Innovation (CFI) is responsible for contributing to these pools of knowledge and expertise. It is an independent corporation that was created by the Government of Canada in 1997 to fund research infrastructure at Canadian universities, colleges, research hospitals and non-profit research institutions. Specifically, CFI programming is designed to:

- attract and retain highly skilled research personnel in Canada;
- stimulate the training of highly qualified personnel through research;
- promote networking, collaboration and multidisciplinarity among researchers, institutions, and sectors;
- ensure the optimal use of research infrastructure within and among Canadian institutions, and thereby
- strengthen Canada's capacity for innovation.

The CFI normally funds up to 40 percent of a project's infrastructure costs, with the remainder arranged by the recipient institutions. These attract funding from provincial sources, private enterprise and non-profit organizations, and they also co-invest in the research infrastructure projects themselves. To date, the federal government has invested $3.65B in the CFI, and nearly 4,300 projects have been funded at institutions in 62 municipalities across Canada.

This report is an analysis of individual progress reports submitted for projects awarded funding by the CFI between 2000 and 2005. Institutions are required to coordinate these project reports and submit these, along with their own institutional reports, for the five fiscal years following the negotiation of a project's Award Agreement with the CFI. The submission rate of the individual progress reports for 2005 was 96%. A total of 2,805 project progress reports were received.

The infrastructure projects funded by the CFI cover all disciplines and vary greatly in size and complexity. The projects which only recently received funding, or which are of unusual complexity, are in many cases still under development but nevertheless included in the analysis. Despite these differences, the CFI considers that the cumulative, 5-year data provides a useful "snapshot" of trends that have been set in motion by its investments.

Key findings of the analysis include the following. **Since 2000**,

- nearly 7,200 researchers have cited research infrastructure as an important factor in their decision to stay in Canada or to come to Canada from abroad– with nearly 1,470 (~20%) coming from the U.S. and 1,230 (~17%) coming from other countries;
- more than 34,100 post-doctoral and graduate students have undertaken research projects where the infrastructure was or is a key resource;

- more than 8,900 students with experience on the latest research infrastructure have completed their training and have joined the institutional, private, public or non-profit sectors in a working capacity in Canada;
- more than 9,600 technical personnel have been trained on the use and maintenance of research infrastructure;
- well over 2000 infrastructure projects, or about 80% of the sample, have enhanced opportunities for collaborative research across organizations;
- nearly 1,500, or 60% of the infrastructure projects, have helped to draw together different disciplines; and
- 1,100 or 44% of the projects have been competitive at international levels, according to the project leaders.

The social and economic benefits that Canada is gaining from these processes are beginning to become evident. Many examples have been provided in the progress reports, demonstrating the critical role that our institutions are playing in social and economic development across the country. Investments in research infrastructure by the CFI at Canada's universities, colleges, research hospitals and non-profit research organizations have clearly played a significant role in moving Canada to the forefront of global research and technology development frontiers. However the world is not standing still, with competition intensifying and new challenges on the horizon. To maintain momentum toward a knowledge economy, and a continued high quality of life, it is important that Canada stay on course.

1. Introduction

1.1 Role of the CFI in Canadian R&D

Canada's future prosperity is dependent on knowledge-based economic growth and improved productivity that will maintain a high quality of life and that of the environment. The source of this productivity is an expanding pool of scientific, analytical and technical knowledge and expertise embodied in people, capital, organizational and other resources. Knowledge transfer at local, regional and national levels occurs through the mobility of people who undertake research and development (R&D) within organizations, and also collaborative R&D that occurs between different organizations. These talented people depend on capital – research infrastructure and equipment, including advanced computing – to innovate. Ultimately these processes lead to products, processes, services, policies and programs that raise living standards, spare the environment, create jobs and generate prosperity.

The Canada Foundation for Innovation (CFI) (www.innovation.ca) is responsible for contributing to these pools of knowledge and expertise. It is an independent corporation that was created by the Government of Canada in 1997 to fund research infrastructure. The CFI's mandate is to strengthen the capacity of Canadian universities, colleges, research hospitals, and non-profit research institutions to carry out world-class research and technology development that benefits Canadians. *Research infrastructure* includes state-of-the-art equipment, buildings, laboratories, and databases required to conduct research. This advanced capital is necessary to keep the Canadian R&D enterprise at competitive levels. Specifically, CFI programming is designed to:

- attract and retain highly skilled research personnel in Canada;
- stimulate the training of highly qualified personnel through research;
- promote networking, collaboration, and multidisciplinarity among researchers, institutions, and sectors;
- ensure the optimal use of research infrastructure within and among Canadian institutions, and thereby
- strengthen Canada's capacity for innovation.

Proposals to the CFI are expected to be aligned with institutional Strategic Research Plans that are also submitted to the CFI. The proposals are assessed on the basis of merit by external experts, and often a review by a multidisciplinary assessment committee that makes recommendations as to which infrastructure projects represent the most effective investments of public funds. Three criteria form the basis of the review:

- Quality of the research and need for the infrastructure;
- Contribution to strengthening the capacity for innovation; and
- Potential benefits of the research to Canada.

The CFI will normally invest up to a maximum 40% share in research infrastructure at the institutions, to support their efforts in strategic planning and to provide the financial basis for partnering with other funders, such as the provinces, private enterprise and non-profit organizations to implement research. The structure of the CFI is such that it can make

secure commitments for long-term funding while retaining the management, disbursement and monitoring of these funds in a responsible but flexible manner.

As of July 15, 2005, the federal government had invested $3.65B in the CFI that, with compounded interest, is expected to grow to approximately $4.85B by 2010. This 40% funding is estimated to bring a total of $11B to the R&D enterprise in Canada. Nearly $3B of the CFI's funds has been awarded to close to 4,300 projects at universities, colleges, non-profit research institutes and research hospitals in 62 municipalities across Canada.

The CFI is one among several funders of Canadian R&D at universities, colleges, research hospitals and non-profit research organizations. It works in complementary fashion with these other agencies and organizations—federal, provincial and local. Research infrastructure projects at institutions span all R&D areas, from engineering to health to economics, for example, and encourage collaboration among the institutional, business, government and non-profit sectors.

1.2 Types of CFI funds

The CFI's program architecture is adapted to the changing nature of research needs and the evolving S&T landscape in Canada. It consists of a suite of funds designed for different purposes and types of institution. A new program architecture implemented in late 2005 replaces previous funds that are either already expended, committed or winding down. Thus this analysis provides information only on awards made under program funds that existed up to and including 2005.

One group of the earlier funds specifically encouraged collaboration and multidisciplinarity among researchers, institutions and sectors. These included:

The **Innovation Fund (IF)**, which enabled eligible institutions, individually or in partnerships, to strengthen their research infrastructure in the priority areas identified in their strategic research plans. Through this fund, the CFI challenged Canadian institutions and their researchers to strive towards novel research approaches, improving their competitiveness, and attaining international leadership. To date the CFI investment in this fund has been greater than all other CFI funds, at $1.7 billion and over 700 projects.

The **University Research Development Fund (URDF)** was created to strengthen the research infrastructure of eligible universities that received, during the 1994-96 period, less than 1% of the total sponsored research funding in Canadian universities. The CFI invested $36 million under this fund between 1998 and 2002.

The **College Research Development Fund (CRDF)** was designed to help Canadian colleges, institutes, and their affiliated research centres develop and strengthen their research infrastructure in areas identified in their strategic research plans. Colleges could submit proposals for projects totalling up to $2 million in eligible costs with a maximum contribution of $800,000 from the CFI. The CFI invested $15.6 million under this fund in two competitions between 1999 and 2000.

The **International Joint Ventures Fund (IJVF)** was created to support the establishment of very high profile research infrastructure projects in Canada which would take advantage of extraordinary research opportunities with leading facilities in other countries. To date, 3 projects have been funded, for a total investment of $87 million.

The **International Access Fund (IAF)** was designed to offer Canadian researchers access to world-class research collaborations and facilities located elsewhere in the world which would allow them to collaborate with the best researchers in many subject areas that are important for Canadians. The CFI invested a total of $71 million in this fund, in 5 projects.

The **Exceptional Opportunities Fund** was created as a rapid response mechanism to assist institutions and their partners to participate in unique opportunities for exceptional and innovative research. Although the nature of most infrastructure projects requires significant time from conceptualization to implementation, there are a very small number of cases where an exceptional research opportunity would be missed if a project had to wait the normal time period of a national competition and subsequent decision. To date the CFI has invested $7 million in 1 project under this fund.

Another group of funds supported institutions in their bid to recruit and retain leading researchers from across Canada and from elsewhere in the world. These included:

The **New Opportunities Fund (NOF)**, which enabled eligible universities to provide infrastructure for newly-recruited faculty members, in their first full-time academic appointment in Canadian degree-granting institutions, so that these researchers could undertake leading-edge research. To date the CFI has invested more than $300 million in over 2,100 projects under this fund.

The **Canada Research Chairs Infrastructure Fund (CRCIF)** was designed as part of a Canada Research Chair nomination to enable universities, together with their affiliated research institutes and hospitals, to include a request for infrastructure support from the CFI. The Canada Research Chairs Program is administered by a tri-agency support mechanism designed by Canada's three federal, sector-based funding agencies that provide research support to universities and research hospitals.[1] The CFI has invested over $180 million in over 1,200 projects under this fund.

The **CFI Career Awards** recognized and supported a limited number of outstanding researchers by providing institutions with the infrastructure that is essential for them to carry out their research. This program was administered in partnership with the three federal funding agencies. The CFI has invested close to $7 million in this fund.

Two further funds should also be mentioned:

Since 2001, the CFI has assisted institutions with the operating and maintenance costs of the new research infrastructure it awards to institutions through its **Infrastructure Operating**

[1] The three federal funding agencies are Natural Sciences and Engineering Canada (NSERC), the Canadian Institutes of Health Research (CIHR) and the Social Sciences and Humanities Research Council (SSHRC).

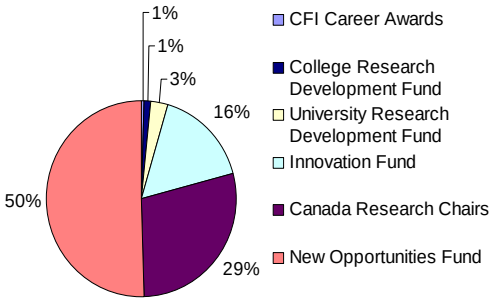
Fund (IOF). No partner funding is required for these funds, allocated to the institution on the basis of 30% of the finalized CFI contribution. In practice, because it funds only 40% of the capital costs, the actual CFI support through the IOF translates into a much smaller proportion of the total operating and maintenance costs.[2] The remainder of these expenses must be sourced from elsewhere. This fund has a maximum allocation[3] of close to $380 million.

The **Research Hospital Fund (RHF)** was launched in 2003 to provide for new, state-of-the-art research infrastructure support to Canada's research hospitals. However to date no awards have been finalized and therefore no progress reports are included in this analysis.

Exhibits 1.2.1 and 1.2.2. below depict the CFI funds according to the number awarded and the amount of financial support.

Exhibit 1.2.1

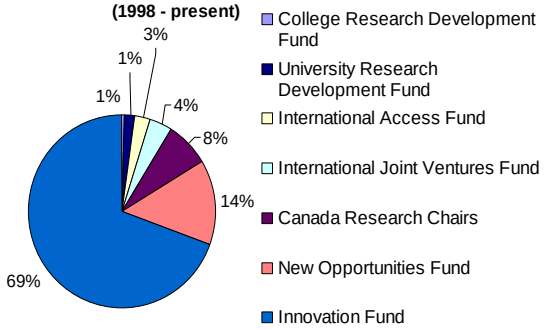
Number of CFI awards by fund type (1998 - present)



Note: Excluded from this exhibit are funds comprising < 1% of the total number of CFI Awards: International Joint Ventures Project, International Access Fund, and Exceptional Opportunities Fund. Also excluded is the Infrastructure Operating Fund.

Exhibit 1.2.2

Investment in CFI awards by fund type (1998 - present)



Note: Excluded from this exhibit are funds comprising < 1% of CFI 's total financial investment in awards: CFI Career Awards, and Exceptional Opportunities Fund. Also excluded is the Infrastructure Operating Fund. The total depicts ~ $2.6B.

2. Methodology

2.1 Data collection

By June 15 of each year, all institutions and projects funded by the CFI must submit an institutional progress report, along with progress reports for each project, through an on-line, electronic process. This requirement applies to projects for the five fiscal years that follow approval of their budgets by the CFI, and the issuing of an Award Agreement with the institution. Institutions and project leaders provide numeric and textual data requested in

[2] The High Performance Computing community in Canada estimates that CFI's IOF provides about 10% of the costs of operations and maintenance.

[3] This allocation represents 30% of the maximum CFI contribution for projects approved starting July 2001 under the Innovation Fund and the New Opportunities Fund.

a questionnaire format. Institutions are asked to prepare an overall report that addresses progress over the past year in achieving the objectives of their strategic research plans. These take into account the various contributing factors for the building of capacity for innovation and the generation of social and economic benefits. All of these reports are posted on the CFI Web site each year.[4] They comprise important sources of data for the evaluation of CFI programs, and will also be significant for "Outcome Assessment Visits" planned for 2006 and beyond (see Section 3.5 for further detail).

The focus of the present analysis is on the individual project reports that have been prepared by project leaders, and reviewed and assembled by their host institutions.

2.2 Nature of the data

The most important characteristic of the data included in the CFI's annual, overall analysis of progress reports is its heterogeneity. The reasons for this are as follows.

First, there is a great variety in terms of the size and complexity of research infrastructure projects. Smaller infrastructure projects, especially those intended to attract and retain researchers, are reasonably easy to plan, purchase and develop, whereas large complex awards such as those provided under the Innovation Fund may take well over a year, and sometimes more, to plan, contract, purchase, construct, assemble, and develop. In sum, the scope and sophistication of such projects affects the speed of implementation, and generation of outputs and outcomes.

Second, there is a diversity of scientific disciplines and areas covered by the projects, and these will evolve in different ways, some falling at the more fundamental end of the spectrum and some at the more applied.

Third, the CFI's database for progress reports submitted in 2005 contains information on projects that have started anytime from April 1, 2000 to March 31, 2005. Some projects will, therefore, have just gotten underway, whereas others will be nearing the end of their cycle of progress and financial reporting and may have been operational for years. Unfortunate as this situation may be, it is currently the best solution available to the CFI for establishing a constant interval between data collections, and to begin to identify the parameters of a baseline year.

Fourth, a characteristic of the data is its subjective nature. Project leaders are asked to provide their personal assessments of the impact of the research infrastructure, taking account of the objectives of CFI programming – such as attraction and retention of researchers, research productivity, social and economic benefits, and so on. It is worth noting that there is little or no incentive to include false information on the forms, as these progress reports have no bearing on potential future funding. More probable is a lack of administrative capacity to fill out forms comprehensively and track all numbers, especially for large, complex projects. Data points can go missing. Although institutions review and

[4] http://www.innovation.ca/publications/index.cfm?websiteid=422

assemble all project progress reports, the degree of quality control is variable and there is no immediate verification of them by the CFI, due to their sheer volume.

Fifth and finally, there is a problem of attribution. The research infrastructure investment made by the CFI is only one contribution to a larger endeavour. There are also the co-funders of the infrastructure, non-infrastructure support of research and training, and many other contributing factors that affect the ability to precisely attribute impacts.

Despite these problems, the CFI considers that the yearly progress reports form a useful source of survey-like data that can be analyzed. The number of reports received annually is nearing 3000. The sheer numbers mean that broad patterns are becoming discernible that can be investigated in similar fashion year over year. Given the large sample size, from a survey point of the view, this is a statistically valid number whose margin of error may be calculated.

2.3 Use and interpretation of the data

In the past, the CFI has posed questions to project leaders and institutions about investments in research infrastructure pertaining to the previous year. This was a reasonable approach when the number of projects supported was a manageable volume, and proportionately few projects were nearing completion. It remains one line of questioning within this analysis. Today, however, many projects have reached a maturity where it is reasonable to ask questions that pertain to the life of the project. Also, at the project leader's level, it is often more meaningful to ask questions about the trajectory of a research project related to research infrastructure from its start–for example, the number and ultimate employment fate of post-graduates who have been attracted to it. Thus, as of this year's 2005 analysis, cumulative data on various topics has been collected.

The cumulative, overview data has its limitations, however. The results provide broad trends, but are not intended to be interpreted as precise numbers. Furthermore, even the trend data will differ for such parameters as start date, type of fund, field of research, and so on. That said, it is useful to see the overall figures, to provide stakeholders with a "snapshot" of the impacts of research infrastructure investments since 2000, and to determine which topics merit greater investigation and analysis.

3. Results

3.1 Overview

With June 15 set as the deadline date for submission, the CFI established July 15 as the cut-off date for inclusion of data from project progress reports. By this date, 2,805 project progress reports had been received, out of a total of 2,937 required, a submission rate of nearly 96%. Of the 113 institutions expected to produce a summary report, 81 had submitted these by July 15.

According to the reports:

- nearly 1,300, or 46%, of projects were fully developed and used for research throughout the past year;
- approximately 1050, or 37%, were partly developed, or developed at some point in the past year but not used for the whole year;
- approximately 450 projects, or 17%, were still under development and had not been used for research in the past year.

3.2 Getting, keeping and producing R&D talent

Attracting, retaining and encouraging the production of creative, skilled personnel in the context of global competition for this talent is a continuing challenge for institutions and indeed other R&D-intensive organizations. Within Canada, the state-of-the-art research infrastructure supported by the CFI's investments are a critical part of the arsenal institutions use to recruit and retain researchers, who in turn are able to entice students and other highly qualified personnel to their facilities. Upon completion of their training some of the trainees leave the institution to join the private sector or government, some join other institutions in Canada or abroad, and some remain at the institution. Canada aims to achieve a net gain in research talent within the country and across different sectors. It can also benefit from the access to world knowledge that is aided by continued contact with departed trainees who go abroad.

*The state-of-the-art infrastructure that is used by a research team working on problems of biodiversity and ecosystem function at **McGill University** has been a significant factor in recruitment in the departments of Biology, Geography, and Natural Resource Sciences, in the Redpath Museum and in the McGill School of Environment. For example a total of 11 new ecologists and evolutionary biologists have been hired in McGill's Biology Department. This has created a research group of 20 individuals, easily among the top few in the world in this research area. The hirings include top calibre individuals at all ranks, including four Canada Research Chairs, from Chicago, Paris, and Florida. It is noteworthy that the Paris recruit is a recent recipient of a Silver medal awarded by the government of France to the best mid-career scientist in any discipline, and president of an international research consortium.*

The analysis of progress reports reveals that investments in research infrastructure are having a significant impact on recruitment and retention of researchers. **Since 2000**, the availability of research infrastructure has been:

- an important factor in the decisions of nearly 7,200 researchers to join Canadian institutions– with nearly 1,470 (~20%) coming from the U.S. and 1,230 (~17%) coming from other countries. Of these:
  - 90% were recruited primarily from academic institutions and research hospitals,;
  - 6% came from the private sector; and
  - 4% came from the non-profit sector.

Exhibit 3.2.1

Geographic area of origin for researchers recruited to infrastructure projects (since 2000)

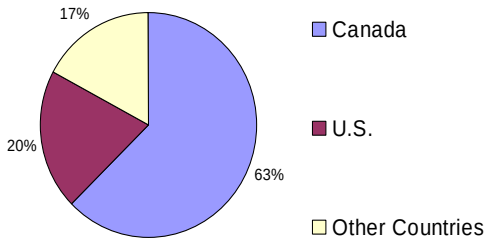
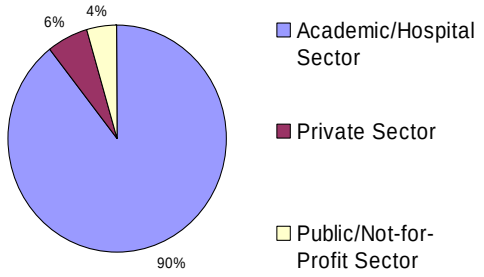


Exhibit 3.2.2

Sectors of origin for researchers recruited to infrastructure projects (since 2000)



It is interesting to observe that 10% of the new research recruits come from outside the institutional sector. The S&T literature reports that researchers with experience in various sectors maintain their contacts and networks in different organizations throughout their career. These linkages help to sharpen their knowledge of different perspectives and applications and can lead to more effective knowledge translation in society. Knowledge translation is also aided by mobile trainees.

*The diversity of infrastructure acquired as part of the Centre for Forest Interdisciplinary Research at the **University of Winnipeg** has provided a very fertile and interdisciplinary research and training environment for faculty, students, and technical personnel. C-FIR continues to engage students from a diversity of disciplines, including biology, geography, chemistry, environmental science, and sociology. The strength of C-FIR lies in its interdisciplinary approach to forest-related research, and the diversity of affiliated researchers continues to expand. C-FIR remains the pre-eminent forest research centre in central Canada, with strong growth in terms of HQP training numbers.*

Trainees, such as undergraduate and graduate students, come from a diversity of fields and backgrounds, and similarly, move on to various positions and career paths in academia, the public and private sector. Thus, C-FIR provides training in many disciplines outside of those commonly associated with forestry.

On the topic of training, data supplied in project reports indicate that in the **past year alone (2004-05)**, the research infrastructure was an important factor in the attraction of:

- more than 4,000 post-doctoral fellows (PDFs); and
- nearly 12,450 graduate students.

The exhibits below indicate the origin for these trainees.

Exhibit 3.2.3

Origin of PDF researchers attracted to infrastructure for their research projects in the past year (2004 - 05)

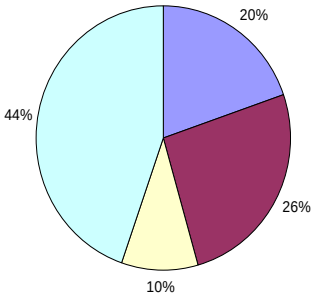
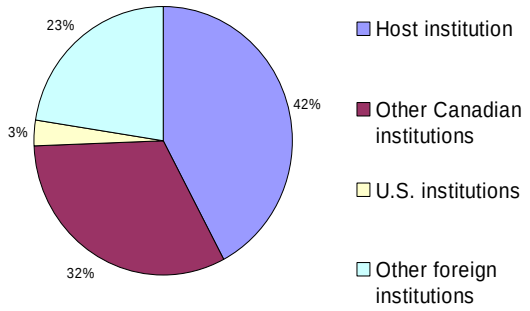


Exhibit 3.2.4

Origin of graduate students attracted to infrastructure for their research projects in the past year (2004 - 05)



The research infrastructure projects appear to be attracting trainees to Canada and retaining some of them. **Since 2000:**

- more than 34,100 post-doctoral and graduate students have undertaken research projects where the infrastructure was or is a key resource.

Project leaders often follow the career paths of the students that have worked in their labs. Additional career data was supplied by them for nearly 29,400 of these trainees. The data indicates that more than half remain at the institution where the research infrastructure is located to complete their training. This is to be expected, given that it is still early in the life of some of these projects. However the five-year trend shows that those students who have completed training on the latest infrastructure are also highly mobile in Canadian society and are moving to join different organizations, as follows.

Since 2000:

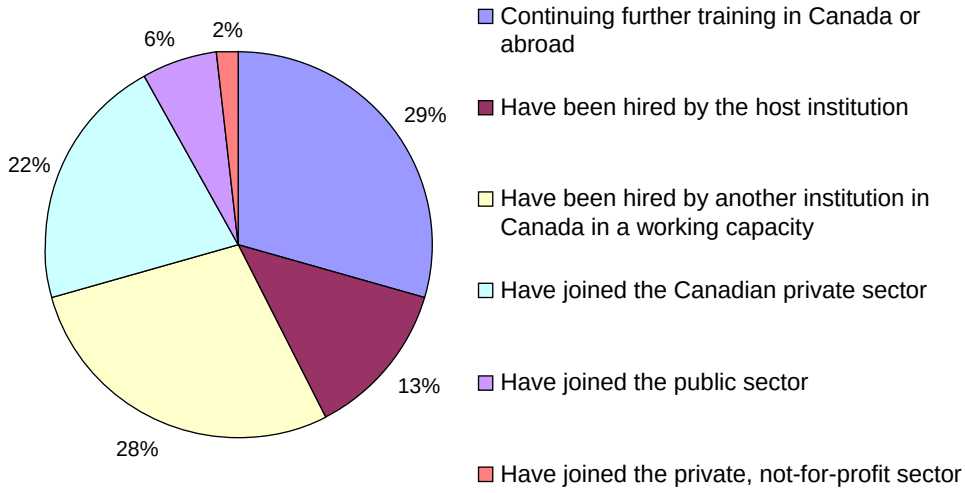
- More than 12,600 (43%)[5] of trainees for which there is data have completed their work at the host institution. Of these, approximately:
  - 3,700 (29%) are continuing further training in Canada or abroad; and
  - 8,900 are employed, as follows:
    - 1,650 (13%) have been hired by the host institution;
    - 3,500 (28%) have joined another academic institution, college or research hospital in Canada in a working capacity;
    - 2,700 (22%) have joined the Canadian private sector;
    - 800 (6%) have begun work with the public sector; and
    - 200 (2%) have joined the private, not-for-profit sector.

*The **Queen's** Facility for Isotope Research (QFIR), which houses the infrastructure, has been instrumental in both the recruitment and retention of new researchers at Queen's. Dr. Linda Campbell, a recently appointed Canada Research Chair in Biology, based part of her decision to come to Queen's on her impression of QFIR. Recent interviews of Canada Research Chair candidates for the Department of Geological Sciences and Geological Engineering were centered around QFIR as facilitating their research and developing new collaborations.*

[5] That is, 43% of the 29,400 trainees for which additional career data was supplied by project leaders.

Exhibit 3.2.5

Career paths of graduates with research exposure to research infrastructure (since 2000)



Investments in sophisticated research infrastructure have required training of highly qualified personnel for the new, complex facilities, databases and equipment that comprise sophisticated research infrastructure installations. These facilities require new types of skills and knowledge that have not existed in the economy before. It may take years for management and technical personnel to develop complete mastery over the new scientific tools and then to pass these skills onto others. Hence, institutions often prefer to retain such people, who may take many years to train.

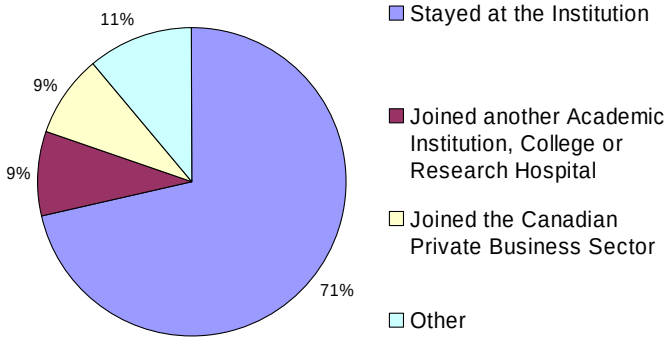
*A team at **Brock University** has stated that "attracting and keeping a skilled technician in the mass spectroscopy area, particularly with skills in proteomics, will be extremely difficult" especially given the high level of competition they will experience with other major facilities and industries such as genomics and proteomics centres and the pharmaceutical and biotechnology industries.*

Since 2000,

- more than 9,600 technical personnel have been trained on the use and maintenance of research infrastructure . Of these:
  - more than 71% have stayed at the host institution;
  - nearly 9% have joined another institution; and
  - close to 9% have joined the private business sector.

Exhibit 3.2.6

Employment fate of technical personnel trained on state-of-the-art research infrastructure (since 2000)



The people who are trained on the leading-edge infrastructure as its managers and technicians are often the same who will be required to upgrade, re-develop or master the new facilities of tomorrow. These highly skilled personnel—such as those capable in high-performance computing, mass spectrometry, robotics, and magnetic resonance imaging are critical to the maintenance of innovation capacity at Canadian research institutions.

3.3 Transforming the nature of research

State-of-the-art research infrastructure is a requisite for the advancement of quality research. It is not possible for the creative researcher to participate in today's frontier areas in the absence of the latest tools to do so.

*At the **University of Waterloo** a researcher explains: "The overall objective of this project is to bridge the critical gap disconnecting electromagnetics hardware from algorithmic software in Multiple-Input Multiple-Output (MIMO) technology. In laymen terms, wireless communication equipments require "brainpower"… consisting of space-time coding algorithms, smart-antennas signal-processing algorithms and optimization algorithms to adjust antennas/electronics hardware for intelligently handling … situations. Th(e)…synergy is, however, hampered by academia's routinely unconnected conceptual development of the algorithmic theories and the hardware theories. Relying on an inter-disciplinary approach, the present project is able to bring together three assistant professors at the …Faculty of Engineering, who offer distinct but complementary research expertise … The infrastructure acquired through CFI provides the indispensably needed computer-simulation software tools and electromagnetics / electronics hardware tools to produce empirical data and to validate the theoretical models/algorithms/architectures…"*

This is the minimum, however. A key feature of the R&D enterprise in advanced, industrialized economies is its transformation to a different mode of knowledge production, referred to as "mode 2"[6]. Multidisciplinary, collaborative R&D is being driven by the complexity of contemporary scientific challenges that demand approaches from different perspectives. In addition, research is accelerating, enabled by information and communication technology which itself is undergoing constant change and upgrading. Many governments actively support the development of networked and other initiatives that encourage multidisciplinary and collaborative R&D, within countries and among countries, such as in the European Union. The CFI holds the view that research infrastructure is a catalyst for these new forms of interaction, and this has been a significant aspect of its programming.

New forms of collaboration around research infrastructure can also help to encourage innovation. Innovation is a complex, social process involving the movement of people and ideas across organizational boundaries – knowledge translation – and the application of resources, including investment, to capitalize on ideas and new capability. Business is unlikely to adopt new inventions and approaches in R&D in the absence of relationships established not only by contracts, but also by trust, mutual comprehension, joint effort and complementary if not similar capabilities. Knowledge carried by trainees or transferred through relationships between research institutions and the public sector likewise requires a collaborative, and often, a reciprocal approach.

[6] A key reference to this form of knowledge production was formulated by Michael Gibbons, in T*he New Production of Knowledge The Dynamics of Science and Research in Contemporary Societies* (Sage Publications: 1994)

Data provided in the 2005 progress reports suggests that investments in research infrastructure, in particular large, complex facilities requiring effort and buy-in by different research groups and funding partners, both enable and provide an incentive for multidisciplinary, collaborative research. Relationships are proceeding in Canada between institutions and their R&D partners in the wider Canadian society, and around the world, catalyzed by the investments in new, sophisticated facilities and equipment.

*According to a **University of Calgary** researcher focused on the characterisation of asteroids and comets in the near-Earth environment, "The infrastructure development is diverse: the telescope retrofits allow discovery of and orbit determination for asteroids and their physical characterization - this constitutes part of the field of planetary astronomy; the MORP (meteorite observation and recovery project) fireball data allow orbit determination for NEO (near earth objects) and cometary fragments falling on the Earth and their physical characterization… – this constitutes part of the field of meteor physics; the meteorite curation facility allows study of the physical properties of meteorites – this constitutes part of the field of meteoritics… Therefore the research infrastructure is allowing unprecedented concentration of these different fields at one Canadian institution with constraints from the different fields contributing towards the same goal – understanding the NEO population."*

In the **last year (2004-05)** approximately:

- 25,200 researchers at the host institutions have advanced their research through use of infrastructure; and
- an additional 12,500 researchers from outside the institution have used the infrastructure.

In the **last year**, the outside users of research infrastructure included nearly:

- 3,000 (23%) researchers located at the municipal level;
- 2,400 (19%) researchers from elsewhere in the province;
- 2,400 (19%) researchers from elsewhere in Canada;
- 2,100 (17%) from the U.S.; and
- 2,800 (22%) from countries elsewhere.[7]

Users of research infrastructure from outside the host institution come from different sectors. In the **last year**, approximately:

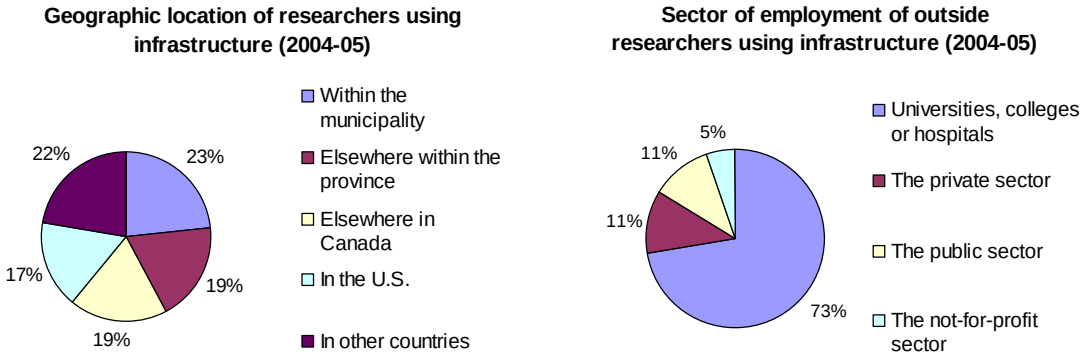
- 9,200 (73%) came from other universities, research hospitals or colleges;
- 1,450 (11%), came from the private sector;
- 1,400 (11%), came from the public sector; and
- 680 (5%) came from the non-profit research sector.

*At the **Memorial University of Newfoundland**, the Centre for Environmental Archaeology and Cultural Systems in Central Labrador "… is geared to the collection and interpretation of human and natural impact on long-term marine and terrestrial resource fluctuation on the central coast of Labrador and was established to support multidisciplinary research from the fields of archaeology and geology. The infrastructure has been used by (many) researchers (in the Department of Anthropology) …who are providing archaeological data gathered from pre-contact and early historic human populations in Newfoundland and Labrador. Collaboration has also occurred with (the) Department of Geography on… geomorphological changes to the landscape …over a 9000 year period…. Research collaborations have recently been established with …University of North Dakota,…McMaster University…and the Labrador Métis Nation who are all using the data generation and analysis infrastructure.*

[7] Trends in attraction of foreign nationals are discussed in the next section.

Is this use by outside researchers indicative of more multidisciplinary, cross-sector collaboration? According to responses to the questionnaire, the answer is yes.

Exhibit 3.3.1



On the measure of multidisciplinarity, project leaders report that, for research projects enabled by infrastructure **since 2000** and up to 2005:

- the infrastructure awards have been playing a significant or critical role in drawing together different disciplines in nearly 1,500, or 60%, of them. However, there were differences between types of fund, as follows:
  - in nearly 300, or 75% of IF projects, infrastructure played a significant or critical role in drawing together disciplines; and
  - in more than 1,780, or approximately 55%, of NOF and CRCIF projects, infrastructure played a significant or critical role in drawing together disciplines; and
  - 450 projects, or nearly 30% of all the projects reporting, were NOF and CRCIF awards where the research was described as not lending itself to a multidisciplinary approach.

As for cross-sectoral collaboration, project leaders report that, for research projects enabled by infrastructure **since 2000** and up to 2005:

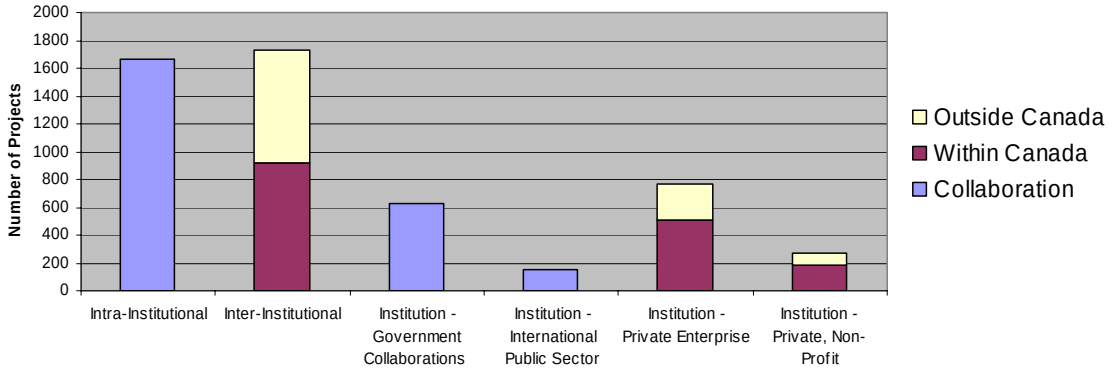
- the infrastructure awards have been enhancing opportunities for collaborative research across organizations in well over 2000, or 80% of them. Once again, there were differences between the different types of funds, though they were less dramatic:
  - slightly less than 80% of NOF and CRCIF projects – the numerically prominent projects in the sample-- reported cross-sectoral collaboration; while
  - nearly 90% of the IF projects reported cross-sectoral collaboration.

L'infrastructure de recherche a permis la mise sur pied du Centre d'Étude des Matériaux Optiques et Photoniques de ***L'Université de Sherbrooke*** *(CÉMOPUS). Ce centre de recherche institutionnel rassemble des chimistes et des physiciens dont activités sont axées sur la modélisation, la conception et la caractérisation des propriétés optiques non-linéaires des polymères et des cristaux liquides. Grâce aux infrastructures obtenues de la FCI, CÉMOPUS connaît un développement rapide et constitue un des centres névralgiques du Centre Québécois des Matériaux Fonctionnels (CQMF).*

Collaborations are taking many forms, and there may be many of them for a given project, especially large awards. **Since 2000**, types and instances of collaboration in the projects include:

- nearly 1,700 intra-institutional;
- well over 1,700 inter-institutional;
- nearly 800 with private enterprise;
- well over 600 with government departments, and
- more than 250 with private, non-profit organizations.

Exhibit 3.3.2
Collaborations enabled by infrastructure (since 2000)



3.4 Enhancing Canadian capacity for innovation in a competitive world

*A group of researchers at the **University of Saskatchewan** indicated that "We are now the only group in the world doing full three-dimensional modeling of teleseismic recordings."*

The advent of the CFI, along with overall increases in public sector R&D funding in the past several years, has made it possible for a dramatic increase of profile of Canadian researchers and their host institutions. Many of these institutions have achieved an international profile; a transformation that is vital for Canada in its efforts to establish an R&D niche in the global economy. At the institutional level, this global outreach requires an approach that is both more collaborative and more competitive. World-class infrastructure catalyzes international research partnerships, attracts students and helps to lever domestic and international financial support beyond the traditional public sector sources. The net result is an advancement in research quality and productivity that can compete with the best.

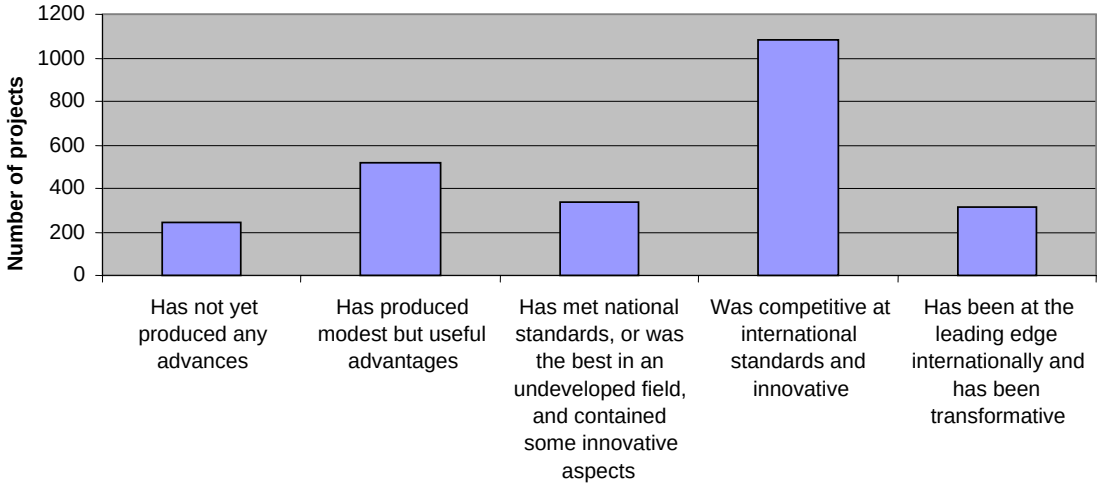
Most of the research infrastructure projects have implications for Canadian linkages with global R&D and its competitiveness in a world perspective. In what follows, an overview of all projects is provided.

With respect to research quality and productivity, project leaders indicate that, for projects started anytime **since 2000** and up to 2005, approximately:

- 1,100 (44%) of them have been competitive at international standards and innovative, and
- 300 (12%) of the research projects have been transformative and at the leading-edge internationally.

Exhibit 3.4.1

Research enabled by the infrastructure since the beginning of the project



Respondents to the questionnaires were asked to provide their own measures of research productivity. They cited traditional indicators such as publications, citations, invited speaking engagements at conferences, research attracted as a result of the infrastructure, patents, spin-off companies and prizes. Other measures were degree of cost recovery, the international popularization of a pioneering technique, media coverage, and claims of a "world's first" facility.

*At the **University of Toronto** one research group reports that the infrastructure has helped it to focus its research effort in areas where it has a critical mass of expertise that is distinctive on the international research stage: "All of our work now involves the application of quantum dots, nanometer-sized semiconductor particles active at infrared wavelengths with applications...in the energy sector, prospectively allowing cheap, efficient harvesting of the suns energy; to medicine, advancing technologies to enable early cancer detection using infrared light; and to communications and networking, advancing a platform technology with which to integrate electronic, optical, and wireless communications. The highest standards of originality, significance, and methodology are imposed in all that we do. Our work is now being published in the very highest-impact journals in the field."*

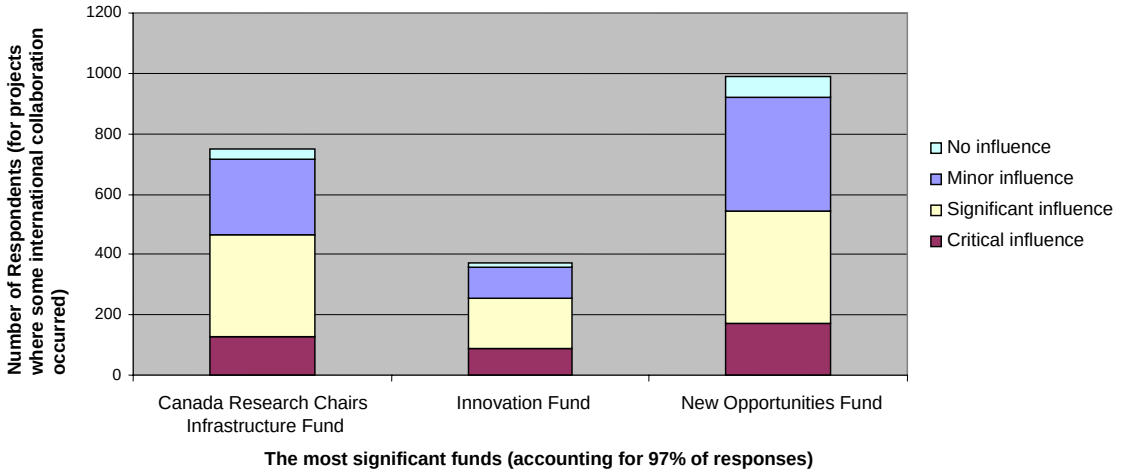
On the question of the influence of research infrastructure in fostering international collaborations **since 2000**, approximately:

- 82% of respondents considered that the infrastructure had some influence in fostering international collaborations, and
- 16% report that the collaboration would not have proceeded in its absence.[8]

[8]International collaboration is defined in terms of joint research, the mobility of students and technical personnel, and participation in international networks.

Exhibit 3.4.2

The effect of infrastructure on international collaboration (since 2000)



The use of Canadian research infrastructure facilities by foreign researchers is increasing substantially. Researchers are coming to Canada to work in partnership and take advantage of facilities. Project leaders reported that **in the past year** CFI-supported infrastructure in Canada has been used by:

- nearly 2,100 researchers from the U.S., up from 1546 researchers reported in 2004 and 943 reported in 2003;
- 2,800 researchers from other countries, up from 2150 researchers reported in 2004 and 942 in 2003.

A key challenge facing governments, especially smaller countries, is the need to lever private sector investments in a manner that enhances the overall, national R&D enterprise. These investments are expected to generate multiplier effects, such as job creation. Policies, programs and strategies are in a process of constant design and re-examination to encourage this in the OECD countries. In Canada, the CFI's approaches appear to be helping with this leverage, including the encouragement of an inflow of R&D investment dollars from international sources.

*Un chercheur du Laboratoire de zooplanctonologie pour l'étude des impacts du réchauffement actuel sur les écosystèmes marins arctiques à **Université Laval** expliquent : « L'infrastructure permet à mon laboratoire de mieux remplir son mandat dans les programmes internationaux CASES (Canadian Arctic Shelf Exchange Study) et ArcticNet. Dans le cadre de ces deux programmes, mon équipe collabore au déploiement à long terme d'Observatoires océaniques dans la Mer de Beaufort, la Mer de Laptev (Sibérie), la Baie de Baffin et la Baie d'Hudson. Nous sommes chargés de l'étude du zooplancton et de la fraction fécale du flux vertical de carbone particulaire en collaboration étroite avec des équipes japonaises et norvégiennes. Les équipements analytiques (CHN, balance, loupes stéréoscopiques, analyseur d'image) associés à l'infrastructure contribuent directement à ces travaux en collaboration avec des chercheurs d' universités japonais et norvégienne.*

Funding from outside the Canadian public sector is quite significant among research projects that also have received infrastructure funding. **In the past year**:

- 1058 project leaders report that they have received Canadian industry funding, an estimated 38% of the projects. Of these :
  - 569 (54%) said that the research infrastructure had a significant impact on their ability to attract these funds;
- 964 project leaders received international funding, and of these:
  - 525 (also 54%) stated that research infrastructure funding had a significant impact on their ability to attract funds from this source.

*The critical importance of infrastructure to acquiring international support was evident in the words of a **University of Alberta** project leader, "we are collaborators on a major grant from the National Science Foundation of the United States (>$4 million) that was leveraged by our ability to contribute portions of our radio-telemetry analysis system to the project… we would not have been able to secure these funds if it were not for the expertise and infrastructure afforded by our CFI equipment."*

3.5 Providing social and economic benefits

As is evident from the foregoing data presented in this report, the CFI's infrastructure investments are having a significant impact on the nature of Canadian R&D and the institutions that it supports, as well as producing highly qualified scientific and technical personnel. But how do these transformations in R&D translate into social and economic benefits for Canada? This is a complex question that many public funding agencies, in Canada and throughout the world, are working on. The CFI is engaged in the development of evaluation initiatives that will contribute to the overall effort. To this end, CFI is developing a process termed "outcome assessment visits". By means of a series of expert reviews, they will contribute to an assessment of the transformative processes taking place at Canadian universities, research hospitals, colleges and non-profit research organizations in given thematic areas. Among other objectives, the outcome assessment visits will help to identify and document social and economic benefits of investments in state-of-the-art research infrastructure.

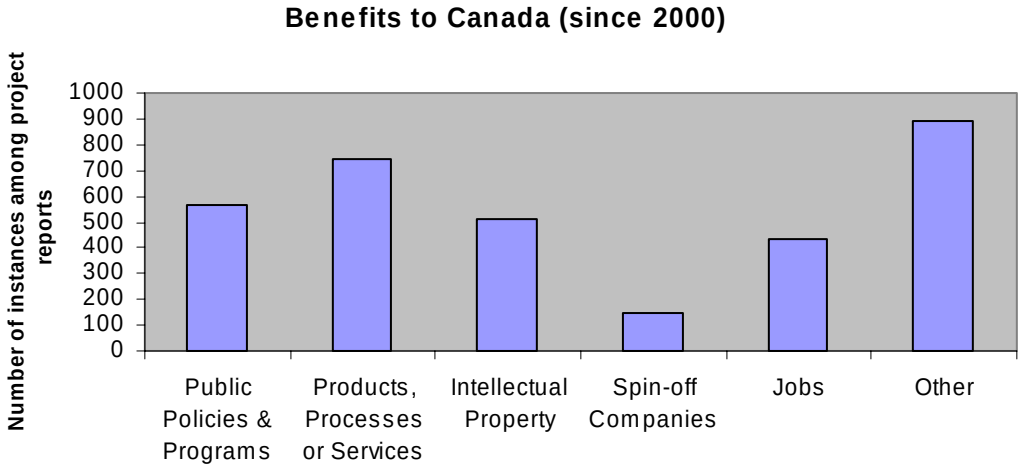
For the purposes of this analysis, overall results are provided that summarize the reported experiences and perspectives of researchers on the topic of social and economic impacts. This is an imprecise measure that is only provided to indicate trends. In addition, a small sample of "mini-case studies" is documented to provide insights on some projects. In the coming year, the database of progress reports will serve as an important departure point for more rigorous studies.

The following overall results can be reported. Of the 2,805 project reports submitted, approximately 2,100 (75%) stated that the research supported by the infrastructure has helped to generate economic and social benefits. Respondents were asked to provide data

on various measures, and the quantitative results were as follows. Note that many reported that their projects had impacts in more than one area, and that the figures refer to the *instances* of the measures. Project leaders report that, **since 2000**, there have been:

- 564 instances of new or improved public policies & programs
- 748 instances of new or improved products, processes or services
- 510 instances of intellectual property rights
- 437 instances of public or private sector jobs created
- 150 instances of spin-off companies, and
- 892 instances of other benefits.

Exhibit 3.5.1



Mini-Case-Studies illustrating social and economic benefits

Telematics has applications in space exploration, disaster management and critical infrastructure. At **Simon Fraser University**, researchers launching the *Telematics Research Laboratory* (TRL) received an investment from the CFI under the **Innovation Fund** in 2000. The infrastructure has been critical for the researchers in their achievement of world status in telematics areas. In space exploration, for example, the team has forged partnerships with the Canadian Space Agency, NASA, and the European Space Agency.

Disaster management and critical infrastructure is a key concern throughout the world, becoming more so in the face of climate change. Simon Fraser's TRL, in collaboration with a range of industrial and government partners, has supported the strengthening of public safety and critical infrastructure protection through a series of applied and policy-based initiatives. In particular, collaboration has helped the TRL be a pioneer in the application of IP based technology for improving the flow and exchange of critical multi-jurisdictional information before, during and after emergency events. Examples include the:

- B.C. spring floods in 2001, where digital photography and wireless communications were introduced and used to document and relay near-real-time flood impact images to B.C. provincial and local community operations centres;

- BC forest fire and flood tactical and site support communications in 2002, where TRL provided conceptual and technical design input for key features of the Real-time Emergency Management via Satellite System for improving its operations;

- The disastrous forest fires in the BC Central Region in 2003, at which time TRL developed a methodology for identifying critical communications infrastructure at risk, plans for protecting sites, plans for assessing impacts from their loss, and back-up communications arrangements. A major breakthrough was the development of an electronic mapping system to facilitate this work as well as apply it to other critical infrastructure areas such as dangerous goods, oil and gas pipelines, bridges, reception centres, etc.;

- Assessment of the B.C. Tsunami Warning System and Related Risk Reduction Practices. This study has been used as a blue print for improving tsunami warning along the B.C. coast and as input for a concept paper for a new national early warning system in Sri Lanka;

- Development in 2004 of an Advanced Mobile Emergency Communications Prototype (AMECom) - a specialized vehicle capable of rapidly deploying advanced communications throughout regions of British Columbia accessible by road. It is equipped with a range of facilities including terrestrial radio and satellite communications, telephone, video, Internet and other systems to enable the vehicle to become a field relay or gateway for critical communications from any location that the vehicle can access - in rural as well as urban areas. This prototype is one of the most advanced in Canada and is intended to serve the needs of British Columbia research and emergency management communities.

These examples of TRL's R&D advances and partnerships comprise only a sample of its undertakings, all of which have been dependent on investments made by the CFI in its research infrastructure.

• • •

At **Dalhousie University** a **Canada Research Chair Infrastructure** award made in 2004 is enabling quantum pharmacology approaches for the design and synthesis of potentially useful compounds for the treatment of disease and other health disorders.

To date, the research infrastructure has aided the identification of a new class of compounds for the treatment of Alzheimer's disease. These have been protected by three patent application filings. The research team is working with Q-RNA Inc. of New York City to enable the continued development of this discovery, with the company providing funding for four new jobs in the Dalhousie laboratory that permit the continuation of the drug discovery process. In addition, working in conjunction with Neurochem Inc., a Canadian

biotechnology company in Montreal, a new class of compounds has been designed for the treatment of epilepsy. These have been protected by multiple patent filings. Finally, as a byproduct of the drug discovery operating in Alzheimer's/epilepsy, a new class of compounds have been identified as potential antibiotics. A start-up company is being planned around these compounds.

Collaborative R&D continues to expand, which is aided by the infrastructure. A working research and development relationship has been developed with the National Research Council's Institute for Biodiagnostics (IBD) in Montreal, with the aim to form a research cluster in the area of Alzheimer's and epilepsy called the BMHI (Brain and Mind Health Initiative). The commercialization of research and technologies focused on the treatment of chronic neurological disease will be one of the major activities of collaboration.

• • •

The aluminum industry makes a significant contribution to the Canadian economy, and its competitiveness is dependent on continuous R&D to improve quality while meeting environmental and other regulations. Infrastructure provided under the New Opportunities Fund in 2000 is considered a starting point for the establishment of a characterization laboratory at the Université du Québec à Chicoutimi (UQAC) that works with industry and other partners. Alcan, the Aluminum Technology Centre of the National Research Council, STAS [Société des Technologies de l'Aluminium du Saguenay Inc] and CQRDA [Centre québécois de recherche et de développement de l'aluminium] have access to the research infrastructure at the laboratory. The research group on aluminium at UQAC, Centre universitaire de recherche sur aluminum (CURAL) has recently obtained $3.6M from Québec's Ministère de la Recherche, de la Science et de la Technologie for equipment that will, in part, be used to update the optical microscope initially obtained with CFI support.

The characterization laboratory is a member of REGAL (Regroupement stratégique en recherche sur l'aluminium) which brings together researchers working on aluminium in Québec. McGill, Laval, and Sherbrooke universities, plus École Polytechnique and Cégep of Trois Rivière are members, along with UQAC. All the members of REGAL have access to the UQAC characterization lab.

Research conducted in the characterization laboratory is applied and leads to design changes and optimisation of industrial processes. This in turn reduces the costs for industrial partners, such as Alcan. Projects are multidisciplinary covering aluminum filtration, wetting, reaction kinetics, microstructure imaging, semi-solid casting, and metal matrix composites of aluminum.

The characterization laboratory also conducts applied research for the analysis of wood, including structural changes occurring during thermal treatment, and the resistance of wood to fungi attack and others. Technology transfer is underway with industry and PCI, for example, has modified the design of their furnace according to recommendations developed by the laboratory. Researchers are also working closely with Hydro-Quebec and other industry partners on the heat treatment of electrical poles. This new technology is regarded as an alternative to chemical treatment of poles, which can be damaging to the environment.

• • •

Food safety is an area of significant concern for the Canadian public, with enormous implications for trade and the economy. In 2000 researchers at the **University of Guelph** were awarded research infrastructure under the CFI's **Innovation Fund** to establish the *Canadian Research Institute for Food Safety*, and in 2003 a second award was made under the IF to further equip the facility. An Executive Director is in place to raise visibility of the Institute, and to attract funding to cover administrative costs. In addition, funding has been provided by the university to hire technical personnel who operate and maintain the research infrastructure.

Multidisciplinary links have been forged between researchers involved in food science, epidemiology, and engineering in the development of projects aimed to track and control sources of food contamination from the farm to the consumer. The Canadian Research Institute for Food Safety and the US National Center for Food Defence and Protection (a Department of Homeland Security Institute) are involved in initiatives to improve training of personnel. Work on antimicrobial resistance being conducted at the facility has gained an international profile and collaborations have been set up with the EU. The expertise developed on instrumentation and techniques acquired as part of the IF award and has led to invitations in scientific advisory groups for EU projects. Researchers from China, India and Brazil, along with students from France and Thailand, have come to use the Institute's facilities in their projects, and the Institute participates in the North American Food Safety Training Consortium (involving universities in Canada, US and Mexico).

The Canadian Research Institute for Food Safety conducts research using state-of-the-art infrastructure, and is positioned to provide research and expertise to various levels of government to ensure a safe food supply. It has secured funding from ACAAF [the Advancing Canadian Agriculture and Agri-Food Program] to develop recommendations for a National Food Safety Strategy. This involved a consultative process with federal government agencies having responsibilities for food safety, provincial governments industry, academia and associations representing producers, processors and consumers. The recommendations emanating from the consultation process are available on the Institute's web site (www.uoguelph.ca/crifs/NFSS/RecommendationsE.pdf).Researchers at the Institute were instrumental in drafting recommendations for improvements to the meat inspection system in Ontario as part of the Expert Scientific Advisory Committee established by Justice Roland Haines.

• • •

A CFI infrastructure award in 2000 to **Brandon University** in Manitoba under the **University Research Development Fund** has been used to assess new mineral resource potential over vast areas of Manitoba, and in significant regions of Utah, the Northwest Territories, Ontario and Peru. Called the *Laboratory for Applied Research in Resource Geology (LARG)*, the state-of-the-art petrographic facility has, for example, aided researchers to undertake metallogenic scoping studies in Manitoba that have detected the presence of mineral deposit types never previously recognized or explored in the province. Through

reliance on the infrastructure, methodologies have been elaborated so that these resources can be explored and further developed.

Three new companies have been formed by Canadian entrepreneurs where a significant part of the foundation and/or discovery work was carried out in the LARG Lab, in areas ranging from well site geology and mineral exploration services. Several other companies have used the research to advantage in a very significant manner. Through different research projects but with reliance on the same infrastructure, the research group is collaborating with the Manitoba Geological Survey, Geological Survey of Canada, and Natural Resources Canada.

• • •

While the aspiration to improve the conditions of modern, human society has long been with us, the capacity to do so has been limited by an ability to methodically collect and analyze empirical evidence. In 2000 a network of researchers, anchored at the **Université de Montréal,** were awarded research infrastructure under CFI's **Innovation Fund** to launch a national network of *Research Data Centres / Centre d'accès aux données de recherché.* Operating funds came from Statistics Canada, the Social Sciences and Humanities Research Council (SSHRC) and the institutions themselves. These centres are building Canadian capacity in longitudinal data analysis, setting the stage for the increasingly sophisticated evidence-based analysis that will underpin the human services of tomorrow.

Thirteen centres and two branch centres have been established at institutions across Canada, collectively called the RDC Network. An estimated 1,248 researchers used the resources of the RDC Network in the past year, an increase of 300 over the previous year. These researchers were assisted by trained data analysts who constantly improve their skills through regular teleconferencing and workshops to keep abreast of methodological and statistical advances.

Universities are using the RDCs as recruiting tools and stepping stones for major developments in advanced, quantitative methodology. Many graduates are taking jobs in federal and provincial governments, and in social agencies where they form the receptive link that can understand and use data from RDCs in the future.

Substantial improvement in the quality of scientific documentation is emerging. A large number of statistical software packages are available in the Centres, from basic to specialized, including bootstrap files, notes and issues which comprise research or Statistics Canada-identified peculiarities and problems with the data sets.

The RDC Network has significantly advanced the collective expertise of the Canadian social science research community. Research is proceeding on the following four themes:

- child development, youth in transition, life course and aging;
- education, labour markets, wages and poverty, and immigration;
- population health, health care utilization and services; and
- statistical modelling

The RDC Network has established a series of national conferences which have reported or will report on data analyzed in the RDCs:

- Economics - McMaster, 2003;
- Health – Calgary, 2004;
- The Family Under Pressure – Montreal, Spring 2005; and
- The Changing Nature of Work in the New Economy – UBC, Fall 2005.

At the University of Calgary conference, for example, 22 papers were authored by 46 researchers from 7 RDCs. Economists are working with sociologists, demographers, epidemiologists, community health experts, and so on.

The research appears to be most effective in identifying emerging trends in society, making sense of complex behavioural processes, including determinants at the individual, family, community and societal level, and monitoring and evaluating the transformation of these social processes. It is becoming valuable for others, with effective interaction beginning to occur between the RDC Network and:

- *other data providers* – Justice Canada, Canadian Institutes for Health Information;
- *service providers* – Data Liberation Initiative, Canadian Association of Research Libraries;
- *other research networks* – the Metropolis Project, Canadian Council on Social Development; Network of Centres of Excellence, the New Investigators Network; and
- *policy agents* -- Health Canada, Human Resources Skills Development, Social Development Canada, Industry Canada, Justice Canada, provincial and local governments, Council of Ministers of Education.

The next phase is to ensure relevance and to enhance links for the joint formulation of research topics by researchers and senior policy experts. A recent discussion of RDC Directors with a provincial Deputy Minister of Education is an example. In sum, knowledge transfer is at the heart of the RDC enterprise.

• • •

The University of Toronto-wide initiative in mammalian models of human disease was launched in 2001 with infrastructure funds provided by CFI under its **Innovation Fund**. Two outstanding and integrative research programs were established - the *Centre for Modeling Human Disease (CMHD)* at **Mount Sinai Hospital** and the *Heart & Stroke Richard Lewar Centre of Excellence (HSRLCE)* at the **University of Toronto**. In addition to these programs, local links were strengthened with the **Hospital for Sick Children** (Sickkids) where CFI infrastructure funds were used to enhance the study of mouse models of paediatric disease.

The investigators that have been brought together through this initiative, both locally and nation wide, hail from a variety of disciplines such as human and mouse geneticists, developmental biologists, veterinarians, clinicians (adult and paediatric), and stem cell biologists, to investigate a basic but complex question – the relationship between genes and human development and disease. At the HSRLCE the genetics behind cardiovascular disease is the focus while at the CMHD and Sickkids a wide range of disease modalities such as diabetes, renal function, behaviour, congenital anomalies, cystic fibrosis, embryonic development, tumour predisposition and more, are probed.

This initiative has enabled the provision of an excellent training environment for undergraduate students, graduate students, post-doctoral fellows, and clinician-scientists in the areas of mouse genetics, comparative pathology, adult and paediatric physiology and disease, and bioinformatics, where a special feature is the opportunity to explore functional genomics in the context of the biology of the whole organism. Training is linked with the Research Training Centres (RTC) at each organization. The RTCs ensure that trainees receive the highest quality of research training by coordinating opportunities, lobbying for funding and improving the quality of mentoring. As an example, the Hospital for Sick Children Research Institute RTC which is in its ninth year of operation is one of the largest facilities of its kind in Canada. It serves close to 700 trainees with diverse backgrounds. Furthermore, scientists train personnel for employment in the biotechnology and pharmaceutical sectors as well as academia.

Since its inception the infrastructure has been utilized by numerous investigators from the University of Toronto and affiliated hospitals, from across Canada and internationally. New collaborations and initiatives have been developed and synergies established with other CFI funded projects including the Mouse Imaging Centre at Sickkids and the Toronto Centre for Phenogenomics, a centralized mouse house under construction. In addition our facilities are made available to external users, and many researchers from regional institutes such as Queens, McMaster, and the University of Western Ontario have benefited not only from the availability of the infrastructure but from the expertise brought together through this initiative in charactering models of human disease. Enhanced research alliance has been a primary benefit of the CFI infrastructure support. Linkages with international consortia such as the International Gene Trap Consortium (www.genetrap.org), and the development of comprehensive research programs such as the large-scale study on leukemogenesis between Sickkids and the La Jolla Institute of Allergy &Immunology, would not exist without the support of the CFI Innovation Fund.

Incorporation of new collaborators is ongoing and each program promotes their platforms to external users through dedicated websites, presentations at conferences and through publications.

There have been numerous patents filed as a result of the research performed using the CFI infrastructure, for example, patent applications for:

- the prevention of primary Sjogren's syndrome caused by a gene deficiency;
- methods for cancer prognosis;
- a transgenic animal model of basal cell carcinoma; and
- pharmaceuticals containing retinal stem cells.

Major discoveries emerging from this resource have included new insights into preeclampsia and kidney disease; heart failure; osteoporosis; anemia; thrombocytopenia; and epilepsy. The tools and information being generated will shed new insight into human biological functions and disease complexities, provide new substrates for drug discovery and new resources for the academic and commercial communities in Canada to exploit for health-related product discovery and applications.

• • •

Computer and related technologies are transforming the way we live, work, interact, create and play. In 2002 researchers at the **University of British Columbia** were awarded research infrastructure under CFI's **Innovation Fund** to establish the *Institute for Computing, Information and Cognitive Systems (ICICS)*. The Institute is an umbrella organization that promotes multi-disciplinary collaboration between researchers that focuses on how machines and technologies can meet human needs.

One example of how the infrastructure is enabling multidisciplinary collaboration and research is the state-of-the-art ultrasound machine; the first such advanced machine in western Canada. It has been used in collaboration with BC Women's and Children's hospital and SFU on health-related issues. A few biomedical examples among the many R&D projects underway include:

- Using data mining techniques to help improve cancer diagnostics and understanding with the BC Cancer Research Centre;
- Image analysis and signal process for biomedical applications, in collaboration with the BC Cancer Agency;
- "Touch your patient", a tactile display of physiological monitoring; and
- The Aphasia Project involving the GF Strong Rehab Centre is creating personal technologies to improve the communicative abilities and, more generally, the quality of life of people with aphasia, a speech and language impairment.

Optical network equipment donated by Nortel is being used to create an experimental research network with UVIC, SFU, UNBC and BCIT to promote innovation and collaboration in internet technologies. In particular, NECTAR is a new network of Canada's leading researchers from 6 universities across Canada. The researchers involved are world-class experts in the field of human-computer interaction and computer-supported cooperative work.

Innovative and diverse *real world* applications are being developed by ICICS. One of these is the invention of AIBO, the Robotic Dog which is currently licensed by Sony. While this mobile robotics technology can be applied to such items as robotic vacuum cleaners, research continues on how it can be adapted to assist mobility-impaired people with security-type applications, and everyday tasks such as cooking and cleaning.

In another example, UBC's Aphasia Project has developed a prototype for a daily planner program that runs on a hand-held computer. It is designed so that people with aphasia, who have fully or partially lost the ability to recognize words or write them down, can schedule meetings and appointments using a combination of images, sounds and some text.

Since receiving CFI funding, 48 invention disclosures have accrued and 18 patents have been filed, including provisional patents. One spin-off company, Chameleon Controls, has been created.

3.6 Sustaining momentum

The CFI's mandate is to strengthen the capacity of Canadian institutions to carry out world-class research and technology development. Part of the current challenge is to sustain the levels of investment to keep Canada at the leading edge.

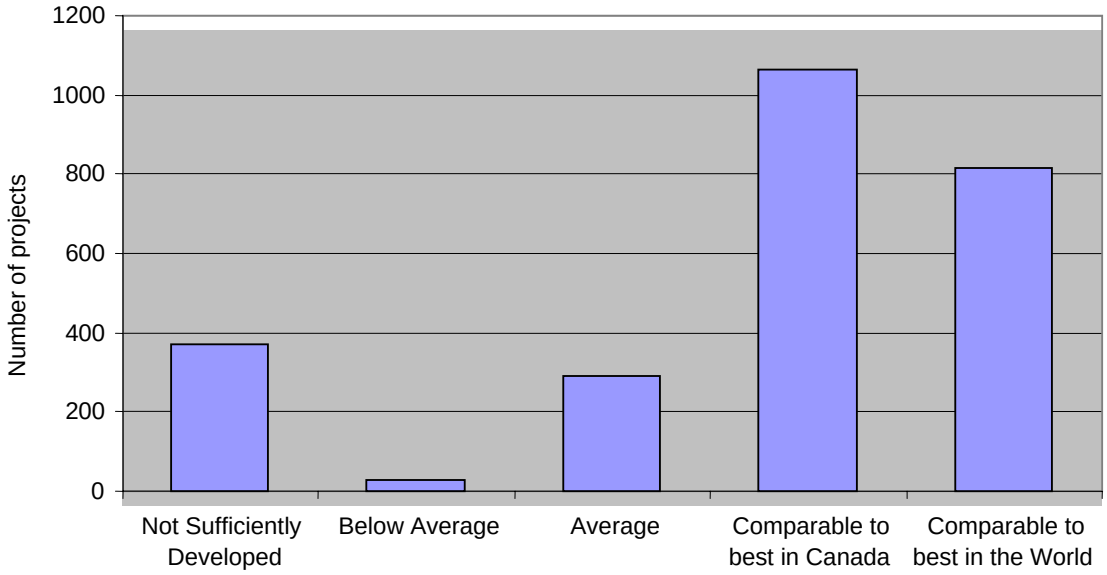
Respondents to the progress questionnaire were asked about the comparability of their research infrastructure with that in the rest of the world. In the **past year,** among the projects fully or partially developed:

- more than 800 (37%) indicated that their infrastructure projects were comparable to the very best in the world; though if only the larger, more complex IF awards are considered, the proportion rises to 51%;
- more than 1,000 (48%) considered that their infrastructure projects were comparable to the best in Canada; and
- 27 (1%) stated that their infrastructure projects were below average compared to other labs.

In a few cases, the sample of below average research infrastructure missed certain components or the equipment had a defect and was being repaired. For many others, the issue was obsolescence, particularly in those areas where technology is evolving rapidly, for example high performance computing.

Exhibit 3.6.1

Infrastructure status (2004 - 05)



On the topic of infrastructure utilization, respondents reported that, for their projects in the **past year**, about:

- 430 (17%) were not sufficiently developed to be utilized.[9]

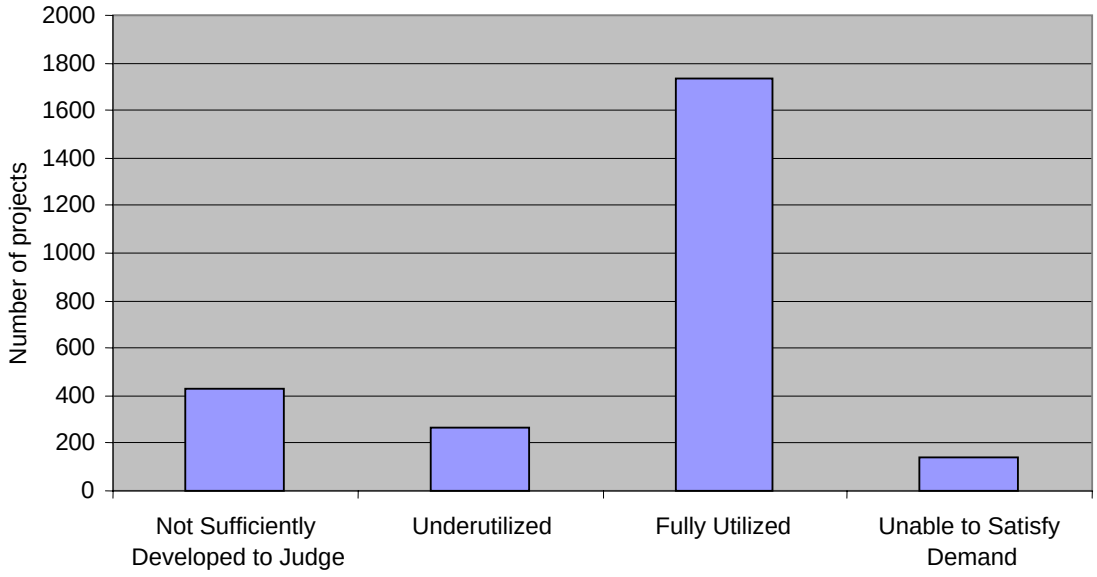
Among the sample of projects that were fully developed in the **past year**, about:

- 1,740 (81%) were fully utilized;
- 140 (6%) were not only fully utilized, but unable to keep up with demand; and
- 260 (12%) were underutilized.

> *A project leader from **The University of Western Ontario** mentions "The current equipment, consisting of multiple computing clusters, is very heavily used, with some systems operating at greater than 99% capacity for weeks. This is due to the growth in the number of researchers turning to HPC to address their research problems, more researchers expanding the scope of their research and the emergence of new application areas, such as bioinformatics and financial mathematics, which rely heavily on HPC. There has also been a growth in the number of students looking to use HPC as part of the research or recognizing its importance in their future careers, whether those careers are in industry or academia."*

Exhibit 3.6.2

Infrastructure utilization (2004 - 05)



[9] The absolute number for this question in the form (question 9) is lower than that reported for the question on infrastructure development and implementation, although the proportion (17%) of undeveloped infrastructure remains the same. Some respondents with infrastructure still under development respond to question 1, and other questions related to the influence of the infrastructure in attracting personnel, but then do not proceed to answer remaining questions as they are not applicable at this early stage.

There are likely different reasons for underutilization. For example, it is known that lack of funds and technical support for ongoing operations and maintenance (O&M) are important factors in the optimal use of equipment that is state-of-the-art. This is borne out by the progress reports. Of the projects sufficiently advanced to require funds, **in the past year**, approximately:

- 437 (20%) found it difficult to obtain sufficient funds for O&M, whereas,
- 1,768 (80%) found it reasonably easy to obtain such funds.

This need for O&M funding has intensified slightly since 2004, at which time approximately 18% of developed infrastructure projects were hampered by a lack of O&M funding. Closer examination reveals that the NOF and CRCIF awards experienced somewhat less difficulty in obtaining O&M funds – with approximately 14% of these projects experiencing challenges. In contrast, nearly a quarter (24%) of the large IF projects have encountered difficulties in obtaining O&M funding.

The CFI recognized this problem in the past, and with the establishment of the IOF, has contributed to the O&M costs of IF and NOF projects approved after July 2001. A total of 605 projects reported benefiting from IOF support. On the basis of the current data, this represents approximately 25% of projects that are sufficiently developed to require O&M funds.

A related issue is the attraction and retention of technical personnel for (O&M). The general trend is an increasing number of these highly skilled personnel at Canadian institutions, as noted earlier in this paper. However it appears that demand continues to grow and that shortages develop in certain areas. In the **past year**, among developed projects, approximately:

- 400 (18%) of project leaders said that recruitment of skilled personnel, such as technicians, was difficult; while
- 1800 (82%) of projects reported that this type of recruitment was a reasonably easy effort;

In some cases the difficulties in recruitment may relate to a lack of O&M funds, and some of the commentary in progress reports supports this. However in certain fields there is great competition for skilled technicians.

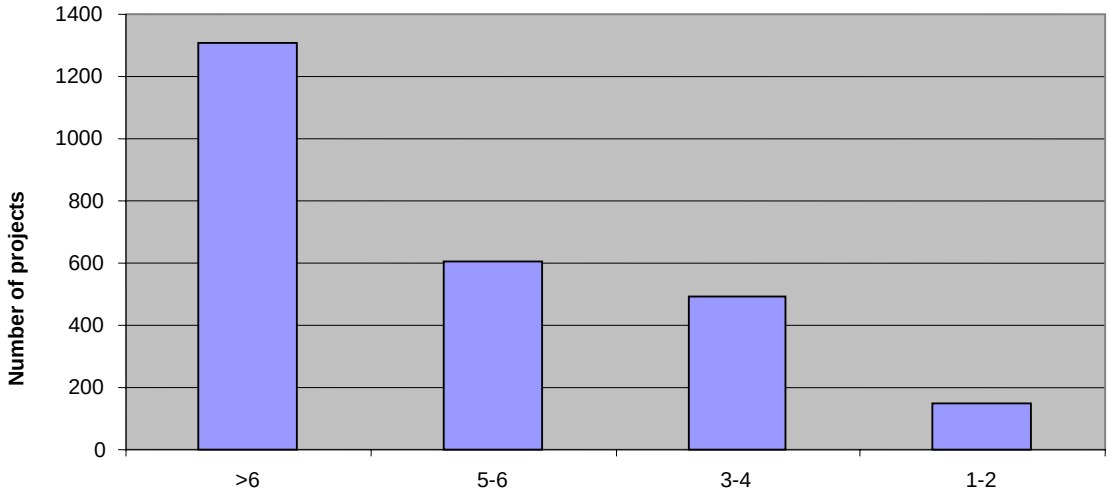
A challenge for Canada is ensuring that research infrastructure at its institutions remains state-of-the-art, especially where research teams with international reputation and profile have been assembled through strategic recruitment and retention. An indicator for this area is the years of useful life remaining on infrastructure projects. As shown in the exhibit below, for projects funded **since 2000**, approximately:

*The project leader of a national project led by **McMaster University** states: "The infrastructure at each institution is comparable or better than that of international centres for humanities computing or lexicographical study. The infrastructure allows the institutions to have a combination of large-scale hardware with XML text technologies. When considered as a whole there is no other single network of humanities computing labs and servers in the world nor is there anything comparable to the TAPoR portal. Specialized systems in the network like the high-performance cluster at New Brunswick are comparable to the best in Canada as is the Usability Lab at Toronto (for its size). Finally, the Université de Montréal LexUM lab is possibly now the most active legal computing facility in the world. In the reporting period the Montréal group succeeded in creating a citator for Canadian Law, has elaborated a new kind of legal portal, and explored automatic abstract preparation."*

- 1900 (75%) of infrastructure projects have more than five years of useful life left;
- 500 (19%) have 3-4 years of useful life left; and
- 150 (6%) have only 1-2 years of useful life remaining.

Exhibit 3.6.3

Years of useful life of infrastructure remaining (2004 - 05)



It is important to note that the 552 infrastructure projects funded and finalized by the CFI in 1998-99 are not included in the sample, for there is no further requirement to submit progress reports with the relevant data. However it is expected that these "older" projects there would be a higher percentage of infrastructure that has fewer years of usefulness remaining. Furthermore, while some of this older infrastructure might be useful, it would likely not be state-of-the-art as new technologies are constantly brought to market. A final point is that the overall assessment of useful life does not capture the differences between disciplines or fields. In some areas, technologies are evolving so rapidly that it becomes more and more difficult to remain competitive. This is the case for High Performance Computing (HPC) infrastructure, among others.

*A project leader at a major **McGill** facility noted: Technologies are evolving rapidly and will not allow us to stay at cutting-edge if there are no major upgrades. Although most of the acquired instruments will be usable for several more years, there are now instruments in genotyping, proteomics, sequencing and informatics on the horizon that will need to be acquired in order for us to stay competitive.*

The topic of sustainability of research infrastructure clearly merits further investigation and analysis. Why are some infrastructure projects underutilized? What is the link between underutilization and O&M funding? Where is O&M funding most scarce and what do researchers recommend? In what specialized, technical areas are shortages of personnel developing? In what fields and disciplines is the research infrastructure depreciating the fastest? These and other topics will be investigated over the coming year.

4. Conclusion

It is evident that investments in research infrastructure by the CFI at Canada's universities, colleges, research hospitals and non-profit research organizations have played a significant role in moving Canada to the forefront of global research frontiers while at one and the same time contributing to domestic social and economic development.

Leading researchers have been attracted to Canadian institutions, and they remain, to undertake sophisticated, globally-networked projects, socially and economically relevant partnerships with other Canadian organizations, and the training of students and sophisticated technical personnel. From their labs highly-qualified graduates are moving to take up employment at other institutions, in business and in government within Canada, everywhere across the country.

Canada is clearly on the path to a knowledge economy, and all the more dependent on the specialized skills of R&D that safeguards the country in areas such as disaster management, combating cancer, advancing communications infrastructure, predicting earthquakes, managing forests and addressing elder and childcare. Likewise, R&D underpins the products and services that we increasingly count on and sometimes take for granted – pharmaceuticals, instant financial services and safer, more durable vehicles, to name a few.

Research infrastructure forms a critical component of the Canadian R&D enterprise, acting as a scaffold to the interconnections that are forming between disciplines and across sectors to address complex R&D issues and problems. But, like all sophisticated machinery, it requires proper operations support and maintenance, and sooner or later it becomes obsolete. These issues need to be addressed.