EVALUATION OF THE INNOVATION FUND, UNIVERSITY RESEARCH DEVELOPMENT FUND, AND COLLEGE RESEARCH DEVELOPMENT FUND:

FINAL REPORT

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Introduction

The Canada Foundation for Innovation (CFI) supports the acquisition of research infrastructure in Canadian universities, colleges, hospitals, and not-for-profit research institutions. The specific objectives of CFI are to: (1) build Canada's capacity for innovation; (2) attract and retain highly skilled research personnel in Canada; (3) strengthen research training[1] of Canadians for the knowledge economy; (4) promote networking, collaboration and multi-disciplinarity among researchers; (5) ensure the optimal use of research infrastructure; and (6) in turn, contribute to economic growth, and improvements in health, environment, society and quality of life. As of 2000/01, CFI had invested $873 million in 1,200 projects distributed among 95 eligible institutions. Virtually every eligible Canadian university and leading research hospital has received some CFI funding. CFI is currently managing a federal contribution of $3.15 billion, and it provided contributions of about $408 million in 2000/01. The anticipated total capital investment by the CFI, the institutions and their partners will be about $9.0 billion by 2010. Only 40% of project support comes from CFI; the remainder is from the institutions and their partners—the provinces, the private sector, and others.

This document reports on an evaluation of three CFI programs: the Innovation Fund (IF), the University Research Development Fund (URDF), and the College Research Development Fund (CRDF).

Methodology

The main methods were: (1) Review of CFI progress reports, documents, and files; (2) Interviews with representatives of the Multidisciplinary Advisory Committees (MACs) and Expert Committees

[1] *The CFI considers "research training" to include training of many types of highly qualified personnel including: technicians; technologists; undergraduate students; graduate students; postdoctoral fellows; and other trainees, etc. That is, it is not just training of future researchers.*

that review applications to CFI; (3) Interviews with representatives of the granting councils, and the provinces; (4) Case studies of specific projects, including interviews with department heads and/or Deans, and with institutional representatives (e.g., V-Ps Research); (5) Benchmarking to other programs worldwide; (6) A scoping study to investigate the feasibility of using "Canada-wide" bibliometrics; and (7) A scoping study to investigate the feasibility of conducting benefit/cost analysis at a later date.

Findings on Program Rationale

The study finds that the rationale for the IF, URDF, and CRDF programs is sound. Many other international programs are similar in intent and structure—CFI was one of the first of such initiatives world-wide, and is regarded very positively by international observers. The ability of CFI applicant institutions to find the necessary 60% matching funds indicates agreement from external partners (especially the provinces) of the importance of these programs, and most of this funding has been incremental. The number of awards have remained relatively constant, and the size of awards in IF and URDF have increased, with no signs of a "plateau" or decline in need within the community. Although this study was not designed to estimate the amount of future funding that is required, figures quoted by individual departments and faculties indicate significant ongoing support will be required. If anything, the need will likely increase as applications from the social sciences and humanities rise.

Findings on Program Impacts

Overall, the programs have had marked positive impacts. There is every indication that these programs are meeting their objectives of building Canada's capacity for innovation, and thus improving Canada's economic and social well-being. The IF, URDF, and CRDF programs have first transformed the quality of infrastructure. Where more than half of the infrastructure in the case studies was poor or fair prior to the awards (and none was world-class), 90% of case study respondents now rate it as excellent or world-class in the disciplines affected by the awards. The projects enabled by the CFI have contributed significantly to the creation of national and (especially) regional "knowledge clusters", and have had an exceptionally strong positive impact on the nature of research that is carried out: more cutting-edge research, conducted faster, with more multidisciplinarity, and with substantially more collaboration (nearly twice as much as before). Smaller institutions in particular reported increased visibility and credibility both nationally and internationally as a result. However, it is too soon to measure impacts on research productivity (e.g., through methods such as bibliometrics.) The institutional strategic research plans required for applications to the CFI have been moderately useful both for host institutions and for the provinces, although some MAC representatives believe that institutions may nevertheless sometimes submit projects that are not central to these plans.

Researchers with access to infrastructure supported by the CFI are able to obtain significantly more research funding, and in the case of private sector and non-Canadian support this represents

incremental funding. The majority of projects enabled by the CFI have also increased the ability to attract researchers, postdoctoral fellows, and students: on average about four faculty members have been attracted per department (including many senior-level scientists), and about 10 students per IF project and 3 per URDF. On average, about 32 students per IF project and 14 per URDF project are being trained on infrastructure supported through CFI.

There is every reason to think the projects, once operational, are being effectively and efficiently used and shared: e.g., almost all available project time is committed, many projects are already oversubscribed, and external (i.e., non-departmental) users take up about one-third of the time available on the projects.

Both implementing the projects and finding financial resources for operations and maintenance has been problematical in many institutions, as has (to a lesser extent) attracting and retaining HQP to operate and maintain the infrastructure. However, this is almost entirely related to the nature of the projects (e.g., their state-of-the-art complexity and sheer size), rather than structural or operational problems with the programs themselves.

There are concerns developing in some provinces in terms of the lack of provincial input to research infrastructure planning and decision-making. However, our interpretation is that these mainly represent problems of success, and that the provinces, together with their research institutions, could usefully take a more active role in strategic S&T planning prior to submitting applications to CFI.

The granting councils have recently experienced increased pressures in many of their programs. However, many of these result from changes to the nature of science (more multi- and cross-disciplinarity, more equipment-intensive, more collaborative, etc.). Although the granting councils have seen increases to the numbers, size, and quality of research grant requests, it proved impossible in this study to say definitively how much—if any—of this was due to CFI.

A number of changes in approach are anticipated by department heads, deans, and V-Ps Research for the next funding rounds. These are primarily a tendency to prepare fewer applications for individual pieces of equipment, instead submitting more expensive, integrated proposals involving larger, more complex, often multidisciplinary projects. Many will involve higher space requirements as well.

Although it is far too early to attempt any meaningful quantitative economic investigation (e.g., benefit/cost analysis) of the social and economic impacts of CFI for Canada , every indication is that these projects will eventually be very significant in these areas. For example, almost two-thirds of the case study projects reported that highly-important impacts were likely to arise from their projects, and the progress reports clearly demonstrate active efforts ongoing or planned for the future by project leaders and institutions to create such impacts.

Companies that have contributed to purchase costs and/or ongoing research costs expected access to intellectual property or expertise to help in product and process development, access to HQP, and

development of more or better relationships with researchers and their institutions. Some of these benefits have already occurred (although most are expected in the mid- to long-term), and to date there have also been indirect impacts such as improved company reputation, improved regulatory climate, training of company staff, and consideration of other collaborative projects with the host institutions.

Overall, in fact, there are many reasons to believe that the community has willingly embraced the "CFI culture", not only (of course) in terms of a focus on research excellence, but also in terms of sharing, collaborating, and using innovation to achieve socio-economic benefits. This is by no means a given in S&T programs, and is a very positive sign for the future.

Findings on Program Design and Delivery

The IF, URDF, and CRDF programs were well-designed and are well-delivered, with very few problems being reported in any area, including relationships with the granting councils. CFI has effectively fixed minor "start-up" problems identified in 1999. The most commonly-reported issue from the Canadian community was that of long-term support for operations and maintenance.

There was insufficient data to say whether the "old" CRDF program was preferable to these awards being rolled into the IF. However, most institutions which had previously received an allocation under the URDF program preferred the older approach.

A review of international programs showed not only that CFI contains all elements considered important in other countries and programs, but also that it is very well-regarded by the international community, and even envied in some quarters. No significant gaps were identified by international sources.

Conclusions

The overall findings on the IF, URDF, and CRDF are extremely positive. These programs have had a major impact on the Canadian research environment at a time when they were sorely-needed, and at a time when international interest in making similar infrastructure investments is exceptionally high. There is every indication that ongoing need for infrastructure investment remains high, and may even increase. CFI is an important factor in helping change Canadian research culture, in that sharing, collaboration, and using innovation to achieve socio-economic benefits are fostered by its programs.

In terms of major strategic considerations, there are three: (1) Maintaining long-term sustainability will require institutions to convince their provincial partners to supply matching funds, and institutions to find O&M support over the long-term. This is the most important long-term strategic issue by far. (2) Additional opportunities for CFI to act as a catalyst for pan-Canadian strategic planning related to research infrastructure should be investigated, possibly including opportunities to

act as "the Canadian voice" in these matters internationally. This needs to be put within the context of the CFI model, however, which has always been to require the applicant institutions and their partners to plan strategically for their infrastructure acquisitions, with a view to generating significant socio-economic returns for Canada. This is in contrast to the various "foresight" exercises and targeted programs adopted by some other countries. (3) CFI and the Social Sciences and Humanities Research Council should continue to investigate ways to encourage involvement in CFI from researchers in the social sciences and humanities.

1 INTRODUCTION

1.1 Purpose of the Study

The Canada Foundation for Innovation (CFI) supports the purchase of research infrastructure in Canadian universities, colleges, hospitals, and not-for-profit research institutions. This document reports on an evaluation carried out in 2002 of three of its programs: the Innovation Fund (IF), the University Research Development Fund (URDF), and College Research Development Fund (CRDF). The study was carried out under contract to CFI by BearingPoint (formerly KPMG Consulting).

The evaluation concentrated on the results of the first two IF competitions, held in 1998/99 and 2000, plus process issues associated with the IF competition in 2002. The URDF review was focused on issues related to the first two years (1998 through 2000)[2] during which these grants were awarded. Similarly the CRDF was reviewed with respect to the first two competitions (decision dates in June, 1999, and July, 2000), again with process issues addressed for the third competition.

[2] *URDF applications were accepted every quarter.*

2 PROFILE OF THE CANADA FOUNDATION FOR INNOVATION

The following is mainly adapted from material available on CFI's website: www.innovation.ca.

2.1 Introduction

The Canada Foundation for Innovation (CFI) was created by the federal government in 1997, with the goal of strengthening the capability of Canadian universities, colleges, research hospitals, and other eligible not-for-profit institutions to carry out world-class research and technology development. It does so by providing grants to purchase and/or build scientific infrastructure. The specific objectives of CFI are to:

1. build Canada's capacity for innovation;
2. attract and retain highly skilled research personnel in Canada;
3. strengthen research training[3] of Canadians for the knowledge economy;
4. promote networking, collaboration and multi-disciplinarity among researchers;
5. ensure the optimal use of research infrastructure; and
6. in turn, contribute to economic growth, and improvements in health, environment, and quality of life.

[3] *The CFI considers "research training" to include training of many types of highly qualified personnel including: technicians; technologists; undergraduate students; graduate students; postdoctoral fellows; and other trainees, etc. That is, it is not just training of future researchers.*

As of 2000/01, CFI had invested $873 million in 1,200 projects distributed among 95 eligible institutions. Virtually every Canadian university and college has received some CFI funding. CFI is currently managing a federal contribution of $3.15 billion, and it provided contributions of about $408 million in 2000/01. The anticipated total capital investment by the CFI and partners will be about $9.0 billion by 2010. (These are very large amounts within the Canadian R&D scene.)

2.2 Overview of CFI Programs

CFI is a cross-cutting organization with a broad mandate—applicants may apply for infrastructure to serve any scientific discipline, and there are no funding "envelopes" for individual disciplines or institutions. Multidisciplinary and multisectoral applications are encouraged. There are several specific programs, briefly described below. (We list all CFI programs in order to provide context for the IF, URDF, and CRDF programs, as well as the strategic issues considered later in this report.)

Programs Being Evaluated:

- The Innovation Fund (IF): This is the major program, providing the bulk of funding, and the principal program being evaluated in this study. More detail is provided below.
- The University Research Development Fund (URDF): Similar to the IF, this was geared towards the needs of small, less research-intensive institutions. These were given allocations, and applications were reviewed four times a year, with funds drawn from an institution's allocation for successful projects. Now rolled into the IF, but with a specially-chosen MAC.
- The College Research Development Fund (CRDF): Like the URDF, but the competitions were for colleges only. Now rolled into the IF, but with a specially-chosen MAC.

Programs Not Being Evaluated:

- The International Funds: There are two separate funds:
  - The International Joint Ventures Fund supports the establishment of a small number of high profile infrastructure projects in Canada, carried out jointly with other countries
  - The International Access Fund provides access for Canadian institutions and researchers to facilities in other countries and major international collaborative programs.
- The New Opportunities Fund: This supplies infrastructure to newly-hired researchers taking up their first full-time Canadian academic position, or to researchers in teaching hospitals and institutes through their associated universities. It can be used to aid in recruitment, since the

proposed individual need not be hired at the time of application. (Of course, final CFI approval depends on the researcher actually being hired.)

- Infrastructure Operating Fund (IOF): Contributes to the incremental operating and maintenance (O&M) costs of infrastructure supported by CFI. It also minimizes the application workload (in their applications, institutions must outline the anticipated O&M costs and sources of funding for the first five years of operation of the infrastructure). Institutions are allocated 30% of the finalized CFI contribution for projects approved between July 2001 and December 2005 for either the Innovation Fund or the New Opportunities Fund.

- Canada Research Chairs (CRC) Infrastructure Fund: The CRC is a separate federal program, with about $900 million to support the establishment of 2,000 Canada Research Chairs in universities across the country by 2005. CRC offers research and salary support, while CFI offers a complementary infrastructure award.

Eligible Infrastructure

A wide range of infrastructure is eligible, including: equipment, specimens, scientific collections, computer software, information databases, communication linkages, etc., so long as they are to be used (or used primarily) for carrying on research. This includes buildings and installations essential for the use and servicing of the infrastructure.

Eligible Costs

Eligible costs include all goods and services required to bring the new infrastructure into service, including warranties included in the purchase price. Leasing is also possible if it is as cost-effective as purchasing. The IF will not provide any part of the ongoing costs of operating a facility; these are provided by CFI through the IOF described above. Some examples of eligible costs include those to:

- acquire, build, modernize, or lease research infrastructure (excluding general libraries).

- ship or transport the infrastructure;

- retain expert personnel to design, manufacture, install, and build the project;

- travel to manufacturers etc. to select the infrastructure;

- purchase an extended warranty or service contract for up to three years;

- modernize or construct space to house and use the infrastructure (excluding costs of real estate);

- build office space that is essential to the use of the infrastructure;
- provide initial training for the institution's staff in operating the infrastructure.

Matching Funding

All grants must be matched by external contributions, with CFI providing on average 40% of total costs. The remaining support comes from other federal departments and agencies (but excluding the federal granting councils), provincial agencies[4], the private sector,[5] the grant recipients themselves (i.e., the successful institutions), etc.

Institutional Research Plans

Applications are made by the institutions—not the individual researchers—and awards made by CFI are similarly provided to the institutions, not individual researchers. (Most other Canadian R&D infrastructure support is applied for by the researchers.)

Because many CFI awards are for projects that will be used collaboratively by a number of institutions, or will be used by many investigators within that institution or in partner organizations, CFI encourages development of national or regional consortia to facilitate this process. To aid in this, and prior to making any applications to CFI, each institution must provide CFI with a strategic institutional research plan that describes priority investment areas. These are used by CFI during the review process to help assess how the requested infrastructure will support institutional strategies. (This is the first time that institutions have been required to submits such plans as part of applications for research infrastructure from any Canadian program).

Selection Criteria

The criteria used to review all applications to the CFI are:

- Quality of proposed research and researchers, and need for the infrastructure;
- Contribution to strengthening the capacity for innovation, including research training and attraction/retention of highly-qualified personnel;
- Potential for social and economic benefits of the research to Canada.

[4] *Many provinces have set up new funding programs to match the CFI funds awarded to their province's institutions.*

[5] *These contributions have usually been in the form of deep discounts on purchase prices.*

There is some flexibility in interpretation of these criteria depending on the size and nature of the infrastructure project.

2.3 Other Major Canadian Research Infrastructure Programs

Understanding how CFI fits into the "big picture" of research infrastructure within Canada is important for the context of the international benchmarking and discussion of strategic issues found later in this report. Briefly, CFI is an important component of this infrastructure system, but there are other funding sources. Discipline-specific programs are available through Canada's three university granting councils: the Natural Sciences and Engineering Research Council (NSERC), the Canadian Institutes for Health Research (CIHR; previously called the Medical Research Council), and the Social Sciences and Humanities Research Council (SSHRC). Differences from CFI include: these programs have much lower total funding available, they are usually used to purchase smaller items (although they supported some Big Science projects in the past), individual researchers or groups of researchers are the applicants, and no matching funding is required. Canadian provinces also provide some research infrastructure funding[6], although in the past this was on a case-by-case basis for major installations only—prior to CFI, there were no provincial programs dedicated to research infrastructure.

2.4 The Innovation Fund (IF)

2.4.1 Overview

This is CFI's major funding instrument, and one of the three funds evaluated in this report. In 2000/01, the IF supported 190 projects at 41 Canadian institutions, with awards of $353 million. Cumulatively as of 2000/01, CFI had supported 377 IF projects with CFI funding of $720 million. The cost of individual projects varies widely, from a minimum of $100,000, to a maximum to date of $140 million. Twenty-one awards of $10 million or more have been made. Only projects with total project costs of $100,000 or more are eligible (i.e., a CFI contribution of $40,000 or more).

2.4.2 Application Review Process

Prior to committee review, CFI obtains expert assessments as warranted by the scope and complexity of the projects. These expert reviews consist of written comments by individual external reviewers or reports from expert committees convened to consider groups of related proposals, in some cases involving a face-to-face meeting with the applicants. The applications and expert assessments are

[6] *Virtually always for projects within their provinces.*

then reviewed by one of CFI's Multidisciplinary Advisory Committees (MACs[7]), which consist of members with broad expertise in research, research management and the use of research results, drawn from academia, the private sector, government and other research organizations, from Canada and abroad. Committee members and external experts use a decision-assist tool (ProGrid™)to assist in rating proposals against detailed criteria. In the most recent competition there were nine MACs, including two with members who were chosen for their understanding of the research environment in less research-intensive universities and colleges. MAC recommendations on project approval and funding are presented by CFI staff to CFI's Board of Directors, who make the final decisions.

2.5 The URDF and CRDF

Until 2001, there were separate funds dedicated to assisting smaller universities and colleges to obtain infrastructure: the University Research Development Fund (URDF) and the College Research Development Fund (CRDF), respectively. Although similar in intent to the IF, there were differences in operation, especially:

- The URDF was a fund designed for eligible universities that received, during the 1994-96 period, less than 1 percent of the total sponsored research funding in Canadian universities. An allocation of approximately $40 million was set aside for these eligible institutions, and there were allocations set aside for individual institutions. Ten competitions were held under this fund every quarter between 1998 and 2000. The review process was expert review where needed (e.g., larger, more complex projects) followed by review by a MAC, with the MAC's recommendation followed by Board decision. The MAC was a Standing Committee, with members participating in meetings from time to time, as needed. The eleventh and last round of competition had a deadline date of March 12, 2001. As of 2001, eligible institutions now submit proposals directly to the Innovation Fund. (Note that under the IF, there is no longer an allocation per institution, or for these universities overall.)

- The CRDF was designed to help Canadian colleges, institutes, and their affiliated research centres develop and strengthen their research infrastructure in areas identified in their institutional research plans. Colleges were permitted to submit proposals for projects totalling up to $2 million in eligible costs with a maximum contribution of $800,000 from the CFI. Two competitions were held for this fund (1999 and 2000), with proposals reviewed by a MAC convened for each competition, followed by a Board decision. As of 2001, eligible institutions now submit proposals to the Innovation Fund. (Note that under the IF, there is no longer a cap to the amount requested by colleges.)

[7] *These are not Standing Committees, but struck for each competition. There were 4 MACs in the first IF competition, 7 in the second, and 9 in the third, most recent, competition.*

Although these two funds were rolled into the IF starting in 2001, the CFI continues to convene MACs with members who are chosen for their understanding of the research environment in less research-intensive universities and colleges, to review proposals from these organizations.

3 STUDY METHODOLOGY

3.1 Overview

Overall, an attempt was made to identify issues and sub-questions that were not fully addressed in the progress reports provided to CFI by Project Leaders and institutions. For example, while the progress reports contain a wealth of useful and interesting data (both qualitative and quantitative), from an evaluative perspective, they also have some gaps. These in particular are related to lack of information on incrementality (what would have happened without CFI, more easily addressed here in terms of contrasting the pre-CFI situation to that post-CFI) and attribution (what proportion of any changes are due to CFI versus other factors). There are also some minor double-counting problems in the progress reports, and there is no data from important partners such as provinces and contributors to individual projects. After a detailed analysis of what was, and was not, available in the progress reports, this evaluation's interview guides were developed to fill gaps and add additional information. Together these two sources of information provide a very complete picture of CFI's accomplishments to date in the IF, URDF, and CRDF, and this integrated evaluation report contains data from both of these sources.

Further, an attempt was made in the evaluation to contact a different set of individuals from those responsible for preparing progress reports, both to avoid undue burden on respondents and to obtain a somewhat different perspective. (This was not entirely successful, for reasons noted below.)

3.2 Evaluation Issues

An *Evaluation Framework*[8] was prepared early in 2002 to identify possible issues to address in the evaluation. That study referred to the evaluation process for CFI as a whole, and was refined in this study. The major issues are shown in Exhibit 3.1

[8] *Hickling, Arthurs, Low,* Evaluation Framework for the Canada Foundation for Innovation, *January 15, 2002.*

Exhibit 3.1—Major Evaluation Issues

Program Rationale Issues

1. How much continuing CFI investment is needed for Canadian research to perform at world class level?
2. What CFI investments have been made in infrastructure?

Impacts and Effects Issues

3. Has CFI-funded infrastructure led to improvements in Canadian innovation capacity?
4. The extent to which world-class, and potentially world-class researchers are being attracted and retained
5. How much additional, high-quality training has been made possible by having new infrastructure?
6. Has CFI promoted research collaboration (e.g., among Canadian institutions, with government or industry sectors in Canada)?
7. Have institutions managed the facilities, and sharing of the facilities regionally and nationally, in an optimal manner?
8. What are the implications of ongoing operating & maintenance costs on the capability of institutions to manage the infrastructure?
9. What is the range and magnitude of socio-economic impacts that have occurred as a result of the infrastructure?
10. Are there other impacts at host institutions?
11. Are there impacts at other funding organizations (e.g., federal granting councils, federal and provincial research funding agencies)?

Program Design, Management and Delivery Issues

11. Is the program well-designed?
12. Is the program well-delivered?

3.3 Detailed Study Methodologies

3.3.1 Review of CFI Progress Reports

There are three kinds of progress report: project, institutional, and financial. Overall, these are a very useful source of information, with some minor shortcomings:

- Two issues not addressed are incrementality (addressing what might have happened if CFI did not exist) and attribution (what portion of impacts arose because of the Innovation Fund *versus* the effect of other programs, agencies, etc).
- In a related matter, there are no data on "pre/post", or "with/without CFI-funded infrastructure" to help gauge progress;

- Some data may be double-counted (e.g., one project leader reporting on impacts from two projects, but it's the same impact recorded twice).

3.3.2 Document & File Review

General Review. This was mainly to document various "tombstone" data that provide basic descriptive information, such as numbers of infrastructure projects supported by CFI, dollar values contributed by CFI and by providers of matching funds, etc. These data are available either from the CFI Annual Reports, its on-line reports, or through its database.

Other Reports. CFI has conducted surveys of institutions, project leaders, and MAC members regarding process issues.

3.3.3 Survey of Representatives of MACs and Expert Committees

We selected 20 representatives from the MACs used in the past two IF competitions, consulting with CFI to identify appropriate, knowledgeable individuals (e.g., those who were Chairs in one competition, and on the committee in another, and including individuals representing the URDF Standing Committee and CRDF issues), as well as those representing all sectors (i.e., university, government, private sector, other user organizations.) Additional data was collected from members of Expert Committees to help identify issues that will benefit from an "outside perspective". A total of 15 completed surveys were obtained from respondents, for a response rate of 75%.

3.3.4 Interviews with Officials of Other Funding Agencies

Interviews were conducted in-person with four representatives of the university granting councils.

3.3.5 Benchmarking

Benchmarking to somewhat similar programs in other countries was done to focus on strategic issues—i.e., how other countries have responded to similar pressures, the nature of their infrastructure program(s), etc. A general review of program information available on agency websites was first conducted. Next, individuals knowledgeable about infrastructure programs in their country/agency were interviewed by telephone[9]. (They were first sent a short description of CFI—similar to that in section 2—plus a list of interview topics.) Programs and systems in the US, Australia, and the UK were reviewed (with brief information collection on EU Framework programs), and ten individuals were contacted.

[9] *Several of these individuals were also reasonably familiar with CFI.*

Note that, because other countries do not have programs exactly like the IF, URDF, and CRDF, we reviewed a sample of programs that have broadly similar intent. This also allowed consideration of program features in other countries that might illuminate gaps and opportunities that CFI might address.

3.3.6 Case Studies

Overall. The major data collection method for the recipients of IF awards was case studies organized around either individual projects, or groups of related projects within individual departments, where such existed. This method was chosen to ensure a high response rate, ensure that there was no response bias, and obtain data of as high a quality as possible. As noted in section 3.1, individual questions addressed were chosen to complement those found in the CFI progress reports.

The CFI awards database was reviewed to select projects that were representative of awards in each program with respect to research discipline, type of institution (i.e., university, hospital, not-for-profit), individual institution (i.e., no more than two cases per institution), and province. Only awards within the study's time scope were selected, although occasionally there were more recent CFI awards clearly related to those selected for investigation. We deliberately tried to avoid contacting individuals (e.g., CFI Project Leaders) who had already provided CFI with data in the progress reports, although sometimes this was unavoidable.

Interviews at Institutions. Interviews conducted at the department and/or faculty level focused mainly on the impacts of these individual projects. (This was done in the hopes of making the interview guide simpler, and dealing with some double-counting issues with the CFI progress reports.) However, some data on CFI's impacts in general were also obtained. Interviews conducted with senior institution officials focused on impacts of CFI overall, rather than the individual projects selected. Our approach was to interview the best person at the department/faculty level— in most cases, we started by contacting the Dean. However, in a number of cases the Dean was either not available or referred us to the Head of Department as the most capable interviewee. Conducting an interview with both the Dean and the department head was often deemed redundant as respondents noted there was a good level of communication and cooperation between the two offices. At several institutions, these individuals explicitly collaborated on their responses. Similarly, in a number of cases, joint responses from the V-P Research and/or Dean of Research and their subordinates (including in some cases the CFI liaison) were provided, giving a comprehensive view from the institutional level. Depending on the individual situation, different individuals were contacted:

- IF—For the larger institutions, the Department Heads were usually selected as well as the VP/Dean/Director of Research for the university. For the smaller institutions, the Faculty Deans and VP/Dean/Director of Research for the organization were generally selected.

- URDF—For the larger Institutions, the Department Heads were usually selected as well as the VP/Dean/Director of Research for the university. For the smaller universities, the Faculty Deans and VP/Dean/Director of Research for the university were generally selected.

- CRDF—The majority of Colleges do not have VP/Dean/Director of Research position. As a result, the President/Dean/Rector of the institution were contacted. In addition department or institution heads/Directors were contacted.

A total of 44 institutions were contacted regarding infrastructure supported by CFI:

- 24 IF projects

- 12 URDF projects

- 8 CRDF project

We obtained data from one or more individuals at 32 institutions, for a case study response rate of 73%. Data from at least 86 individuals were obtained[10]. These institutions are shown in Exhibit 3.2. The percentage of total CFI awards (from the three programs in question) obtained by the case study institutions are also shown[11].

Interviews with Provincial Representatives. The respondents were representatives of provincial programs that have provided matching funds for CFI awards. These interviews focused on impacts of CFI as a whole, rather than tying these interviews to specific case studies. All provinces were contacted, and ten respondents from seven provinces were interviewed.

3.3.7 "Canada-Wide" Bibliometrics Scoping Study

The first IF awards were made in 1998 (about 80 awards from October through December, 1998), with roughly another 100 awards made in 1999). Other major changes to the Canadian research environment include the reorganization of the Medical Research Council into CIHR in 2000, and the introduction of the Canada Research Chairs program in 2001. Thus it is just barely feasible that some general trend in the quality of Canadian research pre-1998 through roughly 2000/01 might be reasonably attributed to CFI. For example, it may be possible to see trends in citation rates, multi-authorship, or multidisciplinarity in Canadian journal publications. During the early stages of the evaluation we checked with the Observatoire des sciences et des technologies (OST) at the Institut

[10] In some cases we know that respondents consulted with other individuals within the institution, but do not know exactly how many. This figure is therefore a minimum.

[11] Of course, the awards for the individual case study projects studied in this evaluation are much smaller. These percentages are shown to demonstrate that institutions representing significant CFI partners were contacted.

national de la recherche scientifique (INRS) to determine if some Canada-wide bibliometric approach was feasible. It was determined that this might be feasible once there is sufficient time for a significant number of research results from use of CFI-funded infrastructure to be published in journal literature, but that sufficient time had not yet elapsed for this to be the case. Thus it was decided to defer this activity for a few years.

Exhibit 3.2—Case Study Institutions

IF Program

University of Alberta	McGill University
University of British Columbia	McMaster University
Concordia University	Université du Québec à Rimouski
Dalhousie University	Université de Sherbrooke
Firestone Institute of Respiratory Health (McMaster University & St. Joseph's Hospital)	Simon Fraser University
University of Guelph	St. Joseph Healthcare London
The Hospital for Sick Children	University of Victoria
Loeb Research Institute (Ottawa Hospital)	University of Western Ontario
University of Manitoba	York University

IF Case Study institutions have 56% of total IF awards in this time period

URDF Program

Brock University	Université de Moncton
École de technologie supérieure	University of New Brunswick
Laurentian University	Université du Québec à Chicoutimi
Nova Scotia Agricultural College	Ryerson University

URDF Case Study institutions have 39% of total URDF awards in this time period

CRDF Program

CEGEP de Lévis – Lauzon	Sault College
CEGEP de Saint-Hyacinthe	Seneca College of Applied Arts and Technology
Olds College	Sheridan College

CRDF case study institutions have 38% of total CRDF awards in this time period

3.3.8 Benefit/Cost Scoping Study

A benefit/cost scoping study was conducted to review whether a formal and detailed benefit/cost methodology could be applied to IF projects[12]. Most information was obtained from existing data collection activities (e.g., from the Deans), plus a review of CFI progress reports. The data from a selected sample of interviews with industry representatives suggested by case study respondents also fed into this analysis.

3.3.9 Industry Interviews

It proved difficult to obtain data from the industry representatives suggested by case study respondents. Thus an additional activity was carried out, in which CFI project leaders and CFI Liaisons at institutions were contacted:

- Project leaders who, in their progress reports, said that infrastructure supported by CFI had had a "considerable" influence on their ability to attract funding from industry; and
- CFI Liaisons from a selection of projects for which institutions had successfully attracted a significant amount of industry matching funding.

A total of 45 project leaders and 16 CFI Liaisons were asked to provide contact information for representatives of firms which had contributed significantly to the infrastructure. In turn, 38 industry representatives were contacted to see if they could provide more information on their reasons for participating (either in helping purchase and implement the infrastructure, or in subsequent research activities). A total of 10 individuals responded by the time this report was written.

[12] *Other data related to the IF's social and economic impacts were obtained through other evaluation activities, such as review of progress reports. The scoping exercise was related to the applicability of a much more detailed "number crunching" methodology.*

4 FINDINGS ON PROGRAM RATIONALE

4.1 Reporting Format

Throughout the next sections, we include representative quotes from respondents[13]. In most cases we refer simply to "CFI-funded infrastructure", although it should be noted that this applies only to infrastructure funded through IF, URDF, and CRDF. Where percentages of case study respondents are discussed, unless noted otherwise these were weighted by the number of respondents in a given interview in cases where two or more individuals collaborated in a joint response. The data refer to all three programs unless there were substantial differences among them; any such differences are noted.

4.2 Summary of Findings

The study finds that rationale for the IF, URDF, and CRDF programs is sound. These programs are consistent in nature with similar major initiatives being taken in many other countries; e.g., OECD nations have recently invested significant amounts in research infrastructure programs and projects. These international investments are all considered to be ongoing ones, rather than one-time "shots in the arm". Canada's efforts in this area through CFI are regarded very positively by international observers. Applicants have been successful in finding the necessary 60% matching funds, indicating agreement from external partners (especially the provinces) of the importance of these programs, and most of this funding has been incremental.

The number of awards have remained relatively constant, and the size of awards in IF and URDF have increased, with no signs of a "plateau" or decline in need within the community. Although this study was not designed to estimate the amount of continuing funding that is required, figures quoted by individual departments and faculties indicate significant ongoing funding is required. This again is consistent with findings in other countries, particularly since research infrastructure over time becomes increasingly sophisticated and key components (e.g., computing) rapidly evolve.

[13] *Where necessary we have edited these slightly for clarity or brevity, but the meanings are identical.*

From the granting council perspective, although some highly-pressing early needs have perhaps now been addressed, they see an evolution of needs in terms of larger and more integrated (and sometimes more multidisciplinary) projects. In particular, SSHRC researchers are still in the early stages of understanding the power of research infrastructure (and are no longer discouraged from applying to CFI); as a result, applications in these fields will likely increase dramatically in future.

4.3 Evolution in Size of Projects

The trend in number and size of awards is seen in Exhibit 4.1[14]. The number of awards have remained relatively constant, and the size of awards in IF and URDF have increased, with no signs of a "plateau" or decline in need within the community.

4.4 Program Rationale Data from the Case Studies

All case study respondents indicated that continued funding was required to bring their institutions up to world-class standards. For individual departments, the minimum amounts required were low, about $100k at smaller institutions, but the maximum amounts were high, up to $42 million, with an average of roughly $8 million[15]. For individual institutions, the range was from $75,000 to $100 million, with a (very) rough average of $27 million.

> *We have or will have several world-class facilities thanks to CFI . . . but more is needed to maintain and upgrade as well as to cover the rising costs of facility operation. On-going CFI funding is required if we are to continue moving towards world-class standards in other areas [V-P Research, large institution]*

> *The life span of infrastructure is seven to eight years. We need on-going infrastructure contributions. [Manager Research, small university]*

Some respondents commented on the issue of sustainability, especially the uncertainty following the termination of CFI's mandate:

> *It is clear that through the IF competitions, CFI has significantly improved the infrastructure for research that is available in Canada…it is more difficult to assess the business of "keeping it there" because once researchers are equipped they get to*

[14] *As noted in section 2, the different programs had different methods and timing for the competitions, thus there are not completely comparable time periods over which to display these data by program.*

[15] *Some respondents could not estimate this amount, others answered in annual increments; therefore this average figure is very approximate.*

work and do research…major upgrades occur as necessary reflecting important advances in technology and the availability of partner funds to go with the CFI money. [MAC representative]

Canada's challenge is sustaining the position beyond the 10 year term of the IF program. [V-P Research, large institution]

Exhibit 4.1—Trend in Award Numbers and Size

	1998-99 First competition	2000-01 Second competition	1998-01 Ongoing competitions	2001-02 Third competition
IF:				
No. of awards	187	190		169
Total amount	$365.1M	$354.3M		$542.8M
Average award	$1.95M	$1.87M		$3.21M
URDF:				
No. of awards			117	24
Total amount			$34.5M	$39.5M
Average award			$0.30M	$1.65M
CRDF:				
No. of awards	19	21		15
Total amount	$7.3M	$8.5M		$7.1M
Average award	$0.39M	$0.41M		$0.47M

4.5 Perspectives in the Granting Councils

Respondents in the granting councils had varying perspective on the evolving nature of infrastructure needs, although certainly infrastructure is regarded as enormously important to modern research, and in the social sciences in particular is likely to increase rapidly in importance.

At NSERC, it was believed that researchers were "thinking bigger", with more reliance on equipment and computing power, especially that supporting large-scale, multidisciplinary research projects. As a result, need for the IF was increasing. At CIHR, it was thought that the need, while still large, might have plateaued somewhat in terms of addressing the most pressing early needs. Earlier applications had perhaps focused on replacing individual pieces of obsolete equipment, but now CIHR sees a shift toward integrated applications from multi-disciplinary research teams (matching the broader trend in research funding), with some emphasis in the fields of imaging, genetics, genomics, biomedical engineering, and proteomics. At SSHRC, it was believed that social sciences and humanities (SSH) researchers were likely to dramatically increase their demands on IF in the future. To date, take-up has been low: only about 3% of funds in the last two CFI competitions went to SSHRC faculty members. This was due to several factors, including:

- Many SSH researchers are just becoming aware of the great potential of infrastructure in their fields[16], and many institutions have not yet developed strong applications in these disciplines.
- Prior to CFI's launch, the program objectives presented to the community by Industry Canada was ambiguous at best about the inclusion of the SSH fields, and CFI program language in the first two competitions did not explicitly encourage SSH projects.
- Other than in Québec, provincial funds do not explicitly encourage submission of SSH-based applications.
- Many SSH researchers are not aware of their eligibility, or of opportunities in their fields, or changes that have been made in CFI program terms to explicitly encourage SSH applications.

It was noted that the changing role of infrastructure in the SSH fields is also being seen in other countries[17].

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[16] *For example, in using common research tools (e.g., TAPoR, Broadband Multi-media Server for the Humanities), common research facilities (e.g., data centres, theE-Communication Research Centre at the University of Alberta, the Human-Computer Technology Lab at Waterloo, the High Performance Computing Facility at Queen's), access to specialized databases such as the recent joint initiative with Statistics Canada, or special lab facilities such as UBC's Museum of Anthropology.*

[17] *For example, see* Arts and Humanities Research Infrastructure, Report to the HEFCE by JM Consulting, *Higher Education Funding Council for England. June 2002.*

4.6 Comparisons to Other Countries

That ongoing infrastructure investment is required and important is consistent with the emphasis being placed on similar programs in other countries. For example, in the US there are literally dozens of programs that supply infrastructure to university and college researchers; the largest routinely support projects worth tens or hundreds of millions of dollars. A recent major US study concluded: "There can be no doubt that a modern and effective research infrastructure is critical to maintaining U.S. leadership in S&E" [18]. This study recommended increased investment in research infrastructure to meet increasing demands and needs.

> *The infrastructure—big, new, exciting—is what keeps people coming back to the US. [US infrastructure program respondent]*

Australia currently has a great interest in infrastructure needs and support mechanisms, much of it driven by national strategic considerations. For example, the Australian Academy of Science is currently conducting a review of all infrastructure programs, plus benchmarking to other countries, while their Department of Education, Science and Technology is working towards a national strategy for communications bandwidth availability across the entire higher education sector, and towards interoperability of on-line education linked to the US IMS Global Consortium. A recent Australian study identified Critical Research Facilities around the world that Australia must have access to, with these related to previously-identified National Research Priorities. Australia is explicitly interested in leveraging their global investment in a non-protectionist and collaborative manner, including negotiations using access to Australian facilities as *quid pro quo* to access others world-wide.

In the United Kingdom, overall there has been a series of recent injections of infrastructure funding. The most recent is the £1 billion Science Research Investment Fund (SRIF) provided in partnership with the Wellcome Trust (a medical charity), to renew the UK's science infrastructure, announced in the Spending Review 2000. This builds on two earlier investments: £750 million in the Joint Infrastructure Fund (JIF) from the 1998 Spending Review, and the Joint Research Equipment Initiative (JREI) launched in 1996. It has recently been strongly implied by the UK government that these incremental funding amounts will be more or less permanent for the foreseeable future. A recent review by the UK Office of Science and Technology recommended that long-term annual investments of roughly 4% of asset value (net of inflation) was required for renewal and replacement

[18] Science and Engineering Infrastructure For the 21st Century: The Role of theNational Science Foundation. *National Science Board. Draft December 4, 2002. (Note that this study did not review infrastructure needs or impacts for other US agencies such as the National Institutes of Health or various federal departments.)*

of buildings and equipment, with a total budget of about £3 billion for remedial action, and £1 billion for "forward investment", including advanced facilities[19].

The EU's Sixth Framework Programme has a large initiative, the Support for Research Infrastructures programmes, specifically aimed at construction and upgrading of research facilities, with a total budget of €665 million (including support for two e-science grid initiatives[20]).

4.7 Leveraging of Infrastructure Funding

4.7.1 Overview

Overall, the ability of institutions to obtain incremental matching funding (especially from the provinces) is a good sign that CFI investments are important to external partners. The fact that 60% of total infrastructure funding has been committed by other sources is a strong measure of the need for this program. CFI records show that, of the 60% matching funding, roughly two-thirds is from the provinces, 15% from industry (often in the form of deep discounts provided by equipment vendors), and 15% from the institutions[21].

Progress report data show that many respondents believe CFI had "considerable influence" on obtaining funding from a variety of other sources. See Exhibit 4.2.

[19] Study of Science Research Infrastructure, Executive Summary and Recommendations. *JM Consulting Ltd for the Office of Science and Technology (UK):* http://www.ost.gov.uk/research/funding/underinvest/sosri/summary.pdf.

[20] *"Grid" computing links dozens or hundreds of computers in many locations together through high bandwidth communications infrastructure, forming virtual supercomputers. E-science builds on this by additionally linking together databases (e.g., through the Internet), and providing consistent applications and methodologies for analysis of the data from remote locations.*

[21] *Of course, some of the institutional support comes indirectly from federal and provincial government sources.*

Exhibit 4.2—Influence on Leveraging of Funding—% of Projects

	Innovation Fund	URDF
The host institution	33	26
Federal granting agencies	61	57
Other federal sources	39	31
Provincial governments	50	38
Canadian industry	34	28
International sources	27	22

Source: CFI progress reports

4.7.2 Infrastructure Funding from Industry Partners

CFI records show that of the about 500 projects in IF, URDF, and CRDF which had finalized their budgets at the time of this study, over 140 (28%) had attracted cash funding from industry (e.g. utilities, telecom organizations, pharmaceutical companies). About 50 such partners provided contributions of over $100,000, and 20 of these provided $500,000 or more. In all, there were over 600 industry cash or in-kind contributions to over 320 (64%) of these projects.

In the small survey of industry partners, five out of ten had contributed cash towards installation of the infrastructure, and one additional firm contributed equipment. Those that did not provide cash funding noted that they were small companies that could not afford to, and/or that they provided in-kind services; one firm noted that it preferred to contribute to operating costs unless it expected to actually use the infrastructure (in which case it might provide a capital contribution). The reasons for participating at all in these projects additionally revealed that most benefits were expected to be long-term ones (see section 5.13.2).

4.7.3 Leveraging of Provincial Funding

Canadian provinces have contributed substantially to infrastructure supported by CFI, and this study found that most of this funding is incremental. It is striking that several provinces (Alberta, BC,

Saskatchewan, Manitoba, Ontario, and Québec) created infrastructure funds specifically to match CFI investments. None of these provinces had funds dedicated to research infrastructure prior to CFI, instead providing infrastructure support through general R&D programs, or on a case-by-case basis through a variety of *ad hoc* measures tied to specific initiatives, or through small mission-driven provincial ministry/agency programs. In response to CFI these provinces either set up new programs or rolled existing programs together, with additional funding in both cases. This funding was to a considerable degree incremental. It is impossible to say by exactly how much, but Alberta, Saskatchewan, Manitoba, and Ontario together have committed incremental funds of roughly $78 million annually (i.e., this amount is additional to what would normally have been spent on infrastructure)[22].

In Atlantic Canada, the Atlantic Canada Opportunities Agency (ACOA) has provided the matching funds through its Atlantic Innovation Fund (which was created after CFI but is not infrastructure-specific), but there is no incremental provincial funding—not from lack of interest, but from lack of ability to free up monies from other sources. Very recently, Nova Scotia, New Brunswick, and Newfoundland have also set up matching fund programs.

4.7.4 Leveraging of Infrastructure Funds within Host Institutions

About 85% of institutional respondents in the case studies noted that CFI has levered a general increase in the annual funding for research infrastructure provided by their organizations. The minimum additional yearly amount was about $100k, and the maximum was $4 million. There were too few data points to estimate a reliable average; several respondents noted that these data were not easily available.

[22] *BC could not provide a specific figure, but a substantial portion of the BC Knowledge Development Fund contribution is also incremental.*

5 FINDINGS ON IMPACTS ON CANADIAN INNOVATION CAPACITY

5.1 Summary of Findings

Overall, the programs have had marked positive impacts. There is every indication that these programs are meeting their objectives of building Canada's capacity for innovation, and thus improving Canada's economic and social well-being. Where more than half of the infrastructure in the case studies was poor or fair prior to the awards (and none was world-class), 90% of case study respondents now rate it as excellent or world-class. Although major universities continue to have the highest-quality infrastructure, smaller universities and colleges now have high-quality infrastructure in the affected disciplines, whereas they had virtually none before. The awards have contributed significantly to the creation of national and (especially) regional "knowledge clusters", although national-level impacts not surprisingly continue to be highest for awards made at larger institutions. Further, the awards have had an exceptionally strong positive impact on the nature of research that is carried out: more cutting-edge research, conducted faster, with more multidisciplinarity and (to a somewhat lesser extent) more cross-disciplinarity, and with substantially more collaboration (nearly twice as much as before).

Researchers with access to CFI-funded infrastructure report that they are able to obtain significantly more research funding. In the case of private sector and non-Canadian support, this represents incremental funding. However, the available evidence is insufficient to determine whether research funding from government and granting councils to investigators using infrastructure supported by CFI is incremental. The majority of projects have also led to increased ability to attract researchers, postdoctoral fellows, and students: on average about four faculty members attracted per department (including many senior-level scientists), and about 10 students per IF project and 3 per URDF. On average, about 32 students per IF project and 14 per URDF are being trained on CFI-funded infrastructure.

There is every reason to think the projects, once operational, are being effectively and efficiently used and shared: most available time is committed, many projects are already oversubscribed, and external (i.e., non-departmental) users take up about one-third of the available time. Overall, CFI is an important factor in helping foster sharing, collaboration, and using innovation to achieve socio-economic benefits.

Both implementing the projects and finding financial resources for operations and maintenance has been problematical in many institutions, as has (to a lesser extent) attracting and retaining HQP to operate and maintain the infrastructure. This is almost entirely related to the nature of the projects (e.g., their state-of-the-art complexity and sheer size), rather than structural or operational problems with the programs themselves.

The institutional research plans have been useful within the host institutions for meeting individual departmental goals, co-ordinating the needs of multiple departments, and co-ordinating with users (although larger universities often noted they simply modified plans already in existence). The plans have also helped define broad provincial S&T strategies. As had been hoped, the presence of infrastructure supported by CFI, coupled to these plans, have often led to synergistic impacts in host institutions in terms of achieving their strategic goals, attracting research partners and contracts, creating more linkages to other institutions, and providing more focus on creating socio-economic impacts. Smaller institutions in particular reported increased visibility and credibility both nationally and internationally.

The provinces reported increased collaboration among their institutions and between the higher education and government sectors. However, all provinces noted that it was difficult to find the resources to provide these contributions, and the situation was by far the worst in the Atlantic provinces. The long-term sustainability of CFI is in jeopardy because the willingness of provinces to continue to implement and support these projects is far from certain. There are some concerns in a few provinces in terms of the lack of provincial input to CFI planning and decision-making. However, our interpretation is that these mainly represent problems of success, and that the provinces, together with their research institutions, could usefully take a more active role in strategic S&T planning prior to submitting applications to CFI.

The granting councils have recently experienced increased pressures in many of their programs. However, many of these result from changes to the nature of science (more multi- and cross-disciplinarity, more equipment-intensive, more collaborative, etc.). CFI is an example of a response to these changes, but in this study we were not able to determine whether CFI itself has created additional pressure in terms of grant requests to the councils.

Finally, although it is far too early to attempt any meaningful quantitative economic investigation (e.g., benefit/cost analysis) of the social and economic impacts of CFI for Canada (it is even too early to attempt bibliometric analysis of the impact on research productivity), every indication is that these projects will eventually be very significant in these areas. For example, almost two-thirds of the case study projects reported that highly-important impacts were likely to arise from their projects, and the progress reports clearly demonstrate active efforts ongoing or planned by project leaders and institutions to create such impacts.

5.2 Changes to the Quality of Infrastructure

The CFI awards have transformed the quality of research infrastructure in the disciplines affected by the grants. First, data from CFI progress reports show that project leaders believe the CFI-funded infrastructure is of very high quality (although these data do not show the change from the situation prior to receiving the CFI award), as shown in Exhibit 5.1.

Exhibit 5.1—Quality of CFI-funded Infrastructure Compared to Other Labs (% of Projects)

	Innovation Fund	URDF
Comparable to best in the world	49	33
Comparable to best in Canada	35	21
Above average	9	30
Average	6	14
Below average	0	2

Source: CFI progress reports.

Second, in the evaluation case studies department and faculty representatives confirmed these findings and additionally noted a striking and significant increase in the quality of research infrastructure within the disciplines affected by the case study projects[23]. These impacts are shown in Exhibit 5.2, and confirm that CFI is not only investing in desperately-needed leading-edge research resources, but is supplying sufficient infrastructure to have a major impact in the affected disciplines.

[23] *The case studies asked respondents to comment **only** about impacts in the research disciplines affected by the individual infrastructure supported by CFI investigated in those case studies. This was done to control for fields in which CFI-funded infrastructure has not been obtained.*

Exhibit 5.2—Impact of Infrastructure on Research by Fund (% of Department/Faculty Respondents)

	The overall quality of department's research infrastructure in the affected discipline *prior* to receiving the CFI awards	
	Fair or Poor	**Excellent or World-Class**
- IF	47	27
- URDF	63	0
- CRDF	83	0
- All three funds combined	59	14
	The overall quality of department's research infrastructure in the affected discipline *now* (or once the specified CFI-funded infrastructure is fully operational)	
	Fair or Poor	**Excellent or World-Class**
- IF	0	100
- URDF	0	88
- CRDF	0	67
- All three funds combined	0	90

Source: Department and Faculty Representatives.

Essentially, there has been a reversal in infrastructure quality. Prior to receiving CFI awards, almost 60% of department/faculty respondents rated the relevant infrastructure as poor or fair, while only 14% rated their infrastructure as excellent, and none rated it as world-class. Conversely, following the awards none of the respondents rated the relevant infrastructure as either poor or fair, while 90% rated it as excellent or world-class. Note that there were strong differences by fund, with major universities naturally continuing to have the highest-quality infrastructure (as represented by IF awards), but with smaller universities and colleges now having high-quality infrastructure in the affected disciplines, whereas they had absolutely none before. The turnaround for colleges is especially striking.

While some infrastructure in the affected fields might have been purchased through other means, department/faculty respondents said that, on average, three-quarters of the change was specifically due to CFI. Thus these changes are mainly attributable to CFI.

Institution case study respondents mainly agreed with these sentiments, with the majority making comments such as the following:

> *In the 10 years preceding the IF program, the state of university research infrastructure declined substantially because of lack of funding. The IF program has been the key factor in bringing Canadian research infrastructure up to world-class standards . . . [V-P Research, large institution]*
>
> *Each IF investment has enabled institutions to move research infrastructure towards a globally competitive level in a major way. This improved infrastructure in turn enables other funding opportunities to be leveraged which will be critical to keep pace with an increasingly competitive global environment. [V-P Research, medium institution]*
>
> *Les infrastructures acquises permettent aux chercheurs de poursuivre des recherches avancées, de niveau mondial. Elles favorisent également le développement de collaboration avec des partenaires universitaires et industriels. Sans le FDRU, il aurait été impossible d'acquérir des équipements aussi performants. [V-P for graduate studies and research, small institution]*

However, a number noted that the impacts were often confined to specific disciplines, and that continuing investment was required (including for operations and maintenance).

> *In the absence of CFI operating funding for URDF projects there are concerns about the longer term viability for the infrastructure. [V-P Academic, small institution]*
>
> *Many of the IF investments have created infrastructure with a maximum vision. The next five years will determine whether the enormous potential is realized.[V-P Research, medium-sized institution].*
>
> *If the total sum of IF dollars had been spread uniformly throughout the University, then we would be up to world-class standards. This is not the case, hence the University has not achieved world-class standard "on average" . . . Averaging over the entire university, I would say that [we are] two thirds of the way to world-class standards "on average". [Associate V-P Research, large institution]*

MAC members also agreed with the strong impact of CFI on innovation capacity. Indeed, not a single respondent disagreed with this finding, although a number commented that much remained to be done, and that the impact arising from the infrastructure itself was still to be determined:

In the two competitions in which I have been involved, I have been very impressed with the importance of the IF in both bringing together Canadian research infrastructure up to international standards in some cases, and in maintaining international standards in others. [MAC member]

Respondents from the granting councils all believed that CFI has had a major impact on university research infrastructure. However, there was some feeling that earlier applications were perhaps replacing obsolete equipment; later applications are for considerably more sophisticated equipment and facilities.

5.3 Creation of Knowledge Clusters

The programs have had a substantial impact on national and (especially) regional knowledge clusters. "Knowledge clusters" were usually defined by respondents as groups of researchers sharing intellectual capital (including research facilities, data, methods, etc.), sometimes within collaborative theme-based projects and in joint publications. Some individuals included the idea of clusters being a central node for socio-economic development, including the ability of external users to approach the cluster for science-based problem-solving. A few respondents believed the definition encompassed involvement of multiple institutions.

[The cluster created by the] CFI project has influenced all levels—federal government, provincial government, industry, and SMEs [Director of Research, small institution]

Over half the Department/faculty respondents rated CFI's influence in creating both regional and national knowledge clusters as large or very large; most of the rest rated it as moderate. Almost none rated its impact as small for regional centres, although about a quarter of respondents said the impact was small or less for national centres. Institution respondents rated CFI's impact even higher—about 80% rated its impact on regional centres as large or very large, and roughly half rated it similarly high for national centres. Very few respondents thought the impact was small in either case. Larger universities receiving IF awards were far more likely to think there had been important national impacts; in fact, none of the smaller institutions obtaining URDF grants and only 13% of CRDF respondents reported large or very large impacts here, compared to three-quarters of the IF award holders[24]. These impacts are also found at the college level:

The program has definitely stimulated increased research activity in technology, engineering, health and science . The colleges are presenting increasingly

[24] *The data were less clear for regional centres: too many URDF respondents said "don't know" to allow interpretation. IF and CRDF were, however, relatively similar on this score: half of CRDF respondents reported large or very large impacts, versus three-quarters of IF respondents.*

innovative and soundly-developed proposals and seem to have broadened the scope of their research networks. [MAC member]

5.4 Impact on the Nature of Research

Overall, the awards have had an exceptionally strong impact on the nature of research that can be conducted. First, progress report data shown in Exhibit 5.3 show that most researchers believed their research conducted on CFI-funded infrastructure was of very high quality.

Exhibit 5.3 — Quality of Research Done on CFI-funded Infrastructure (% of Projects)

	Innovation Fund	URDF
Too early to tell	8	2
Modest advance	10	12
National standards	15	32
International standards	44	46
Breakthrough	20	7
No answer	3	0

Source: CFI progress reports

Second, the evaluation case studies investigated the change from the pre-CFI condition: faculty/department and MAC respondents noted that this high research quality represents an upward change from the previous situation—the CFI-funded infrastructure has had a very strong positive impact on the nature of research that can be conducted. For example, nearly 95% of case study respondents said the projects allowed higher or much higher ability to address leading-edge problems. Exhibit 5.4 shows the nature of these impacts. The areas where the infrastructure has had the least impact to date (although still having a strong positive impact) is ability to address high-risk topics and cross-disciplinarity projects[25], while the impact of CFI on multidisciplinarity is the most striking.

[25] *Of course, for much research it is not appropriate to be cross-disciplinary.*

By fund, there were only modest differences on the influence of the infrastructure on addressing leading-edge topics, speed of research, or multidisciplinarity (the most impact was for IF, a bit less for URDF, and less still for CRDF, but all still close), but there were notable differences for cross-disciplinarity (90% of IF reported this as higher or much higher, versus 67% for URDF and only 13% for CRDF) and the ability to address high-risk topics (67% for both IF and URDF, but only 25% for CRDF). On the whole, such differences across funds seem sensible given the nature of work being conducted in the different types of institutions; e.g., colleges are unlikely to tackle high-risk or cross-disciplinary projects to begin with.

Exhibit 5.4—Impact of CFI-funded Infrastructure on Nature of Research

	% of Respondents Saying "Higher" or "Much Higher" Now	
	Department/ Faculty Respondents	**MAC Respondents**
Multidisciplinarity (integrating several sub-fields within the general discipline)	94	93
Ability to address leading edge or groundbreaking problems	94	93
Speed with which research can be conducted	91	79
Cross-disciplinarity (integrating two or more "major disciplines"; e.g., physical sciences and health sciences, or health sciences and social sciences)	69	78
Ability to address high-risk topics	57	78

Source: Interviews with department and faculty representatives, and MAC members.

A number of departmental/faculty respondents made comments such as: the infrastructure has permitted working on research problems that could not previously be addressed, the institution now contained a research centre unique in Canada (or the world) containing cutting-edge equipment, and the facility allowed collaborations among large numbers of investigators in multiple fields.

Granting council respondents believed that CFI has helped hugely, to the point where CFI-funded infrastructure is indispensable for the kind of work being conducted, especially regarding the speed of the work and the quality. Knowing they can access world-class equipment is also thought to add a big psychological boost to Canadian researchers. However, there is also a sense that Canada is "getting there, but hasn't arrived", with particular weakness in the ability to find operating funds for increasingly-expensive facilities.

5.5 Usefulness of Institutional Research Plans

The institutional research plans were rated as moderately or highly useful by roughly two-thirds of department/faculty level respondents for co-ordinating the needs of individual departments within the institution, for meeting departmental goals, and for co-ordinating their research with the needs of private sector and other user organizations. They were not quite as useful for helping avoid mistakes, but even here about half the respondents said they were moderately or highly useful (and 20% didn't know).

At the institutional level, these opinions were mirrored, but even more strongly; e.g., about 80% of respondents rated the plans as moderately or very useful for meeting corporate goals, for co-ordinating the needs of individual departments (75%), and for co-ordinating with industry and other user organizations (77%). However, roughly a quarter of these respondents did not find the plans very useful: it was noted that CFI plans were often in line with corporate strategies already in existence, rather than being completely novel entities.

> *Used the plan to create a strategic research plan which guides decision-making, resources, research, graduate program development and accreditation. [Director Research, small institution]*
>
> *It has helped the institution develop its "brand". Internally , it has had less impact since as a medium-sized institution this has always been the ability to coordinate efforts across campus.[V-P Research, medium-sized institution]*
>
> *It has been very useful in "creating" a good sense of "we have a plan". Now that research is so new to colleges, this gives us a foundation to build on. [COO, President, college]*

Across all measures CRDF recipients were most likely to find these plans helpful, while IF and URDF recipients found them somewhat lower in usefulness. This may well point to a lack of strategic planning in the colleges prior to CFI, or perhaps the lack of a need to do so given the earlier poor state of college research infrastructure. The areas in which there were the most notable difference were:

- Avoiding costly mistakes: over 80% of CRDF respondents rated the plans as moderately or highly useful, compared to 45% of IF and 38% of URDF respondents; and
- Co-ordinating with the private sector: 100% of CRDF, versus 67% of IF and 50% of URDF.

MAC members also found these plans useful during the application review process—over 85% rated them as moderately or highly useful. Where problems were mentioned, they related to plans being

too lengthy and complex, or applications clearly representing the needs of small groups of researchers rather than true institutional needs.

> *The institutional research plan has been very useful in that it has given a lever to university presidents etc. to force discussion among competing faculties and researchers on relative strengths and priorities. It is the exercise that was valuable rather than the output per se. [MAC member]*

5.6 Leveraging of Research Funding

In addition to leveraging *infrastructure* funding as described in section 4.7, case study respondents reported that the presence of the infrastructure supported by CFI has in many cases allowed researchers, departments, and institutions to lever additional *research* funding. The sources of this incremental funding[26] were reported by departmental/faculty respondents to be:

- the provinces (83% of respondents);
- the granting councils (81%);
- the institutions (75%);
- Canadian industry for joint projects (60%);
- international sources (55%);
- other federal sources (47%); and
- Canadian industry for contracts (39%);

There were some differences according to program:

- IF and URDF awards were much more important than CRDF in levering institutional funds (probably representing a lack of such support in colleges to begin with); and
- IF awards were somewhat more important than URDF and much more important than CRDF in levering research funds from the granting councils, provincial sources, and industry contracts;

[26] *Respondents were specifically asked about research funding that could not have been obtained without the infrastructure supported by CFI.*

The average additional amount of research funding reported by case study department respondents was about $2.1 million per department from provinces, $1.8 million from the institutions, $1.6 million from granting councils, and $2.3 million from international sources. (Other sources were much smaller in amount.) Respondents at the institution level confirmed these impacts. Almost 65% of institutional respondents reported increased research funding being made available because of CFI investments. (None reported lower research funding.) The minimum yearly amount reported for institutions as a whole was $100k, and the maximum was $5 million annually.

On the other hand, as discussed below in section 5.12 these opinions were not entirely confirmed by provinces, and it proved impossible to say exactly what impact CFI has had on pressures on granting council programs (and in particular, whether researchers with access to infrastructure supported by CFI are more successful at obtaining research grants from the councils). With respect to provincial sources, only one province (Alberta) noted that it had recently increased research funding[27]. Our conclusion is that researchers using infrastructure supported by CFI may be better able to attract government and council research support than those with older, outdated equipment, but with existing data this cannot be confirmed. However, it does appear that there is an incremental net leveraging in the case of private sector and non-Canadian research support.

5.7 Extent of Attraction and Retention of World-Class Researchers

In CFI progress reports, three-quarters of IF respondents and about two-thirds of URDF respondents noted that availability of CFI-funded infrastructure had been an important factor over the past year in the decision of researchers[28] to join the institution (i.e., "attraction"). The origin of these researchers is shown in Exhibit 5.5[29].

In the evaluation case studies, the average department reported being able to attract about four faculty members (or researchers, in the case of hospitals) at least partially because of the existence of the infrastructure supported by CFI under investigation. Exhibit 5.6 shows a rough breakdown by type; although many are junior-level, a significant proportion of these are senior-level individuals.

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[27] Alberta has roughly tripled its research expenditures over the past five years. This is not directly in response to CFI, however.

[28] Defined in progress reports as faculty members, postdoctoral fellows, and other researchers

[29] These data are based on some double counting,, as some new researchers could use more than one CFI-supported infrastructure project..

Exhibit 5.5—Origin of Researchers Attracted in Past Year in Part by Infrastructure Supported by CFI (% of Projects)

	Innovation Fund	URDF
Canada	58	69
United States	16	8
Other countries	26	23
Academia	93	82
Industry	4	8
Public sector	3	10

Source: CFI progress reports

Exhibit 5.6—Nature of Faculty Members Attracted to Departments in Part Because of CFI-funded Infrastructure

Canadians transferring from other Canadian institutions	35%
Junior level ex-pat Canadians returning to Canada	30%
Junior level non-Canadians (e.g., assistant professor level)	17%
Senior level ex-pat Canadians returning to Canada	10%
Senior level non-Canadians (e.g., associate professor & above)	8%

Source: Interviews with department and faculty representatives

In the college community the ability to attract and retrain these leading faculty is absolutely critical to the development of college programs which lead to highly qualified people at many levels. Without the ability to attract qualified staff, the college programs will be difficult to maintain. [MAC member]

5.8 Training of Highly-Qualified Personnel (HQP)

In the progress reports, both IF and URDF project leaders noted that the infrastructure had helped them recruit students from outside their institution—an average of about 10 students per IF project and 3 per URDF. The bulk of these (about 68%) were from Canada, with 28% attracted internationally, but only 3% from the US . The progress reports also note that many students are trained on the CFI-funded infrastructure, an average of about 32 students per IF project and 14 per URDF.

The progress report data do not show the change from pre-CFI conditions; this was investigated in the evaluation case studies. Almost 95% of case study department/faculty respondents noted that their ability to attract and train high quality undergraduate students (or technician trainees, in the case of colleges) was higher or much higher because of the CFI-funded infrastructure. The equivalent impact for graduate students and postdoctoral fellows was slightly lower: 50 - 60% of respondents, respectively, but the remainder (nearly half) did not know. By fund there was not much difference for attracting undergraduates and/or technicians (although CRDF impacts were the highest of all), and a moderate difference for graduate students and postdoctoral (IF recipients found somewhat more impact than URDF); of course colleges do not have postdoctoral fellows to begin with.

Our graduate programs are quite new, but undoubtedly the presence of the infrastructure has improved our attractiveness to graduate students. [V-P Research, small institution]

5.9 Impact on Research Collaboration

Progress report data indicate that the CFI-funded infrastructure has been instrumental in creating a variety of collaborative arrangements, especially informal linkages with colleagues in the same institution and formal research collaborations (roughly two-thirds of projects report these two impacts), with a somewhat lesser impact on formal signed relationships and international collaborations (about a third report these impacts). There is little difference between IF and URDF on these effects.

The case studies provided more quantitative information: respondents in the departments/faculties noted that access to the specific CFI-funded infrastructure investigated in the case studies had nearly doubled the number of collaborative projects typically undertaken at any given time by faculty

members using the projects—from about 22 such collaborations typically ongoing prior to receiving the CFI awards, to about 39 now (or expected when the projects are fully operational)[30]. See Exhibit 5.7. There were increases reported for every type of collaboration, but proportionally these were especially great for those involving government organizations, collaborations with non-Canadian institutions, and collaborations with other departments within the institution. Of interest is that almost 30% these collaborations (and the single most common type) are contracts with the private sector: a total of roughly 11 contracts ongoing or expected when the projects are operational (up from just under 8 prior to the awards).

Exhibit 5.7—Number of Collaborations Ongoing at Any Given Time (i.e., in Typical Recent Year)

	No. prior to receiving IF infrastructure	No. now (or expected when operational)	Increase Factor Pre/Post CFI
TOTAL Collaborations	21.6	39.3	1.8
Research collaborations with Canadian government organizations	2.8	7.1	2.5
Research collaborations with non-Canadian institutions	2.0	4.2	2.2
Research collaborations with other departments in your institution	2.9	6.2	2.1
Research collaborations with other Canadian research institutions	3.3	5.7	1.8
Research collaborations with the Canadian private sector (excluding contracts)	2.9	5.2	1.8
Research contracts with the Canadian private sector	7.8	11.0	1.4

Source: Department & faculty respondents.

5.10 Efficient Use of CFI-funded Infrastructure

5.10.1 Usage

CFI progress reports indicate that nearly 90% of IF projects and 85% of URDF projects are adequately utilized, or even oversubscribed. By far the most common reason for IF underutilization is that the infrastructure is not operational (or not fully so). For URDF, however, there are also other reasons, including faculty turnover, maternity leave, lack of students, lack of time for research and high teaching loads (which mean that equipment is fully used in the summer only), and equipment

[30] *A "collaboration" was defined as one faculty member engaging in one collaboration with someone outside the department—i.e., one person engaged in two separate interactions was "2 collaborations".*

being very specialized so that it is normal that only a few students use it. These differences point to the relative lack of HQP within smaller institutions to make use of research infrastructure, and thus the vulnerability to underutilization if just one researcher is not available.

The evaluation case studies supplemented this information with data on the percentage of time the infrastructure was being used. For case study infrastructure that was currently operational, department/faculty respondents said that the infrastructure was being used almost 95% of the time. Further, roughly half the projects are reported as being oversubscribed, on average by about 33%[31]. These figures indicate highly-efficient usage over virtually all the time available.

5.10.2 Sharing

The CFI-funded infrastructure is being effectively shared. Overall, CFI records show that 118 of the projects under review are shared in a formal manner among two or more institutions—107 IF projects, three CRDF, and eight URDF.. The shared projects tend to be quite large, with CFI's total contribution being about $300 million, or an average of $2.5 million per project. The relatively high proportion of IF projects of this type speaks to an effective effort to maximize the efficient usage of these large facilities.

In the progress reports, respondents were asked how many researchers advanced their research by using CFI-funded infrastructure. About three-quarters of IF projects and half the CRDF projects have benefited more than three researchers, of which about 13% of IF and 22% of CRDF users were from industry or government. There was an average of about 23 researchers per IF project and 6 researchers per URDF project.

The evaluation case study data also indicate considerable sharing of the infrastructure: the projects were used roughly two-thirds of the time by investigators within the departments, but one-third of the time by users outside it. External users were varied, as seen in Exhibit 5.8; note that users outside the department where the infrastructure is housed take up about 44% of total time.

[31] *These figures are averages per department; i.e., not weighted by the number of respondents per department.*

Exhibit 5.8—Sharing of Operational Infrastructure Supported by CFI

Type of user	% of Time
Currently not being used	7
Researchers in same department	60
Researchers in other departments in same institution	18
Researchers from other Canadian research institutions (excluding government and industry)	12
Researchers from Canadian government organizations	8
Researchers in the Canadian private sector	4
Researchers from non-Canadian organizations	2

5.10.3 Implementation, Operation, and Maintenance

If there are substantial difficulties implementing the projects (i.e., purchasing and/or building the projects, getting them up and running, etc.), then it is difficult to use them effectively, at least in the early years. Many case study respondents at departmental/faculty levels noted that both implementation and finding financial resources for operations and maintenance (O&M) were difficult or very difficult[32]. From the institutional perspective, the infrastructure supported by CFI also tend to be problematical, both in and of themselves , and in comparison to other projects. The reasons cited included the sheer size and number of projects, the complexity and state-of-the-art nature of many infrastructure projects supported by CFI (especially those involving multiple institutions and/or entirely new facilities), the difficulty of securing matching funding, red tape and "micromanagement" from CFI, unexpected building costs, fluctuating exchange rates, and delays in award confirmation. Note that many of these factors are related to the nature of the projects, rather than problems with the program itself. Exhibit 5.9 shows department/faculty and institutional perspectives.

[32] *Note that some O&M funds are available separately. For instance, NSERC runs the Major Facilities Access program, but to obtain funding the facility must be highly-important regionally or nationally.*

Exhibit 5.9—Implementation Problems

	% of Respondents Saying "Difficult" or "Very Difficult"	
	Department/ Faculty Respondents	**Institutional Respondents**
Implementing the CFI-funded infrastructure	41	45
Operations (e.g., consumables, power, etc.) & maintenance funding	41	91
Attracting & retaining HQP for operations & maintenance	35	16
	% of Respondents Saying CFI-funded Infrastructure is "Worse" or "Much Worse" Than Usual	
Implementing the infrastructure	11	46
Operations (e.g., consumables, power, etc.) & maintenance funding	16	20
Attracting & retaining HQP for operations & maintenance	0	0

Although 90% of institutional respondents said that finding O&M resources for infrastructure supported by CFI was very difficult, about three-quarters also found this to be true of other similar projects—only 20% said it was worse than usual. Finding HQP to operate the equipment and facilities was not a significant issue for the institutional respondents, and about 20% believed that infrastructure supported by CFI was actually a bit better than others in this regard. However, a number of individuals commented that future O&M costs would strain both institutional and provincial resources.

By fund:

- IF and URDF respondents had relatively similar problems regarding implementation, whereas none of the CRDF recipients reported any implementation difficulties.
- For O&M, IF awards were the most difficult, while both URDF and CRDF were somewhat less problematical.
- For attracting HQP to operate the infrastructure, IF and URDF recipients reported similar problems; far fewer were noted by CRDF respondents.

Interestingly, a few respondents noted it was *easier* to find HQP to operate and maintain infrastructure supported by CFI than is usually the case—this may reflect the attractiveness of working with state-of-the-art equipment. By fund, URDF recipients reported more implementation difficulties compared to infrastructure purchased through other programs than did IF award holders (URDF recipients being perhaps being less familiar with large projects); IF and URDF were roughly the same on O&M and HQP issues; and CRDF respondents generally could not make these comparisons, presumably because they were previously unfamiliar with obtaining large infrastructure grants[33].

> *These are early days and many of our major IF projects are just becoming operational. . . as these facilities come on board over the next few years, this will greatly tax the federal agencies' budgets. [V-P Research, large institution]*

5.11 Other Impacts at Host Institutions

5.11.1 Corporate-Level Impacts

Institutional respondents mentioned a number of additional impacts. On the positive side, these included the following (roughly ordered from most to least common):

- Synergistic impacts across the institution; e.g., better support for strategic goals, ability to attract provincial and corporate partners for research (in some cases leading to support for the research personnel necessary to optimize use of the facilities), advancements in multidisciplinary and cross-disciplinary projects (including those accessing common resources such as databases), additional research contracts, and higher self-sustainability of research.

- More focus on generating socio-economic impacts; e.g., project leader developing a business plan to attract outside users to the CFI facility, additional links with government and industry users, investment impacts for associated local industries and for institutional research facilities, spin-off companies, etc.

- Additional multi-institutional linkages.

- Increased visibility and credibility (especially for small institutions).

[33] *But the URDF and CRDF data were from a very small number of respondents, so this should not be taken as gospel.*

The IF projects are of a scope that exceeds other programs and, therefore, their impact on the institutional image and strategic research direction is correspondingly greater. [V-P Research, medium-sized institution]

On the negative side, impacts included the following::

- Increased indirect costs for preparing applications, administration, and reporting, in some cases involving hiring additional staff or pressures on existing staff.
- Increased need for O&M support.
- Perceived inequities in support between science/engineering and other disciplines.

Such problems are not uncommon to large projects, but respondents noted that the size, scope, and complexity of infrastructure supported by CFI often exacerbate them. Respondents from smaller institutions also noted that infrastructure projects supported by CFI are larger and more complicated than these institutions are used to handling.

The magnitude of the IF funding and the projects which involve major construction and/or renovations is unprecedented. [V-P Research, large institution]

Arranging and securing partner funding, even when commitments are made at application time, is very time-consuming. The level of detail required in the CFI process, and the degree of micro-management of funds exerted by CFI leads to added levels of administration and causes delays. Integrating new equipment into the existing dated infrastructure adds to the cost of operation and maintenance. Completion of reports requires time-consuming input and follow-up. [V-P Research, large institution]

5.11.2 Departmental- and Faculty-Level Impacts

Roughly half of these respondents noted the awards had had unexpected impacts. With only one exception, these were positive and generally mirrored the institutional-level impacts noted above. Some additional impacts mentioned here were:

- Increased visibility, which in turn has levered major collaborative partnerships with Canadian universities, international organizations, and industry. In some cases this recognition is "trickling down" to the rest of the department, and is improving the ability to attract HQP from abroad.
- The ability to quickly attract additional research funding.

5.11.3 Changes Intended for Future Applications

Almost three-quarters of the institutions and about half the departments/faculties planned to change the nature of their applications as follows (ordered roughly from most to least common):

- Larger and more space-intensive projects (in several cases being more integrated; i.e., involving a small number of large projects, but fewer individual applications);
- More emphasis on multidisciplinarity and collaborations, with projects better-integrated into departmental and/or corporate strategies that focus on common needs and integrated research planning;
- More consideration of O&M needs, including staffing, financial resources, etc.;
- Entirely new research programs;
- More external partnerships.

It is unclear to what extent these changes reflect changing needs within the organizations *versus* changes in what is perceived necessary for success in applying to CFI (however, no one mentioned the latter option).

5.12 Impacts at other Funding Organizations

5.12.1 The Provincial Perspective

As noted in section 4.7.3, many provinces have provided matching funding. Their goals in doing so were generally in line with those of CFI itself—i.e., to invigorate the provincial research capacity and generate downstream socio-economic benefits, often in line with provincial S&T strategies. (There was also certainly an element of competitive flavour as well, in that none wished to "fall behind" their neighbours on this score.)

On the positive side, all provinces agreed that CFI has had major impacts on their provinces' research infrastructure[34] and innovation capacity (including many examples of regional knowledge clusters). Provincial respondents also noted some other positive impacts, notably:

- Project-level collaborations have increased somewhat among their universities (in some cases among institutions that have traditionally had great rivalry). This is still hindered by inter-

[34] *Although none of the provinces contacted currently have a system for tracking infrastructure.*

institutional competition; e.g., the desire of each institution to be the one through which project funding flows, giving it the "credit" for the investment.

- There has been a number of relatively high-profile collaborations between the higher education and government sectors with respect to joint research projects and/or construction of research facilities (in some cases involving a number of ministries and departments, each supplying a different component of the facility).

- The institutional research plans have been used in some cases to help define broad provincial strategic areas[35], to contribute to annual institution research roundtables, and to encourage universities to apply for infrastructure supported by CFI in areas relevant to provincial priorities. Some universities have used their CFI research plans to market their research capacity to provincial ministries. Of interest is that none of the Atlantic universities have reportedly tried to collaborate on their research plans; i.e., to develop a regional S&T "master plan".

On the negative side, every province noted that it was difficult to find the resources to provide these contributions, but the situation was by far the worst in the Atlantic provinces. Their universities have relatively poor infrastructure, a small research foundation, very little access to industrial contributions, and little ability to support indirect costs. Additionally, the provinces had very little R&D funding to begin with. Matching funds came from the federal/provincial Economic Diversification Agreements (EDAs), but these agreements have terminated. Without these EDAs, it is unclear whether these provinces would have benefited at all. Recently the Atlantic Canada Opportunities Agency (ACOA) has "stepped up to the plate" to provide matching funds through its Atlantic Innovation Fund, but this is not the primary intent of this program. The Atlantic provinces believe that CFI should recognize that applying the same matching formula equally across the country is inherently discriminatory towards them.

> *It should be noted that the provision of matching funds was exceedingly difficult for a small province like [ours] and was only possible because of the existence of a program such as the EDA managed through the federal department of ACOA. [Atlantic Canada provincial representative]*

> *The continuing lack of automatic CFI matching in the Atlantic provinces has been a discouraging factor and is likely to continue to restrict scope of projects in this area. The Atlantic Innovation Fund as a potential matching source is much more restrictive than programs in other programs and requires an onerous, second application process. [MAC member]*

[35] *Not all provinces have an S&T strategy, however.*

There are also some concerns in some provinces which feel out of the loop in terms of strategy and implementation, and feel they have little ability to direct CFI awards towards projects with high regional priorities[36]. In some cases, this has led to a competitive atmosphere between universities that poorly serves regional innovation strategies. Provinces also have little control over the total amount of matching funding they are being asked to provide, and this has caused strain on provincial coffers. And finally, although it is not yet a significant problem, the provinces see themselves as "on the hook" for large, continuing O&M costs, especially when IOF funds terminate.

> *It is evident that CFI is making significant investments in our province's research infrastructure. [But the awards] have been challenging in terms of cash flow and available funds. . . In short, most provincial funds are oversubscribed. [Provincial representative]*

With respect to providing input to CFI policy and procedures, some provinces do not really wish to become involved, but others certainly do. At the very least, a recognition that the provinces are equal partners of CFI—coupled with more direct communication and consultation—would be appreciated by some. The more eager provinces would like to participate directly in strategic planning, identification of priority investments, and project review and approval for at least the largest projects (say, those of $2-4 million and up) and those involving construction of new buildings.

> *This has been a wonderful, noble initiative. But we have to grow up in this country, all sit down around the table. We're only inhibited by our imagination and our confidence in each other. [Provincial representative]*

> *This was a much-needed shot in the arm . . . But I'm not sure if it accomplished the ability to collaborate and share on things; instead it encouraged independence and competition. [Provincial representative]*

5.12.2 Conclusion

Having discussed some provincial concerns, we would like to note that, by virtue of its mandate, CFI considers universities, research hospitals, colleges, and other eligible institutions to be its primary clientele, and views the provinces as partners to these institutions. Although it is clear that mis-matches are possible between the priorities of institutions and their provincial partners, it is entirely possible (and appropriate) that these could be resolved by these parties in advance of applying to CFI.

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[36] *Québec does pre-screen applications prior to submission to CFI. Several other provinces have explicit strategies to focus S&T investments in a few key areas of relevance and excellence (and aim to stay out of the rest), but do not pre-screen CFI applications.*

Our general conclusion is that many of these concerns are in fact problems of success. The many successful projects now require ongoing support and, in hindsight, better coordination among participating institutions and between the institutions and their respective provinces[37]. This in turn would require a new process that is more integrated with respect to provincial S&T strategies, and ideally towards a more pan-Canadian viewpoint.

> *The coordination with programs from the Federal Agencies and provinces is crucial. This has already been identified as desirable, but needs acceleration and commitment by all parties. [V-P Research, large institution]*

We emphasize that these are early days for CFI. Some increased co-ordination and strategic planning is already occurring at the institutional level; e.g., V-Ps Research now often manage the institutional research plans and the nature of applications to CFI. Time will tell whether this evolves into broader planning.

5.12.3 The Granting Council Perspectives

In general, the granting councils are under significantly greater funding pressure than before because of a combination of factors that include restricted institution budgets and more interest in pursuing high-cost areas such as biopharmaceuticals. Most relevant here are pressures related to the changing nature of science. Science is now more multidisciplinary, more cross-disciplinary, more and internationally-collaborative. It increasingly relies on equipment, computing facilities, and other research infrastructure such as databases. Other recent initiatives such as the Canada Research Chairs program, the Networks of Centres of Excellence, Genome Canada, other CFI programs such as New Opportunities, and initiatives within the granting councils themselves (e.g., the reorganization of the Medical Research Council into the Canadian Institutes of Health Research, which has added new disciplines to those supported earlier; plus more support in the councils for new investigators) have increased resources for science but also created pressures associated with following up on successes (e.g., by pursuing new research and commercialization opportunities).

How much has CFI contributed to these pressures on the councils? Although the granting councils have seen increases to the numbers, size, and quality of research grant requests, it proved impossible in this study to say definitively how much—if any—of this was due to CFI[38].

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[37] *Including, perhaps, that the provinces could usefully take a more active role in their institutions' strategic research planning prior to submitting applications to CFI.*

[38] *A definitive answer as to whether users of infrastructure supported by CFI request, and obtain, more granting council funding would require comparisons of data from "users" versus "non-users", and perhaps "pre-CFI"vs "post-CFI". Ideally, all types of grants would be investigated. The study would be difficult for IF, URDF, and CRDF given the large number of users other than the Project Leaders, since it would be difficult to ascertain exactly who the "users" are. (It would be easier in CFI's New Opportunities Fund.)*

From the applicants' perspective, investigators in the SSH fields have greater barriers to overcome than those in other disciplines. First, they do not have the same level of institutional support for submitting CFI applications (one group of successful applications estimated it cost $100,000 to prepare the submission). Second, it is often more difficult to find regional matching funding for SSH applications. Finally, collaboration for SSH researchers with investigators in other fields is still problematical. None of these is directly a CFI problem, but they limit the ability of CFI to use its programs to lever increased innovation in the social sciences and humanities.

> *`It should be noted that the program (while not excluding social sciences* per se*) seems to have done relatively little to contribute to a creative synergy between the "hard sciences" and the social sciences. [MAC member]*

5.13 Range and Magnitude of Socio-Economic Impacts

5.13.1 Overview

This evaluation was not intended to conduct a detailed investigation of social and economic impacts (it is too early), but instead to assess the likely range of such impacts, and whether a benefit/cost (B/C) analysis would be appropriate for measuring them. Our conclusion is that CFI is highly likely to produce substantial benefits in a very wide range of fields, and (equally important) that project leaders and institutions are in many cases already actively pursuing such applications. However, it will be several years before B/C methods would be appropriate for estimating dollar values of these benefits.

5.13.2 Nature of Impacts

The small sample of 10 industry contributors contacted revealed a wide range of reasons and expectations for contributing to the purchase, installation, and/or ongoing research costs associated with infrastructure supported with CFI. These included:

- Access to tools, methods, and research results that might assist the company in their process and product development (7 of the 10 firms mentioned such impacts, although for all but one this would occur in the mid- to long-term)

- Access to highly-qualified personnel, including faculty members as well as students who might eventually join the company (4 of the 10 firms mentioned such HQP impacts).

- Continuing and/or better relationships with the investigators and their institutions (5 firms).

Some of these were already happening (e.g., students working on company projects, reduced risk in company processes, access to better research and test facilities, hiring of HQP trained on the CFI-

supported infrastructure, creation of new research projects, use of the infrastructure for product development), other were expected in the future (e.g., one new product is not expected to be commercialized for 10 years), but there were also indirect impacts associated with impacts such as "word of mouth" within the scientific community (resulting in sales to other universities), improved regulatory climate, training of company staff, and consideration of other collaborative projects with the host institutions.

The CFI progress reports contain a great deal of data on projects that have created benefits "in the past year", shown in Exhibits 5.10 and 5.11. (An internal CFI review noted that many respondents appear to have also reported benefits from the time the infrastructure became operational, and/or impacts expected in the near future, not just impacts in the past year as requested, so the numbers appear higher than might be expected.)

Exhibit 5.10—Benefits Provided by IF-funded Infrastructure (% of IF Projects)

	No benefits	Some benefits	Considerable benefits	No answer
Intellectual property	44	37	16	3
Knowledge clusters	8	35	55	2
Spin-off companies	70	19	8	3
Cost savings	34	44	18	4
Public policy improvements	73	18	5	4
Health benefits	50	38	8	4
Social benefits	68	23	4	5
Environmental benefits	56	27	11	6

Source: CFI progress reports.

There is also a great deal of qualitative information in the progress reports on the nature of impacts to date. Much of this is related to attraction and retention, new research collaborations, important scientific findings, etc., but some is related to potential social and economic impacts. A number of

these reports demonstrate projects which appear to show signs of tangible socio-economic outcomes, and a very rough review indicates that it was common to have 3 – 5 such projects within the "top 10" Canadian universities, and perhaps 1 – 2 such projects at other medium and small institutions. These impacts are in fields ranging literally from agriculture to zoology, with potential users from all sectors. Precursor activities to exploitation (e.g., joint projects with users, patenting, creation of spin-off firms) are also not uncommonly reported (see section 5.13.3).

Exhibit 5.11—Benefits Provided by URDF Infrastructure (% of URDF Projects)

	No benefits	Some benefits	Considerable benefits	No answer
Intellectual property	70	19	11	2
Knowledge clusters	12	54	33	0
Spin-off companies	91	8	1	2
Cost savings	36	40	24	3
Public policy improvements	70	23	6	4
Health benefits	73	26	1	3
Social benefits	66	30	4	4
Environmental benefits	51	34	14	5

Source: CFI progress reports.

There is also a great deal of qualitative information in the progress reports on the nature of impacts to date. Much of this is related to attraction and retention, new research collaborations, important scientific findings, etc., but some is related to potential social and economic impacts. A number of these reports demonstrate projects which appear to show signs of tangible socio-economic outcomes, and a very rough review indicates that it was common to have 3 – 5 such projects within the "top 10" Canadian universities, and perhaps 1 – 2 such projects at other medium and small institutions. These impacts are in fields ranging literally from agriculture to zoology, with potential users from all

sectors. Precursor activities to exploitation (e.g., joint projects with users, patenting, creation of spin-off firms) are also not uncommonly reported (see section 5.13.3).

Exhibit 5.12 shows examples of potential applications discussed in the progress reports. These examples were selected on the basis of research that had clear application outside the research community, including showing concrete thinking about exploiting the research, such as activities designed to identify and attract investors and users, etc., and in which project leaders and institutions clearly indicated that it was the infrastructure supported by CFI that had allowed these impacts to occur. The exhibit shows examples only, and is not intended to be comprehensive: that any given institution or project is not included is no reflection of its success or importance. Note that all data are as of February/March, 2002.

Exhibit 5.12—Examples of Social and Economic Applications from Infrastructure Supported by CFI*

Host Institution	Nature of Research and Application
University of Alberta	Multimedia advanced computational infrastructure: Investigates the performance of very small supercomputers, with four institutions involved in this high-performance computer consortium, and one faculty member attracted to date. A wide range of applications identified include: exploration seismology (e.g., high-resolution imaging for oil & gas industry, resulting in cost savings), in which four firms are already actively collaborating; 3D computer simulations for urban planning, heritage site mapping, etc.; and design & modeling of automotive catalytic converters.
Brandon University	Microscopy and molecular systematics research lab: 2 faculty members attracted because of CFI-funded infrastructure, collaboration in mycology with private sector, negotiations with Parks Canada re: population structure of wolves,
University of British Columbia	Molecular biophysics: 8 “hubs” distributed around UBC provide instrumentation for the physical characterization of biological macromolecules, with four faculty members recruited to date. Applications include development of artificial substitutes for blood platelets, relieving the limited supply of platelets available from donated blood, providing both therapeutic benefits and significant economic and social value. Collaboration with industry has already begun.
British Columbia Institute of Technology	Internet Engineering Lab: Network performance evaluation facility, with major involvement of a large US/UK test equipment firm. Collaboration with all local universities, plus at least 4 local firms, and involved in major North American consortium. Applications in areas such as Internet security, and several local SMEs have used facilities, including one firm extensively for product testing.

Exhibit 5.12—Examples of Social and Economic Applications from Infrastructure Supported by CFI*	
Host Institution	**Nature of Research and Application**
University of Calgary	Magnetic Resonance Centre: effects of neurological disease on brain structure and function, response of novel treatment strategies, & monitoring of neurosurgical treatment. Several key individuals attracted to Centre. System shown to optimize surgical planning & reduce surgical morbidity. Numerous Canadian and international collaborations, including with NRC and private sector, plus Calgary Health Region. Resulting product now being marketed world-wide, plus several other commercial initiatives underway. One spin-off to date. Poised for introduction of robotic-assisted surgery in collaboration with a Canadian firm.
Carleton University	Advanced Materials Research: collaborative research in photonics, including novel organic materials, polymers, and device applications. One senior faculty member attracted. Two patent applications, collaboration with major Canadian firm, a Canadian microelectronics consortium, and a UK research group.
Concordia University	Biotechnology & bioinformatics facility: two faculty attracted partially because of facility, and 4 more being recruited. Major US protein chip firm has established field site at the facility, in turn helping train centre staff and providing free access to company's equipment and software. Method identified to efficiently identify genes & enzymes of commercial therapeutic value, & patent filed on protein production system.
Dalhousie University	Studies on petroleum compounds: several studies in collaboration with Canadian oil industry consortium. Applications include better quality diesel fuels, potential cost savings in extraction & upgrading processes, and lower pollutant emissions. Overall, 6 faculty members retained because of CFI-funded infrastructure.
École Polytechnique de Montréal	Virtual Enterprise Laboratory: In the past 2 years, over 3000 individuals, mostly from SMEs, have benefited from the Virtual Enterprise Laboratory by being involved in technology transfer. CFI-funded infrastructure allowed the university to create ePoly, a Centre of Research Expertise in electronic commerce. The laboratory has contributed to a significant increase in collaborations between institutions, both inside and outside of Canada. CFI funding has also allowed the creation of approximately 20 new positions.
École de technologie supérieure	Low Radiation 3D Numerical Radiology: a research network to develop technology that will enable radiographs to be taken at very low radiation levels, using multi-institutional and multi-disciplinary research teams. Existing partnership agreement with major multinational, which as a result of the partnership, has opened a Montreal affiliate. One patent filed. Other potential applications beyond medical field include airport security field (luggage scanners).
University of Guelph	Technology to assess and enhance agro-ecosystems: collaborations with mining and agri-food industries. Applications include reduced metal wastes and better disposal of organic wastes, most research targeted at environment issues such as water quality & climate change; impacts to date in agricultural best management practices.

Exhibit 5.12—Examples of Social and Economic Applications from Infrastructure Supported by CFI*	
Host Institution	**Nature of Research and Application**
Lakehead University	Paleo-DNA lab: first molecular biology lab & training at Lakehead. One US patent already for medical diagnostics filed by spin-off, which has collaborations with US and US, and uses incubator space. Lab has contract to identify victims of Titanic sinking.
University of Manitoba	Data infrastructure for health and human capital: Although incomplete, recruitment of 7 key faculty members, and collaborative use of CFI-funded infrastructure by Ministries of Health, Education & Training, and Family Services to facilitate data collection. Results have generated funding for collaborative project with Manitoba government and all 11 Regional Health Authorities. Applications to date in include changes in flu vaccination programs in Manitoba and Ontario.
McGill University	Genome Centre: research includes genotyping, gene sequencing, and "DNA chips" (microelectronic chips capable of conducting specialized DNA analysis). Already working with one other centre as a core facility using CFI-funded infrastructure, and with industry, plus several large research projects (e.g., involved with Human Genome Project); 3 patents filed related to gene-influenced diseases. Transgenic mouse facility: CFI-funded infrastructure has greatly increased amount of research funding and interactions and collaborations among participants in 4 different departments and another centre. Patents pending in animal models for neuron regeneration and diabetes resistance, the latter being used in screening tools being developed by more than a dozen companies, and may lead to improved patient treatments.
McMaster University	Manufacturing Research Institute: metal working research, 10 new researchers (5 from outside Canada), CFI-funded infrastructure allows extensive collaboration around campus and with other institutions. Considerable industry interest, including in patented high-speed inspection system for automotive components, developed collaboratively with local firm; potential spin-off company for this product.
Université de Montréal	Research Data Centres in 9 locations across Canada for social statistics. Regional consortia of universities, and collaboration (and special access to data) with Statistics Canada. Applications include greatly increased use of statistical data in the social sciences (e.g., sociology, health, statistics and actuarial science, economics, demography), including (for the first time) access to StatsCan's longitudinal data. International collaboration with UNESCO.
Mount Allison University	Coastal Wetlands Research Facility: atmospheric and climate research, provides microscopy, energy dispersive x-ray spectroscopy, molecular and analytical facilities. Attraction of one faculty member, retention of another. Collaboration with ACOA, other Canadian government agencies, and private sector. Production of videos, patents, and marketable biotech products.

Exhibit 5.12—Examples of Social and Economic Applications from Infrastructure Supported by CFI*	
Host Institution	**Nature of Research and Application**
Queen's University	Long-term Climatic and Environmental Change Research: CFI-funded infrastructure allows state-of-the-art analysis of climatic and environmental changes. Potential multitude of applications: acidification, eutrophication and other water quality problems, fisheries research, and research in climatic change.
University of Toronto	Epilepsy Research Group: multidisciplinary, comprehensive approach to epilepsy (including genetics, molecular biology, biochemistry, physiology using both cellular and animal models, clinical research & treatment), close collaboration with another institution, more than 50 HQP being trained (including collaboration between basic and clinical scientists). Potential application of discovery of gene causing an inherited form of progressive epilepsy. Functional genomic, proteomics, and bioinformatics: CFI-funded infrastructure attracted key scientist back from Europe, and retaining others who receive frequent offers from abroad. A spin-off company formed that already has offices in three countries and is a leader in proteomics. Two patents filed and one in progress, with potential applications including inhibition of bacterial infections.
Sault College	Forest ecosystems, forest management: Upper Lakes Environment Research Network, a partnership among academic, government and private sector organizations (many new to research). Three projects have already led to potentially-commercializable products; e.g., for forestry field measurement tool being tested by local firms. Other applications include: re-establishing extirpated elk population, and revised policy & regulations for sustainable forest management and water allocations.
Hospital for Sick Children	Applied Genomics: A national, integrated world-class facility for research into the genetic basis of disease. The Centre's 6 core facilities provide the infrastructure for comprehensive genomics research, and serves more than 400 principal investigators and their teams. At least 4 key people retained and 3 scientists attracted. Partnerships to date with 2 large international research facilities and two biotech companies.
Sunnybrook and Women's College Health Sciences Centre	Multidisciplinary breast cancer research: collaborations involved clinicians (medical and radiation oncologists, radiologists, surgeons), physicists and molecular biologists, pathologists and epidemiologists. CFI-funded infrastructure has retained one key scientist and attracted 3 others. Existing collaborations with two international firms for digital mammography. Several patent applications being prepared, and expect spin-offs within about 2 years, followed in longer-term by more effective therapy, earlier detection and mortality.
Waterloo University	IT Labs: Research projects in the areas of computing, networking, and communications, recruitment of 40 faculty members in IT over 2 years, partially because of CFI-funded infrastructure. Major collaborations with private sector. Applications include: human resource tools, better decisions re: how IT investment affects performance, security technology, better Internet services. Five patents filed, involving two collaborating firms, and 4 spin-offs began operations in 2001.

Exhibit 5.12—Examples of Social and Economic Applications from Infrastructure Supported by CFI*	
Host Institution	**Nature of Research and Application**
University of Western Ontario	Chemical Reactor Engineering: research will focus on environmentally-friendly products & processes, with 3 partner universities. Although not fully operational, a patent application for novel method of reforming methane, and CFI-funded infrastructure has allowed collaboration with 4 firms involved with an NSERC Industrial Chair in Nanomaterials, plus promotion of a local SME to investors, and assistance to a BC spin-off.
St. Joseph's Health Centre (London)	Imaging research: multidisciplinary collaborations in biochemistry, medical biophysics, kinesiology, neuroscience, paediatrics and child health. CFI-funded infrastructure has attracted 2 scientists from the US. One spin-off to date and one being considered. One US patent awarded, one disclosure, and other patent filings in Canada, EU, Japan, and 2 International Patent Co-operation Treaty filings. Existing application due to infrastructure includes multi slice X- ray CT; associated firm is presently shipping more than 200 of these units world-wide per year.

* The examples were randomly selected from a large number of projects that demonstrate potentially interesting applications. That any given institution or project is *not* included is no reflection of its success or importance. Note that all data are as of February/March, 2002.

In the evaluation case studies, respondents were asked whether any infrastructure supported by CFI had already led (or were likely to lead in the foreseeable future) to really significant social and/or economic benefits. Roughly 60% of department/faculty respondents indicated that there were such projects within their department (in this case, we asked about *all* infrastructure supported by CFI in the departments, not just those in the case studies)[39], and all but one institutional representative indicated likewise, often mentioning several projects in various faculties and departments. Thus the case study data confirm those from the progress reports. (The case study data are perhaps more conservative, although this may reflect a difference in how the questions were worded.)

That project leaders and institutions are already thinking about or actively pursuing exploitation opportunities is especially important: it indicates that CFI's selection process has succeeded in identifying applications which are likely to produce such benefits, and that award recipients and infrastructure users are taking seriously CFI's mandate to contribute to Canadian social and economic

[39] *Actually, 80% identified such projects, but one project was mentioned several times; we have adjusted for this.*

well-being. In our experience, neither can be taken for granted[40]. Here, however, there appears to be genuine acceptance in the community of the CFI "culture".

5.13.3 Applicability of Benefit/Cost Analysis to Infrastructure Supported by CFI

Benefit/cost (B/C) analysis is increasingly being used to estimate the economic benefits of science and technology (S&T) programs. A common methodology is "partial" B/C analysis, in which the net benefits of a few "big winner" projects[41] are compared to *total* program and partner costs. Is this methodology applicable to IF, URDF, and CRDF projects? We would say definitely "yes", but not yet. Certainly it will be applicable at some point: both the case studies and the progress reports show that many projects have impacts amenable to this type of analysis. However, many are still at a very early stage of development. We thus recommend that CFI hold off attempting any type of formal B/C analysis until several years have elapsed. Note that this by no means implies there will ***be*** no tangible social or economic benefits, only that it is currently impossible to reliably estimate their size. From the nature of information provided in the progress reports and case studies, we are very confident that a future B/C study of CFI programs will show positive results. Infrastructure projects supported by CFI show every sign of potential high returns that can be measured: (1) They were originally selected with an eye towards future exploitation; (2) Active exploitation and technology transfer efforts are already underway in many projects; (3) Many of the applications are in areas that will clearly result in substantial benefits; and (4) Through the progress reports, it will be moderately easy to identify a "first cut" of projects to investigate for B/C purposes.

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[40] *The Networks of Centres of Excellence (NCE) program, for example, has a similar goal with respect to practical applications. In the early days of NCE, however, it was common for researchers to think of grants as "business as usual" (i.e., focusing on pure research rather than applications). It was several years before changes in thinking began to appear. (We are not criticizing NCE particularly, as many other programs had similar problems, and the situation is certainly very different in NCE now.) See* NCE Interim Evaluation*, The ARA Consulting Group (now part of BearingPoint), February, 1993.*

[41] *"Big winners" are those with very large impacts that are clearly incremental (i.e., would not have happened without the program) and are mainly attributable to the program in question (i.e., as opposed to support from other sources). Ideally, one studies impacts that are easily measured in dollar terms, although some techniques are available for other types of benefits such as increased health and safety, better environment, etc. This technique works well because typically the lion's share of benefits arise from a small proportion of projects.*

6 FINDINGS ON PROGRAM DESIGN AND DELIVERY

6.1 Summary of Findings

The IF, URDF, and CRDF programs were well-designed and are well-delivered, with very few problems being reported in any area, including relationships with the granting councils. CFI has effectively fixed minor "start-up" problems identified in 1999. The most commonly-reported issue from the Canadian community was that of long-term support for operations and maintenance. There was insufficient data to say whether the "old" CRDF program was preferable to these awards being rolled into the IF. However, most institutions which had previously received an allocation under the URDF program preferred the older approach.

A review of international programs showed not only that CFI contains all elements considered important in other countries and programs, but also that it is very well-regarded by the international community, and even envied in some quarters. No significant gaps were identified by international sources.

Having said this, there is room for more encouragement to the social sciences and humanities to apply to CFI. There are also two important long-term strategic issues that should be addressed: (1) Maintaining long-term sustainability will require institutions to convince their provincial partners to supply matching funds, and institutions to find O&M support over the long-term; and (2) Pan-Canadian planning of facilities, research methodologies, and models relevant to entire research disciplines and/or cross-disciplinary communities, potentially co-ordinated with international bodies as appropriate. CFI already facilitates pan-Canadian planning to some extent, but a more active role is certainly feasible if done in conjunction with other relevant organizations such as NRC, research-performing federal and provincial agencies, etc.

6.2 Program Design

6.2.1 Overall

Overall, most respondents of all types considered these programs to be well-designed. The application process and review/selection processes were considered effective or very effective by about three-quarters of department/faculty respondents, virtually all institutional representatives, and 100% of MAC respondents. There was somewhat less enthusiasm for the reporting required of project leaders (about 25% of these respondents said this was ineffective or very ineffective; the institutions did not complain about this), but even here there were few serious complaints. There were no significant differences by fund. See Exhibit 6.1

6.2.2 The "Old" URDF and CRDF Programs

About three-quarters of institution respondents involved with URDF preferred the "old" program. There is insufficient data to tell for CRDF[42]. MAC representatives had the same opinion, although many did not know: of those few with an opinion, most preferred the "old" URDF.

6.3 Program Delivery

6.3.1 Researcher and Institutional Perspective

With respect to awards administration, communication and advice from CFI, and the quality of program guides and forms, the large majority of respondents of all types found these to be effective or very effective. See Exhibit 6.1. No serious problems were reported (although delays in obtaining final grant approval were mentioned by several people), and a number of respondents commented that the system was delivered very well, and mentioned the competence and helpfulness of program officials and staff. By fund, however, IF recipients were far more likely to be dissatisfied with the application process than the others: almost 40% of IF found this ineffective or very ineffective, compared to none of the URDF and CRDF recipients. This likely relates to the much more complex and lengthy process required to apply for large IF projects.

[42] *Two of the three individuals who responded about CRDF on this question, however, thought the new and old systems were about the same.*

Exhibit 6.1—Effectiveness of Program Design & Delivery

	% of Respondents Saying "Effective" or "Very Effective"		
	Department & Faculty Respondents	**Institutional Respondents**	**MAC Respondents**
Application process	74	89	100
Review & selection process	77	82	100
Reporting required of project leaders & institutions	56	78	Not asked
Award administration by CFI	68	92	Not asked
Communication and advice from CFI	74	96	93
Program guides, forms, etc.	91	96	100

> *The CFI program is well run, responsive to the community, efficient, flexible and accountable. [V-P Research, large institution]*

There were some complaints about reporting burden. A few people mentioned that reporting on progress for items such as economic growth or HQP was difficult (and therefore frustrating) in the first few years of infrastructure operation. A particular concern of institutions in Atlantic Canada was the differing requirements of CFI and ACOA with respect to reporting:

> *ACOA and CFI require separate annual reports with different dates; should be able to submit one report for both. [V-P Research, small institution]*

6.3.2 Changes Over Time

The results quoted above, while quite positive to begin with, appear to be an improvement over those from a 1999 study of CFI processes[43]. The earlier study found that program design and delivery were well-regarded in terms of the application and review process, award notification and administration, communications, and CFI staff competence and helpfulness. At the time, however, it was relatively common for researchers, institution representatives, and MAC members to request

[43] Canada Foundation for Innovation Process Improvement Study Summary. *The Impact Group, July 1999.*

more clarification regarding the details of how to properly complete applications and the nature of the review process, plus some concerns about the qualifications of MAC members, the adequacy of the review process, and attention to the needs of smaller institutions and colleges. In this evaluation, we received essentially no commentary about lack of clarity, while concerns related to the assessment process were muted (though still with emphasis on properly reviewing applications from smaller institutions). Thus it appears that CFI has responded effectively to concerns voiced very early in its lifetime.

> *In my opinion and also that of others in the Atlantic, generally the CFI is to be commended for being one of the most responsive and adaptive federally-sponsored institutions. Each change has addressed difficulties noted by [past] participants and has done so quite well [MAC member]*

We are in fact unaware of any S&T program employing peer review which does not receive occasional complaints about lack of reviewer qualifications and/or conflict of interest, the lack of time available for proper review, or the undue amount of work required to prepare applications. These are especially common for programs which employ reviewers outside academia. The findings for CFI compare very favourably to these other programs.

6.3.3 Granting Council Perspective

All the council respondents noted that there was excellent communication with CFI at the senior policy levels. CFI and the granting councils have been actively trying to coordinate certain aspects of their operations. For example, CFI has been working with the Tri-Council university monitoring activities (focused on financial probity), and sits as an observer on the steering committee for developing an MOU to lay out the responsibilities of the funding agencies versus the recipient institutions. At the individual council level, NSERC and CFI have discussed possible overlaps in Big Science initiatives (e.g., astronomy, particle physics, oceanography), and the possibility of conducting joint reviews in these areas. At CIHR, there has been excellent cooperation around the CIHR Distinguished Investigator Awards, for which CFI has agreed to allocate funds for associated infrastructure project awards.

Having said this, all respondents also agreed that more coordination is desirable (e.g., common CVs were mentioned, although work is already proceeding in this area[44]), and especially that there should be more communication at the program and program officer level. Currently there is little involvement of the councils in CFI review and approval processes, although it is unclear whether this is either desired or desirable. Finally, there was a suggestion that more CFI communication directed towards individual researcher needs was required:

[44] *A granting council respondent in another study commented that this alone was astonishingly difficult to coordinate.*

CFI's communications system, and the web-based project inventories in particular . . . are designed to address the interests of institutions and government decision-makers . . . It is impossible to find out who is involved in any given projects or what was actually purchased with the funds. Such information would be of great help to researchers seeking advice, exploring possibilities for collaboration and determining the eligibility of infrastructure items. [Council respondent]

6.4 Suggestions from the Community for Improvements to Design and Delivery

6.4.1 Minor Changes Suggested by Community

Relatively minor suggestions for change from the community were:

- More feedback on the review of applications;
- More lead time on Calls for Proposals, and additional time to the due date for applications'
- Better representation of colleges in the review committees;
- Better structure of the progress reports to account for impacts external to the host departments and/or host institutions, particularly for multi-partner projects;
- Integration of ACOA and CFI reporting requirements and timing;
- Less repetitive and more concise application forms (but no examples were given).

MAC representatives also made a few suggestions for improving the application and review process:

- More focus on requiring truly integrated institutional research plans, and better coaching to institutions on important application inputs.
- For the expert reviews: asking reviewers for a more consistent depth of review (perhaps through clearer instructions on what was expected, providing the reviews to MACs earlier in the process, giving more information to the MACs on the qualifications of the reviewers.
- Providing MACs with better explanation of how to grade applications (especially for high-risk projects)

6.4.2 Major Strategic Changes Suggested by Community

Roughly 40% of department/faculty representatives[45] and roughly 60% of institution and MAC respondents thought that CFI should consider some major changes for the remainder of its term through 2010. A wide variety of suggestions were made, including the following:

- Find a means to help support indirect costs such as O&M, including the human resources aspect and assistance to projects funded in earlier competitions to access the IOF. Some respondents specifically mentioned that these costs will be the responsibility of institutions once the term of the IOF ends. (This was the suggestion most frequently voiced by far. Implicit within this is continuation of the CFI program although this was specifically mentioned by only a few respondents, probably because 2010 still seems distant.)

- More focus on multi-institution collaborative applications, including those that serve regional and/or Canadian strategic needs and create synergies. (Of course, there is nothing to prevent the institutions themselves from more focus in this arena.)

- More focus on multidisciplinary applications.

- More focus on small institutions and those that have not historically had a research focus. (CFI already has made efforts here; no specific suggestions were made.)

- Additional coordination with other federal agencies and provincial organizations. (See section 5.12.2.)

- More focus on the social sciences, including the arts and humanities. (This might require some flexibility in how "research" is interpreted, since many facilities are also used for instruction.)

- More international activities, including more international review of applications.

Interestingly, only one respondent complained about the need to show socio-economic relevance in CFI applications (and one respondent actually asked for additional emphasis here!).

[45] *These mainly represented IF and URDF respondents; almost all CRDF recipients did not have an opinion.*

6.5 Perspectives from the Benchmarking Exercise

6.5.1 Introduction

A number of infrastructure support programs in other countries were reviewed[46]. The intent was to identify the nature of other programs, and to obtain outsiders' perspectives on gaps and opportunities for CFI and Canada. A general finding is that CFI's model is a good one that is highly-respected by foreign observers, and none of the individuals familiar with other schemes thought that CFI was missing any major opportunities[47].

Advantages of the CFI model compared to many others include: "one-stop shopping" for most major infrastructure and associated construction needs, across all disciplines and types of research, and hosted in a wide variety of organizations (many other countries have a bewildering array of programs, each focused on specific disciplines, sectors, targets, users, etc.); CFI has been set up with a relatively lengthy mandate (some other countries have a series of short-term programs, each somewhat different); the amount of CFI funding, both overall and per project, has been large (and even envied in some major countries), and there is no upper cap; and CFI supports the higher education and hospital research sector generally, as well as not-for-profit organizations (many other programs focus exclusively on universities).

Some common pressures facing Canada and the international community include: all countries reviewed are treating infrastructure investments as crucial to the conduct of internationally-competitive R&D; the equipment "sophistication factor" is increasingly important; many countries are formally or informally attempting to identify key national infrastructure priorities, which in turn requires collaboration on an unprecedented scale; all programs requiring matching funding from industry find that this is a difficult feature; there is increasing focus on the need to develop cyberinfrastructure, including development of grid computing, the capability to deal with very large databases (e.g., bioinformatics, astronomy), interoperability among systems, and high speed Internet access; operating and maintenance costs tend to be at issue everywhere; and a number of countries have found insufficient infrastructure being developed in the social sciences, including the arts and humanities.

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[46] *This was not intended to be a comprehensive review of* all *major infrastructure programs in, say, OECD countries. Because of the huge number of programs, this would be a difficult task, and indeed several other countries (e.g., US, Australia) have commissioned special studies simply to identify the programs and facilities in existence. Instead, our exercise was intended to illuminate mechanisms and pressures with broad applicability to Canada.*

[47] *Respondents were commenting on the entire portfolio of CFI programs, rather than only the three under review here. They were provided with background information on CFI policies and all CFI programs.*

6.6 Strategic Issues for the Future

It is worth repeating that the CFI model has no significant gaps, and has advantages compared to those in some other countries. Two significant items of strategic interest include the following:

Maintaining Sustainability. The issue of sustainability is clearly the most pressing one for CFI to address. This has several aspects. At the least, it concerns the ability of institutions to operate and maintain the infrastructure purchased through CFI, with or without explicit assistance from the program. More generally, it concerns the ability of institutions to convince their partners—and especially the provinces—to continue to provide matching funds to meet CFI awards. And at a global level, is concerns the basic philosophy of CFI *vis-à-vis* revitalization versus sustainability, put nicely by one of the granting council respondents:

> *One of the key issues with the IF is whether it: (1) Provides only for infrastructure that supports truly innovative new concepts and approaches; or (2) Should be a fund that provides for the acquisition and renewal of all types of research infrastructure, regardless of whether that infrastructure supports programs that are "new", so that it allows upgrades and renewals of infrastructure previously funded [and requiring] a redefinition of "innovation".. [Currently this] is left to the funding councils and institutions. This ambiguity places researchers and Councils in a difficult position. [Council respondent]*

Investigating Opportunities for Broader-Scale Infrastructure Planning. There is an opportunity for CFI to act more forcefully as a central node for development of national and international policy issues related to research infrastructure; i.e., to act in a more pan-Canadian manner. CFI already conducts some activities in this area, especially through its sponsorship of workshops on emerging areas of research such as high performance computing, genomics, population health, etc. Formalizing a larger strategic role could have several advantages—without in any way compromising its response-driven process. These include:

- Helping identify and support pan-Canadian research infrastructure needs (e.g. uni-, multi-, and cross-disciplinary facilities and; integrated networks of laboratories; and e-science initiatives.
- Better reacting to provincial S&T strategies.
- Helping manage the Canadian interface with international bodies addressing infrastructure needs.
- More proactively identifying and supporting development of technologies and research models that are applicable across a wide range of disciplines, including related support for development of the instrumentation industry, technician training, etc.

On the other hand, such activities would need to be put within the context of the CFI model, which has always been to require the applicant institutions and their partners to plan strategically for their infrastructure acquisitions, with a view to generating significant socio-economic returns for Canada. This is in marked contrast to the various "foresight" exercises and targeted programs adopted by some other countries.

Increase Involvement of the Social Sciences and Humanities (SSH). Information from both Canadian and international sources indicate that SSH fields increasingly require state-of-the-art infrastructure, and SSH researchers are more and more aware of how this infrastructure can benefit their work. It is fair to say that these opportunities are as yet poorly-understood, but potentially very important. However, many barriers remain to participation of SSH researchers in CFI. The Social Sciences and Humanities Research Council and CFI should continue to investigate ways to encourage involvement in CFI from researchers in the social sciences and humanities.

7 CONCLUSIONS

Overall, the programs have had marked positive impacts. There is every indication that these programs are meeting their objectives of building Canada's capacity for innovation, and thus improving Canada's economic and social well-being. These programs have had a major impact on the Canadian research environment at a time when they were highly-needed, and at a time when international interest in making similar infrastructure investments is exceptionally high. The programs have been outstandingly successful in levering matching funds from partner organizations, primarily the provinces (many of which have for the first time created infrastructure-specific funds), but also the institutions and—to a more limited extent—the private sector. There is every indication that ongoing need for infrastructure investment remains high, and may even increase as social sciences and humanities researchers begin to apply for more grants. .

A major initial impact of these programs has been to transform the quality of infrastructure. This is true in all host institutions, including the smaller universities and especially colleges. Access to this high-quality infrastructure has led to the hoped-for benefits in terms of innovative capacity through better and faster research, more multidisciplinarity and (to a somewhat lesser extent) more cross-disciplinarity, and more collaboration (nearly twice as much as before). In turn, access to the projects has facilitated creation of national and (especially) regional "knowledge clusters". The infrastructure and knowledge clusters have attracted many researchers, postdoctoral fellows, and students; many students are also trained on CFI-funded infrastructure.

Departments and faculties have also enjoyed indirect benefits, such as when their higher research profiles attract additional national and international research funding and partnerships. Similarly, the institutions have obtained benefits at the corporate level. There is particularly an increased visibility and reputation for smaller institutions that previously had little research profile, with consequent benefits through being better able to negotiate collaborative research projects and attract HQP.

The institutional research plans required by CFI applications have often been beneficial, in that they have helped departments and institutions co-ordinate their research strategies and infrastructure needs, and co-ordinate with the needs of external users (although larger universities often modified plans already in existence). In some cases, the plans have also assisted provinces in understanding

what their universities are doing, and in co-ordinating institutional and regional socio-economic priorities. However, some MAC representatives believe that institutions may nevertheless sometimes submit applications to CFI that are not central to these plans.

The projects appear to be effectively and efficiently used and shared both by internal departmental users and by external users (who take up about one-third of the available time) in other departments and institutions, or in government and industry. CFI has made an effort to ensure infrastructure is shared, and its records show that about a quarter of IF projects are shared among two or more institutions; appropriately, these tend to be the larger projects.

Overall, CFI is an important factor in helping change Canadian research culture, in that sharing, collaboration, and using innovation to achieve socio-economic benefits are fostered by these programs, and the community it serves appears to have accepted, and in some cases embraced, these goals[48]. The benchmarking exercise indicates that Canada is a leader in such efforts world-wide.

It proved impossible within this study to say whether CFI has created additional pressures on the grant programs of the granting councils (doing so would require a dedicated study). There are certainly some shifts in the number and type of applications the councils receive, but many reflect changes to modern research (e.g., increased multidisciplinarity, more reliance on equipment) that they, as well as CFI, are responding to. Researchers in the social sciences and humanities (SSH) are still not well-integrated into CFI. They have had to overcome some initial discouragement of SSH projects, they lack as much ability to obtain matching resources, and the institutions and researchers have less experience with large applications, especially collaborative ones. However, this is changing rapidly as SSH researchers come to understand the power of research infrastructure. While communication between the councils and CFI is excellent at the policy level, it could be improved at the program, project, and officer level.

Implementing the projects is often difficult. Problems range from difficulty finding sufficient matching funds (especially when there is a long time lag between preparing the application and project initiation, so that inflation and varying exchange rates affect costs), to finding HQP to operate the equipment, to covering the indirect costs of running large facilities, to obtaining adequate long-term operations and maintenance (O&M) funding. Although such problems are common to all infrastructure programs, the sheer size, complexity, and cutting-edge nature of many infrastructure supported by CFI considerably amplifies these difficulties; i.e., as opposed to any uniquely problematic features of CFI program design or delivery.

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[48] *It has been our corporate experience that such acceptance is far from a given in any S&T program, in that there is a natural inertia within the research community that resists change. CFI is the first major Canadian program that requires consideration of ultimate benefits to society when research infrastructure is being requested. (Of course, this criterion is sometimes used when special allocations are made to large, one-off facilities.) In fact, to our knowledge, it has some of the strongest such emphasis of any non-targeted program world-wide.*

There are concerns developing in some provinces in terms of the lack of provincial input to research infrastructure planning and decision-making. However, our interpretation is that these mainly represent problems of success, and that the provinces, together with their research institutions, could usefully take a more active role in strategic S&T planning prior to submitting applications to CFI.

Although it is far too early to attempt any formal economic analysis of the social and economic impacts of CFI for Canada (it is even too early to attempt bibliometric analysis of the impact on research productivity), every indication is that these projects will eventually be very significant in these areas. For example, almost two-thirds of the case study projects reported that highly-important impacts were likely to arise from their projects, and the progress reports clearly demonstrate active efforts either ongoing or planned for the future by project leaders and institutions to create such impacts. For example, many project leaders reported that the infrastructure has already led to results of interest to government and industry users, patents applied for and granted, spin-off companies formed, substantial Canadian and international collaborative agreements being signed, etc. Nor are industry users alone represented: many projects report active involvement of government users such as regulators, ministry program, health services, etc. Such a focus on longer-term impacts is by no means a given in S&T programs, and is a very positive sign for the future. Overall, in fact, there are many reasons to believe that the community has willingly embraced the "CFI culture", not only (of course) in terms of a focus on research excellence, but also in terms of sharing, collaborating, and using innovation to achieve socio-economic benefits.

CFI's program design and delivery are both very highly-rated by most respondents, and relatively minor problems identified earlier in CFI's lifetime appear to have been solved. A benchmarking comparison to other infrastructure programs world-wide indicates that CFI's model is very strong, and one that is viewed with envy in many quarters. Some features that are well-suited to the Canadian landscape include "one stop shopping" for all types of infrastructure, in all disciplines, coupled with a long-term (and large) funding commitment with relatively stable program regulations. On the other hand, by comparison with other countries Canada does not have nearly the emphasis on identifying and supporting either "deep infrastructure" such as e-science initiatives, or infrastructure centres that serve pan-Canadian needs either within individual disciplines or across disciplines, whether these are tied to socio-economic goals or strictly scientific ones. (This is not to say such planning does not occur; it is a common feature in Big Science disciplines such as astrophysics, and CFI has initiated some activities of this type already. However, it has not been done to as significant a degree for the more modest infrastructure that underpins many other disciplines, or for cross-cutting infrastructure).

A number of changes in approach are anticipated by department heads, deans, and V-Ps Research for the next funding rounds. These are primarily a tendency to prepare fewer applications for individual pieces of equipment, instead submitting fewer, but more expensive integrated proposals involving larger, more complex projects, often with more multidisciplinarity. Many will involve higher space requirements as well.

One of the more challenging aspects of CFI is its sustainability in the face of resource constraints. At the project and institutional level, the long-term availability of funding for O&M and other indirect costs is unclear. Although CFI now provides some O&M support through the IOF, this only applies to newer projects, and will lapse in 2005. Longer-term O&M funding must come from the institutions, or in many cases directly or indirectly from the provinces. The latter are far from certain that they can continue to provide these resources, much less to continue to match CFI awards at the levels that have been required to date. This is not to say that provinces think the investments are unnecessary, only that the awards have strained provincial budgets. In cases where CFI awards do not seem to closely mirror provincial priorities, the provinces may re-visit their commitments.

Thus in terms of major strategic considerations, there are three: : (1) Maintaining long-term sustainability will require institutions to convince their provincial partners to supply matching funds, and institutions to find O&M support over the long-term. This is the most important long-term strategic issue by far. (2) Additional opportunities for CFI to act as a catalyst for pan-Canadian strategic planning related to research infrastructure should be investigated, possibly including opportunities to act as "the Canadian voice" in these matters internationally. This needs to be put within the context of the CFI model, however, which has always been to require the applicant institutions and their partners to plan strategically for their infrastructure acquisitions, with a view to generating significant socio-economic returns for Canada. This is in contrast to the various "foresight" exercises and targeted programs adopted by some other countries. This allows research to take its course, while focusing the attention of project leaders and institutions on ultimate impacts. Any additional attention paid to such strategic planning would have to be within this "CFI context". (3) CFI and the Social Sciences and Humanities Research Council should continue to investigate ways to encourage involvement in CFI from researchers in the social sciences and humanities.