Analysis of reports on impacts and outcomes of infrastructure projects funded by the Canada Foundation for Innovation and other funding partners

Volume 2–Highlights by Fund

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1 Introduction

This analysis summarizes the information found in:

1. institutional reports submitted in February and March 2002 by 66 universities and other institutions; and
2. 796 project reports submitted by project leaders at the same time.

Reports cover infrastructure projects finalized by CFI before 31 December 2001 and for which expenditures occurred in 2001. Reports include information on outcomes that occurred in 2001. Approximately 300 other project leaders have informed CFI that they were not submitting a detailed report at this time because the infrastructure was not operational.

Many of the infrastructure projects involve the acquisition, construction, development and testing of complex facilities. Therefore, a significant number of reports (357 or 45%) relate to infrastructure that will not be fully operational until later in 2002, and much later in the case of major projects that involve construction and development.

2 Institutional reports[1]

Institutions were asked to submit brief reports (maximum 5 pages), in two parts:

1. To report on the impacts of CFI investments in achieving the objectives and priorities of the institution's research plans in the past year. In so doing, institutions were asked to keep in mind the following objectives of the CFI:

   > Building capacity for innovation;
   > Attracting and retaining high quality faculty, other researchers, and trainees;
   > Promoting collaborative and multidisciplinary research;
   > Promoting partnerships;
   > Ensuring optimal use of infrastructure; and
   > Generating social and economic benefits to Canada.

2. To report on any problems incurred in the implementation and utilization of the infrastructure and explain any significant delays or barriers in the implementation of infrastructure at the institution in the past year.

[1] Institutional reports are available on CFI's web site, www.innovation.ca.

The following analysis synthesises the 66 reports received by CFI by 30 April 2002. Reports were representative of eligible institutions in the sense that universities of all sizes, hospital research institutes and colleges submitted reports.

2.1 Impacts

Only a small number of institutions focussed on progress made in the implementation of their strategic plans. Most chose to highlight the impacts of the various projects by providing examples of outcomes under each of the aforementioned CFI objectives. This is understandable as it provides institutions with an opportunity to showcase their most successful projects. Indeed, CFI posts institutional reports on the web, but not project reports. On the other hand, it becomes difficult to analyze both institutional reports and project reports without becoming repetitive. Therefore, and since readers have the opportunity to consult institutional reports on the CFI website, the analysis of institutional reports will be brief and rather general in nature. Readers are advised to turn to individual institutional reports for specific examples of the major impact of CFI infrastructure on individual institutions.

There is no question that investment in infrastructure by CFI, provincial governments and other partners of the institutions has a major impact on research at Canadian institutions, particularly on:

- increasing the quality of research and research productivity
- attracting and retaining excellent faculty members
- transforming research
- fostering the development of partnerships with the provinces and others
- encouraging research planning
- generating enthusiasm in the research community
- attracting students and providing them with better training
- encouraging collaboration and multidisciplinary approaches
- generating concrete social, economic, health and environmental benefits
- increasing research funding.

The impacts are growing given the growing investment, of course, but also given that more and more projects are generating interesting results and that students who used the CFI infrastructure are now graduating and finding rewarding jobs.

2.1.1 Transforming research

The synergy between CFI infrastructure and other new programs that fund human resources such as Canada Research Chairs, the Canadian Institutes of Health Research and a plethora of provincial initiatives in some provinces, particularly Ontario, Québec and Alberta, is truly remarkable. This has completely transformed Canadian research, boosted morale, attracted individuals and increasingly made Canadians real partners in international collaborations:

> "We regard the CFI as the federal program that has contributed the most to Canada's innovation strategy for the 21st Century".

> "The investment of funds in priority research programs, complemented by the provision of adequate operating support through the granting councils and other sources, is helping to transform the landscape of the University and Canadian university-based research and innovation".

> "There is a major impact on the capacity to undertake innovative research, on research productivity and on the quality of research".

> "The presence of this new infrastructure has enabled and will continue to enable researchers to add new dimensions to their programs of research that were not previously possible".

> « Le financement de la recherche dans les domaines du Génie des tissus et des biofilms, des Dispositifs médicaux intelligents (DMI) ainsi que de la Bioperformance des dispositifs médicaux évolue rapidement vers un financement conjoint privé-public dans un marché international, qui ne sera accessible qu'à des institutions dotées d'infrastructures de haut calibre. »

2.1.2 Developing partnerships with the provinces

> "The University's research relationship with the provincial government has been strengthened significantly through their increased participation in project and proposal development. Joint planning with respect to research and economic development is taking place and newly acquired research infrastructure is being accessed by the provincial government both to inform policy development and as a means of stimulating development in growth sectors of the provincial economy".

"The number of partnerships created through this infrastructure is phenomenal. By providing partial funding, the structure of the CFI program requires that applicants seek out additional partnerships. [Universities in the province are] lucky that the provincial government became a partner early on, supporting our efforts by matching the CFI investment. The remaining contributions for the infrastructure come from a variety of sources, including the university, industrial partners, government, and not-for-profit sectors".

2.1.3 Research planning and infrastructure sharing

Not only did CFI encourage institutions to focus on their strengths, it encouraged them to pool resources and join in the development and sharing of infrastructure. This joint planning and sharing is evident across the country but above all in Canada's largest cities that have a number of universities, hospital research institutes and colleges. For example: BCIT/Simon Fraser and UBC in Vancouver; numerous universities and hospital institutes in Montreal; and, joint planning efforts between the University of Toronto and its many health research institutes. These are only examples; there are many more in these cities and elsewhere. In all regions, there is evidence of increased collaboration among institutions of all sizes and all types.

"The CFI program has brought about a new era in collaboration. Starting with the first CFI competition in 1997, institutions within the Greater Toronto Area began to work together to ensure that large-scale infrastructure would be shared and that there would be no unnecessary duplication. Looking back five years later, it is clear that the level of collaboration has evolved. In 1997, The Hospital for Sick Children, Mount Sinai Hospital and the University of Toronto put forward a successful application for mouse facilities. At that time, it was not considered possible to have a joint centre because of different policies and standards of animal care, and so three nodes were planned. However, by 2001, the Toronto hospital research institutes were so accustomed to collaboration and sharing of infrastructure that they planned a joint mouse housing and research centre, which was led by Mount Sinai and awarded in the January 2002 competition. That level of co-operation might not have happened without the opportunities provided by the CFI program".

"The philosophy of the Research Institute has been to use CFI funding to create specialized core facilities, a strategy that allows us to obtain the level of expertise needed to take full advantage of

this highly complex infrastructure. These core facilities support researchers [within our institution], within the [local] research community and across Canada, and so give the Canadian government the maximum impact for its investment".

"The development of the initial CFI Institutional Research Plan was beneficial, particularly in terms of focussing our research mandates to areas of importance to [the province] and Canada".

"Increased capacity has also positively affected our relationships with our health research partners".

2.1.4 Generating enthusiasm

"CFI investment brings a new synergy to the research environment, infuses researchers with enthusiasm, and adds a broadened perspective to the training of students and PDFs".

"There is a renewed sense of optimism and a feeling that a career in research is viable and rewarding, and that Canada harbours a most favourable and positive environment in which to pursue such a career".

"CFI investments have served to deepen relationships already in place as the research capabilities are enhanced through the establishment of new infrastructure".

"The enthusiasm and excitement felt across campus is palpable. Academics are attracting attention to their research, increasing not only national and international collaborations, but industrial contract research activity".

2.1.5 Attracting and retaining faculty members

CFI has an impact on attracting and retaining faculty members, graduate students and other trainees. The combination of Canada Research Chairs and CFI infrastructure is particularly powerful. It provides institutions with major development tools at the time when they are renewing their faculty complement.

"The combination of a Canada Research Chair and an associated CFI infrastructure grant has allowed [the University] to make some spectacular recruitments at both the senior and junior levels; in

addition, retention CRC's have also confirmed that infrastructure awards have been important to staying [here]".

"The access to CFI funds in combination with CRC awards also provides significant incentive for our established researchers not to leave the country because they are able to expand and/or upgrade their research infrastructure here".

« La majorité des projets financés ont contribué au recrutement et à la rétention de chercheurs de haut calibre et de nouveaux chercheurs des plus prometteurs. La disponibilité de nouvelles infrastructures de pointe a constitué un facteur d'attraction important. »

"A Professor from MIT resigned in favour of an appointment [here] which included [infrastructure] from CFI. This enabled access to world-class instrumentation... The CFI opportunity was a career-making event for this awardee".

"The research infrastructure acquired through CFI has provided [the institution] with up-to-date, unique research facilities and capabilities that have assisted NSAC in increasing its visibility as a research institution and has assisted in the recruitment and retention of personnel". (From a smaller institution.)

"It would be difficult to overstate the effect these successes have had, not only on the enhancement of Laurier's research capability in a wide range of areas, and on its ability to attract and retain talented researchers, but also on the morale of all members of the Laurier community". (From a smaller institution.)

2.1.6 Attracting students and providing them with better training

Some reports note that numbers of graduate students in high tech areas have increased in the last year, due in part to the private sector slowdown. These new students arrive at a time where morale is high and equipment is world-class in universities, thus increasing the breadth and quality of training and future employment prospects.

"New infrastructure is enabling training in high-tech areas where there is a recognized critical need for highly trained individuals. Many projects have seen students and postdoctoral fellows move on to top jobs in academe and industry. Another way in which these programs are helping the "best and the brightest" realize

their full potential is through exposure to industry. Top graduate students were once exposed to and primarily prepared for academic positions only. Now many are seeing how their research talents can be applied in the private sector."

2.1.7 Encouraging collaboration and multidisciplinary approaches

New intra-institutional collaborations are developing around shared infrastructure. This is particularly remarkable in institutions that have moved to a system of major shared facilities. Such facilities also assist in the effective management and use of infrastructure.

> "Opportunities for multi-disciplinary collaboration have become an important and exciting aspect of CFI funding. Developing relationships between researchers usually begins well before applications are conceived, but we have also observed useful and unexpected collaborations emerging as infrastructure becomes available".

> "CFI infrastructure helps transform the way research is done. It enables researchers to participate in international projects to which they would never have been invited before".

> "The CFI has provided the impetus for innovation not only in terms of research but also in terms of bold and creative collaborations".

> « Un autre élément important est le potentiel, la capacité acquise de participer à des projets majeurs, d'envergure nationale et internationale.»

Reports contain many examples of local, regional, national and international collaborations made possible with CFI-supported infrastructure.

2.1.8 Increasing the quality of research

Most institutions note the impact of CFI infrastructure on research productivity, mentioning that researchers are now able to add new dimensions to their programs of research and to conduct studies that were previously not possible. CFI enables greater depth and breadth of investigation, in addition to accelerating the research.

> "One very important but perhaps under-appreciated benefit has been mentioned by more than one researcher: access to world-

class infrastructure has allowed groups to take risks in research that would otherwise not be possible. Rather than be conservative, new directions are being explored, often with unanticipated yet remarkable results".

2.1.9 Generating benefits to Canada

Institutions report specific outcomes such as patents, licences, spin-off companies, environmental benefits, applications to public policies, etc.

> "Research that deals with issues such as genetic modification, environmental monitoring, disease modeling, and agricultural impact of new biotechnologies is now just starting to produce material for public policy researchers. There is a growing interest from public policy makers, social scientists and the general public in the new biotechnologies and their impact on human, animal, plant, and ecosystem health. The ongoing research at CFI-funded centres on campus is necessary if we are to understand the implications of these new biotechnologies".

> "CFI funding has *already* driven intellectual property development in diverse fields. In 2001, research supported by Project # X disclosed 15 inventions, with 5 patents filed and 4 licenses in negotiation. Members of Project #Y have been inventors on a total of 8 patent applications. Additional applications are now being assembled. In addition, the research supported by the infrastructure has acted as a catalyst to create one spin-off company. The company has grown in the past year from 20 to 60 employees and raised 40 million dollars in a private placement".

> "The close ties between basic research, clinical research and clinical practice … ensures that new scientific knowledge and discoveries translate into clinical care to help benefit children (and adults) across Canada and the world".

2.1.10 Increasing research funding

Finally, as was the case last year, all institutions, but especially smaller ones, are convinced that the new infrastructure has already had a major impact on the ability of researchers to obtain research funding from a variety of sources.

> "The infrastructure has been critical to our participation in various research networks such as GEOIDE, Sustainable Forest

Management and the Interfacial Chemical Engineering Cluster. It has allowed researchers to collaborate with faculty at a number of other institutions". (From a smaller institution.)

« Une des retombées les plus directes de ces nouvelles infrastructures est l'impact qu'elles ont eu sur la capacité des chercheurs qui en bénéficient à obtenir du financement de la part de partenaires industriels afin de supporter des projets de grande envergure et conséquemment à attirer de nouveaux étudiants et de nouveaux collaborateurs. » (Petite université.)

"The levels of research funding from national agencies [at the institution] since the implementation of the CFI infrastructure programs have increased impressively. For example, the annual revenue received from NSERC has increased [by more than 70% between] 1998-1999 and 2001-2002" (From a small university.)

"One of the most significant, and gratifying, developments that emerged in the case of [a] Laboratory, is the greatly increased level of private sector funding that has been contributed since the approval of the initial awards by CFI and the province". (From a College.)

2.2 Utilization and implementation

2.2.1 Delays

Most institutions report delays in infrastructure implementation for numerous reasons, from delays in obtaining final CFI approval, delays in securing matching funds, delays in obtaining approval from the province, backlog with construction projects on campus, lack of administrative resources, long regulatory approval process, lack of space and complex process to find adequate space, complex planning of complex projects, delays in delivery of equipment, defective equipment, changes in technology, etc. More details are provided in the analysis of project reports.

« Plusieurs projets financés dans le cadre des programmes de la FCI visaient notamment la rénovation ou la construction d'édifices ou de laboratoires de recherche. La mise en place de telles infrastructures exigeait beaucoup de temps et un travail soutenu des responsables de projets et des gestionnaires de la recherche, ainsi que la collaboration et la concertation de plusieurs intervenants. Certains délais au niveau de la réalisation des

travaux de construction ont parfois entraîné des retards en ce qui a trait à l'installation des infrastructures de recherche. »

"With the exception of the addition to [a] building, most of the major projects at the University are still in the implementation phase. The primary factor in length of time to implementation is that they involve substantial construction".

"The most frequent delays were associated with late arrival of equipment, as well as longer time frames than planned being required to acquire space and/or complete needed renovations."

In general, smaller projects generally face shorter delays, whereas delays of one year or more are not unusual for larger projects involving construction. Major construction projects take time even when there are no major delays.

2.2.2 Funding problems

In 2001, the change in government in British Columbia, which entailed a complete program review, delayed the approval of matching funding by several months. In Atlantic Canada, finding matching funding can be difficult:

"One problem we continue to have is that a number of our awards from the Innovation and New Opportunities Funds have not been able to be activated because of the lack of availability of matching funds. We now have projects that have been approved for over one year from the CFI, that we are still awaiting word on matching funds for through various federal and provincial government bodies. This has delayed a number of worthwhile projects and threatens our retention of well-qualified new researchers. The University is working hard with our provincial and federal partners to close this gap and we hope for success soon[2]".

Several universities mentioned that it has been a struggle to find operating funds and are happy that CFI will now contribute to funding these costs.

"While the funding for development of research infrastructure has been a major boost for research, it has been a struggle to fund the ongoing operating costs of these facilities; especially in the context of a small university with limited financial resources. For this

[2] At the time of writing this analysis (April 2002) there is renewed hope that a solution will be found shortly, with some provincial governments and the federal government developing mechanisms to overcome the issue.

reason, we applaud CFI's decision to provide funds for the operating costs of research facilities".

A number of universities mention cost overruns, particularly with respect to unforeseen expenses associated with construction projects. The additional resources had to be found, sometimes at the expense of other areas of the university:

> "One factor that emerged more than once was the need for additional essential infrastructure components that had not been anticipated in the original submission to CFI. These were items such as power upgrades to the buildings and/or air conditioning, which involved substantial additional cost. They were provided to the projects from institutional resources".

> « Les plus grandes difficultés rencontrées par… à cet égard relèvent du manque chronique d'espace, de la désuétude des équipements de services (climatisation, ventilation, etc.) et des procédures lourdes (appels d'offre, etc.) enrobant inévitablement la multiplication des projets de construction simultanés engendrés par les investissements FCI. La réalisation de ces derniers nécessite des réaménagements ingénieux mais longs et laborieux, ainsi que des investissements imprévus et considérables de plusieurs millions$. En fait, de tels bouleversements amènent même parfois une certaine opposition entre la fonction universitaire d'enseignement et celle de la recherche. »

> "With opportunities come challenges. Some delays are being experienced in major construction and renovations projects due to unforeseen changes, reconfiguration of projects and opportunities for construction partnership. In addition, in particular for round one projects, we have found that actual costs of construction and renovation projects far exceed original estimates. This escalation in cost has taxed institutional resources".

2.2.3 Infrastructure utilization and management

In general, institutions report that infrastructure is used adequately, with a small number of projects where infrastructure is being under-utilized and some where infrastructure is so heavily used that it cannot meet demand.

One university is organizing workshops to "advertise" under-utilized infrastructure to a broader community of potential users:

> "For those infrastructure projects funded before July 1, 2001, that do not have access to CFI Infrastructure Operating Funds, many report that finding sources to cover incremental operating expenses has been challenging. While many have found interim sources of funding, sustainability is uncertain. In addition, in some cases, the anticipated usage of certain facilities by potential users inside and outside UBC has been overestimated. Both of these issues and related topics will be discussed at an upcoming workshop that will involve principal investigators and co-applicants from CFI-funded projects. This session is meant to facilitate ideas that will lead to optimal use of infrastructure".

For the operation of large infrastructure, a management system is in place to ensure smooth operation and utilization.

A number of institutions, large and small, are strong proponents of shared, centralized facilities. They consider this the best means to ensure an efficient and economical use of complex infrastructure.

> "The modern technology needed to support internationally competitive research is often extremely complex and expensive. Not only is it impractical to have only one or two laboratories using complex infrastructure, but it is also not feasible operationally. Equipment such as mass spectrometers, for example, needs highly trained specialists to run them. Therefore, the philosophy has been to use CFI funding to create specialized core facilities, a strategy that allows us to obtain the level of expertise needed to take full advantage of this highly complex infrastructure".

3 New Opportunities

CFI recently commissioned an independent evaluation of this Program[3]. The project reports submitted by researchers benefiting from this Program confirm the results of this evaluation which relied in part on a survey of researchers: this program is timely, highly relevant and has a major impact on Canadian research.

[3] Hickling Arthurs Low, 2002. Final Report-New Opportunity Fund Evaluation (Available on CFI's website, www.innovation.ca).

In accordance with CFI's revised evaluation framework adopted in 2001[4], project reports submitted in 2002 consisted of two parts:

- a web-based survey that had many questions in common with those asked in the evaluation survey, and
- a narrative part where researchers described in their own words the results attributable to their CFI-infrastructure.

This analysis covers the 445 reports received by CFI by 30 April 2002. All these infrastructure projects had been finalized by CFI at the end of 2001 and they were paid totally or partially[5]. At reporting time (February 2002), a number of projects were not operational, were partially operational or had become operational very recently. Nevertheless, all responses are included in the analysis because some outcomes occur before the infrastructure is in place (e.g., attraction/retention, some collaboration).

3.1 Innovative research capability

3.1.1 Recruitment and retention of faculty

Researchers were asked whether the availability of the infrastructure had been an important factor over the past year in the decision of researchers (faculty members, PDFs and other researchers, but not students) to join the institution. Of the 445 responses, 286 answered yes, and 146 (33%) answered no. Note that the question concerns the past year only and "attraction" only, not retention of researchers.

The origin of the 861 researchers attracted to these projects is as follows:

Table 1–Origin of researchers attracted to Canada in the last year

Canada: 461 (54%)	US: 153 (18%)	Elsewhere: 247 (29%)
Academia: 759 (88%)	Industry: 54 (6%)	Public: 48 (6%)

Note that there may be double counting, as some researchers and postdocs are using more than one CFI-supported infrastructure. This note of caution applies to all totals mentioned in this analysis.

[4] Hickling Arthurs Low, 2001. Evaluation Framework for the Canada Foundation for Innovation.
[5] CFI awards totalling more than $400,000 are paid in instalments that can span several years depending on the complexity of the project. Smaller projects can also be paid in instalments if the forecast cash flow spans a period of time.

In the narrative part of their reports, researchers stressed the importance of the infrastructure in attracting and retaining faculty members, researchers and PDFs in Canadian institutions. The following citations are but a few examples of the enthusiasm of respondents:

> "The infrastructure that we have put in place as a result of funding from CFI and other partners has had a significant effect on our research capability. It has become a major part of our effort to recruit new faculty. In virtually every one of our academic recruitment competitions, the quality of the infrastructure has been a source of excitement… An important outcome is reflected in the success we have had in attracting our top ranked candidates to the University".

> "As an industrial engineer/applied mathematician, in making my decision to come [here], it was very important to have both experimental and computational facilities, to complement my analytical work. Now, after less than 2 years here, I have 7-8 graduate students (and increasing). This would not have happened anywhere else in the world I feel, and CFI has a large part to play in this".

> "The award of this infrastructure grant has been one of the most significant if not the most significant reason for the ability of our laboratory to attract first class researchers. Since the attainment of this award I have been able to recruit two excellent post-doctoral fellows and two graduate students".

> "In my travels around North America and Europe, I have not seen a facility which is better equipped than the one that this grant established".

> "The possibility of obtaining CFI funds was key in my decision to come back to Canada after completing my graduate and postdoctoral work in the United States".

> "The infrastructure has been a large part of why I have stayed in Canada to develop my research program".

> "I have seen how much more enticing the CFI is making our department–both in terms of the infrastructure already available through my lab and in terms of its potential to help new hires build up similar programmes".

"This award was instrumental in recruiting me… I had an offer from [a US university] (and have subsequently been re-offered the position). The facilities at the University were good, and interdisciplinary research was encouraged. However, the CFI New Opportunities award has allowed me to return to Canada and to initiate research which will pull together research teams from a broader range of disciplines than was available there".

« L'exode des meilleurs scientifiques vers les États-Unis est un désastre économique pour le Canada. Cependant, il est possible de lutter contre ce phénomène et notre centre de recherche le prouve avec le recrutement de chercheurs étrangers qui sont des autorités dans leurs domaines respectifs et le rapatriement des meilleurs étudiants. »

3.1.2 Recruitment of students

Project leaders were asked whether, in the past year, the infrastructure contributed to the recruitment of students from outside their institution. The answers to this question are summarized in Table 2. A vast majority of projects recruited students in the last year.

Table 2–Recruitment of students

Number of projects reporting students recruited from Canada (1021 students, 66%of total)				
1 student	2 students	3 students	>3 students	none
96 (22%)	66 (15%)	41 (9%)	96 (22%)	146 (33%)
Number of projects reporting students recruited from the US (51 students, 3% of total)				
1 student	2 students	3 students	>3 students	none
16 (4%)	7 (2%)	1	1	419 (94%)
Number of projects reporting students recruited from abroad (478 students, 31% of total)				
1 student	2 students	3 students	>3 students	none
82 (18%)	42 (9%)	19 (4%)	38 (9%)	264 (59%)

In general, project leaders are satisfied with the quality of the students they recruited:

"CFI investments have allowed the recruitment of the very best students (1 M.Sc. and 2 Ph.D.), who were attracted by the quality of the research and the installations… acquired directly with CFI funding".

> "All the graduate students working on this project have succeeded in obtaining funding (trainee stipends) from outside agencies".

On the other hand, a small number of New Opportunity researchers note that they were not successful in recruiting students:

> "The project is scheduled to be finished by March 2002. It is expected the project will be delayed by six months. The main reason for the delay is that I cannot recruit enough graduate students to do the research".

3.1.3 Recruitment of professional and technical staff

Project leaders were asked whether the infrastructure facilitated job creation in the past year. From the narrative part of the report, it is obvious that most respondents understood this to mean whether or not positions had been created in their laboratories (rather than the longer-term outcome of job creation attributable to application of their research results). Sixty-four percent of respondents mentioned that jobs were created thanks to the infrastructure (Table 3). They generally referred to the research assistants, research associates, technicians, postdocs and students who joined in the past year. Most project leaders mention that their group is still growing.

Table 3–Number of projects reporting influence of infrastructure on job creation

No influence	Some	Considerable	Total
153 (36%)	205 (48%)	69 (16%)	427

> "The infrastructure has also allowed me to recruit two research technicians with the future employment of a summer student and part-time technician starting in July of 2002".

> "With my research contract funding, I've specially hired (part-time) an expert technician (20 year experience) to help with the analytical load here".

> "The infrastructure has allowed me to recruit high quality Canadian and US research staff. As a specific example of this, over 50% of my students and PDFs are on scholarship support".

3.1.4 Access to world competitive infrastructure

For more than half the projects, more than 3 researchers (faculty, PDFs and other researchers) have substantially advanced their research in the past year because of the availability of the infrastructure (see Table 4). Of these researchers, 303 came from the private or public sectors.

Table 4–Researchers who advanced their research thanks to infrastructure

Number of projects reporting such researchers (2331 researchers in total)

1 researcher	2 researchers	3 researchers	>3 researchers	none
48 (8%)	63 (12%)	66 (12%)	228 (58%)	40 (10%)

Researchers think highly of the quality of their infrastructure, as shown in Table 5 and in the comments they make in their reports:

Table 5–Quality of infrastructure compared to other laboratories

Number of projects stating that the infrastructure is:

Below average	Average	Above average	Comparable to best in Canada	Comparable to best in the world	No answer
5 (1%)	49 (11%)	82 (19%)	170 (39%)	133 (30%)	6

"The CFI-funded plant genomics core has allowed us to maintain competitiveness with a major US lab with approximately 20 times the level of operational funding"

"Over the past year the infrastructure has allowed the development of a world class program… The infrastructure has allowed the group to participate in leading edge international programs."

"The set-up is unique in Canada and ranks among the most advanced of its kind in the world… A referee commented: The performance of [the] machine is comparable to similar machines recently built at Sandia and Berkeley".

"Over the past year the Orthopaedic Biomechanics Laboratory… has been revitalized to an international calibre research facility through the support of the Canada Foundation for Innovation".

3.1.5 Collaboration

A vast majority of respondents say that the presence of the CFI-supported infrastructure helped them to create, maintain or strengthen collaborations, particularly international collaborations (Table 6). In the narrative part of the reports, project leaders go on to describe many of these linkages.

Table 6–Influence of infrastructure on creating/maintaining/strengthening:

	Number of projects reporting:			
	None	Somewhat	Considerable	No answer
Informal linkages with colleagues at the institution	11 (4%)	85 (29%)	194 (67%)	155
Research collaborations	10 (3%)	102 (35%)	176 (61%)	157
Formal signed partnerships	145 (52%)	73 (26%)	61 (22%)	166
International collaborations	89 (20%)	203 (47%)	143 (33%)	10

> "The complementarities of the infrastructure purchased are also greatly facilitating interactions and collaboration between the new recruits as well as established scientists in the research institute".

> "The CFI-funded environment has created a novel interdisciplinary environment. Ongoing meetings located in this environment presently attract clinicians, mathematicians, physiologists, engineers and computational scientists. This is not only facilitating existing collaborations and research partnerships, but also building new ones".

> "Since this CFI-funded facility is jointly run, it naturally promotes collaboration between the labs. The lab is collaborating on a genomics project (made possible by the CFI infrastructure) with 3 laboratories worldwide".

> « L'infrastructure nous a permis de créer des collaborations entre les membres de notre département, de la faculté et avec des partenaires étrangers (France, Russie, Belgique, etc.). »

> "The infrastructure is an important asset for us when considering collaborations with other universities (including international) and with companies".

> "As a result of our infrastructure we have formed close ties with Stanford University (even to the extent of exchanging COOP students)."

> "The infrastructure has helped me build close research links with world competitive research infrastructure. A specific example of this is our ongoing collaboration and student exchange with the Biotechnology Process Engineering Centre at the Massachusetts Institute of Technology".

> "We collaborate with international groups from Japan, USA, Italy and Germany that are interested in pacemaker channels".

A number of researchers collaborate with equipment suppliers in the development of instrumentation:

> "The laboratory was recently chosen by [the equipment supplier] as a beta test site for new equipment applications due to the resident expertise in the use of the equipment and accompanying software".

A significant number of researchers report collaborations with companies, with the National Research Council and with other government laboratories.

> « Des collaborations avec le secteur privé ont été établies grâce à l'infrastructure. »

> "… a broad collaborative research agreement with the NRC's Industrial Materials Institute (IMI). This agreement covers IP sharing…"

> "There has been a translational aspect of the research being performed in these laboratories, with long-term collaborations with Biotech companies and the creation of one biotechnology company".

3.1.6 Creation of, or support for, centres of excellence

Numerous researchers have been invited to participate in Networks of Centres of Excellence and some of them have played a leading role in the development of winning proposals in the most recent competition. They state that this would not have been possible without the infrastructure:

> "The infrastructure has facilitated additional research, as part of NCE Auto21 program".

Other centres and networks are being created around the infrastructure, a significant number with provincial funding:

> "The current infrastructure has been seminal in allowing us to obtain collateral funding for a province-wide, cross-sector collaborative project funded by Valorisation-Recherche Québec".

> "The CFI research infrastructure which supports this research program has been important in assisting the creation of a New FCAR Centre (Regroupement stratégique)".

And, one CFI infrastructure often leads to another:

> "The co-applicants of this New Opportunity CFI were also co-applicants on a successful 2001 CFI Innovation Fund application to set-up a Centre for Advanced Materials Joining Research. The applicants' participation in this centre is based on the equipment and expertise they have developed with their CFI funding".

3.2 Innovative research productivity

Researchers who received funding in the first rounds of New Opportunities are starting to build impressive research records and a significant fraction state that the CFI-supported infrastructure helped them generate world-class results as shown in Table 7. In fact, two thirds of respondents (for whom it is not too early for results) estimate that their research is at or exceeds international standards:

Table 7–Self-assessment of the quality of research in the last year

Too early	Modest advance	National standards	International standards	Breakthrough	No answer
32	61 (15%)	74 (18%)	223 (55%)	51 (12%)	4

> "To my knowledge, my laboratory remains one of very few internationally that are tackling the problem of integrating virtual reality and functional magnetic resonance imaging".

> "The performance increase afforded by this workstation not only made our existing simulations run faster; more importantly, it allowed us to carry out new and more complex simulations than had previously been possible, which in turn led to our pioneering development and application of image-based, patient-specific modelling."

> “The facilities purchased with the infrastructure grant have already made a major contribution to our research output. These facilities have also enabled us to broaden our experimental approaches making our laboratory one with multidisciplinary capabilities.”

> “I believe that the infrastructure has truly been transformative in the sort of problems that we have been able to tackle”.

More recent researchers have recruited students and initiated collaborations in the last year, but they cannot yet state that their infrastructure has helped them generate innovative research results.

> “In Part B of this report I have indicated that the advances produced by this equipment are modest but useful. They are only modest because we are in the early stages of operation. I would expect, within the next two years, to produce advances… that at least meet international standards and in some cases are exceptional by these standards”.

> “The technology that we have established certainly ranks at a national level and is playing a major role in promoting our research program from a national level to an international level”.

One recurring comment is that the new infrastructure enables researchers to start their research program more quickly and to generate high quality results faster and more effectively than they would have otherwise:

> « L’obtention de cette infrastructure bien que récente a permis d’accélérer considérablement le rythme de nos recherches. »

> “Having this newly acquired infrastructure has greatly enhanced the quality of research that we can carry out in addition to allowing us to be more efficient in our data analysis.”

3.2.1 Publications and dissemination of results

In the narrative part of the report, some researchers chose to list the numerous publications and presentations that were generated with the help of CFI-funded infrastructure. Others stressed the high quality of their discoveries.

> “A number of these papers have had a significant impact on our field, indicated by the fact that our work has been covered in the National Post on two occasions this year”.

"CFI investments have allowed major advances in our research projects, and have directly contributed to our competitiveness by allowing us to innovate and produce high impact research studies".

"As a consequence of this increased productivity, our work is now recognized by the international scientific community in this field, as evidenced by invitations to International Conferences".

"The Infrastructure has enabled us to carry out truly world-leading research in advanced materials and systems. With the availability of the new tools, we have published a manuscript in a prestigious Applied Physics Letter. The paper has already generated tremendous interests worldwide including… press coverage from United Press International".

3.2.2 Level of risk of research undertaken

Researchers were invited to talk about the level of risk in the research undertaken. As seen in the following excerpts, respondents interpreted this question in various ways. There is also a difference in approach among respondents. Indeed, some researchers believe that taking risks early in their career could jeopardize future chances of research funding. Others are taking the gamble and saying that the infrastructure helped them in this regard as they could get better results faster.

«Nous ne pouvons pas prendre énormément de risques, spécialement dans mon cas puisque l'ouverture de mon laboratoire est récente. Un risque mal calculé pourrait entraîner la perte de subventions. »

"At this point, the research undertaken is of relatively low risk because we feel that our research program has a very high chance of success. We are the only researchers in Canada that have this type of equipment which provides us with an excellent opportunity in a relatively unexplored area."

« Les travaux de recherche en cours et futurs représentent un risque élevé du fait que les approches poursuivies… [sont] nouvelles et donc peu documentées. Toutefois, le risque de découvrir et d'améliorer nos hypothèses de recherche est très élevé. »

"The level of risk in our research is always higher than is usual in most aspects of biological science, as very few researchers around the world have access to the facilities required to carry out this kind of work".

« Les recherches entreprises par le moyen de l'infrastructure sont de niveaux de risque très variés. Dans certains cas, des hypothèses tout à fait novatrices sont testées, alors que d'autres projets consistent à appliquer des connaissances développées. »

3.2.3 Multidisciplinary nature of research activities

No less than 96% of respondents replied that the availability of the infrastructure had enhanced their opportunities for interdisciplinary research in the last year:

Table 8–Number of projects reporting that interdisciplinary research has been enhanced

No	Somewhat	Considerably
16 (4%)	176 (40%)	249 (56%)

"CFI has enabled this lab to be created and to recruit surgical, medical, nursing, psychology, psychiatry, pharmacy, clinical laboratory, emergency medicine and critical care professionals together, to focus on research in hand held computers in pain and many other disciplines within the hospital".

"The opportunity to solve health care problems through front line research at the bedside is an opportunity which is not readily available for technical, computer and business professionals and students. Your funding has made this possible".

"The infrastructure is being used for multidisciplinary work. The laboratories employ cell biological, biochemical, and molecular biology techniques in their studies on interaction of pathogenic bacteria with human host cells".

"The project has benefited greatly from interactions of various highly qualified personnel with backgrounds in electrical engineering, chemistry, and physics".

"Much of this research is intrinsically multi-disciplinary as those carrying it out must wed expertise in one or more fields of study

with techniques of high performance computation. In addition, the computational challenges and solutions that are often common to different research areas encouraged cross talk among the researchers, and more efficient approaches to the research being undertaken often emerged".

3.3 Nature and relevance of training for research and other careers

Very large numbers of students at all levels utilize the infrastructure, as shown in Table 9. They are trained in a multidisciplinary environment and researchers are convinced that they are gaining skills that will help them find employment.

Table 9–Students using the infrastructure

	Number of projects with no student	Projects with 1 student	Projects with 2 students	Projects with 3 students	Projects with >3 students
Undergraduate (total 1906)	121 (27%)	54 (12%)	73 (16%)	57 (13%)	140(31%)
Masters (total 1752)	68 (15%)	72 (16%)	80 (18%)	62 (14%)	163 (37%)
Doctoral (total 1143)	116 (26%)	87 (10%)	91 (20%)	53 (12%)	98 (22%)

3.3.1 Multidisciplinary nature of training

"Because of the cross-discipline nature of the collaborations fostered by the CFI infrastructure, cross-disciplinary training is becoming a reality. The infrastructure facilitates our collaborations with industry, and this provides the students with more industrially relevant training and contacts".

"The research performed is highly multidisciplinary, and the students are trained not only in basic electronics and electrical engineering, but also in electrophysiology and medicine".

"The students work in a strongly collaborative multidisciplinary environment. They travel frequently to our partners in Edmonton and abroad".

"The training received by HQP using the CFI infrastructure spans the disciplines of chemistry, geosciences and biology. This breadth is essential if complex environmental problems facing Canada in the future are to be understood and managed effectively".

"Our work, facilitated by the infrastructure, provides training in applications of physics and engineering to the life sciences".

"The training of students, postdocs and other HQP in the [lab] has given them the opportunity to work constantly across a variety of disciplines. Thus, for example, students of linguistics have been learning to work with disordered speakers, while electrical engineers learn to consider linguistic theory in their modelling of speech for synthesis. This has provided students with a breadth of training and understanding that will enable them to access a much broader range of employment in the future".

"The laboratory has provided a strong environment in which fellows, residents and engineering students have collaborated on clinically focused experimental bioengineering projects".

3.3.2 Collaborative, international, and cross-sector nature of training

« Les travaux effectués par les étudiants du groupe d'assainissement constituent une excellente opportunité pour ceux-ci de créer des liens étroits avec nos partenaires privés. »

3.3.3 Employability or employment of graduates

Researchers are proud of the employment record of their graduating students. Only a handful mentioned that their students had spent some time looking for work. A number note that graduating students choose to continue their studies abroad or find employment abroad.

"All of my students have jobs even before they finish. There is an open door with Environment Canada in their group working on standards and regulation as well as at Health Canada in their group working on pesticide regulation as well as in food inspection. The students are also pursued for positions in industry and academia".

"Despite the current tight economic situation in North America all of the graduate students that have completed their degree under the supervision of the project investigators have been employed at leading companies in Canada. These companies include Nortel Networks, IBM Canada and General Electric".

“We have delivered highly qualified personnel for Canadian industries. Our research is industrial oriented and our students are well received by industry. In the last year alone, one PDF and two graduate students from this group, who had used the infrastructure, were employed by Alberta industries”.

“One of our students has started a spin-off company …which now has several employees of its own”.

“A former graduate student … has been awarded the Martin Walmsley Fellowship for Technological Entrepreneurship by the Ontario Centres of Excellence… The goal of this fellowship and [his] objectives are to establish a commercial enterprise based in part on the research he completed as part of his thesis… To this end [he] has incorporated a spin-off company to pursue commercialization of the technology”.

“Placement of our graduates in their field is maintained at 100%”.

« Une de mes étudiantes à la Maîtrise a trouvé un poste dans une entreprise de biotechnologies. »

“The infrastructure helped train a significant number of graduate and undergraduate students who currently contribute as employees in the Canadian high technology industry. It is safe to say that more than 70% of our graduate students stay in Canada after graduation”.

« Tous les étudiants formés au laboratoire ont trouvé un emploi dans l'industrie canadienne œuvrant dans le domaine des communications et composants à fibre optique, sauf un étudiant qui travaille maintenant aux États-Unis. »

“The students who graduated are all presently employed by major companies in Canada, the USA, and in Europe”.

“The infrastructure has directly provided training for two bioinformaticists. They both have obtained lucrative positions in the United States, one in Philadelphia and in Denver. All the graduate students trained in the infrastructure have secured positions before they left us”.

“Each of my graduate students and former employees were employed almost immediately (current titles: head of research for a

Canadian company, graduate student, PDF, assistant professor, research coordinator, physician)".

"Two students graduated in the last year. Unfortunately, both have relocated to the U.S., one to a biotechnology company in New Jersey, and one to do further training at the Massachusetts Institute of Technology".

"Although it is difficult to assess the contributions that CFI infrastructure has made to the careers of people who have recently left my lab, several have gone on to excellent positions… It is clear from the latter two cases that even though we in Canada train excellent, globally competitive personnel, the best students are still lured away to other countries in an effort to raise their career profiles".

3.4 Economic and Social Benefits

Table 10 indicates the number of projects reporting various types of benefits enabled by the infrastructure in the last year.

Table 10–Benefits[6] enabled by the availability of the infrastructure

	# of projects reporting no benefits	# of projects reporting some benefits	# of projects with considerable benefits	No answer
Intellectual property	276 (64%)	97 (23%)	56 (13%)	16
Knowledge clusters	79 (18%)	182 (42%)	169 (39%)	15
Products and services	228 (53%)	135 (32%)	65 (15%)	17
Spin-off companies	372 (88%)	35 (8%)	14 (3%)	17
Cost savings	193 (45%)	171 (40%)	61 (14%)	20
Public policy improvements	354 (84%)	59 (14%)	7 (2%)	25
Health benefits	262 (61%)	138 (32%)	28 (7%)	17
Social benefits	342 (82%)	72 (17%)	5 (1%)	26
Environmental benefits	305 (72%)	88 (21%)	29 (7%)	23

[6] Numbers may appear high in this table. In reading the reports, it is obvious that a number of respondents mentioned benefits generated since the infrastructure first became operational as well as benefits that are likely to occur in the near future. One must also remember that the table refers to number of projects. Researchers report the same benefits in all the projects in which they are involved.

In the narrative part of their reports, researchers were not asked specifically to describe the knowledge clusters that were enabled with their CFI awards. However, as noted above, a significant number of researchers discuss their participation in various centres and networks and virtually all of them describe local, national and international collaborations.

Other outcomes are summarized below.

3.4.1 Intellectual property

Among the 153 projects that mention intellectual property, most report patents (applied for and granted), some mention software, others licences.

> "Over the last year, my lab has filed three provisional patents. Two of the patents were based on the research results by one of my graduate students and the other one by one of my PDFs".

> "The many collaborations by the applicants have translated into several patent applications on their own or in collaboration with other groups, for a total of 6 patent applications".

> "Since these groups are conducting basic scientific research, short-term benefits are very intangible. Yet in the short time since the project has begun [the] lab has filed a patent."

> "In collaboration with …[a] biotech company, a protected technology originally optimized using the CFI-funded [infrastructure] is now being developed for commercial release".

> "Two patents (one issued, one pending) were developed, and one software copyright".

> « Une licence a été octroyée pour l'exploitation de cette technologie à une compagnie en démarrage de la région. »

3.4.2 New/improved products, processes, or services

Two hundred projects mention that the infrastructure helped them with the development of new or improved products, processes or services. Interesting examples follow.

> "Improvements have been generated in chemical manufacturing processes that will lead to cleaner and more efficient

manufacturing technologies, at both the synthetic and the process control levels".

« Plusieurs compagnies (Sorentec, EPS, QMP) ont pu profiter des résultats de ces études pour poursuivre le développement de leurs produits (moteurs électriques, matériaux magnétiques). »

« Les travaux… sur l'étude de l'interaction procédé-qualité des aliments déshydratés ont contribué au développement et à l'amélioration des nouvelles technologies alimentaires de conservation visant à réduire les coûts, tout en maintenant ou augmentant la qualité des produits. »

"The facility has also benefited the private sector. Over the past year, the unit has conducted testing for a number of companies that require environmental testing of their products for prototyping, product development, and regulatory requirements".

"The facilities are being applied for product design to facilitate the design of automotive components using an injection molding process and for the development of products for positioning and on-line compensation of errors in precision manufacturing and assembly operations in the electronics industry".

"Experimental research findings… have already been translated to the improvement of products being used in fracture fixation applications… The recommendations supported by our research findings are changing the product at the manufacturing level throughout North America".

3.4.3 Creation of spin-off companies

We saw in Table 10 that the infrastructure had an influence on the creation of spin-off companies in 49 projects. A few examples follow:

"[The principal investigator] is also in the process of establishing a new biotech venture with two other scientists from the University, under the guidance of the Innovation Foundation and UTech Services".

"From CFI funded infrastructure a new concept in making extremely precise patterns of light with sufficient intensity to "machine" materials from the inside-out using light with materials that would be transparent at low laser peak powers. This approach

uses diffractive optics in combination with high peak power femtosecond laser pulses (patent awarded 2001). A spin-off company has been started to exploit this technology for fabrication of telecommunication components. This invention is also expected to have a significant impact in medicine for laser-based surgery".

"A recent example of spin-off applications of the industrial plasma research is the Edmonton nano-technology company Aurora who are marketing a product that uses laser plasma deposition to calibrate scanning electron microscopes. The work in space weather forecasting has led to an application to the technology transfer program in Alberta".

"In collaboration with the University of Guelph, several of my colleagues at McMaster and myself are establishing a company for the development of immunotherapies for friendly animals (cats, dogs, horses). The equipment acquired through my New Opportunities award will be critical for the development of the non-viral therapeutic component of this new venture".

"This work has led to the filing of two provisional patents and the establishment of a new spin-off company: ZonaGen Inc".

"Through our gene discovery project, we formed NeuroStasis Inc. in collaboration with [another researcher]. This year, we employed one person outside of the laboratory, a business manager, who will oversee the growth of the company. Additionally, last year, NeuroStasis hired 8 scientists on either a full or part time basis".

"As a specific example, research from my laboratory was instrumental in the forming of a new company ("CellWorks Inc.) and in the support of a small Canadian biotechnology company (BoneTec Inc.)".

3.4.4 Policy improvements, social benefits and health improvements

As shown in Table 10, a substantial number of researchers believe that their research will ultimately lead to health improvements, policy improvements and social benefits and that the infrastructure will play a role in these outcomes. However, in these areas, the time lag between the actual research and the outcomes is longer than in the "high tech" area (including information technology, advanced materials and biotechnology) where patents, spin-offs and process improvements can occur in a relatively short time frame.

"We demonstrated to both researchers and practitioners how one can use a virtual collaboratory to conduct knowledge studies to enhance decision making in the workplace. We were able to bring together practitioners, policy makers and researchers in the virtual collaboratory to work through complex knowledge resources to make sense of the knowledge within the local settings".

"Advances have been made in the area of real-time identification of high-risk freeway traffic conditions. Traffic flow, weather, and collision data from a 10-km section of the Gardiner Expressway in Toronto were compiled for a 13-month period. Statistical models were developed to identify traffic flow conditions that are significant in predicting the occurrence of crashes. This research is the first step in developing a real-time roadway safety management system - an important step to pro-actively monitor the roadway to reduce the frequency of crashes on freeways".

"Several of the scientists from the molecular genetics program have been heavily involved in establishing the policies and procedures for stem cell research in Canada".

"Advancement of our understanding in this area could lead directly to the development of more cost-effective therapies for the successful management of infertility".

"We are also developing programs with indigenous people who are now realizing that there are high levels of mercury in the fish that they eat. We are doing analysis and developing joint programs with them to try to reduce the mercury consumption in their diet".

"The infrastructure helped immensely in developing technology that can be very helpful for improving the health of Canadians, particularly in combating functional gastrointestinal disorders like gastroparesis and chronic idiopathic constipation".

3.4.5 Environmental improvements

« D'autre part, les travaux en assainissement ont permis de développer, au cours des dernières années, divers procédés de décontamination permettant d'enlever les métaux potentiellement toxiques à partir de diverses matrices polluées (boues municipales et industrielles, cendres volantes, sols et sédiments, etc.). Ces

technologies sont présentement en cours de commercialisation par nos partenaires privés. »

« Les impacts prévus de l'infrastructure de recherche sur la société se feront sentir au niveau d'une meilleure gestion de nos ressources naturelles (principalement l'eau), d'un environnement plus sain et d'une qualité de vie supérieure des Canadiens. »

"Work… promises to modify current forest resource management planning procedures, with novel and more effective ways to incorporate public attitudes and perceptions into scientific resource management. This is providing unparalleled learning opportunities for students, faculty, and researchers".

"The research in the areas of nuclear waste disposal and pipeline corrosion has significant environmental and economic benefits to Canada".

"Much of our recent work is on mercury and how it moves through the ecosystem".

"Many innovative research programs have already been accomplished and several more are anticipated because of the acquired infrastructure. My research lab group is at the international 'cutting edge' of climate change and land-use change research in wetland ecosystems.

"The knowledge gained from this research is applied to both public and private sector ecosystem restoration and mitigation - promoting university-industry partnerships. I am now working with a consortium of peat horticultural companies on a long-term ecosystem restoration project to enhance carbon sequestration in restored wetlands. Also through collaboration with researchers at the National Water Research Institute we plan to provide best management practices to ensure that temperate wetlands and riparian areas remain net green-house gases sinks."

3.4.6 Cost savings

With a few exceptions, the question on cost savings was interpreted not as long-term cost savings to the Canadian economy thanks to project outcomes (e.g., saving in health, education or correctional costs), but cost savings in the labs, due to the fact that the research is more effective and efficient.

> "Much of the research conducted in my laboratory would be prohibitively expensive. However, the CFI-funded plant genomics core has reduced the cost of using display technologies and DNA sequencing by almost 10-fold".

> "By providing centralized research support, the infrastructure has been extremely valuable to researchers in saving time and costs of research. This is evident from the number of users of the infrastructure. We expect the use of the infrastructure will grow dramatically in the coming year as we become better known and are able to provide additional support".

But cost savings attributable to research outcomes are starting to occur:

> "We have developed a novel way of removing mercury from coal prior to combustion that will save the generating industry millions of dollars. We are working with this industry and with Environment Canada as well as Petroleum Producers to come to terms with mercury contamination of the environment. The health of people is an obvious benefit (particularly first nations people who eat a lot of fish). Currently, most large fish from most lakes in Canada exceed human consumption guidelines for mercury consumption".

3.5 Awards, recognition (international, domestic)

The leverage effect of CFI infrastructure is impressive. Respondents are convinced that the infrastructure has helped them increase their funding. Most impressive is the influence of the infrastructure on federal granting agency funding, provincial funding and industry funding. Respondents also mention prizes and awards and invitations to prestigious international conferences.

Table 11–Impact of the infrastructure on the ability of its users to attract funds				
Funding source	# of projects with no CFI influence	# of projects with some CFI influence	# of projects with considerable CFI influence	No answer
Institution	140 (33%)	175 (42%)	105 (25%)	25
Federal granting agencies	65 (15%)	129(30%)	237 (55%)	14
Other federal	210 (54%)	93 (24%)	83 (22%)	59
Provincial government	110 (27%)	120(29%)	184(44%)	31
Canadian industry	195(48%)	118 (29%)	97 (24%)	35
International	211 (53%)	113 (29%)	72 (18%)	49

An impressive number of New Opportunity Researchers have subsequently been awarded Canada Research Chairs.

> "I was a recipient in 2001 of a junior Canada Research Chair. I attribute success in this award to early research productivity as an independent researcher and believe that my CFI New Opportunity award played an important part in that research productivity".
>
> "I have recently been awarded a CIHR/Rx&D HRF Career Scientist award. This prestigious award is only given to 2 Canadian scientists per year".
>
> "I have also received the Premier's Research Excellence Award, which grants monies for salary support for trainees".
>
> "The infrastructure provided by the CFI award was a major factor in securing an Industrial Research Chair co-funded by NSERC and Ontario Power Generation".
>
> "One cannot over emphasize the tremendous impact the CFI infrastructure has already had on research funding… [XX] was successful in five out of five grant competitions".
>
> "As a direct result of the access to this infrastructure, our Centre has faired extremely well in the latest rounds of CIHR competition: 4 out of 5 grants submitted by our new faculty have been approved and each with an annual budget of well over $100,000/year. Success breeds success and our original CFI award has been the catalyst".

"The MRC (CIHR) grant has now been renewed (this time ranked 2nd in the competition) for a five year period and at twice the operating budget of the original grant".

"Since obtaining the CFI/ORDCF and matching University funding in 1999, over $3 million dollars in funding has been directly or indirectly obtained by myself".

"An NSERC Strategic grant project ... would not have been possible without the infrastructure obtained through the CFI".

"The existence of this infrastructure was undoubtedly beneficial in helping me, along with a collaborator, win a 5-year grant from the US Defense Advanced Research Projects Agency which is expected to exceed US $1,000,000".

"I believe that the doubling of our NSERC Research Grant during the last funding cycle was also in large part due to what we were able to accomplish with this infrastructure".

"We have major collaborations with scientists in the United States funded at >$4 million to conduct the research that our infrastructure makes possible. In addition, we have $3 million in research support for research in Canada funded by a diversity of industrial, government, and non-profit organizations".

« Toutes ces activités ont fait l'objet de nombreux prix, dont celui du *Best Paper Award 2000* de l'*American Society for Engineering Education*, ainsi que le prix Projet par Excellence 2000 de Forces et Avenir. »

3.6 Public dissemination of research outcomes

A number of researchers mention that their research has been featured in various media in the past year:

"Magazines: McLean's Magazine, University of Toronto, Applied Science & Engineering, Skulematters. Newspapers: Boston Globe, Rochester News, University of Toronto Bulletin, The Catholic Registrar, The Globe and Mail. Television: Research work discussed during World News with Peter Jennings, CBC National News".

"The laboratory has hosted visits from many media sources (the Discovery Channel, Space Channel, City TV, CTV, The Toronto Star, The Globe and Mail, etc.), a regional MP, as well as the "Science behind the headlines" class from Humber College".

"Our work has drawn public attention to the issue of global transport and fate of persistent chemicals like PCBs and organochlorine pesticides. Studies of this kind provide a scientific basis for global efforts to restrict or reduce the production and use of organochlorine substances. Our research has been featured on the radio programs As It Happens, Quirks and Quarks, and D'un soleil à l'autre. There was a full-page feature called 'Rocky Mountain Blight' in the Globe and Mail in October, 1998, and other features since then in the Ottawa Citizen, Le Droit and Canadian Geographic. Globally, our research has been featured on CNN, the ABC News web page, Le Figaro (a national newspaper in France), Chemical and Engineering News (The American Chemical Society's news magazine), Swiss Radio, and Biotech Focus, among others".

3.7 Efficient management, use and sharing of infrastructure

In the narrative part of their reports, researchers describe measures taken to ensure the efficient management, use and sharing of the infrastructure. In the quantitative part of the report, they were asked to comment about delays and to discuss whether or not the infrastructure was adequately utilized.

3.7.1 Delays

About half the projects experienced delays of some sort, most of them minor, some major. Major delays have been discussed with CFI.

Reasons for delays include: long delay before award finalization, long delay before the province came up with matching funding, time required to secure industrial matching funding, long delay before a government department provided its in-kind contribution, time required to secure adequate space, delays in delivery, defective components, longer than anticipated implementation, construction and renovation delays, lack of personnel, delay in training personnel to operate the infrastructure, etc.

This long list looks like a disaster story, but as shown from the impressive list of outcomes, most of these delays were overcome and the infrastructure is now up and running (except for more recent projects).

3.7.2 Infrastructure Utilization

Researchers are very satisfied with the quality of their infrastructure, as shown in Table 5 (above), with 88% of respondents stating that their infrastructure was above average, comparable to the best in Canada or comparable to the best in the world.

With respect to utilization, 89% say that their infrastructure is used appropriately or is oversubscribed.

Table 12–Utilization of infrastructure

Under-utilized	Adequate	Over-subscribed	No answer
47 (11%)	335 (77%)	54 (12%)	9

Of the 47 who say that the infrastructure is under-utilized, 43 note that the infrastructure is not operational or not fully operational. The 4 others give the following reasons for under-utilization:

- lack of technical support and low NSERC funding;
- lack of human resources to operate the equipment;
- reluctance of researchers to pay user fees;
- experiments need to be completed before the infrastructure can be used, and these experiments are time consuming.

Some respondents who state that their infrastructure is used adequately hint at under-utilization in the narrative part of the report. They generally say that they expect that use will increase in the next year because their group is growing or that they hope that they will find the necessary human or financial resources to enlarge their group. Some new researchers would like to have more graduate students. The barrier is not necessarily lack of funds, but lack of students, given that their laboratory is relatively new.

3.7.3 Management of the infrastructure

Smaller infrastructure is managed by the principal investigator(s) and shared on an informal basis. More complex facilities are managed more formally.

If there are problems, they are due to lack of personnel to operate, maintain and repair the infrastructure. This is due to lack of resources for technical personnel (due to the fact that the university has no money or the researchers have insufficient research funding) or to shortages of qualified people to run

sophisticated equipment. The creation of the CFI Infrastructure Operating Fund will help in this regard, but does not apply to infrastructure projects approved before mid-2001.

> "The infrastructure continues to be well maintained and managed through a combination of the efforts of the three post-doctoral fellows on site and the project leader. However, the longer term technical staffing of the infrastructure is an area of on-going concern".
>
> "A manager oversees the day-to-day operation of the infrastructure. The manager is responsible to the scientific director and the scientific committee".
>
> "We have found in the past that shared facilities within the Centre help to maximize use and minimize waste of equipment. This has been borne out with the current infrastructure which has been utilized by virtually all of the >50 personnel".
>
> « Il convient de souligner l'articulation parfaite de l'infrastructure en question avec le reste de l'infrastructure technologique du Centre de recherche... et de l'Université… [cryostats, centrifugeuses, systèmes de microscopie confocale et d'imagerie, PCR en temps réel]. Cette intégration/complémentarité souligne l'excellence de la planification du développement technologique au niveau institutionnel…»
>
> "The infrastructure items are in high demand and are in constant use. It is fairly typical in Canadian academic science that individual labs share their specific infrastructure items and generally, high quality pieces of equipment are widely used around the campus".
>
> "One important limitation has been for maintenance of the CFI equipment. At the time I received the award there was no provision for funds for maintenance and upgrade".
>
> "The lack of matching operational funds to support a fulltime laboratory technician to operate and supervise a particular component of the infrastructure (GC\MS - $120,000) has caused that piece of equipment to be seriously under-utilized".
>
> « La difficulté majeure réside dans le fait que mes étudiants ont été principalement impliqués dans la gestion quotidienne (mesures, calibrage, etc.) de l'infrastructure. Avec la demande croissante des gens, une solution acceptable serait l'engagement

d'un technicien ou d'un ingénieur junior pour prendre en charge ces travaux [ce qui mènerait à un] avancement plus rapide des travaux de recherche des étudiants. »

4 Canada Research Chairs Infrastructure Fund

Holders of Canada Research Chairs have the opportunity to apply to CFI for infrastructure to support their research program. The Canada Research Chairs Program being fairly recent (first Chairs announced in late 2000), only a small number of Chairs are reporting research outcomes that can be attributed to their new CFI infrastructure. As mentioned in other sections of this analysis, a significant proportion of Canada Research Chairs were already benefiting from CFI infrastructure thanks to the New Opportunities, Innovation and Research Development Funds.

As of 30 April 2002, CFI had received 43 "quantitative" reports from Chairs, many incomplete, given that the infrastructure is not operational. Of the 43 projects reporting, only 8 were fully operational at the end of 2001.

In the narrative part of the report, a significant number of Chairs state that the Chair and the infrastructure played a role in attracting new faculty members in the last year (in addition to attracting/retaining the incumbent). They also mention recruitment of postdocs and students and expectations of higher funding from various sources, especially industry. Finally, some mention that the infrastructure will bring their equipment to world-class standards, enabling them to expand their research horizons.

5 Innovation Fund

This analysis covers the 211 reports received by CFI by 30 April 2002. All these infrastructure projects had been finalized by CFI at the end of 2001 and they were paid for totally or partially. At reporting time (February 2002), a number of projects were not operational, were partially operational, or had become operational very recently. Nevertheless, unless otherwise indicated, all responses are included in the analysis because some outcomes occur before the infrastructure is in place (e.g., attraction/retention, some collaboration).

Funds awarded by CFI to the 211 projects range from $33,000 to $20 million, as shown in Table 13:

Table 13–Innovation Fund–Number of projects by funding range	
Range	Number of projects
<$300,000	73 (35%)
≥$300,000 and ≤$1M	65 (31%)
>$1M and ≤$5M	62 (29%)
>$5M	11 (5%)

It is important to note that some projects do not lend themselves well to quantitative analysis of research outcomes. Campus networks that are used by all faculty members and students at the university are an example of this; or national facilities with large number of users. In such cases, it is next to impossible to estimate research outcomes that can be attributed, in whole or in part, to the infrastructure.

5.1 Innovative research capability

The CFI infrastructure has facilitated the creation or expansion of major centres in genomics, proteomics, bioinformatics, neurosciences, rehabilitation, tissue engineering, medical devices, drugs, information technologies, advanced materials, transportation, earthquakes, geomatics, manufacturing, food, agriculture, aquaculture, water, oceans and environmental sciences to give only a few examples.

CFI funding has enabled the creation of centralized instrumentation centres in numerous departments and faculties across Canada, particularly, magnetic resonance and imaging technologies. It has also facilitated the renewal of campus networks and the creation of high performance computing facilities accessible to researchers across the country.

CFI infrastructure has contributed to the modernization of animal care facilities. It has provided researchers with access to numerous data bases on the health and social conditions of Canadians. It has provided clinical researchers in the biomedical sciences with equipment and infrastructure to study major diseases and conditions.

5.1.1 Recruitment and retention of faculty

Researchers were asked whether the availability of the infrastructure had been an important factor over the past year in the decision of researchers (faculty members, PDFs and other researchers) to join the institution. Of the 206 responses, 169 answered yes, and 37 (18%) answered no. Note that the question concerns the past year only and “attraction” only, not retention.

The origin of the 1642 researchers attracted to these projects is shown in Table 14:

Table 14–Origin of researchers attracted in the last year

Canada: 955 (58%)	US: 264 (16%)	Elsewhere: 423 (26%)
Academia: 1519 (93%)	Industry: 71 (4%)	Public: 52 (3%)

Note that there is double counting, as some researchers and postdocs are using more than one CFI-supported infrastructure. This note of caution applies to all totals mentioned in this analysis.

In the narrative part of their reports, researchers stressed the importance of the infrastructure in attracting and retaining faculty members, researchers and PDFs. For example:

> "We now have a very committed group of researchers, who are not looking elsewhere (often to the USA) at opportunities where adequate research infrastructure was already in place. Because each member of the research team was involved in designing the research space and purchasing their necessary research equipment, we have a very satisfied research team".
>
> "Five new faculty members who were recruited to the Faculty of Medicine and Dentistry last year have an absolute requirement for either confocal or multiphoton microscopy. They would have been unable to accept a position in the Faculty without access to this instrument".
>
> "The infrastructure has been instrumental in retaining within Canada [three researchers] who are pioneers in the field of genomics".
>
> "Over the last year, the department… has hired two new faculty members who will be directly involved in the activities of the Centre… Both of these individuals were recruited from the US".
>
> "We are in the process of attracting highly qualified individuals. Two such cases are significant. Both are Canadian presently working or studying abroad, and both are eager to return to Canada. The first case is that of an individual with a distinguished career in the telecommunications industry whom we have proposed for a Canada Research Chair. The second, is the case of an individual presently completing his Ph.D. at … whom we are

considering for a faculty position. Both individuals have been very appreciative of the existence of the facility, and the existence of this facility is playing a major role in our recruiting effort".

5.1.2 Recruitment of students

Project leaders were asked whether, in the past year, the infrastructure contributed to the recruitment of students from outside their institution. The answers to this question are summarized in Table 15. A vast majority of projects recruited students in the last year.

Table 15–Recruitment of students

Number of projects reporting students recruited from Canada (1415 students, 68% of total)				
1 student	2 students	3 students	>3 students	none
22 (10%)	27 (13%)	17 (8%)	97 (46%)	48 (23%)
Number of projects reporting students recruited from the US (71 students, 3% of total)				
1 student	2 students	3 students	>3 students	none
14 (7%)	8 (4%)	3 (1%)	6(3%)	180 (85%)
Number of projects reporting students recruited from abroad (589 students,28% of total)				
1 student	2 students	3 students	>3 students	none
33 (16%)	20 (9%)	13 (6%)	48 (23%)	97 (46%)

"Electrical engineering/computer science at Waterloo: improvements in lab facilities, growth in faculty (and perhaps the economic climate in information technology) have contributed to an increase in graduate student over 2000 levels of more than 125 students".

"For the first time, I find that I am able to compete with USA universities to recruit grad students and technical staff".

"The Centre has been recognized internationally for its innovative research and as such receives a considerable number of inquiries from potential postdoctoral fellows, graduate students, and faculty members planning to take a research leave".

5.1.3 Recruitment of professional and technical staff

The quantitative part of the report did not ask project leaders about the number of staff they recruited. However, there was a question on job creation. From the narrative part of the report, one may conclude that a majority of those who answered that the project had an influence on job creation were talking about jobs in the lab (or jobs associated with the project). Only a small number were apparently referring to jobs created in spin-off companies. Table 16 shows the number of projects where the infrastructure played a role in job creation. In looking at the data, it should be kept in mind that it is not possible to distinguish between these types of jobs.

Table 16–Number of projects reporting influence of infrastructure on job creation

No influence	Some	Considerable	Total
44 (21%)	117 (57%)	45(22%)	206

> "The availability of this infrastructure has further allowed us to successfully pursue funding for large-scale proteomics projects from other federal, provincial and international funding agencies. This has translated directly into technical jobs and training opportunities for numerous postdoctoral fellows and graduate students and has put us in the position of being world leaders in the area of functional genomics and proteomics".

> "Six new jobs have been created in addition to about 20 graduate students".

> "18 high quality jobs have been created directly, plus another 15-20 due to impact on local projects. Assessment of effect on jobs outside of the centre is difficult but there are likely many".

> « Sur le plan socio-économique il est important de préciser la création d'emplois directs et indirects. Les emplois créés sont à la fois au sein des organismes partenaires, Dynaco, Innotag et BOMEM, qu'à l'Université au niveau des laboratoires et des facultés associées. »

> "Currently 22 technicians are employed; with the Genome Canada money, the Centre will hire an additional 20 FTEs".

Of course, the recruitment of professional and technical staff is limited by research funding available and by the availability of funding to operate, maintain and repair the infrastructure, and some project leaders so note in their report:

"Technical support for our facility remains inadequate".

"To be brutally honest, I think we require some additional technical support in order to take full advantage of the facility, and we are working hard to secure this".

"Although infrastructure programs are good, we need to get serious operational funding to staff the facilities".

5.1.4 Access to world competitive infrastructure

For more than three quarters of the projects, more than 3 researchers (faculty, PDFs, but not students) have substantially advanced their research in the past year because of the availability of the infrastructure (see Table 17). Of these researchers, 652 came from the private or public sectors.

Table 17–Researchers who advanced their research thanks to infrastructure

Number of projects reporting such researchers (4905) researchers in total)

1 researcher	2 researchers	3 researchers	>3 researchers	none
4 (2%)	12 (6%)	15 (7%)	161 (76%)	19 (9%)

Project leaders think very highly of the quality of their infrastructure, as shown in Table 18 and in the comments that follow.

Table 18–Quality of infrastructure compared to other laboratories

Number of projects stating that the infrastructure is:

Below average	Average	Above average	Comparable to best in Canada	Comparable to best in the world
1 (0%)	12 (6%)	19 (9%)	73 (35%)	101 (49%)

"Initial CFI support has been crucial in obtaining a dramatic increase in the quality of the infrastructure through additional private and public sector contributions that have increased the original CFI construction budget of $157,000 to our current construction budget of $1,010,000. This has been accomplished through an exemplary building design for this laboratory, provided pro bono, by Architect…, and through private sector contributions from the construction industry. currently totalling approximately $450,000. An additional $400,700 has been provided for the building's construction by Western Economic Diversification Canada. This significant additional support has been very gratifying, and has

provided a larger laboratory that will set a national standard for architectural design".

"The new facility is one of the top probe labs, if not the top probe lab, in North America, as witnessed by the fact that it is the manufacturer's demonstration lab for all potential probe buyers in North America. To say it provides access to world competitive infrastructure is an understatement".

"The scope of each of these investigations is internationally competitive and would not have taken place if the SHARCNET computing infrastructure did not exist".

"The state-of-the-art imaging facilities are also attracting researchers not only from other centres in Canada but also from the US and abroad".

"As of mid-February 2002, Statistics Canada says that 96 projects [involved in the Research Data Centres] are using the facilities, involving more than 150 researchers (but there were only about 60 projects at the end of 2001 in the six CFI funded centres, and new proposals come into the peer-review system about every day now). Clearly, the word is rapidly spreading around that new research now can be done on Canadian data, and researchers are beginning to incorporate Research Data Centres in their plans and strategies. We have every reason to expect this trend to accelerate".

"The Centre for Applied Genomics (TCAG) is a national facility operating at a world-class level for innovative research into the genetic basis of disease. The Centre's core facilities -- Genome Resources, DNA Sequencing, DNA Synthesis, Gene Isolation and Expression, Genetic Analysis, and Bioinformatics -- provide the infrastructure required by modern biomedical researchers for comprehensive genomics research. TCAG is a core facility that serves more than 400 principal investigators and their teams".

"We are likely the only facility in Canada with a fully integrated confocal – scanning probe microscope instrument, and perhaps one of a handful of such installations in the world".

5.1.5 Collaboration

A vast majority of respondents say that the presence of the CFI-supported infrastructure helped them create, maintain or strengthen collaborations, particularly international collaborations (Table 19). In the narrative part of the reports, project leaders go on to describe many of these linkages.

Table 19–Influence of infrastructure on creating/maintaining/strengthening:

	Number of projects reporting:			
	None	Somewhat	Considerable	No answer
Informal linkages with colleagues at the institution	1 (1%)	43 (29%)	104 (70%)	63
Research collaborations	4 (3%)	49 (33%)	94 (64%)	64
Formal signed partnerships	44 (31%)	48 (34%)	51 (36%)	68
International collaborations	26 (12%)	113 (54%)	70 (33%)	2

> "A major and immediate impact of CFI funding was the increased interaction between the applicants. They were associated with four different departments and a centre, the purchase of common equipment has increased collaboration efforts. This has resulted in greater scientific exchanges and more joint publications".

> "Interactions between skeletal health researchers at McGill and those at École Polytechnique, Université de Montréal and IRCM have increased dramatically over the past year as a consequence of joint decision making processes (Bone Centre Steering Committee) and joint funding applications (VRQ, CIHR Training Program)".

> "The UBC Laboratory of Molecular Biophysics has provided a model for effective multidisciplinary research at UBC and has in part stimulated the subsequent development of a number of innovative programs across campus that have been funded by the CFI. Access to this equipment has made it possible to expand the nature of experiments proposed in applications to major funding agencies".

> "The infrastructure has fostered deeply collaborative work between computer scientists, mechanical engineers, and orthopaedic surgeons. Researchers and students use the infrastructure to develop new surgical techniques, plan surgeries, guide the surgeons in the operating room, and analyze how a

patient's joint moves before and after surgery. The teamwork is highly productive and the researchers are respected worldwide for their innovations".

"This project brings together researchers across Canada and internationally to study globalization. Included in this project is the study of global media and the impact of new media".

"Our Centre for Clinical Trials…has allowed us to design, fund and execute major international multicentre studies in which we are the hub of a network investigators extending around the world. New trials using the infrastructure have begun in treating heart arrhythmias, preventing stenosis of coronary arteries and improving the outcome of heart disease by intervening at the psychosocial level".

« Ainsi nous avons unifié trois groupes de chercheurs en provenance de quatre institutions universitaires (Laval, McGill, École de technologie supérieure (ÉTS) et l'UQAM) et deux institutions collégiales (le Cégep et l'Institut de technologie agroalimentaire de La Pocatière). Nous avons alors mis en commun trois infrastructures majeures obtenues de la FCI, totalisant plus de 13 000 000 $. »

« Au cours de programmes internationaux dans l'Océan Arctique menés antérieurement par le Canada…, la piètre qualité et la vétusté des équipements de pont et des laboratoires disponibles a surpris plusieurs de nos collaborateurs étrangers. La disponibilité des fonds FCI pour assurer des équipements de pont de première qualité pour les programmes futurs a fortement encouragé nos partenaires étrangers habituels et de nouveaux collaborateurs à se joindre au projet CASES (Canadian Arctic Shelf Exchange Study). CASES, qui regroupe les efforts de 72 laboratoires dans 11 pays a été financé à 100% par le CRSNG et nous croyons que le financement du projet par la FCI a été un facteur important dans la réussite de la demande. »

"The Telematics Research Laboratory, with its unique combination of satellite and terrestrial wireless infrastructure interconnected to Canada's high speed fibre backbone, is recognized as having technology and resources not available to most other national and international research communities".

« Participation de l'INRS-Eau au projet européen SNOWPOWER, projet financé par le 5^{e} programme cadre. Le but final du projet est

de développer un instrument et des méthodes permettant d'améliorer l'estimation de l'équivalent en eau et de la teneur en eau du couvert de neige par des mesures sur le terrain en continu et une corrélation simultanée avec les données de télédétection. Le volet canadien comporte 4 objectifs dont les 3 premiers sont directement liés aux objectifs du projet européen. »

5.1.6 Collaboration with the private and public sectors

"The CFI funded infrastructure for grain storage research is comparable to the best in the world. The infrastructure has created a solid foundation for long-term collaborative research. The researchers at the University of Manitoba work closely with the researchers at the Cereal Research Centre of the Agriculture and Agri-Food Canada in Winnipeg on all aspects of storing grain".

"The improvement in the core transgenic facility allowed it to expand its interaction with the biotechnology industry. For example, an initial contract with Nexia Biotechnology for transgenic models was extended for the following year. Three other companies are in various stages of discussion to initiate similar contracts and collaborations. These contracts provide an excellent means to cover the cost of salaries and supplies for the transgenic core".

"Collaboration with Bell Canada has soared under this investment and several Bell people have significantly increased their research as a result".

"The mechanical testing and ultrasonic testing equipment (Processing and Characterization of Inorganic Materials) have been used in a $1.4M contract from Pratt and Whitney (Canada)".

"We also have increased interaction with the mining industry in connection with metals in the environment, and we have increased our linkages with industries needing to dispose of organic wastes on land in a safe manner".

"Inter-sector collaboration CFI funds have been helpful in creating and cementing links with industrial partners including CAE, PCI Geomatics, VisionSphere Technologies, Good Vibrations Engineering, Natural Resources Canada, MD Robotics and IBM".

5.1.7 Creation of, or support for centres of excellence

The CFI infrastructure is contributing in a large way to the creation and expansion of research clusters, centres and networks.

> "This CFI grant is creating an innovative research capability in the humanities. It is developing a new research resource and a model for electronic publishing, and this is bringing students and scholars to the University of Alberta and having significant impact on the development of humanities computing (including the development of a graduate degree program) in the Faculty of Arts".

> « À l'instar du Centre de caractérisation des matériaux qu'il a mis sur pied, l'Institut des matériaux et systèmes intelligents a regroupé les infrastructures informatiques pour le calcul scientifique à haute performance en créant le Centre de calcul scientifique. Ce Centre vient d'être doté d'une enveloppe budgétaire d'environ 9 millions de dollars dans le cadre du Réseau québécois de calcul à haute performance. »

> "The research group is part of a five country, eight institution collaborative network studying resistance and susceptibility to infections, which includes some of the top scientists in the HIV and sexually transmitted infections field. The databank created by the CFI grant is unique in the world and has significantly enhanced the quality of existing collaborations and attracts more. The University and Health Canada and Provincial partners have recently agreed to jointly develop an International Centre for Infectious Diseases which will unite the different elements of microbiology and infectious diseases in Manitoba into a multidisciplinary virtual research centre. The unification of these resources into a synergistic whole will create the largest organization dedicated to microbiology and infectious diseases in Canada and one of the larger centres of its kind in the world".

> "The most significant event of 2001 for the Montreal Genome Centre (MGC) was its selection by Genome Canada as the Centre of Expertise of Genome Quebec and its leadership role in a large-scale project entitled "Regulatory Genetics", as well as its core facility role in the "Steroid Atlas Project" led by the Centre hospitalier de l'Université Laval. Together, these investments represent $36 million of funding for the next three years for the MGC. The MGC facilities are involved in four national Networks of Excellence".

« L'année 2001 a vu le lancement officiel du Réseau de recherche Ligniculture Québec qui implique cinq universités et sept partenaires industriels. Le but de ce réseau, qui est financé par Valorisation-Recherche Québec, est de fortifier la R&D en biologie forestière devant mener au déploiement de plantations à croissance rapide sur une grande échelle. »

"The existence of the infrastructure played a pivotal role in the negotiations that eventually led to the establishment of the NRC National Institute for Nanotechnology as a collaborative partnership involving the National Research Council, the Government of Alberta, and the University of Alberta. This is a $120 million initiative over the initial five years of operation".

"The anticipated presence of a Research Data Centre at the Université de Montréal has been instrumental when UNESCO selected this campus as the site for the headquarters of its Institute for Statistics (the move took place in August 2001)".

"Research collaboration with institutions in London, Toronto and Ottawa have resulted in the successful application to the Ontario R–D Challenge Fund for the Ontario Consortium for Cardiac Imaging to develop a program to determine critical anatomic and functional information for assessment, treatment planning and intervention monitoring of heart disease in Ontario".

"The existence of the infrastructure played a considerable role in the establishment of the Manitoba Centre for Proteomics".

5.2 Innovative research productivity

The CFI-supported infrastructure helped researchers generate world-class results in a vast majority of projects, as shown in Table 20. In fact, 72% of projects for which it is not too early for results report research that is at or exceeds international standards:

Table 20–Self-assessment of the quality of research in the last year

Too early	Modest advance	National standards	International standards	Breakthrough	No answer
17	22 (12%)	31(16%)	93 (49%)	42 (22%)	6

Research is also more efficient, with results coming faster:

"Time efficiency. In the past, a single crystal structure determination in our department entailed waiting in a queue of at least a dozen samples which would typically take 3-4 weeks".

5.2.1 Publications and dissemination of results

A few examples of interesting results:

"The facility has been used to help develop Canada's petroleum reservoirs by understanding their micro-structure, understand Alberta's native gemstone, ammolite, understand corrosion in pipelines, understand how concrete rots, understand how good is the steel made from recycled materials, and many others listed above. All these topics have economic and/or social benefit".

"The results from this data have shown that we have been able to grow highly oriented crystalline materials as layered structures by a low temperature process which operates in air. To put these results in perspective: we have been attempting this growth for three years and we were nearly ready to give up on the process… Now that they can be made in a relatively inexpensive process, the materials could be used in integrated devices such as computer chips or cellular phone components".

"The discovery … of DNA sequences containing catalytic activity for processes normally executed by protein catalysts. This discovery has implications for the broad question of the origins of prebiotic life and has potential for the development of therapeutic agents".

"Breaking new ground in exploration seismology. [The] research focused on seismic imaging and inversion plays an important role in the oil and gas industry since new developments in high-resolution imaging save time and money for industrial exploitation. Working in collaboration with industrial leaders…[the] research group has been able to test seismic imaging development directly increasing interest generated in the oil and gas field".

"A researcher at the University of Alberta is exploring new dimensions of catalytic combustion". In collaboration with industrial stakeholders, [he] is developing new design methodologies for automotive catalytic converters. Spearheading what is becoming the most advanced research group in the world in this area, [he] is

pushing the envelope in computer-based catalytic converter design and modelling".

"The discovery of new blue-emitting electroluminescent materials… is an important breakthrough in the development of full colour electroluminescent flat panel displays... In 2001, this work resulted in 6 publications in high profile journals".

"A paper published in Nature in 2002… described the first high throughput mass spectrometry analysis of yeast protein-protein interactions. This landmark proteomic paper was a successful collaboration between the academic group at SLRI [Samuel Lunenfeld Research Institute] and MDS Proteomics, a Toronto-based company that has grown out of the work made possible by CFI support".

"Over 30 research papers were published by Montreal Genome Centre scientists (or users of core facilities) in 2001. This includes four publications in Nature Genetics – one of the highest rated journals in biomedicine. These works included new discoveries in the genetics of asthma and inflammatory bowel diseases".

5.2.2 Level of risk of research undertaken

"Because some of the infrastructure can be used for projects that do not have to be individually defended in regular grant proposals it is possible that more 'risky' experiments without a guaranteed outcome can be attempted".

"[We are] 'pushing the envelope' of the technologies themselves. These projects would be considered high risk, in that they are developing and/or using the instrumentation in ways that are not established. They are also expected to be high impact".

"Some research is high-risk, but most of it is very applied and often include industrial collaborations. Most of the projects involve at least two of the following sectors: physics, chemistry, engineering, biomedical devices, photonics, precision instruments, microelectronics".

"The [Centre for Advanced Coating Technology] has committed itself to the development and validation of a complete model of coating formation. Considering the inherent challenges that this

problem poses, the risk is considerable. Fortunately, this effort has paid off handsomely".

"This attempt to create a critically sophisticated textbase, able to respond to interrogation on complex interpretive issues, is unique in humanities computing. The development of the data structure -- the DTDs -- is a bold venture in the linking of literary theory and technology. The risk has been high: this project is an experimental intervention in the modes of scholarly publication in the humanities. It will raise the bar for the complex electronic structuring and delivery of research results in the human sciences".

"The template this project is providing for the management of large-scale electronic publishing projects in the humanities is a new contribution to Canada's research and publishing infrastructure. So too is its pioneering of new ways of transmitting knowledge electronically--specifically the kind of deeply contextualized qualitative knowledge of socially-embedded phenomena that is difficult to organize and retrieve via electronic media".

5.2.3 Multidisciplinary nature of research activities

No less than 96% of respondents replied that the availability of the infrastructure had enhanced the opportunities for interdisciplinary research in the last year (Table 21).

Table 21–Number of projects reporting that interdisciplinary research has been enhanced

No	Somewhat	Considerably
8 (4%)	70 (34%)	127 (62%)

"The Centre for Food & Soft Materials Science is by its very nature interdisciplinary and collaborative. Examples of new collaborative projects enabled by the CFI funding include work on the physical properties of biofilms (microbiology, physics), biological membranes (biophysics, biochemistry), active packaging systems (food packaging engineering, physics, microbiology), and incorporation of food enzymes in novel wound dressings (molecular biology, bioengineering, physics)".

“The very nature of our research is multidisciplinary, in that it lies at the interface between the ecological and molecular sciences. In addition, through our proposals to the NCE and Genome Canada, we have included researchers from the humanities and social sciences”.

“Projects involve multidisciplinary collaborations between scientists in disciplines such as biochemistry, medical biophysics, kinesiology, neuroscience, paediatrics and child health”.

« Les recherche effectuées par les chercheuses et les chercheurs de l’Institut des matériaux et systèmes intelligents permettent aussi l’avancement des connaissances dans plusieurs champs d’application, dont la santé, l’aérospatial, le transport, la métallurgie, l’environnement et le secteur énergétique. »

“The research being carried out using the facility relates to fields that include optoelectronics, electronics, genomics and even cosmology. Collaborations between research groups involved in quite different areas are common, and one of the real benefits of having the facility”.

“The availability of the Research data centres has also allowed their users from different disciplines such as sociology, health, statistics and actuarial science, economics, demography, and from various institutions, to interact informally, discuss issues and exchange ideas pertaining to the use of longitudinal data and surveys. These informal exchanges can be seen as a stepping stone for more formal collaboration, and they are actively encouraged…”

“The research activities are at the intersection between electronics, semiconductor physics and technology as well as materials science and chemistry”.

“One of the higher-level goals of this research is to provide compute intensive applications with compute cycles at low costs. The acquired infrastructure has brought together researchers in computational economics (London School of Economics), astrophysics (Canadian Institute for Theoretical Astrophysics), computer engineering (University of Toronto), computer science (University of Toronto), and medical applications (Defense and Civil Institute for Environmental Medicine). Although in each case the research goal is to provide accurate simulation models for realistic problems, currently progress is inhibited by the lack of

low-cost compute cycles. The CFI infrastructure and the related research provide compute cycles at low cost and enable researchers to explore more effectively the configuration space in their areas of interest".

"PolyLAB CFI funding has introduced a unique blend of physics, computing, communications, social policy, sociology, ethnography, and space science to tackle a wide range of problems".

"The infrastructure has enabled a very wide range of research in genomics and proteomics, integrative biology, early cancer detection and population health. There are users from outside biomedicine: mainly in chemistry and engineering".

"Multidisciplinary: wide range of techniques including photobiology, photonics, cell biology, neurophysiology, fluorescence and acoustic microscopy, IR, acoustic and laser spectroscopy, fast electronics, computer control of experimental apparatus and ultra high vacuum technology".

5.3 Nature and relevance of training for research and other careers

Table 22–Students using the infrastructure

	Number of projects with no student	Projects with 1 student	Projects with 2 students	Projects with 3 students	Projects with >3 students
Undergraduate (total 3262*)	51(24%)	20 (9%)	27 (13%)	14 (7%)	99 (47%)
Masters (total 3750*)	30 (14%)	15 (7%)	20 (9%)	23 (11%)	123 (58%)
Doctoral (total 2728*)	32 (15%)	18 (9%)	19 (9%)	18 (9%)	124 (59%)

*Note that a National Facility (National Site Licensing or "digital library" and a field station account for 1250 of the undergraduate. The Library and a campus network account for 1340 Master's and 455 doctoral students.

Table 22 shows that large numbers of students at all levels benefited from the infrastructure in the last year. The following excerpts show that project leaders are convinced that students are trained in a multidisciplinary environment that will prepare them well for the job market.

5.3.1 Multidisciplinary nature of training

"The Living Laboratory provides a rich venue for applied research training of graduate students, and for partnerships at both SFU and BCIT for researchers in gerontology, kinesiology, engineering science and health applied research... the Living Laboratory also provides an ideal research and development training venue for architects, biomedical engineers, industrial designers, interior designers, occupational therapists, planners and other professionals concerned with creating the day to day environment and equipment needed for elderly persons and persons with disabilities".

« L'infrastructure FCI a certainement contribué à accentuer le caractère multidisciplinaire de nos travaux en ouvrant de nouveaux secteurs autrement inaccessibles. Nos étudiants de 2ème et 3ème cycle participent donc à une très vaste gamme d'approches scientifiques. Ceci est très bénéfique pour leur formation. »

"All staff and students are exposed to research training in more than one disciplines. They all receive bioinformatics training plus training in one or more of the following: protein biochemistry, protein production, protein engineering, image analysis, transcription profiling, molecular genetics, high-throughput sequencing, and high-throughput target identification".

"Examples of cross-disciplinary training are: developmental biologists using cellular approaches; classical physiologists using optical techniques; pathologists performing molecular imaging; biophysicists and engineers using cell and molecular techniques; all disciplines learning image processing and analysis. This infrastructure represents a cross-road between biological and physical sciences".

"We are seeing more co-supervised and cross-department students in our graduate program, due to the increasing diversity of projects and need for a broad range of expertise. Projects now involve areas as wide as physics, chemistry, optometry, earth sciences, biology, engineering and math on various elements of the CFI infrastructure".

5.3.2 Collaborative, international, and cross-sector nature of training

> "The infrastructure facilitates our collaborations with industry, and this provides the students with more industrially-relevant training and contacts. For example collaborations are working between CVR [Centre for Vision Research] members and CAE, Good Vibrations, MD Robotics and IBM which all present training opportunities for the students involved".

> "Skills in these advanced micro-imaging techniques are important in several industry sectors, so that the training and experience makes the trainees attractive to industry".

5.3.3 Employability or employment of graduates

Graduates find good jobs:

> "The infrastructure permits training in modern techniques of polymer characterization and testing. These skills are highly valued in the polymer manufacturing and processing industry, which are a strong component of Canadian economy".

> "PEARL is proud of our 100% employment record. The new infrastructure has allowed us to expand our training into the methods and assumptions of isotopic dating techniques, image analysis and database organization. Almost all Ph.D. graduates take on careers as professors, although some have developed private consulting companies. M.Sc. graduates have typically gone to work as limnologists in a variety of public and private sectors".

> "Western was a pioneer in establishing an interdisciplinary graduate training program in neuroscience. In fact, we were the first university in Ontario and are one of only a few in North America to offer a Ph.D. in neuroscience. As successful as our program has been, the field is shifting so rapidly that, to provide the kind of interdisciplinary training that graduate students (and PDFs) need, we must continue stay abreast of new developments in methodology and theoretical paradigms in the broad field of neuroscience… The need for such trainees in Canada and elsewhere is evident from the number of positions available for 'cognitive neuroscientists' that are going unfilled across the continent and overseas".

> “The technology developed as a result of this infrastructure is at the cutting edge of mass spectrometry of biological molecules, and the new field of proteomics. As a result, researchers gain experience in instrument design and in its biological applications. They are in high demand with instrumentation manufacturers and biological firms. The graduate student involved has spent a summer with MDS Sciex, and has been offered a position with Wyeth Amherst”.
>
> “Several graduates work in the optoelectronics industry, for both large and small companies”.
>
> “PolyLAB personnel have gone on to form the cornerstone of development in high tech companies, ranging from local multimedia companies like Blast Radius to large-scale international corporations like Microsoft, helping demonstrate Canada’s cutting edge knowledge in these fields. PolyLAB has also trained students in the larger social implications of advanced collaborative, Internet, and space technologies, producing students who will go on to shape Canadian social policy and development”.
>
> « La formation que nos chercheurs acquièrent augmente considérablement leur « employabilité » dans ce monde de haute technologie. Ils apprennent à gérer des projets d’envergure et à résoudre des problèmes d’une grande complexité à l’aide d’outils de pointe, aussi bien matériels que logiciels. »
>
> “Graduates are currently working in a typical chemical industry such as Bayer Canada, but most of them are working in high-tech companies, government labs and biomedical/pharmaceutical industries such as Xerox in Mississauga, Ballard Power in Vancouver, National Research Council of Canada and TWLinks (a start-up company). Therefore, this infrastructure serves as the best training base that provides the HQP to fulfill the need for Canada's economic and social development”.

Some are lured to the USA:

> “Among five students who graduated in 2001, three were employed at Canadian companies, one was hired by an American company and one joined a spin-off company (TWLinks)”.
>
> “The infrastructure has directly provided training for two bioinformaticists. They both have obtained lucrative positions in

the United States, one in Philadelphia and in Denver. All the graduate students trained in the infrastructure have secured positions before they left us".

"All our graduates and postdocs are gainfully employed. As a matter of fact, most of our recent alumni have taken up positions in the U.S.A. because Canadian firms could not muster competitive offers. Our two best alumni have moved to California in the last 2 years to join Conexant and Agilent".

"Our graduate students have typically secured jobs before finishing their degrees. Most of the graduates have remained in Ontario; although some have moved to other parts of Canada and to the US".

5.4 Economic and Social Benefits

Table 23 indicates the number of projects reporting various types of benefits enabled by the infrastructure in the last year.

Table 23–Benefits[7] enabled by the availability of the infrastructure

	# of projects reporting no benefits	# of projects reporting some benefits	# of projects reporting considerable benefits	No answer
Intellectual property	92 (45%)	79 (39%)	34 (17%)	6
Knowledge clusters	17 (8%)	74 (36%)	116 (56%)	4
Products and services	64 (31%)	93 (45%)	48 (23%)	6
Spin-off companies	148 (72%)	40 (20%)	17 (8%)	6
Cost savings	72 (35%)	92 (45%)	39 (19%)	8
Public policy improvements	154 (76%)	38 (19%)	11 (5%)	8
Health benefits	105 (52%)	81(40%)	17 (8%)	8
Social benefits	143 (71%)	49 (24%)	9 (4%)	10
Environmental benefits	118 (59%)	57 (29%)	24 (12%)	12

[7] Numbers may appear high in this table. In reading the reports, it is obvious that a number of respondents mentioned benefits generated since the infrastructure first became operational as well as benefits that are likely to occur in the near future. One must also remember that the table refers to number of projects. Researchers report the same benefits in all the projects in which they are involved.

In the narrative part of their reports, researchers were not asked specifically to describe the knowledge clusters that were enabled with their CFI awards. However, as noted above, a significant number of researchers discuss their participation in various centres and networks and virtually all of them describe local, national and international collaborations.

Examples of other outcomes are given in the following subsections.

5.4.1 Intellectual property

> "In the past year, five patent applications have been submitted. Two of these involved collaborators at IBM. Three others, submitted by Nortel, protected innovations in coding".

> "There is significant potential for intellectual property based on the use of coordinates for drug design. [The researcher] has filed a patent which Quorex wishes to licence. The patent relates to an enzyme involved in quorum sensing, which would inhibit bacteria from reaching a critical mass and causing infection. [Another researcher] has received a patent for a betaglobin expression cassette that has shown therapeutic amounts of betaglobin in transgenic mice. If delivered to patient bone marrow, it promises to have a therapeutic effect in sickle cell anemia".

> "Three patent applications have been submitted or are in preparation stemming from research directly related to laser micromachining and the researchers using the Laser Micromachining Facility".

> "One patent on a small droplet generator has been granted. A second patent application is about to be filled. This patent is on an attachment for the high velocity oxy-fuel gun that improves the quality of coating considerably. Sulzer-Metco is already negotiating to examine the invention and possibly acquire its rights".

> "Three patents were filed – describing disease associations with genetic polymorphisms".

> "The equipment has been directly used with a project with an Ontario based company. This project has led to the formation of a new type of water-vapour exchange membrane. This technology is currently being transferred to the company and a pilot plant is being built to fabricate the membranes. The water treatment

membranes are being considered for commercialization by one company at present. Three other companies have expressed interest in the technology".

"We are presently pursuing a patent on technology that was developed at the McMaster Manufacturing Research Institute related to high-speed inspection of automotive components. This technology was developed with a local company that is working to implement the technology in their factory. This technology will solve a problem that is a major bottleneck in their process and allow them to increase the confidence in the quality of the products they are delivering. Producing and supporting the final product represents an excellent opportunity for one of our students to license the technology and start a company. We are also looking for further applications of this novel technology in other industries".

5.4.2 New/improved products, processes, or services

"CFI support for the multi slice X- ray CT provided the infrastructure needed to develop a significant technology here in Canada and General Electric Medical Systems is presently shipping more than 200 of these units world-wide per year. This has provided significant funding to London institutions and this funding is being re-invested to create jobs and maintain the infrastructure initially funded by the CFI".

"Building on the success of the program, we have established a collaboration with MD Robotics for the design and construction of a MR compatible robot for neurosurgery. MD Robotics is the Canadian company that constructed the CanadArm for the space shuttle, and recently the CanadArm 2 for the international space station…. Without the support we have received from CFI for our current projects, this new and exciting Canadian development would not have been possible".

"The developments stemming from this facility have economic significance in that they enhance the efficiency of seismic imaging and the resulting resource exploration. This has obvious positive impact upon the Canadian economy".

"Development of protective eyewear for electrical utility workers".

"The new infrastructure considerably supports R–D in industry, especially in the oilsand mining industry. The facilities help better understand wear behaviour of materials used for oilsand mining and handling facilities, so that more appropriate wear-resistant materials can be selected or designed".

"We have developed the world's fastest heterojunction bipolar transistor: to put things in perspective, these devices should enable fibre optic transmission at 80-100 Gigabits per second, which is to be compared to the current commercial standards of 2.5-10 Gigabits per second. The potential of this technology could affect the development of Internet bandwidth (telecom, e-commerce, etc) for years to come".

"Several companies have already changed their manufacturing processes after R–D at the Laser Micromachining Facility. The facility supplied at least 4 companies with prototyping and small-run production help last year".

"Two patents are filed/to be filed for the powder coating and pulmonary drug delivery technologies. New ultrafine powder paints will soon be on the market, in Canada and US. Two major product quality problems have been resolved for the sponsoring company in the area of solids mixing and drying".

5.4.3 Creation of spin-off companies

"Two companies are being created. One is called Converzyme Inc. and it is in its first round of financing. A second will be a Canadian subsidiary of GangaGen from Palo Alto, a company specialized in the area of phage therapy. GangaGen Canada Inc will start its operations in Ottawa on May 1st 2002. Its main goal is to eliminate E. Coli contaminations from our water system. It will attack the problems arising from the Walkertown tragedy. We have deposited one patent in the last year while the other patents on the convertases have been licensed exclusively to Converzyme Inc.".

"Four spin-off companies moved from the planning stage to actually begin staffing and operating in 2001. These are all based in Waterloo: Bioinformatics, Ignis, Sirific and 3C Infotech. In total, they employ about 35 people, all new jobs created during 2001".

"Enhanced collaborative research begets enhanced economically beneficial activity in the hiring of research staff and in extension into the commercial sphere. Collaborations… have led to the creation of two spin-off companies".

"A spin-off company (Simulent Inc.) has now been registered in Ontario. The company is commercializing the software developed at the centre. It currently employs three full-time researchers and two part-time consultants. It has been successful in obtaining major contracts from multinational companies".

"The new capabilities have led to a new and larger contract with FONA Technologies, Inc. Researchers who were in [the] group have now been moved off-site as the new spin-off company was launched, and close interactions including use of facilities are in place (charged at commercial rates)".

« Au cours des deux dernières années, plus de trois nouvelles entreprises ont été créées afin d'exploiter et de développer de la technologie issue des activités de recherche du Centre d'optique photonique et laser (60 emplois). Nos laboratoires continuent d'appuyer le développement de ces entreprises et de plusieurs autres tant par l'accès aux équipements que par la formation de personnel qualifié. »

"The CFI-supported research has been essential for the founding in 2001 of MDS-Proteomics (MDSP), an international company that has already established itself as a leader in the field of proteomics. MDSP is centred in Toronto, with additional facilities in Denmark and the US".

"The research enabled by the CFI support has resulted in collaborative research and has already generated interest in the industry. A new start-up company in the area of medical applications is supporting the research and/or using the expertise that has been acquired by the researchers involved in this work".

5.4.4 Policy improvements/social benefits

"Results of this research have already had impacts on "best management practices" in agriculture. They will continue to influence public policy and to have positive impacts on health and the environment, and hence result in social improvements.

We expect these influences to accelerate when we get all our instrumentation operational".

"Cost-effective methods of controlling and preventing pest infestations of stored grain and preservation of stored grain quality will assist the world in feeding the increasing population. The results of the fundamental and applied research obtained using the facility are valuable to farmers, managers of grain storages and federal regulatory agencies responsible for maintaining grain quality".

"Bringing research to bear on key policy issues is what the Manitoba Centre for Health Policy is all about. Nowhere is this role more critical than when MCHP research challenges basic beliefs and perceptions about health and health care. MCHP research has shown that people who live in the poorest social circumstances tend to be sicker than those in the middle, who are sicker than those in the wealthiest surroundings. A measure of MCHP success is that this income-illness gradient is now widely known. As a result of MCHP report, "Seasonal Patterns of Winnipeg Hospital Use," there was an expanded flu vaccination program in Manitoba and the Ontario government credited this report for its decision to fund universal flu vaccinations"

"The unifying objective is to assist elderly and disabled persons to live safely in their own homes and maximize their quality of life".

"PolyLAB and TRL have demonstrated many issues in the evolution of wireless networks and our dependency on them. PolyLAB Arctic research has shown how remote communities in Canada must be supported through appropriate national communications infrastructure policy".

5.4.5 Health improvements

"The multi channel power refractor has enabled investigation of oculomotor functions in pre-school children, measurement hitherto not possible with children of this age. The device has been instrumental in supporting more rapid, and therefore more cost effective, vision screening".

"A major impact of the transgenic core was the development of animal models for neuronal regeneration and resistance to

diabetes (U.S. patent pending). The latter has led to the development of drug screening programs in more than a dozen pharmaceutical companies. Obviously, the successful development of compounds for the treatment of both diabetes and neuronal damage would be of tremendous benefits to Canadians. We believe that in addition to the recently initiated projects and collaborations, additional genes and systems will be identified leading to further public benefit".

« Premièrement, grâce au partenariat avec l'industrie, des travaux sont réalisés afin d'arriver au développement de drogues susceptibles de mener à un traitement de diverses maladies, entre autre l'épilepsie (collaboration entre notre groupe et Merck Frosst). »

"The discovery… of a new class of glycosidase inhibitors for the treatment of Type 2 diabetes; the discovery of a new and effective vaccine against Group A Streptococcus; the discovery… of a peptide-based candidate vaccine against HIV".

"Thanks to CFI and other funding partners, we can now use the state-of-the-art quadrupole/time-of-flight mass spectrometer to obtain peptide sequencing information. Several novel proteins related to cancer biology have been discovered by using this instrument in the past few months".

"In a large country like Canada, techniques such as tele-surgery, in which a surgeon in a large medical centre can operate on a patient in a remote community via a video-controlled robot, are likely to become more and more common. Over the past year, we have been developing links with other groups interested in remote and instrument-guided surgery including the NRC Integrated Manufacturing Technologies Institute in London".

"The infrastructure has helped the researchers to develop new surgical techniques that are faster to perform, and that patients recover from more rapidly. In particular, the researchers have used the infrastructure to remove deep bone tumours from children and young adults through tiny incisions, and have developed a new way of correcting congenitally malformed hips (hip dysplasia) in young women suffering from early arthritis".

"The Magnetic Resonance programs have had a direct effect on health care. We have shown that intraoperative MR (iMR) program imaging optimizes surgical planning and intervention. The High

Field Program has contributed to improved outcome following stroke".

"Work from Centre for Vision Research labs has led to glare disability screening tests for drivers. CVR work to be published soon in Science describes a neural mechanism for the neurological syndrome torticollis".

5.4.6 Environmental improvements

"Techniques and procedures developed for the study and monitoring of long-term environmental change have a multitude of applications, ranging from acidification, eutrophication and other water quality problems, fisheries research, and research in climatic change. All these issues are very relevant to Canada's economic and social development".

"The potential long-term benefits of research in environmental genomics are enormous. There are also short-term benefits in the areas of wildlife forensics, bioremediation and the detection of toxins".

"A highlight in 2001 was an intensive urban air sampling campaign conducted in July as the Canadian contribution to the U.S. Environmental Protection Agency's super–site program. This campaign involved simultaneous sampling throughout July in a number of urban locations in Canada and the U.S., so as to get a better understanding of the impact of long-range transport on urban air quality".

"The nanofiltration membranes we have developed offer enormous potential for industrial and potable water treatment. Given the enormous publicity associated with incidents such as Walkerton and the very real improvement in water treatment technologies offered by our membranes they have a very large potential environmental and health impact".

"The level of risk taken in research has increased One example is that of a publicly sensitive project… evaluating the quality of various commercial bottled waters using the new… instrument to detect the presence of markers for pathogenic bacteria. This work has demonstrated the presence of E. coli in the products from certain bottled water manufacturers… This type of project has opened opportunities to work with new industrial partners,

and has opened communication with the Ontario Ministry of Health, Health Canada, and the Canadian Food Inspection Agency, all of which are in discussions about research and methods development".

5.4.7 Cost savings

"There are significant potential savings from the inorganic resist process, and probable beneficial impacts on the environment. For example, the changes it makes possible in microfabrication if it can be successfully implemented may reduce the water requirements in microchip factories to 10% or less of the current needs. This in an industry that uses about 2000 kilograms of water to manufacture a finished wafer (a disk that contains several hundred microchips)".

"The importance of parallel computing is increasing, as more and more disciplines need access to compute cycles. To accommodate these needs, it is very important to design and build affordable, high-performance parallel systems. One of our recent publications demonstrates that for certain types of applications this architecture performs comparably to tightly coupled multiprocessors that cost at least one order of magnitude more".

5.5 Awards, recognition (international, domestic)

Table 24 show that the availability of the infrastructure has a major impact on the ability of users to attract funding from a variety of sources.

Table 24–Impact of the infrastructure on the ability of its users to attract funds

Funding source	# of projects with no CFI influence	# of projects with some CFI influence	# of projects with considerable CFI influence	No answer
Institution	42 (20%)	96 (47%)	67 (33%)	6
Federal granting agencies	18 (9%)	63 (30%)	127 (61%)	3
Other federal	67 (35%)	52 (27%)	75 (39%)	17
Provincial government	35 (17%)	67 (33%)	104 (50%)	5
Canadian industry	57 (28%)	79 (39%)	69 (34%)	6
International	81 (41%)	63 (32%)	53 (27%)	14

A significant number of projects mention the subsequent awarding of a Canada Research Chair to users of the infrastructure.

> "During the last year, members of the Centre have been awarded a variety of honours including Canada Research Chairs, the Culling Medal, and a Steacie Fellowship".

> "The Centre's infrastructure now supports components of 3 prominent CIHR funded research groups in heart failure, vascular biology and atherosclerosis. Together this represents 14 well-established junior and senior investigators. The Centre has also partnered in two successful CIHR-industry funded projects over the past year, on gene therapy in angiogenesis and prevention of heart failure".

> "Co-investigators on a recently funded SSHRC MCRI on Globalization and Autonomy".

> "The availability of the infrastructure helped secure an NIH subgrant of $5 million over 5 years".

> "The CFI facilities have provided impetus for a successful Major Facility Access [NSERC] application which has enabled us to employ two technical staff".

> "[Researchers at] the Toronto Centre for Applied Genomics were able to leverage the existing infrastructure into a successful Genome Canada proposal with a total project budget of $14M over the next 3.5 years. CIHR funding also supports the operation of the facility".

> "Two researchers in the Faculty of Medicine and Dentistry who rely on the confocal/multiphoton instrument for their research programs are recent recipients of large research Awards from the Howard Hughes Foundation in the United States. These are highly prestigious awards, few of which are given outside the Unites States".

> "As PI and one of the15 original team members in this proposal, I can directly attribute 8 new grants and contracts (totalling roughly $500k/yr more than I received in previous years) due to the potential of his infrastructure".

"At least four new CFI grants funded in subsequent CFI competitions developed at least in part from the creation of the UBC Laboratory of Molecular Biophysics".

5.6 Public dissemination or research outcomes

A number of projects mention that their research and the infrastructure have been featured in various media in the past year:

5.7 Efficient management, use and sharing of infrastructure

In the narrative part of their reports, researchers describe measures taken to ensure the efficient management, use and sharing of the infrastructure. In the quantitative part of the report, they were asked to comment about delays and to discuss whether or not the infrastructure was adequately utilized.

5.7.1 Delays and time needed for implementation

About 60% of the projects experienced delays of some sort, most of them minor, some major. Major delays have been discussed with CFI. The reasons for delays have been given in the section on New Opportunities (section 3.7.1). With respect to the Innovation Fund, major construction projects take time, even when there are no major delays. Therefore, a number of very large infrastructure projects funded in the first CFI competition are not fully operational yet. In most instances, equipment has been purchased and is used for research, but benefits of the infrastructure will increase when all the user groups move to a new building.

5.7.2 Infrastructure utilization

With respect to utilization, 89% say that their infrastructure is used appropriately or is oversubscribed.

Table 25–Utilization of infrastructure

Under-utilized	Adequate	Over-subscribed	N/a
22 (11%)	143 (70%)	40 (20%)	6

Of the 22 who say that the infrastructure is under-utilized, 17 state that the infrastructure is not operational, is partially operational or is being developed

(data bases, for example). Two projects are taking action to increase utilization. of the infrastructure.

5.7.3 Management of the infrastructure

Smaller infrastructure is managed by the principal investigator(s) and shared on an informal basis. More complex one is managed more formally, with a manager in charge or with governing committees for larger infrastructure.

There are problems due to lack of personnel to operate, maintain and repair the infrastructure. This is due to lack of resources for technical personnel (due to the fact that the university has no money or the researchers have insufficient research funding) or to shortages of qualified people to run sophisticated equipment. The creation of the CFI Infrastructure Operating Fund will help in this regard but does not apply to infrastructure projects approved before mid-2001.

6 Research Development Fund (Universities)

Reports were submitted by 81 projects (from 22 universities) ranging in size from $27,000 to $1.9 million.

6.1 Innovative research capacity

Researchers were asked whether the availability of the infrastructure had been an important factor over the past year in the decision of researchers (faculty members, PDFs and other researchers) to join the institution. Of the 81 projects, 77 responses were received, with 51answering yes, and 26 (34%) answering no. Note that the question concerns the past year only and “attraction” only, not retention of researchers. The origin of the 169 researchers attracted to these projects is shown in Table 26:

Table 26–Origin of researchers attracted to Canada in the last year

Canada: 116 (69%)	US: 14 (8%)	Elsewhere: 39 (23%)
Academia: 139 (82%)	Industry: 13 (8%)	Public: 17 (10%)

Note that there may be double counting as some researchers and postdocs are using more than one CFI-supported infrastructure. This note of caution applies to all totals mentioned in this analysis.

Researchers stressed the importance of the infrastructure in attracting and retaining faculty members, researchers and PDFs. For example:

> "We have also been able to recruit faculty to new positions including CRC's and NSERC Industrial Chairs by using the Oliver Ecological Research Centre opportunities as a recruiting point".
>
> "At the time the equipment was requested, our faculty and collaborators were much smaller in numbers. Since acquiring the equipment, our faculty has grown by 3 members and each of us now has many more research collaborators".
>
> "The establishment of the Acadia Centre for Microstructural analysis represents a significant enhancement to the research capabilities of Acadia University. Over the last year, it has led directly to the recruitment of four outstanding new faculty members, two in the Department of Chemistry, one in Biology specializing in plant ultrastructure and one in Physics, this later being also a Canadian Research Chair".
>
> "The NMR facility was instrumental this year in recruiting one new faculty member, a postdoctoral fellow, an out-of-town graduate student and, in addition, a medical physicist hired by the Northwestern Ontario Regional Cancer Centre. It has also been a critical factor in attracting high calibre applicants for three faculty openings we currently have in the Department of Chemistry".
>
> "The CFI award was the initiative which helped the UNB MRI Centre become a large scale research facility. A new faculty member has recently joined the MRI Centre from the UK where he worked in industry. Two post doctoral fellows were recruited in the last year, one a former NSERC International, to the MRI Centre".
>
> "I would not have remained at UNB if I did not have access to this infrastructure. It helped me to recruit other researchers (PDF and students) to work on this project".
>
> « L'implantation de l'infrastructure a permis d'attirer une professeure-chercheure en biochimie et deux nouveaux professeurs-chercheurs spécialisés dans des domaines de pointe de la biotechnologie alimentaire. »
>
> "The microscopy facility has been instrumental in the advancement of the research program of the two junior applicants in this grant. A faculty member in Biochemistry

was recently hired, and the presence of the microscope facility was a major factor in his decision to come here".

6.1.1 Recruitment of students

Project leaders were asked whether, in the past year, the infrastructure contributed to the recruitment of students from outside their institution. A vast majority of projects recruited students in the last year, mostly from Canada and countries other than the US. Only one of the 260 students was recruited from the US and 80 came from other countries.

Table 27–Recruitment of students

Number of projects reporting students recruited from Canada (179 students, 69% of total)				
1 student	2 students	3 students	>3 students	none
13 (16%)	8 (10%)	6 (7%)	20 (25%)	34 (42%)
Number of projects reporting students recruited from abroad (80 students, 31% of total)				
1 student	2 students	3 students	>3 students	none
13 (16%)	9 (11%)	1 (1%)	6 (7%)	52 (64%)

"The development of the Trent Water Quality Centre has provided Trent with the ability to attract and retain highly skilled students and PDF's. Traditionally, Trent has had relatively few Ph.D. students compared to MSc students. However, that trend is now starting to change because of the interest of students in working in this facility".

Agriculture and Agri-Food Canada has placed a dairy research scientist at the Nova Scotia Agricultural College, partly because of the opportunities in pasture research.

"We have more requests for M.Sc. training and undergraduate research employment than we can accommodate. Currently there are four M.Sc. students and several undergraduates involved directly in pasture research at the Centre".

"Three technical staff were hired on NSERC grants specifically to work with the new instrumentation, and a curator for the new herbarium facility was jointly hired with the Atlantic Canada Data Conservation Centre, an organization with which we are developing a very strong and productive relationship".

6.1.2 Recruitment of professional and technical staff

The quantitative part of the report did not ask project leaders about the number of staff they recruited. However, there was a question on job creation, and from the narrative part of the report, it is evident that most of the answers referred to jobs in the lab (or jobs associated with the project). Table 28 shows the number of projects where the infrastructure played a role in job creation.

Table 28–Number of projects reporting influence of infrastructure on job creation

No influence	Some	Considerable	Total
17 (21%)	51 (63%)	13 (16%)	81

> « Le récent développement de l'infrastructure informatique du fichier nous a permis d'obtenir une importante subvention (1,6 million pour trois ans) de Valorisation-Recherche Québec. Ainsi, 18 nouveaux emplois de nature technique ont été créés, nous permettant d'accélérer très sensiblement l'expansion du fichier. Cela nous permet aussi d'envisager à court terme une augmentation significative de son exploitation qui entraînera une consolidation des emplois du personnel spécialisé (informaticiens, spécialistes de fichiers de population, techniciens, etc.) et la création de postes d'assistanat de recherche. »

6.1.3 Access to world competitive infrastructure

For more than half the projects, more than 3 researchers (faculty and PDFs) have substantially advanced their research in the past year because of the availability of the infrastructure (see Table 29). One hundred and one users came from the private or public sectors.

Table 29–Researchers who advanced their research thanks to infrastructure

Number of projects reporting such researchers (468 researchers in total)

1 researcher	2 researchers	3 researchers	>3 researchers	none
7 (9%)	14 (17%)	13 (16%)	44 (54%)	3

The opinion of project leaders on the quality of their infrastructure is reflected in Table 30 and in the comment that follows. More than 80% state that the infrastructure is above average or better.

Table 30–Quality of infrastructure compared to other laboratories					
Number of projects stating that the infrastructure is:					
Below average	Average	Above average	Comparable to best in Canada	Comparable to best in the world	No answer
2 (2%)	11 (14%)	24 (30%)	17 (21%)	27 (33%)	2

"In my opinion, CFI is the mechanism to take an ordinary research facility and make it an extraordinary international facility".

6.1.4 Collaboration

A vast majority of respondents say that the presence of the CFI-supported infrastructure helped them to create, maintain or strengthen collaborations, (Table 31). In the narrative part of the reports, project leaders go on to describe many of these linkages.

Table 31–Influence of infrastructure on creating/maintaining/strengthening:				
	Number of projects reporting:			
	None	*Somewhat*	*Considerable*	*No answer*
Informal linkages with colleagues at the institution	4 (6%)	21 (33%)	39 (61%)	17
Research collaborations	0 (0%	21 (33%)	42 (67%)	18
Formal signed partnerships	16 (27%)	22 (37%)	21 (36%)	22
International collaborations	16 (20%)	39 (48%)	26 (32%)	0

"International collaboration continues with research foresters in the USA and UK, and with contaminants researchers in Poland, Mexico and the UK".

"One of the most salient impacts of having the infrastructure provided through the CFI is the promotion of collaborative research. The equipment has allowed our researchers to apply for, and receive, substantial funding from other agencies. These grants have generated collaborative projects among our researchers and researchers at other Canadian, American and International Universities as well as collaborations across disciplines and with public service and business partnerships. Each of these programs is multidisciplinary and includes members from Universities as well as the public and private sectors. In addition, members of the research team have formed research

partnerships with local school boards for example, the Waterloo Region District School Board".

"The new infrastructure has had an impact on our research capabilities that has gone beyond the obvious opportunities it offers in terms of new and innovative approaches to our research questions. It has not only generated interactions with two other universities, but has also changed the dynamics of our own laboratories. With the sharing of new ideas, there has been an increase in the level of exchange between the labs. There are obvious benefits of this informal collaboration to the research and for the students involved".

"Also solely due to the infrastructure, the University is fostering new relationships with other universities and with other research organizations (e.g. Atlantic Canada Petroleum Institute)".

"[A researcher] has collaborated with EXFO of Mississauga, a manufacturer of light-based curing systems. The project, to study the effects of different curing conditions on the microscopic surface structure of commercial adhesives, required the AFM and Raman microscopes. The work was supported by Materials and Manufacturing Ontario".

"Researchers have undertaken innovative research projects in collaboration with the public sector (BC Ministry of Forests), private enterprise (Canadian Forest Products, Vernon Seed Orchard, West Fraser Timber) First Nations Bands and international institutions".

"I have had requests for collaboration since this is the only commercial instrument, to my understanding in the world, that can store the radio-frequency ultrasound data at these high frequencies required for the spectroscopic analysis. We have patented our method, and looking for commercialization opportunities. Furthermore, we are in close contact with the Ontario start-up company that has developed the machine (www.visualsonics.com) to further improve the instrument functionality".

"Finally, the Centre for the Study of Commercial Activity (CSCA) has been able to introduce private sector companies and government organizations to the advantages of using spatial data visualization and data mining procedures. In this arena, CSCA has partnered with the LCBO to explore the use of business geomatics

and data visualization software to assess longitudinal corporate store performance".

« La grande retombée de l'infrastructure en 2001 fut l'obtention de la chaire TransÉnergie sur la simulation et la commande des réseaux électriques à l'École de technologie supérieure (ÉTS). Cette chaire est l'aboutissement d'un partenariat d'une dizaine d'années entre l'IREQ, TransÉnergie Technologies et l'ÉTS… Comme on le sait, ce centre a fait de l'ÉTS l'une des universités les mieux équipées au monde dans le domaine de la simulation de réseaux électriques. »

« L'acquisition de l'infrastructure nous a de plus permis de créer un nouveau partenariat de recherche avec la compagnie Biospace Instrument. En plus d'établir une convention de recherche avec nos équipes, cette compagnie française a décidé d'implanter une filiale à Montréal, Biospace Radiologie Québec. Par ailleurs, une nouvelle compagnie en incubation, Solution YD3, s'est aussi montrée intéressée par l'exploitation commerciale éventuelle des retombées de nos recherches. »

«L'infrastructure qui a été mise en place au cours de la présente année permet de répondre de façon plus adéquate aux besoins des partenaires industriels et gouvernementaux œuvrant dans le domaine des transports. En effet, l'infrastructure complétée permet d'une part de satisfaire les besoins des activités d'homologation des manufacturiers nord-américains et européens de produits antigivre commerciaux pour aéronefs tels que Dow Chemical (EUA), SPCA (France), Clariant (Allemagne), Octagon (EIA), BASF (Allemagne), Lyondell (EUA) et Kilfrost (Angleterre).»

"The research facility has attracted an industry collaborator Ropak Canada Inc., in Springhill Nova Scotia, and another collaborator Engel Canada Inc., one of the world's largest injection molding machine manufacturer located in Guelph, Ontario. The current injection molding machine is one of a kind in the world since it provides an open architecture for innovative research".

6.1.5 Creation of, or support for centres of excellence

Smaller universities have definitely increased their participation in various networks of centres of excellence and Ontario Centres of Excellence. They are also included in multi-institutional projects funded by Valorisation-Recherche Québec.

The availability of the CFI-supported infrastructure has triggered the creation of centres:

> "Perhaps more important that this, however, is the fact that the installation of the High Performance Computer, along with the new Canada Research Chairs Programme, has provided Saint Mary's University with an opportunity to make a significant national and international impact on astrophysics. …the University has allocated two of its six CRCs to start an Institute for Computational Astrophysics (ICA). The ICA, if successful, will provide the Canadian and International community with a unique resource---a concentration of computational astrophysicists who can share algorithmic and visualisation techniques with their colleagues, advance the general state of knowledge of the Universe, and provide an environment for astrophysicists around the world to come and study areas of current interest that require intensive computational methods".

6.2 Innovative research productivity

The CFI-supported infrastructure helped researchers generate world-class results in a vast majority of projects, as shown in Table 32. In fact, 54% of projects for which it is not too early to tell report research that is at or exceeds international standards:

Table 32–Self-assessment of the quality of research in the last year

Too early	Modest advance	National standards	International standards	Breakthrough
2	2	10 (13%)	26 (33%)	37 (47%)

A few examples of interesting research:

> "In 2001, the acquired infrastructure was used in an efficient and innovative manner. The CFI investment positively influenced publication and dissemination of research results. The level of risk of our research significantly increased and we are targeting a number of fundamentally important multidisciplinary problems in the filed of organometallic chemistry, involving computational and X-ray crystallographic work".

> "[The researcher is developing a non-invasive technique to map out the brain representations of the body surface. This technique

could eventually replace highly invasive electrical stimulation mapping studies that are routinely conducted on pre-surgical patients. A non-invasive brain mapping technique would be of great benefit to patients requiring neurosurgery".

"The CFI infrastructure substantially improved the productivity of research, as we can now conduct research into advanced controls of wind and solar energy control systems without waiting for a particular wind and solar condition. With the availability of the CFI infrastructure, the scopes of our research activities have been expanded to include not only power electronics and electrical machines, but also advanced controls and distributed power generation and energy storage".

"CIMTEC (Centre for Integrated Monitoring Technology) is an information hub, a Mecca of data collecting, processing, monitoring, and application. CIMTEC is a vehicle to catalyze creativity, innovation, new applications, and new technologies. It will produce a highly valuable skill set in Northern Ontario to build partnerships and meet the needs of a global economy. This highly specialized research facility will help researchers and their collaborators derive useful information from large-scale data sets, with far-reaching implications. First, there has been a fundamental shift in the type of research the university can pursue and offer to industry, particularly in visualization in the areas of mining and exploration. The visualization component of CIMTEC is the first Virtual Reality Laboratory in the world that specializes in mining and exploration. With this banner title, CIMTEC is garnering national and international interest from researchers in the public and private sectors. There has also been much interest from other sectors, including civil tunnel design and urban planning. As a result, Laurentian University is expanding its roster of research initiatives".

"Despite being only recently commissioned, and still not fully functional, the infrastructure has supported much productive research, as evidenced by: gene sequences deposited in GenBank, invited review articles, numerous refereed journal articles, as well as articles in conference proceedings, that have all been made possible by the new infrastructure. In addition, collaboration with governmental agencies and private industry has led to the production of reports, videos, patents, and marketable biotech products".

"Research conducted with the facility has resulted in several high impact publications this year on aqueous silicon-carbohydrate chemistry in addition to the first ever in-vivo detection of organic silicon complexes in a living organism. The findings have received international attention in Chemical and Engineering News (twice), Chemistry in Britain, Science News, The Alchemist and New Scientist, and resulted in many visiting speaker invitations".

« Le projet consiste à renforcer et à améliorer l'infrastructure informatique du fichier de population BALSAC. Le travail relié à la construction du fichier a été complété pour la région du Saguenay (1840-1971) et celle de Charlevoix (1680-1971), et plus de 500 000 actes de mariages de l'Est du Québec ont été saisis... Pour étendre l'éventail des recherches et répondre adéquatement aux exigences des chercheurs, il faut étendre le fichier de population à l'ensemble du Québec… L'infrastructure renouvelée permet d'appuyer d'une manière beaucoup plus efficace à la fois l'expansion du fichier BALSAC et les travaux des chercheurs qui utilisent le fichier… Avec l'achèvement du fichier BALSAC (qui sera alors le plus gros fichier de population au monde), le Canada sera le seul pays à disposer d'une infrastructure de ce genre (pour une population de la taille de celle du Québec). Cela permettra d'accroître sa visibilité internationale et d'apporter une contribution tout à fait novatrice à la recherche en génétique humaine. La possibilité est ici offerte à la recherche québécoise et canadienne de consolider son avance dans ce domaine et même d'affirmer un important leadership à l'échelle internationale. »

"The development of the Water Quality Centre has dramatically increased the level of innovative research at Trent University".

6.2.1 Multidisciplinary nature of research activities

No less than 97% of respondents replied that the availability of the infrastructure had enhanced the opportunities for interdisciplinary research in the last year (Table 33).

Table 33–Number of projects reporting that interdisciplinary research has been enhanced

No	Somewhat	Considerably
2 (68%)	24 (30%)	54 (3%)

“The facility enabled by the CFI award is utilized by UNB researchers in physics, chemistry, geology, forestry, mechanical engineering, chemical engineering, electrical and civil engineering”.

“Research… is at the interface of engineering and science and involves a range of collaborations across disciplines in chemistry, microscopy, biochemistry, environmental science, chemical engineering, and microbiology”.

“Some of the functional neuroimaging work conducted in this laboratory has involved collaboration between physicists (MRI image acquisition), computer scientists (data visualization), and psychologists (experimental design, data collection and analysis)”.

«Un des avantages de l’infrastructure est de permettre le contact entre des chercheurs de divers domaines : finance, économie, méthodes quantitatives, comptabilité. Plusieurs équipes de recherche multidisciplinaires ont été créées, justement pour répondre aux nouveaux besoins méthodologiques requis pour l’utilisation efficace des outils. »

« De par sa vocation, la plate-forme de recherche est multidisciplinaire, multi-institutionnelle, multi-sectorielle et internationale. Elle favorise ainsi la cross-fertilisation des échanges et des formations du personnel hautement qualifié, autant à travers les sciences (génie, informatique, mathématique, physique), les disciplines (génie, physique, médecine) que les cultures (Canada, France). »

“The Enhanced Forestry Laboratory has been instrumental in bringing together like-minded researchers from a variety of disciplines including forestry, biology, and geography”.

“New research teams within the NSAC have been formed to address environmental and economic issues that can be ameliorated through changes to cropping systems. These teams include agronomists, horticulturalists, economists, engineers, climate change specialists, soil scientists, nutrient management specialists and animal scientists”.

“The processing of polymer in this research facility encompasses all aspects of engineering. These areas include computational fluid dynamics, mathematical modelling, material

characterization, advanced control and instrumentation, intelligent sensing and software development, new materials, recycling, resin and colorant blending, and a new area of nano-composites manufacturing".

6.3 Nature and relevance of training for research and other careers

Table 34–Students using the infrastructure

	Number of projects with no student	Projects with 1 student	Projects with 2 students	Projects with 3 students	Projects with >3 students
Undergraduate (total 577)	15 (19%)	5 (6%)	10 (12%)	8 (10%)	43 (53%)
Masters (total 404)	10 (12%)	12 (15%)	18 (22%)	6 (7%)	35 (43%)
Doctoral (total 165)	37 (46%)	16 (20%)	9 (11%)	8 (10%)	11 (14%)

"Our research provides information that is applicable to crop breeding and agriculture, and the students trained in our labs are qualified to work in various aspects of plant breeding and agricultural research".

"The presence of the Paleo-DNA laboratory has had its greatest impact to date on student training. Prior to the development of the Paleo-DNA lab there was no molecular biology at Lakehead University".

"The most substantial outcome is the training of masters graduate students. One master's student completed his experiments on the genetic variation of trembling aspen in response to changes in atmospheric CO_2 concentration. Without the infrastructure, it would not have been possible to do this project at Lakehead University".

"Most of the postdoctoral fellows and graduate students are working on research projects supported or defined by Canadian companies. It is expected that upon completion of their program, they will be employed directly by these companies. In 2001, Rockwell and Honeywell employed a Master's graduate, a Ph.D. candidate and a postdoctoral fellow from Ryerson. All of them were trained in the Laboratory for Electric Drive Applications and Research".

"Two M.Sc. students who graduated this past year relied on the CFI infrastructure. Both of these students worked on mining

problems and were supported by the private sector. A third M.Sc. student, also supported by a private company, is currently completing his thesis".

"Most research has a mix of soil, climate, plant and animal components, and experts representing each are involved in research training".

"Graduates who have been trained in electron microscopy and X-ray energy dispersion analysis are able to find employment in a very wide of fields because the instrumentation is a common research tool in fields as diverse as: insect morphology; cement characterization; forensic science; materials science research; and mineral exploration".

6.4 Economic and Social Benefits

Table 35 indicates the number of projects reporting various types of benefits enabled by the infrastructure in the last year.

Table 35[8]–Benefits enabled by the availability of the infrastructure

	# of projects reporting no benefits	# of projects reporting some benefits	# of projects reporting considerable benefits	No answer
Intellectual property	55 (70%)	15 (19%)	9 (11%)	2
Knowledge clusters	10 (12%)	44 (54%)	27 (33%)	0
Products and services	29 (36%)	34 (42%)	18 (22%)	0
Spin-off companies	72 (91%)	6 (8%)	1 (1%)	2
Cost savings	28 (36%)	31 (40%)	19 (24%)	3
Public policy improvements	54 (70%)	18 (23%)	5 (6%)	4
Health benefits	57 (73%)	20 (26%)	1 (1%)	3
Social benefits	51 (66%)	23 (30%)	3 (4%)	4
Environmental benefits	39 (51%)	26 (34%)	11 (14%)	5

[8] Numbers may appear high in this table. In reading the reports, it is obvious that a number of respondents mentioned benefits generated since the infrastructure first became operational as well as benefits that are likely to occur in the near future. One must also remember that the table refers to number of projects. Researchers report the same benefits in all the projects in which they are involved.

In the narrative part of their reports, researchers were not asked specifically to describe the knowledge clusters that were enabled with their CFI awards. Examples of other outcomes are given in the following subsections.

6.4.1 Economic benefits/Costs savings

> "One of the principal Investigators has started working on a US patent application in the area of electromagnetic device design for high power motor drives".
>
> "The infrastructure is in the process of making significant economic and social contributions, with intellectual property being generated that has involved the generation of patents. [A researcher is in the process of patenting stress-preventing bioactive compounds, and it is envisioned that these activities will continue with patents in the fields of phytoremediation, stress prevention, and contaminant detection (e.g., E. coli)".
>
> « Ainsi, on peut mentionner comme exemples de transferts technologiques déjà réalisés : la soufflerie mobile développée [ici] à l'usage des manufacturiers de fluides aéronefs; le câble déglaçable par impulsions électromagnétiques; trois codes numériques développés aux fins de l'industrie du givrage. »
>
> « L'infrastructure a permis à des chercheurs à l'emploi de deux nouvelles sociétés à capital de risque d'évaluer la performance de leurs produits dégivrants et anti-givre nouvellement développés, ces derniers étant beaucoup moins dommageables au plan environnemental que les fluides dits classiques.»
>
> "We have advanced substantially in commercialization and technology transfer of our research outcomes. Two patents were granted. We have entered a commercial agreement with Neill and Gunter, an international consulting and engineering firm, in commercializing the P_M process developed in our laboratory".
>
> «Le projet BALSAC se trouve placé à un point crucial de son développement. Dans la conjoncture où se trouve actuellement la recherche en génétique et dans la perspective du développement de médicaments et de thérapies géniques, il devient possible de convaincre les multinationales pharmaceutiques de faire davantage d'investissements de recherche au Canada plutôt qu'en Amérique latine, en Estonie ou en Scandinavie, régions dont les populations présentent des traits semblables à ceux de la

population du Québec. L'existence d'une infrastructure comme celle du fichier de population BALSAC devient alors un atout considérable. »

"It is expected that the Super High Power Motor Drive project, upon its completion, will generate as least $12.5 million revenue for Rockwell Automation. The Next Generation Motor Controller developed for Honeywell Aerospace is to be shipped to Boeing for field-testing in March 2002. It is expected that Boeing will purchase a number of NGMCs in the near future. Allanson International has put a substantial amount of effort and manpower in commercializing the Microcontroller Based Protection Module. It is certain that the successful development of these new products will have a positive impact on job creation and therefore stimulate Canada's economic growth".

"There are a number of economic and social benefits that have resulted from our new infrastructure. We have been particularly successful in developing new protocols for the analysis of inorganic compounds with our microwave digestion apparatus".

"The Nova Scotia Agricultural College established a company in 1999 (Performance Genomics Inc.) to develop and commercialize DNA markers for reproductive longevity in livestock. The infrastructure has been crucial in finding genes and markers".

"The presence of the Paleo-DNA laboratory and our mtDNA research focus has led to the development of Genesis Genomics, a private company focusing on medical diagnostics using mtDNA. This company has filed a major patent in the United States and has developed affiliations with researchers in the UK and in the US."

"[A researcher's] work on new methods for measuring radioactive isotopes using mass spectrometry has decreased the cost of analysis for selected isotopes by a factor of 10 and decreased the time of analysis by a factor of ten. As a result, it will soon be possible to use these methods to monitor releases from nuclear power stations or wilful releases from terrorist activity".

6.4.2 Policy improvements/social benefits/health improvements

« Au plan des bénéfices reliés à la qualité de la vie et à la santé humaine, l'infrastructure BALSAC se signale surtout par l'appui

qu'elle procure aux travaux de recherche en génétique. Dans certains cas, BALSAC permet aussi de contribuer plus directement au plan épidémiologique et même au plan clinique. Enfin, nous avons montré à propos du Saguenay comment l'exploitation de l'infrastructure BALSAC peut apporter une contribution directe aux stratégies de prévention des maladies héréditaires. Le développement informatique de cette infrastructure permet d'étendre plus rapidement à d'autres régions du Québec et du Canada ce type de contribution. »

"[A researcher's] work on drug residues in wastewater effluents has had a direct influence on government interest in developing new regulations to manage these compounds".

« L'infrastructure nous a permis de répondre aux questions fondamentales dans le domaine de la recherche environnementale ainsi que d'aider une communauté à avancer d'un projet "pilote" vers un programme commercial dans le domaine de l'aquaculture. »

"The research that has taken place as a result of having the equipment involves topics central to many serious social issues today. For example, the work at the NCE (Health Canada) examines youth engagement. In particular, the research focuses on youth volunteerism and creating environments for youth that will provide mechanisms for recovery and assistance to street youth. The work at the NCE Canadian Language and Literacy Research network is directed toward understanding the needs of young children regarding language and literacy. The work on inter-generational relationships is particularly important for aging populations and understanding the impact they have in shaping behaviours and beliefs in younger generations".

6.4.3 Environmental improvements

"The research focus is on climate change, air pollution impacts and biodiversity. This feeds directly into national and international organizations, and the Canadian climate change program".

L'impact socio-environnemental des projets de recherche élaborés par le Centre de recherche sur les chaussées à revêtement bitumineux (LUCREB) se traduit par une plus grande satisfaction des usagers de la route (sécurité, performance et efficacité des interventions) et dans la conservation des ressources naturelles. Le LUCREB préconise le recyclage de matériaux de chaussée

aussi bien comme matériau granulaire de fondation que pour la confection de matériaux stabilisés ou d'enrobés avec un liant hydrocarboné.

"The work of the COMERN mercury network will have a direct impact on the management of mercury in the environment, one of Canada's most pressing environmental issues. In all these cases, the research enabling these improvements could not have occurred without the development of the Water Quality Centre".

« Information importante dans le domaine des sciences de l'environnement. (p. ex. la formulation des recommandations pour réduire l'impact du déversement de tourbe en milieux estuarien). »

6.5 Awards, recognition (international, domestic)

Table 36–Impact of the infrastructure on the ability of its users to attract funds

Funding source	# of projects with no CFI influence	# of projects with some CFI influence	# of projects with considerable CFI influence	No answer
Institution	22 (28%)	37 (46%)	21 (26%)	1
Federal granting agencies	9 (11%)	25 (32%)	45 (57%)	2
Other federal	24 (32%)	27 (36%)	23 (31%)	7
Provincial government	31 (40%)	17 (22%)	29 (38%)	4
Canadian industry	25 (32%)	31 (40%)	22 (28%)	3
International	39 (53%)	19 (26%)	16 (22%)	7

A significant number of projects mention the subsequent awarding of a Canada Research Chair to users of the infrastructure. Other personnel awards include a Steacie Fellowship and Premier's Research Excellence Awards (Ontario). With respect to research funding, it is definitely increasing. Various sources are mentioned, including the federal granting agencies, Networks of Centres of Excellence, industrial contracts, Valorisation-Recherche Québec and subsequent CFI awards.

6.6 Efficient management, use and sharing of infrastructure

In the narrative part of their reports, researchers describe measures taken to ensure the efficient management, use and sharing of the infrastructure. In the

quantitative part of the report, they were asked to comment about delays and to discuss whether or not the infrastructure was adequately utilized.

6.6.1 Delays

About 50% of the projects experienced delays of some sort, most of them minor, some major. Major delays have been discussed with CFI. The reasons for delays have been given in the section on New Opportunities (section 3.7.1).

6.6.2 Infrastructure Utilization

With respect to utilization, 85% say that their infrastructure is used appropriately or is oversubscribed.

Table 37–Utilization of infrastructure

Under-utilized	Adequate	Over-subscribed	n/a
12 (15%)	59 (74%)	9 (11%)	1

Of the 12 who say that the infrastructure is under-utilized, 3 state that the infrastructure is not operational or is partially operational. The others give the following explanations:

- 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);
- equipment is very specialized and it is normal that only a few students use it.

A dozen projects that state that the use is adequate hint at under-utilization in the comments they make: lack of students (1), faculty turnover (1), implementation is a long process (1), cyclical use (1), not completely operational (7), other PI's not using the equipment (1).

Lack of staff and lack of funds cause problems in a number of cases and this may eventually lead to under-utilized, especially if equipment cannot be maintained in a timely fashion. The CFI Infrastructure Operating Fund will help future projects, but not those who reported this year.

6.6.3 Management of the infrastructure

Smaller infrastructure are managed by the principal investigators. Larger projects have more formal management structures.

In some cases, sharing of the infrastructure is facilitated by the centralization of equipment:

> "The sharing and use of our infrastructure is assisted by the centralization of our equipment in either the Lakehead University Instrument Laboratory or the Environmental Laboratory".

7 Research Development Fund (Colleges)

Only 16 projects, from 9 colleges and from the British Columbia Institute of Technology and the Technical University of British Columbia had sent reports to CFI by 30 April 2002. Half of these projects were not operational, were partially operational or had just recently become operational. Most others had become operational in 2001. Awards ranged from $68,000 to $764,000.

As is the case of other funds, some outcomes, such as attracting staff or initiating collaboration, occur even before the infrastructure becomes operational.

In the past year, the availability of the infrastructure was instrumental in the recruitment of researchers for 13 of the 16 projects; 27 researchers were recruited, 4 from the USA and 5 from other countries; 63 advanced their research with the help of the infrastructure in the past year.

More than 100 students were recruited, most coming from Canada and 734 were trained with the infrastructure, 20 of them at the graduate level.
All projects state that interdisciplinary research and collaborations were enhanced with the infrastructure.

The infrastructure had an impact on research funding from all sources, particularly from institutional and industrial sources, and, for about half the projects from federal councils and provincial agencies.

Excerpts from reports show the impact of the infrastructure to date:

> "Through the collaborative partnerships fostered by CFI investment, 37 term and full time jobs were created as a result, which is especially important given the unemployment problems in northern Ontario. Many Sault College faculty members are

relatively new to research. Our approach has been to partner closely with federal and provincial government, academic and corporate researchers to form multidisciplinary research teams. The training that Sault College faculty, staff and students have received working with experienced researchers has been invaluable.

The number and variety of partners involved in this research has resulted in very efficient use of infrastructure. All partners have signed agreements with Sault College that outline each institution's role, including the sharing of equipment operating and maintenance costs. This has ensured that equipment is well utilized and that each partner has realized substantial cost savings. Research partners have also pooled resources to share operating costs, including hiring of research assistants. Sault College students have been involved in collecting and analyzing data for several of the projects, leading to further cost savings.

Three of the research projects have resulted in products that have potential for marketing. For example CFI investment has helped to develop a handheld tool for field measurements in forestry applications. Sault College students tested the product, suggested refinements, and the product is currently being tested by a number of companies in the field. Sault College and partners will be placing a greater emphasis on other development opportunities that arise from this research in the future.

Several of the projects have resulted in environmental improvements, including re-establishing an extirpated elk population along the north shore of Lake Huron. In other projects the research results will lead to revised policy & regulations on forest management and water allocations.

CFI investments have resulted in over $6.5 million in additional funding leveraged from a variety of sources for capital and research operating costs".

« Dans les domaines des géosynthétiques et du textile, les deux départements du Groupe CTT, c'est à dire le Centre des technologies textiles et SAGEOS, sont considérés comme des chefs de file en ce qui a trait à la recherche appliquée. Cependant, alors que dans le passé ils œuvraient principalement sur le territoire québécois, l'infrastructure récemment acquise a eu un impact majeur en ce qui a trait à l'obtention de contrats de recherche sur une base géographique plus large,

comptant notamment les autres provinces canadiennes ainsi que les États Unis. »

“A new, start-up biotech company has initiated negotiation with Biotechnology Centre for Applied Research and Training (on the Seneca @York Campus of Seneca College) to do some research and development work on proteomics and immunodiagnostic systems. In addition to conducting applied research and providing co-op experiences for students, BART aims to provide professional development and training in the use of this sophisticated equipment to faculty, students and staff. Training sessions were offered to our faculty and some were open to personnel from biotech companies”.

“Since the establishment of the Centre for Rehabilitation Engineering and Technology that Enables (CREATE) facility, the two partners in CREATE (the British Columbia Institute of Technology and the Neil Squire Foundation) have been actively able to secure both private and public sector funding. This has happened both on the domestic and international fronts. Examples follow:

> Development of an innovative lift devices to reduce Musculoskeletal Injury among home support workers in BC, funded by the Worker’s Compensation Board;
> Development of an innovative pill-crushing device for use by health care workers to reduce MSI, funded by Occupational Health & Safety Agency for Healthcare in BC (OHSAH).

Virtually all of the work done in the CREATE facility is multidisciplinary in nature. This includes the training of students using the facility (mechanical engineers, industrial designers, an industrial psychologist, plastics technologists, electrical engineers and prosthetists/orthotists)”.

“Although completed only in September 2001, the presence of the Shared Virtual Environment (SVE) Lab facilitated the recruitment to the Technical University of British Columbia of five new Interactive Arts and Interdisciplinary faculty members from the United States, Australia and the United Kingdom. TechBC's fundamental approach to learning and research is multidisciplinary. At TechBC interactive research involving information technology, new media, arts and business is conducted in partnership with key stakeholders in BC’s high tech sector”.

8 Conclusion

This analysis of the 2002 institutional and project reports submitted to CFI has shown that CFI-funded infrastructure is having a major impact on research and that research results are starting to generate benefits to Canada. This confirms the conclusions of the recent independent evaluation of the New Opportunities Fund.

Institutional reports mention the impact of CFI not only in leveraging matching funding for the infrastructure, but its effects on increasing provincial government investments in research as well. The fact that research planning is now commonplace in Canadian research institutions can also be linked directly to CFI requirement for research plans.

CFI investments have enhanced considerably the ability of institutions to attract and retain faculty members and researchers. The coupling of Canada Research Chairs and CFI infrastructure is increasing this impact by providing universities with better tools to renew their research workforce.

Not only is CFI influencing research capacity, it is also helping to transform the way research is done. Perhaps most remarkable is the impact on interdisciplinary research, where 96% of respondents state that the availability of the infrastructure had some or considerable influence on the interdisciplinary character of the research.

The nature and quality of training given to students and other trainees is also enhanced by their exposure to state-of-the-art infrastructure. Again and again, researchers comment that graduating students are better prepared for employment.

The availability of state-of-the-art infrastructure also helps increase the quality of research, as results are more reliable and can be generated faster. As a result, research productivity is enhanced.

The research conducted with CFI infrastructure is starting to generate benefits to Canada in terms of the development of products and services, creation of intellectual property, health, social and environmental benefits. Reports promise more in the future.

Clearly, the CFI is achieving its intended objectives. However, there are some implementation problems. A significant proportion of projects experience delays. In some cases, these are due to difficulties in finding matching funding. In others, these are due to unforeseen complexity and increased costs.

Overall, infrastructure is used adequately but there is a danger of underutilization for lack of human and financial resources. The new CFI Infrastructure Operating Fund will help solve the situation for new projects but projects approved prior to mid-2001 (those that reported this year) will not benefit from this fund.