

**Analysis of reports on infrastructure projects funded by  
the Canada Foundation for Innovation  
(and other funders)**

Prepared for the Canada Foundation for Innovation  
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# **Analysis of reports on infrastructure projects funded by the Canada Foundation for Innovation (and other funders)**

## **Introduction**

This report summarizes the information found in:

1. the institutional reports submitted in the fall of 1999 by universities and affiliated institutions that benefited from research infrastructure funding from the Canada Foundation for Innovation (CFI); and
2. the project reports submitted by principal investigators in infrastructure projects funded by the CFI and institutional reports submitted by colleges.

This report talks about the impact of the CFI infrastructure. Of course, this means the impact of the infrastructure provided by CFI **and** by the institutions and all the other organizations that contributed 60% of the costs of this infrastructure (and are now contributing to its operation and maintenance).

## **1. Institutional reports (universities and affiliated institutions<sup>1</sup>)**

University research administrators are busier than ever. After years of restraints, the federal government is announcing and launching new programs, and a number of provinces have also launched new initiatives. Each of these initiatives comes with its own requirements and tight competition deadlines. It is therefore impressive to note that busy university research administrators took the time to prepare thoughtful institutional reports to CFI under short notice. The most useful reports relate the CFI investment to the university research and development plan and reflect on the transformation of university research that is taking place thanks to CFI, provincial government programs, and other federal initiatives.

A number of universities did not have time to stand back and reflect on the impact of the CFI on the institution and its research and development plan. In such cases, the institutional report consists mainly of the summary of individual reports prepared by principal investigators.

To avoid repetitions, this analysis will focus on those parts of institutional reports that do not duplicate project reports.

Institutions are convinced that the research infrastructure supported by CFI will have major social and economic benefits, but all agree that it is too early to

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<sup>1</sup> College reports are found in section 2.5

provide solid evidence in this regard, although progress reports contain numerous examples of early benefits. Most institutions also noted the impact of CFI infrastructure on research productivity, noting that researchers were 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. All also commented on the increased quality of training and on the importance of exposing research trainees to cutting edge equipment and facilities: "they will be exposed to new research paradigms with unprecedented levels of interdisciplinary collaboration". Three universities noted that CFI had contributed to increased visibility of university research: "CFI programs and funding have drawn the attention of the community to the quality of our institution."

But, after reading institutional plans, one can conclude that the real impact **to date** is in four major areas:

- impact of CFI on institutional planning processes;
- impact of CFI on the morale of the research community;
- the transformative effect of CFI on the way research is done;
- impact of CFI on funding from other sources.

### **Impact of CFI on institutional planning process**

"This process alone served the purpose of creating links and establishing contacts where none existed before and enhancing interactions that already existed. As such, this exercise brought the research community a step closer together."

"Perhaps, one of the most significant impacts is the new, unprecedented level of collaboration between the university and its affiliated hospitals..."

"University administrators are learning to use CFI to support their own objectives..."

"Provincial government officials are also learning how to use CFI as a planning and developmental tool within their respective university systems."

"The CFI has assisted the university in moving forward with its strategic vision and goals."

### **Impact of CFI on the morale of the research community**

"One initial impact of these awards is an overwhelming boost to the morale and optimism of our researchers. The creation of the CFI and

complementary provincial programs has led to a new sense of opportunity and excitement in our research community."

"We have experienced the beginnings for a brain drain reversal by recruiting senior research scientists from major US universities, based on the facilities that will be available to them here."

"There is no question that the New Opportunity Awards Program is one of the most important platforms in the CFI mandate. It allows the University system to attract the best and to make them internationally competitive very quickly. It allows the system to respond to new challenges very quickly and to establish infrastructure in the newest and hottest research areas."

"The New Opportunities program is notable for providing an important incentive for new faculty members... with the infusion of capital for their research, this adjustment period is made easier in terms of enabling faculty to focus on their research, not on patching together a research program using antiquated equipment."

"This has contributed to an increase in numbers (preliminary statistics indicate over 250 persons) of faculty, technicians, undergraduate, graduate, and postdoctoral researchers being attracted (here) because of facilities we are able to provide."

### **The transformative effect of CFI on the way research is done**

"CFI infrastructure promotes partnership between university and hospital researchers."

"Close interaction of clinicians and basic scientists... receptors of research results working with and participating in the creation of new technologies."

"The greatest single legacy of the CFI program may well be the new and enhanced cross-disciplinary activity that it has engendered."

"The general spirit of collaboration has increased markedly not only within the university, but with other universities, all levels of government and industry."

"It is in this area that the earliest and most obvious benefits to the university have occurred. The degree of interchange between university faculties, departments and research centres has been remarkable as researchers were drawn together to work on more complex interdisciplinary programs of research. Similarly, a number of our

applications have created connections with other institutions that had previously not existed."

"In short, one of the key underlying assumptions of CFI, the emphasis on bringing multiple perspectives to bear on complex challenges, has "infected" the research culture at our institution. This effect is, in our estimation, highly positive."

"Various departments have noticed that there is a new "spirit of cooperation" evident in discussions for use of shared equipment. Prior to the CFI competitions, it was often perceived that individual laboratories or departments needed to have their own dedicated equipment in their research labs."

"In addition to providing research capacity, the CFI program has acted as a catalyst to bring together different research disciplines, not anticipated at time of application. We anticipate major advances in innovation research which we know occurs at the boundaries between disciplines."

"Faculty members from different departments discovered common research interests and complementary skills that allowed pursuit of specific, new, avenues of research."

"Stimulated participation of university in network of centres of excellence proposals... increased collaboration with local college" (from a university participating in the Research Development Fund).

**Impact on additional funding** (especially on provincial recognition of the university research enterprise)

"Example of two levels of government working together for benefit of the research community and Canadians."

Most universities have been successful in obtaining matching funding from provincial governments, from industry and from other partners, and have high hopes that their researchers will be successful in attracting additional funding from all sources. There is evidence that this is already started.

However, the University of New Brunswick (which participates in the Research Development Fund), is extremely concerned that the CFI matching requirements demonstrate a "lack of understanding of the environment and requirements of the research community in Atlantic Canada<sup>2</sup>. Put simply and crudely, the rules for supporting innovation in the new economy are being

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<sup>2</sup> Although UNB is the only institution to have expressed this concern in its institutional report, most universities in Atlantic Canada are worried about matching fund.

drawn to reward those who benefited most over the past twenty years. The wealthy provinces have the resources to provide matching funds; they also have the corporate base."

## **2. Project reports**

The guidelines suggested that researchers briefly describe the infrastructure, its effects on the research (done or proposed), and then report on the impact (real or anticipated) of the infrastructure on:

- the training and retention of highly qualified personnel (HQP)
- collaborations, partnerships and knowledge exchange
- social and economic benefits
- sources and amount of research funding.

This report follows the same order. The guidelines also asked researchers to provide quantitative information on sources of operating funds, annual operating budget, number of technical staff running the infrastructure, number of trainees and research funding. This information has not been aggregated at this time, since many projects have not yet started. However, the information will be used by CFI as a baseline for the evaluation of the program which will take place at a future date.

Each funding mechanism is presented in turn, as follows:

- 2.1 New Opportunities
- 2.2 Innovation Fund (<\$350,000)
- 2.3 Innovation Fund (institutional/regional-national >\$350,000)
- 2.4 Research Development Fund (Universities)
- 2.5 Research Development Fund (Colleges)

### **2.1 New Opportunities**

Reading the progress reports submitted by New Opportunities researchers, one is struck by the sheer number of high quality new academic staff that benefit from new infrastructure. Never before in Canada had new faculty members had such an opportunity to equip their laboratories with modern, state-of-the-art equipment.

The results of the initial competition for New Opportunities were announced in July 1998, and some of the new faculty members had been appointed as early as 1995. Therefore, awards approved in the first competition have been paid and the infrastructure is in place.

### **Description of the infrastructure**

The most striking impact is in the life sciences. Reading the progress reports, one has the distinct impression that most of Canada's laboratories were not properly equipped to be fully competitive participants in the revolution caused by advances in genetic engineering and molecular biology. A significant number of molecular biology and genetics laboratories from coast to coast are now equipped to use modern techniques and their students are acquiring skills that respond to the needs of the companies, laboratories and hospitals that will employ them. Infrastructure for research in environment, advanced material and information technology has also been acquired. Appendix 1 (section A) provides examples of the type of equipment acquired, by broad field.

### **Impact on research**

Appendix 2 gives examples of the fields of research that will benefit from the infrastructure. The life sciences dominate, with environment and materials close behind. There are very few researchers in the social sciences and humanities.

The list of areas shows the convergence of some areas of research: materials applied to microelectronics or biotechnology, biotechnology and environment, bioinformatics, new materials with environmental or health applications, etc.

To date, the major benefits have been on the research itself: the infrastructure accelerates the research (bottlenecks have disappeared, steps are automated, etc.), and makes it more efficient. Results are more reliable and researchers and students can explore new ideas and approaches. There is room for greater breadth and depth. Laboratories are now world class and have access to the most powerful and advanced approaches (to identifying gene function, for example). To quote some researchers:

"It is important to point out that this new infrastructure has really allowed me to be unrestricted in thinking of new directions that we could pursue in my laboratory. In the absence of such funding and resources, one tends to be more conservative and unwilling to take risks and pursue truly novel ideas, even though these are often the ones that lead to an exciting and unpredictable discovery."

"This program allowed me to equip my laboratory to a state-of-the-art level, and do the very best science I can do at an early stage in my career."

### **Impact of the infrastructure on highly qualified personnel**

In the life sciences especially, researchers often state that the availability of infrastructure was crucial in their decision to remain in Canada. The infrastructure enables the training of graduate students on state-of-the-art

techniques. This is extremely important in the life sciences, as biotechnology and pharmaceutical companies are looking for personnel with broad skills in modern techniques. Student productivity is also much higher since results come out much faster with modern equipment.

In information technology/microelectronics, fields where there are acute personnel shortages, researchers hope to attract more students and provide them with training more relevant to industry. In all other areas, researchers report no difficulties in attracting high quality graduate students to their laboratories. They attribute part of their success in this regard to the new infrastructure.

The infrastructure also facilitated the recruitment of more faculty members in related areas, including some that were attracted back from prestigious US universities:

"This grant has had a major impact on the productivity, optimism and future capacity of my laboratory, which the #1 factor contributing to my contentment at this university and the main contributor to my not considering other job prospects at other institutions or in the United States."

### **Collaboration, partnerships, knowledge exchange**

Canadian researchers collaborate. This is well documented in studies of publication patterns of researchers and in analyses of funding sources. It is therefore not surprising to read in the reports that CFI researchers collaborate with departmental colleagues, with other researchers in the institution, with other university researchers in Canada or elsewhere, with government researchers and with industry.

How much of this is due to CFI infrastructure? This is difficult to say, but there is definitely an impact:

"Sharing equipment promotes collaboration."

"(We have) increased external collaboration because we are able to collaborate on an even playing field and to deliver timely results to collaborators."

"(We are working on) instrumentation development with companies providing the equipment (new uses for equipment)."

"...development of a promising collaboration between two laboratories in the same institution."

"Shortly, we will be using the facility in an unanticipated fashion" (service work for a company).

"...discussions with industry (product developers), practitioners and patients (users) to understand their needs in terms of testing and products."

Several reports also mentioned that the infrastructure enables truly interdisciplinary research:

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

"...multidisciplinary team of engineers and physicians from four institutions."

"Faster incorporation of results into clinical practice."

Of course, not all research is conducive to collaboration. In such cases, though, the availability of infrastructure promoted sharing and may eventually lead to increased collaboration:

- some of the equipment is shared by several researchers, but there is no collaboration;
- sharing of techniques between groups of different disciplines using the equipment (may lead to future collaboration);
- because of the communal design and shared facilities, the CFI infrastructure is being used to train and recruit new HQP to all of the six research laboratories.

## **Benefits**

CFI researchers are productive and some of their research has already been applied. How much of this is due to the CFI infrastructure? Again, this is very difficult to say, since most CFI researchers have research support from many sources and are active in networks of centres of excellence research. But there are strong indications that the infrastructure is making a difference.

We are told that it is too early to talk about job creation outside the university/hospital system, but the very presence of the infrastructure definitely increased the size of laboratories and created more technical and research assistant positions.

But the research supported by the infrastructure has immense potential for socio-economic benefits:

"The proposed infrastructure has the potential to lead to new therapies, which would impact both cost savings and job creation, as well as, in the long term, improve quality of life and health of Canadians."

"Potential for improved prosthetic devices, novel diagnostic tests, other value-added medical products and devices."

"May lead to identification of new genes, target for future drug development."

Potential for decrease in health care costs, potential for improved health services, potential to integrate research results in policy decision making and potential environmental impacts are also mentioned by a number of researchers.

Finally, there are potential applications to the following industrial sectors:, aerospace, automotive, chemical manufacturing, construction, electronics, environmental technologies, food, mining, pulp and paper, software, etc. Several CFI researchers have filed patent applications and report increased industrial contacts; others are hoping to launch spin-off companies shortly.

### **Impact on research funding**

All CFI researchers report remarkable success with major granting agencies, but, of course, universities recommended very strong researchers, and CFI selected the best among them in the initial competition. Many in this first competition were already in receipt of research grants before they received the infrastructure. Some were holding prestigious salary awards from NSERC (women faculty awards), MRC, provincial health research councils, for example. However, it is still early to assess the impact of CFI infrastructure on their ability to attract funding (they attract funding because they are good and they get CFI funds because they are good).

Some newer researchers are just now applying for their first grants, and they are extremely confident that they will be successful. Reading the reports, one wonders where hard pressed granting agencies will find the money to meet the expectations of these enthusiastic researchers. Of course, the pressure on equipment grants programs of granting agencies may indeed decrease. To quote a researcher: " I will ask for more funding for assistants since less will be required for equipment". (This is an unintended impact of CFI, since its programs were not supposed to substitute for granting council programs.)

The following examples demonstrate the success of researchers to date in raising funding for their research (not counting the matching funding which paid for 60% of the infrastructure):

- successful in 5/5 grant applications;
- success with NIH, MRC, Heart and Stroke, NSERC strategic, Health Canada's TSRI (toxic substances research initiative), US Office of Naval Research, Research Innovation Award from an American organization, etc;
- already leveraged industrial support;
- infrastructure used by others who pay user fees;
- graduate student won a research grant.

### **Other impacts, issues and problems**

Few problems were reported by researchers (note that the question was not asked explicitly in the guidelines for preparing the reports). In one case, construction is not started because estimates are far too high and the group is working on decreasing costs. Under this mechanism, there are apparently no problems with matching funding. On this latter point, and to conclude the analysis of New Opportunities project summary:

"CFI is built on a matching fund basis. This can provide difficulties in some fields as partners for the matching funds are not necessarily easily found in all research fields. However, over the long run, it certainly did tease a lot of money out of what was perceived to be a very dry financial environment. What it shows is that there is money out there, and the matching funds turned out to be a great way to leverage it. Thanks!"

### **2.2 Innovation Fund < \$350,000**

Under this mechanism, there are several projects where the **infrastructure** will be developed rather than purchased off the shelf., i.e. either the development of laboratory infrastructure (microscopes, mass spectrometers), or the development of databases or data banks. Appendix 1 (section B) provides examples of the type of equipment being developed or acquired.

Appendix 2 (section B) gives examples of the fields of **research** that will benefit from the infrastructure. There are a number of social sciences projects under this mechanism, mainly as applied to health. One group noted that the equipment gave the researchers the opportunity to move from theoretical studies to experimental ones. Several mentioned increased research productivity because the research was so much more efficient. Others noted that they were tackling new research that could not be carried out without the specialized equipment. One report sums up the impact on the research:

"After several years of slowly building up the equipment needed for this facility through the conventional Canadian mechanisms (beg, borrow, and steal), during which we saw our lead in two key areas of research gradually disappear, it was very refreshing to be able to relatively quickly obtain the CFI support that pushed us over the top and provided what has already become a heavily used resource."

With respect to **highly qualified personnel**, several reports stress that the new equipment helped attract graduate students, clinical scientists and faculty members. The equipment also enables better and more efficient training of students.

Several project reports mention increased **collaborations** (within and outside the institution), including interdisciplinary collaboration. Some mention involvement in networks of centres of excellence. Other note increased collaboration with industry or social services agencies.

In the area of social or economic **benefits**, some researchers report new contract work with industry. Others mention the likelihood of commercialization of results or the possibility of positive impact on health or on the environment. Two researchers have already established companies, others have filed for patents. The infrastructure enables the easier and faster dissemination of research results to the end-users.

In general, researchers that benefited from the infrastructure report a positive impact on research funding. One report reported **problems** with matching funding: "This project has run into unanticipated problems with funding. The major contributing company was forced to withdraw support after it was taken over by another company. The university is still in dialogue with the new company and other sources to obtain funding."

### **2.3 Innovation Fund (institutional/regional/national) > \$350,000**

These large awards were announced, for the most part, in the spring and summer of 1999. A number have not yet been paid, pending various conditions, such as securing the necessary matching funding. Many others will not be completed for several years to come, as they require construction, development, installation, etc. Reports generally stress that benefits will be in the future. In cases where the infrastructure is not yet operational, it is not unusual for the project reports to have been "cut and pasted" from the original application to CFI (which, of course, had to demonstrate the promise of enhanced training, collaboration and socio-economic benefits, in addition to research excellence). Yet, many reports stress that some impacts are already being felt. This section will focus mainly on these.

First, **the infrastructure**. Appendix 1, section C, gives examples of the types of facilities and instruments that will be built, developed or acquired with funds from CFI and other funders.

Appendix 2, section C, highlights research areas that will benefit most from the new infrastructure. The impact of this mechanism on **research** is already being felt in all institutions. Indeed, institutions are taking advantage of the opportunities offered by CFI to transform the organization of research to respond to the research needs of the 21st century. Research is taken out of the traditional discipline department and moved to interdisciplinary centres where research questions require the collaboration and insights of specialists from many faculties and departments, and where sophisticated equipment can be shared by research teams. The advent of CFI has enabled institutions and research groups to move in that direction. This was not possible before: such a transformation was a dream, but the resources were simply not available. For example:

"The Centre will be unique within Canada, consisting of a large, interdisciplinary team with a wide breadth of expertise and techniques who will solve challenging problems in the new emerging field ."

"Centralized infrastructure makes the research much more efficient and foster collaboration."

"We are re-inventing the university by designing programs across traditional departmental and faculty boundaries".

"We will finally be on par with international research groups."

"There is a paradigm shift towards a new culture of scientific and engineering research. Old barriers between disciplines are being broken down, and a heightened level of interdisciplinary collaboration is enabled by a concentration of resources and expertise into the CFI-funded facility, which is acting as a springboard for future research investment."

The impact of the new facilities on the **morale of faculty members**, graduate students and other trainees cannot be overstated:

"The biggest impact is on morale of faculty members. So many projects have been stifled for lack of adequate facilities."

"To have access to top quality equipment to answer difficult research questions is a rare joy."

The impact on the **quality of the research** is already felt: results come faster, in greater depth and breadth:

"This decreases the cost and improves the efficiency of the research, as well as allowing access to approaches that are not feasible without the infrastructure."

"We are ideally positioned for breakthrough discoveries."

The new infrastructure already has an impact on the ability of institutions to attract and retain **highly qualified personnel**, i.e. faculty members, researchers and graduate students:

"Many of the scientists would not have come without the promise of the facility."

"We recruited two Canadians who had left the country."

"Infrastructure is what retains people here."

"Our centre is a driver of new faculty recruitment."

"We recruited senior people from the United States."

Large CFI infrastructures are in institutional priority areas where recruiting is taking place and graduate programs are expanding. Some groups report success in attracting more and better graduate students and postdoctoral fellows who are interested in learning the new technologies and having hands-on experience with state-of-the-art facilities. Some groups have advertised positions and are optimistic that they will attract excellent individuals. For example, in areas such as information technologies, where universities simply cannot compete with industry for salaries, they hope that the quality of the facilities will help fill positions. Training of undergraduates is also mentioned.

All reports state that training will be better, given the hands on experience on modern equipment, and given that results will be more reliable and come out faster.

The infrastructure is already having a major impact on **collaborations**:

"Simply knowing that this infrastructure is to be put in place has generated new and potential opportunities for multidisciplinary research and technology development which would never otherwise have taken place."

"The planning that culminated in the present proposal has, itself, been very important in forming new scientific collaborations and strengthening

existing ones" (joint venture between biomedical scientists, engineers and chemists).

Many groups from university with medical schools candidly admit that collaboration between university-based and hospital-based researchers had been a rare occurrence. The CFI competitions have brought these groups together, reluctantly at first, but now, genuine collaborations are reported. For example:

"Although hospital-based research institutes have been part of the medical research scene for a number of years, they have often not been well integrated into the university research community. It has been our contention that the best way to ensure the building of a research environment of outstanding quality is to work together on as many common fronts as possible."

"The initiative has softened the traditional boundaries separating medicine and science."

Among other positive impacts of collaboration:

"This culture of collaboration will drive breakthroughs in this age of increasing specialization."

"Regrouping people around infrastructure promotes shared use, avoids redundancy, fosters collaboration."

"Both the process of putting together this application and the resultant discussion with local industry have already had a positive impact in bringing materials scientists from different areas together."

"Having laboratories by function rather than personal labs makes a big difference to collaboration."

Collaborations with companies are increasing. Instrument development offers opportunity for immediate collaboration: "There are new partnerships with equipment suppliers, to expand use of equipment and extend its capabilities."

Collaborations with government laboratories are also on the increase.

In terms of **socio-economic benefits**, some of the new centres have already led to spin-off companies; for most others with the potential for intellectual property, commercialization is expected to take place in the future (for example: new drugs, new materials, new medical devices, new environmental technologies), either through spinning off new companies or granting licences to existing ones. Interaction with existing companies and creation of new ones will

also enhance receptor capacity in Canadian industry. Among the industrial sectors mentioned: aerospace, agriculture, automotive, biotechnology, food, forestry, medical devices, pharmaceutical, power generation, resource extraction, etc.

Major impact on the health of Canadians is expected through new approaches to disease treatment, new therapeutic treatments, new diagnostics, new drugs, new medical devices, reduced costs to the health system. Many of the potential applications are unforeseen at this time. Major impact on the environment and quality of life of Canadians is also expected from the research supported by the infrastructure. Some of the research results are expected to be incorporated in policies (resource management, environment, health care, etc.)

Direct **job creation** is taking place now. CFI and other funders have invested millions of dollars in construction/fitting of new research space and renovations of existing laboratories. Instruments are being developed, installed, operated and maintained. Laboratories are expanding, creating new research and technical positions. Funding for these new positions come from increased research grants and contracts from public and private sources, provincial programs and institutional sources. In the longer term, job creation outside the research system is expected to take place through the transfer/commercialization of research results.

In terms of **funding**, the reports state that the CFI funds, in addition to attracting matching funding, have already helped increase external funding, from provinces, Networks of Centres of Excellence, granting councils, industry and US sources. User fees are starting to come in as well. Expectations are very high for the future, based on the fact that increased research productivity will make the groups more competitive. This undoubtedly means increased pressure on granting councils programs in years to come, especially that most reports count on this source for operating costs.

There are a few **problems**: not all awards are finalized yet, as raising all the necessary matching funding is difficult. Another difficulty comes from the fact that, often, CFI did not provide the full amount, resulting in delays until the necessary funding can be found. One group is concerned about the long delay (almost a year) between the announcement of the award and its payment.

## **2.4 Research Development Fund (Universities)**

Appendix 1 (section D) provides examples of the type of **infrastructure** being developed or acquired. Appendix 2 (section D) gives examples of the fields of **research** that will benefit from the infrastructure. Given that participating universities do not have medical schools, the life sciences and health are less present than in other mechanisms. The environment (including energy, forests, oceans) is the predominant area of application.

Many infrastructure projects enable the researchers to tackle projects that were not previously possible:

We are able to "address cutting-edge research applications that until now have been inaccessible."

"The development and set up of the infrastructure itself is a research project which already offers new avenues."

"The university is a world leader in the area, and the infrastructure will help maintain this position."

"CFI support enables us to move into experimental work (previously limited to theoretical)."

With respect to **highly qualified personnel**, several reports stress the importance of exposing undergraduate students to research:

"Our students will have unusual mix of capabilities in cross-discipline areas".

"Students gain experience valuable to the petroleum and pharmaceutical industry".

Most universities that reported also have graduate programs and institutions were optimistic that the new infrastructure will help attract graduate students and postdoctoral fellows.

At the faculty level, universities hope to be in a better position to attract and retain faculty members: "Historically, the scientists recruited have been relatively junior and have stayed for only a few years before moving on as their skills and experience outgrew the ability of our environment to provide adequate support. Through the development of this infrastructure, most of the necessary facilities will now exist to make the region attractive to scientists."

With respect to **collaboration**, there were several mentions of increased participation in networks of centres of excellence, thanks in part to the availability of the infrastructure, and the development of new NSERC industrial research chairs.

Interdisciplinary research is becoming much more prevalent: "The structuring of our research agenda across disciplinary boundaries, and the necessity of interdisciplinary interactions for addressing true forest ecosystem-based research will result in larger and sustained partnerships."

Increases in internal and external collaborations are also reported. There are collaborations with other Canadian universities, universities abroad, government laboratories and industry:

"Numerous partners are coming forward with proposals for collaboration."

"The need to find matching funding forced us to look throughout the province and the country for collaborations and partnerships."

"In many cases, graduate students have been funded by industry; and the research projects are planned and carried out in full cooperation with the partner. We recognize the benefits to be gained by early consultation and collaboration with sectors and/or individuals who will implement the research results under operational conditions."

"Essentially, the infrastructure will permit our university to start to move from a strictly esoteric research image to one that will help create meaningful associations with the private sector that result in real world solutions to real world problems."

It is too early to talk about **socio-economic benefits**, but there are indications that such benefits will materialize in the future. Some reports mention patents and collaboration with spin off companies. Others discuss potential for benefits on the economy (e. g., decreased costs for pulp and paper industry, increased technology adoption in agriculture, development of standards), health benefits (e. g., new treatment, new wound dressing), on the environment (resource management, fisheries policies, global change) and on quality of life. In terms of job creation, a number of reports mention that companies are expressing interest in students graduating from the laboratory. One institution is beefing up its innovation and commercialization team to increase the transfer of research findings to the private sector. Several reports mention the potential for increased job creation in the local economy through commercialization. Institutions are in a much better position to support local industries by producing a highly qualified workforce with advanced technical skills.

In terms of **funding**, some institutions report that the infrastructure helped obtain more grants or contracts. Some of the facilities are operated on a user-fee basis. Because the research is more efficient, productivity will increase, therefore, several researchers are optimistic that they will be more successful in national grants competitions.

Some of the projects were delayed because it took a long time to obtain matching funding. Some project leaders find it more difficult to find resources to support their laboratories, given that the new infrastructure means additional operating costs.

## 2.5 Research Development Fund (Colleges)

Examples of infrastructure are given in Appendix 1 and of fields of research in Appendix 2 (section E in both cases). Since most awards were approved in the spring and summer of 1999, impacts will be in the future. In many cases, construction is not started or equipment is not yet ordered. Colleges are involved in applied R&D, not in basic research. For the most part, they work closely with industry and provide services to companies. The fact of being recognized by CFI has been important to a number of colleges who had never received sponsored research support before:

"External partners and faculty are now showing a greatly increased level of interest and willingness to support research activities."

"Funding of this project by CFI recognizes the college's capability and commitment to do applied research that meets high standards."

"The establishment of the lab through CFI funding set a precedent for inspiring a significant number of other researchers at the college to pursue their own research initiatives."

"As a result of this award, we have established our applied research credibility and gone from \$0 to over \$6M in peer-reviewed research funding in this discipline alone, garnering awards."

In one case, the college has set up an office of research services to provide support to faculty members interested in conducting R&D projects.

With respect to **highly qualified personnel**, reports mention the experience that will be acquired by faculty members, the training of technologists, continuing education for employed individuals, including teachers, technicians in biotechnology, fishers (especially in data collection). It is also expected that some of the research results will be incorporated in curricula. In a few cases, graduate students registered at a nearby universities do part of their experimental work at the college, under the direction of college faculty.

"The applied nature of the research conducted and the industrial tools needed to achieve such research will expose researchers to the problems and opportunities of the manufacturing sector of the economy, practical experience that would be almost impossible."

In terms of **collaboration and partnerships**, college researchers collaborate with universities (including networks of centres of excellence and hospitals),

with government laboratories and agencies, with international colleagues and with industry:

"(We are) including Internet service providers, local high technology firms, equipment vendors, corporate IT groups, university researchers, and government agencies in the governance structure for the lab. The lab is expected to be widely used by these groups."

"The Centre will support collaborative, ecosystem-based research in the sustainable management of water, fisheries, forestry, and wildlife resources. Planning for the establishment of the Centre has forged stronger linkages between the original partners and has attracted new collaborators to the College."

"The CFI Project Leader is being asked to consider adjunct appointments at two partner universities (something that was not occurring earlier). Similar arrangements are also being developed in reverse - an adjunct research position at the college for an individual at the hospital is being finalized."

"Our centre complements the academic institutions by offering research capabilities to small biotechnology companies and by providing training of current technology in a practical, hands-on approach to the students and technologists in the biotechnology industry."

"The centre will foster collaboration with school boards who are also very concerned about the critical shortage of qualified teachers in the sciences and technology."

The first **benefit** mentioned in reports is the direct creation of jobs in the centres or institutes that will receive CFI support: "We estimate that the establishment of the Centre will result in the creation of an additional 40 seasonal and full-time jobs directly associated with the research projects in the first year alone."

Social benefits are expected, with impact on the environment, education, health, quality of life. Economic benefits are also forecast:

"In the past, technical developments in fisheries mostly came out of Japan (fishing efficiency), Norway (fish detection and other electronic equipment) and Iceland (design and manufacture of fishing gears and netting, etc.). With the new infrastructure and through the development of collaborative research relationships and working with industry, a healthier "made in Canada" approach to fishing operations and research is noticeably evolving."

"We expect the number of companies using the lab to grow to 10 or more within the first year of operation, and have commitments from 5 already."

## Appendix 1—Examples of infrastructure acquired with CFI funding

### A. New Opportunities

#### Life sciences and biotechnology

##### *a) Molecular biology, biochemistry, genetics, biotechnology*

- centrifuges
- computer equipment (hardware, software, workstations, etc.)
- facility for established and emerging bacterial pathogens
- cytofluorometry equipment
- equipment for laboratory studying blood cell formation and leukaemia
- gas phase chromatograph
- genomic and molecular biology facilities
- image analysis systems, nuclear and tomographic imaging, cell imaging facility, molecular imaging, phosphorimaging, fast magnetic resonance imaging, digital imaging
- level 3 facility
- mass spectrometers of all kinds
- microscopes of many types
- new cellular/molecular biology diabetes research laboratory
- nuclear magnetic resonance equipment
- nutrition research facility
- patch clamp workstations
- protein crystallography equipment
- protein purification system
- spectrometers of many types
- transgenic facility
- transport laboratory (molecular)
- X-ray crystallography

##### *b) biomedical and health*

- behavioural neuroscience laboratory
- electroencephalograph
- equipment for computer assisted surgery
- equipment for microvascular surgery
- infrastructure for perinatal unit
- infrastructure for the study of circadian rhythms
- infrastructure to study human motor performance
- multidisciplinary laboratory for the study of dementia
- orthopaedic engineering research facilities

- rehabilitation equipment

### **Environment and earth sciences**

- 3-D seismic processing and imaging equipment
- anemometry system
- aquatic toxicity testing facility
- atmospheric chemistry laboratory (infrared and Raman spectrometer, high pressure liquid chromatograph)
- biogeochemistry facility
- infrastructure for a centre for industrial mineral innovations
- computer equipment for ocean measurements
- mercury vapour analyzer
- mobile laboratory for field analysis
- molecular marine microbiology and virology
- marine seismo-acoustic system
- weather station
- satellite navigation equipment and geographic information system
- upgrade of an environmental physiology unit

### **Materials**

- chemical analysis equipment
- equipment for art conservation
- extrusion equipment
- facility for processing polymer composites
- material imaging and analysis facility
- material characterization laboratory
- microscope (instrument development to observe chemical reactions)
- rheometer
- scanning calorimeter
- spectrometers (infrared, uv, etc.)
- transparent furnace and automated powder feed system
- tunable laser system
- ultrafast laser sources
- x-ray crystallography equipment

### **Information technology/telecommunications/computation**

- complex dynamic system monitoring and control
- computers and networking switches
- equipment for vision research
- high performance computing (involves many other disciplines)
- infrastructure for high frequency and microwave integrated circuits
- high speed data acquisition system and automated machine control
- intelligent telerobotics system
- laser system and time-of-flight mass spectrometer

- microelectronics equipment
- photonics equipment
- process control research lab
- robotics equipment

## **Others**

- anechoic chamber upgrade
- facility to study turbulent shear-layer wall interactions
- infrastructure for fluid dynamics.

### **B. Innovation Fund < \$350,000**

- Automated moisture measurement system
- automated sequencer
- cellular and molecular analysis laboratory
- communication equipment for remote control vehicle
- computer equipment (hardware, software, work stations)
- data collection and analysis infrastructure for agricultural and environmental biotechnology
- development of a databank
- facility for manufacturing and testing composite materials
- field equipment for forest research
- genetic analysis facility
- imaging equipment
- infrastructure for molecular and environmental microbiology (high performance liquid chromatograph, electrophoresis equipment, digital imaging, spectrofluorometer)
- infrastructure for oral health and pain control
- isothermal titration microcalorimeter
- laboratory infrastructure for environmental studies in cold climates
- laser micromachining facility, nanofabrication laboratory
- mass spectrometer (instrumentation development)
- microscopes (imaging microscope, optical sectioning microscope, scanning electron microscope, two- photon scanning microscope).

### **C. Innovation Fund (institutional/regional/national) > \$350,000**

- Anechoic chamber and advanced acoustic measurement equipment
- animal care facilities (including facilities for transgenic animals)
- biological station
- biotechnology facilities
- cleanroom semiconductor fabrication facility
- coating technologies equipment
- computer and computation equipment, including high performance computer and networks
- core centre for growth and development (children and women health)

- data base for assessing historical conditions of health and environmental problems
- equipment for computer assisted surgery
- equipment related to food processing/packaging and equipment related to food chemistry and molecular biology
- genomics facilities (including functional genomics, proteomics, bioinformatics, etc.)
- grain storage research facility
- high temperature furnaces
- infrastructure for R&D in global information networking
- infrastructure for biomolecular design, cellular and biomolecular research and many other facilities for modern biology/biochemistry/chemistry
- infrastructure for photonics and electronic materials
- infrastructure for studies of musculoskeletal diseases
- instruments of all kinds (chromatographs, diffractometers, electroencephalographs, electron probes, imaging facilities, magnetic resonance facilities, microscopes, positron emission tomographs, spectrometers from near IR to X-ray, etc.)
- level 3 containment facility
- metal working research equipment
- modern biotechnology equipment for forestry research
- network of ecological research sites
- outdoor laboratory for agriculture research
- radiochemistry laboratory
- phytotron
- synthetic and biosynthetic materials research facility
- telecommunications research facilities
- telescope upgrade
- testing and measuring facilities for the behaviour of structures
- vaccine and therapeutics facility.

#### **D. Research Development Fund (Universities)**

- Animal facilities
- atomic absorption spectrometer
- chromatographs (gas and liquid)
- climate controlled chamber
- cold tunnel
- computer equipment, software, workstations, databases (acquisition and development), data acquisition and processing equipment, data storage capabilities
- development of a database on SME's
- DNA laboratory equipment
- Doppler SODAR system
- environmental monitoring equipment
- environment simulation system
- fibre optic sensing system
- field research facilities
- forest product facility, infrastructure for interdisciplinary forest research
- geographic information system
- greenhouse and adjacent laboratories

- infrastructure for engineering research centre
- infrastructure for geomatics
- infrastructure for research in cool climate oenology and viticulture
- infrastructure for the development of measurement systems
- magnetic resonance imaging
- mass spectrometers
- meteorological station
- microscopes (confocal laser-scanning microscope, infrared)
- microstructural analysis equipment
- nuclear magnetic resonance equipment
- Nucleic acid analysis, sequencing and processing facility
- photonics equipment
- pilot equipment for paper gluing/pilot plant for pulp bleaching
- power network simulation equipment
- process optimization and simulation equipment
- real time computing equipment for electronics applications.
- surface and interfacial testing facility
- test bench for the design of hydrogen tanks
- test facility for wind and solar energy conversion
- upgrade of pilot plant for mechanical pulp refining.

#### **E. Research Development Fund (Colleges)**

- Aquaculture facility
- biomedical instrumentation
- computer and networking equipment and software
- facilities to support computer animation
- laboratory to study the design and management of advanced Internet networks
- molecular biology equipment
- photovoltaic testers and other electrical equipment
- specialized geomatics software
- technical equipment for instructional resource development
- upgrade and expansion of equipment for geotextiles and textile research
- upgrade of equipment for applied fisheries technology research.

## Appendix 2—Examples of fields of research of CFI researchers

### A. New Opportunities

#### Life sciences and biotechnology

##### a) *Molecular biology, biochemistry, genetics, biotechnology*

- agriculture and plant biotechnology
- AIDS
- Alzheimer's
- antifreeze proteins
- bioinformatics
- biotechnology
- blood disorders
- bone marrow grafting
- cancer
- cardiac cell growth and death
- cardiovascular (histology/immunohistochemistry)
- cell biology
- diabetes
- enzyme engineering
- evolutionary biology
- genetic engineering (applications to food and animal health)
- genomics (neurology, cancer, etc.)
- heart (cardiac membrane, pacemaking, microvascular surgery, transplants)
- hormone regulation
- immunology
- infectious diseases
- microbiology
- mitochondrial biology and neurodegenerative disorders
- molecular biology, gene expression
- molecular endocrinology
- molecular genetics
- molecular marine microbiology and virology
- molecular physiology
- nephrology (from molecule to clinical care)
- neurobiology, neurology, neuroscience
- oral diseases
- pharmacology
- plant genomics
- protein crystallography
- proteomics (interdisciplinary approach)
- respiratory diseases/asthma
- structures of biomolecules

## b) *biomedical and health*

- biomechanics
- biomedical engineering (detection of blood vessel diseases using MR angiography)
- brain (geriatrics)
- epilepsy
- gastrointestinal disorders
- health informatics
- hypertension
- kinesiology
- mental health (forensic, mental retardation)
- neurodegenerative disorders
- obstetrics
- orthopaedics engineering (bone loss)
- pain
- psychology
- rehabilitation
- vision science

## **Environment and earth sciences**

- anthropogenic impacts on freshwater and terrestrial systems
- atmospheric chemistry
- atmospheric sciences/fluid mechanics/engineering
- bioremediation
- climate change
- environmental contamination of aquatic systems
- environmental engineering
- environmental molecular biology
- geological sciences and geological engineering
- geomatics
- hydrology
- marine geology
- measurement of atmospheric mercury
- photochemistry
- plant genomics
- resource management
- soil ecology
- stable isotope techniques to measure anthropogenic carbon, nitrogen, and sulphur in selected forested and agricultural ecosystems

## **Materials**

- biological materials
- characterization of materials with unique (bio-) electrochemical properties
- composites

- fibre-reinforced polymers (for civil engineering structures)
- effect of molecular structure and chemical interactions on the function of electroactive materials
- industrial materials applied to fine arts
- materials chemistry
- material properties of surface and interface (optoelectronics applications)
- metals
- mining and minerals
- molecular structure and dynamics
- photochemistry
- polymer characterization, rheology (polymer blends, composite materials and polymeric foams, polymer synthesis, polymer design)
- powder processing
- process metallurgy and high temperature corrosion
- solid state materials
- superconductors, semiconductors, magnetic materials, and organic polymers)
- synthesis of new materials with biological, optical and electronic applications
- wood products

### **Information technology/telecommunications/computation**

- advanced networking (next generation internet technologies)
- artificial intelligence and robotics applied to medicine and environment
- circuit design/microelectronics
- computation visualization (applications to computer vision and fluid dynamics)
- computer mediated telepresence
- distance learning
- high performance computing
- high speed networks
- human visual attention processes
- intelligent systems
- mathematics (cryptography, bioinformatics)
- microelectronics/computer assisted design
- microwave/antennas
- photonics/quantum optics, lasers
- robotics
- vision systems
- software engineering
- systems
- wireless

### **Others**

- agrifood (cereals, grain, understanding molecular and genetic basis of carbohydrate functionality)
- civil engineering
- fluid mechanics

- food/nutrition (animal, from molecule to whole animal)
- mechanical engineering
- petroleum engineering.

## **B. Innovation Fund < \$350,000**

### **Health and life sciences**

- Aboriginal health
- asthma, pulmonary diseases
- biotechnology related to medical applications and health care
- cancer, oral cancer
- cellular neurobiology and circulatory physiology
- genomics
- gerontology
- histology
- human communication (psychology, physiology, linguistics, audiology)
- human development (interdisciplinary)
- infectious diseases
- mental illness (social research)
- medical devices
- microbiology

### **Environment and earth sciences**

- cold climate environment engineering (decontamination of sites)
- forest research
- geology and geophysics
- geomatics/software
- oceanography
- microbiology with application to the environment
- soil science, environmental engineering

### **Materials**

- advanced materials and composites (fatigue, texture, etching)
- catalysis
- interdisciplinary research on the chemistry and engineering of advanced organic materials
- materials and process engineering

### **Information technology/telecommunications/computation**

- advanced communication (disaster communications, telelearning and telemedicine)
- computational chemistry
- mathematics with industrial applications

## **Others**

- physical anthropology (study of ancient DNA)
- instrument development.

### **C. Innovation Fund (Institutional/regional/national) > \$350,000**

## **Interdisciplinary**

- Agriculture/agricultural engineering (environmental monitoring and management of agroecosystems, plants, genetically modified crops or animals, transgenesis, cloning, bovine genome, multidisciplinary approach to grain storage)
- food, food safety, nutraceuticals
- intra-campus networks and high performance computers support virtually all disciplines that need high speed networks and complex computation
- interdisciplinary between science and medicine for non-invasive measurement of biological structure and function in humans and animals

## **Life sciences/health**

- biomedical engineering (biomechanics, prosthesis design tissue/cartilage restoration, biological performance of medical devices/biomaterials, image guided surgery, dental materials)
- biotechnology (structure of complex biological molecules)
- bioinformatics
- epidemiology
- genomics, proteomics, protein structure
- gynaecology and reproductive biology
- molecular biology and biotechnology
- neurology (brain surgery and stroke)
- population health (determinants of health, health systems evaluation, historical conditions of health)
- rehabilitation
- research on diseases, such as AIDS, Alzheimer's, arthritis, bone and connective tissue defects, brain disorders, cancer, cardiovascular diseases, children diseases, diabetes, endocrine and renal diseases, genetic abnormalities, hearing disorders, infectious diseases, infertility, multiple sclerosis, neurodegenerative diseases, obesity, oral diseases, osteoporosis, Parkinson's, respiratory illnesses, schizophrenia
- research space and a new exercise centre for seniors, spinal cord injured, and those undergoing cardiac rehabilitation

## **Environment and earth sciences**

- ecotoxicology and genomics, environmental genomics
- environment (application of molecular biology and biotechnology to)
- environment (conservation, fisheries, limnology, climate change, remediation, etc.)

- environmental engineering (biofilms in drinking water)
- forest regeneration and biotechnology (from gene to ecosystem)
- forest research
- groundwater/surface water systems and biological systems

## **Materials**

- ceramics
- chemistry
- coating technologies
- geochemical and material sciences
- material analysis and characterization
- polymer production, processing, synthesis
- semiconductors

## **Information technologies, telecommunications and engineering**

- civil engineering (structures)
- electronic commerce
- emerging technologies, device prototyping, optoelectronics
- engineering design/process design
- industrial engineering
- information technologies and telecommunications robotics (for work in harsh environments)
- manufacturing processes
- multidisciplinary engineering research centred around system design
- network architecture
- photonics and electronics materials (characterization and testing)
- RF/Satellite millimetre systems, antennas
- software engineering
- telemedicine and telelearning
- wireless

## **Others**

- astronomy
- space (biological systems in space or harsh environments).

## **D. Research Development Fund (Universities)**

### **Health and life sciences**

- Cell biology, physiology (fish)
- dermatology (wound healing, scarring, plastic surgery)
- interdisciplinary research on human populations (social sciences, genetics, epidemiology)

## **Environment and earth sciences**

- agriculture (crops, oenology and viticulture, soil, berries, pasture, environmental impact)
- alternative energy (multidisciplinary)
- aquatic systems
- atmospheric sciences (air pollution, meteorology)
- detection of trace pollutants in environmental media
- earth sciences
- environment
- field station
- food and nutraceuticals
- forestry (ecosystem based research)
- forestry (forest management, pulp and paper, sustainable development)
- forestry (impact of climate on boreal forest growth)
- forestry (northern forest regeneration and management, bioremediation)
- genetics (mycorrhizal fungi)
- geomatics
- planetary and space science
- water ecosystems
- water protection

## **Materials**

- artificial intelligence and robotics applied to metallurgy (aluminium)
- catalysts
- chemical engineering (plastic injection molding and extrusion)
- chemistry
- materials (structure and characterization, composites)
- hydrogen (tanks, hydrides, batteries, renewable energy)
- pulp and paper
- surface science

## **Information technology/telecommunications/computation**

- computing
- high speed communications, fibre optics
- industrial electronics
- internet protocols and programming languages
- metrology and microsystem measurements (microelectronics)
- photonics and optics (including computer equipment for theoretical research)

## **Others**

- anthropology (ancient DNA)
- engineering (icing and de-icing of power lines, planes, etc.)

- fur animal (carnivore nutrition and animal genetics)
- management science (performance indicators for SME's)
- mining (exploration, monitoring, health and safety, geomechanics, environment and land rehabilitation, etc.)
- non medical magnetic resonance imaging (technique development)
- power engineering (electrical networks, conversion of renewable energy).

### **E. Research Development Fund (Colleges)**

- Aquaculture
- bioinformatics
- computer animation
- education (teachers' training in IT areas, curriculum development, learning for people with brain injury)
- fisheries
- geomatics (applied to marine environment)
- information technologies
- photovoltaic applied research
- rehabilitation engineering and technologies
- resource management
- textiles and geotextiles.