Final Report

EVALUATION OF THE NETWORKS OF CENTRES OF EXCELLENCE PROGRAM

Prepared for
The NCE Program Evaluation Committee

Prepared by
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NOTE:

This evaluation study was conducted independently by the ARA Consulting Group Inc. The content of this report reflects the views of ARA, and does not necessarily reflect the views of the Social Sciences and Humanities Research Council of Canada, the Natural Sciences and Engineering Research Council of Canada, the Medical Research Council of Canada, or Industry Canada.

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Executive Summary

Introduction

The Networks of Centres of Excellence (NCE) program is intended to establish networks of university researchers across the country to conduct world class research in areas crucial to Canada's economic competitiveness and quality of life. The four current objectives of the program (paraphrased) are to:

- Stimulate leading-edge fundamental and applied research in areas critical to Canada's economic development;
- Develop and retain world-class scientists and engineers in essential technologies;
- Manage multidisciplinary, multisectoral, national research programs that integrate stakeholder priorities through partnerships; and
- Accelerate the exchange of research results within the networks and accelerate technology transfer to users for social and economic development.

The program is administered by an NCE Directorate representing the university granting councils: the Natural Sciences and Engineering Research Council (NSERC), the Medical Research Council (MRC), and the Social Sciences and Humanities Research Council (SSHRC), as well as Industry Canada.

Phase I of the program lasted from 1989/90 through 1993/94 and, after an extensive application and selection process, saw 15 networks funded in areas such as biotechnology, natural resources, telecommunications, infectious diseases, and so on. Total program funding was about $240 million in Phase I. For Phase II, beginning in 1994/95 and terminating in 1997/98, ten of the Phase I networks were renewed after another intensive competition. In addition, targeted competitions were held for the first time, resulting in four new networks being funded. The total NCE budget for Phase II is about $197 million. In both phases, external partners such as industry, the provinces, some federal agencies and departments, and the universities have contributed substantial amounts — in recent years roughly 20-30% of the networks' cash budget is from these other sources, and in-kind contributions have been similar in extent. This report is an evaluation of the NCE program carried out by the ARA Consulting Group on behalf of the NCE Program Evaluation Committee.

Methodology

Methods used for this study included:

(1) review of NCE Directorate and network data;

(2) interviews with network scientific leaders, managers, Board Chairs, Vice-Presidents (Research) and officers at University Industry Liaison Offices (UILOs) at participating universities, NCE program officers, external partners, and representatives of potential partner organizations;

(3) surveys of a census of the network researchers in new, renewed, and non-renewed networks; and surveys of a census of major network external partners in the private sector, government, hospitals, etc.;

(4) case studies and partial benefit/cost analysis of individual projects likely to be "big winners" in terms of providing economic benefits; case studies of individual projects likely to be "big winners" in terms of providing social, health, or environmental benefits; and case studies of the nature and results of the collaborative process; and

(5) a workshop with network and NCE Directorate participants to discuss preliminary study findings.

Evaluation Issue 1: To What Degree has the Program Achieved its Objectives?

Overview

The program has been very successful overall, and has been successful in achieving all four of its primary objectives. The structural aspects of the program and of the networks ensure that the program goals are explicitly addressed — e.g., the thorough external review of applications for Phase II ensured that funded networks strongly addressed each program goal, and each network has formal and informal mechanisms for reviewing its research, training, and technology transfer activities. Some findings specific to each program objective are discussed below.

Quality and relevance of NCE research

Network research and researchers are both of high quality. In the case of the scientific leaders and principal investigators, many of these individuals are the leading investigators world-wide in their field. For the research, some of the network work is groundbreaking in nature. The research is clearly in areas of high strategic importance, either because of existing Canadian industrial capability (e.g., in telecommunications), or because significant social, health, or economic benefits may be expected (e.g., in biomedical areas). Most elements of the networks' research programs were of medium or high relevance to their external partners.

Impact on developing and retaining scientists and engineers in relevant fields

The networks are providing high quality training to many graduate students and post-doctoral fellows through a very strong — and often innovative — training system. For example, the system provides unique exposure for graduate students and post-doctoral fellows to the expertise of scientists across the country, to methods used in other scientific laboratories, and to user needs. In a typical recent year, about 1,000 graduate students and 300-400 post-docs are involved with the networks. About 70% of these take jobs in Canada after leaving the network, and about 45% take jobs in Canadian industry. Since only about 60% of graduate students are Canadians, there is probably a small net "brain gain" to Canada. In addition, the existence of the networks and/or the network researchers have been moderately important factors in helping retain researchers in Canada, and moderately or very important factors in attracting foreign investigators into Canada (although many other factors such as salary differentials between countries are also important).

Extent of management of multidisciplinary, multisectoral, integrated research programs

As indicated by the networks' research topics and types of investigators, the networks are indeed multidisciplinary and multisectoral (in the sense of involving universities, industry, and government), especially in new networks. The research projects represent true collaborative efforts among scientists in different disciplines, as well as among increasing numbers of participants from industry and government. Most university researchers and external participants have found this collaboration to be distinctly beneficial.

Overall the networks are being managed reasonably well. Although the degree and quality of management and integration vary somewhat from network to network, this variation is more a function of individuals than of the management model used. The external partners have had significant input into the research and they are generally satisfied with the degree of this input. Another measure of external participation that in recent years the NCE funding has leveraged 20-45% more cash funding from non-NCE sources, with in-kind external support being of roughly similar magnitude. Both cash and in-kind support have tended to increase over the years.

Degree of acceleration of exchange of research results and technology transfer

There has been a tremendous increase in knowledge exchange among university researchers, especially through inter-laboratory and cross-Canada knowledge sharing. The networks have also increased knowledge exchange with users: fully 80% of partners expect the networks to be highly useful or very highly useful to them in some way. Many opportunities (and models) are being actively explored for significant technology transfer. This may occur through training highly-qualified personnel (HQP), or through providing industry with access to university expertise and new product/process ideas, with consequent sales revenues or cost savings. Far more, and far more varied, formal and informal mechanisms for exploitation of research results exist than in any other university-based program we are aware of. Many benefits to education,

health, quality of life, the environment, and other areas can also be expected. Exploitation of some network research may lead to truly substantial impacts. Examples of exploitation include better telecommunications equipment and wireless access to services, detection and potential treatment of genetically-influenced diseases such as Alzheimer's, longer-lasting concrete bridges and other structures, improved detection and treatment of bacterial diseases such as sexually-transmitted ones, regeneration of severed nerves, reduced incidence of childhood asthma, etc.

The results of the partial benefit/cost analysis are very positive for an R&D program of this type. In fact, to our knowledge they are the most positive of any university-based program. The discounted, deflated, projected net benefits from just nine "big winner" projects are anticipated to more than cover (by $34 million) all program and partner costs to date, as well as all future commercialization and production costs for those nine projects. (The methodology used was highly conservative.) Furthermore, it can reasonably be expected that substantial economic benefits will accrue from other projects for which benefits cannot yet be quantified (since many projects will reap benefits 5-10 years from now, or the benefits are associated with training impacts). There are also substantial non-monetary benefits from many network projects, such as improvements to health, quality of life, and the environment. However, there are still risks associated with commercialization of the "big winners" — only one has actual sales or cost savings yet.

The current four-year life span of support for individual networks is too short to allow the full "life cycle" of exploitation (from conducting research through commercialization) to be realized.

Evaluation Issue 2: What Factors Have Influenced the Achievement of Objectives?

Impact of program design on objectives achievement

The program fills a unique niche in the portfolio of Canadian R&D programs, and its goals and policies are accepted by most participants. Although the current goals and policies are equally appropriate for all sectors, the nature of impacts varies according to different user needs — e.g., in telecommunications, impacts are mainly through access to HQP; in biomedical fields, mainly through access to intellectual property (IP).

Program funding uncertainty has made it harder to interest researchers and industry in joining, makes student support more difficult, and makes it less likely that university partners will support individual networks. Some administrative policies (e.g., not allowing networks to carry over more than 10% of funding from year to year, and provision of diminishing funding over time) were not successful but have recently been modified. During the competition period between Phases I and II, the competitive selection process promoted noticeable competition and lack of cooperation among some networks.

Impact of different management styles

Every network has a different management model — and rightfully so, as each sector and set of users has different needs. At this time, most networks have either incorporated or are thinking about it — advantages are mainly related to being better able to attract and negotiate with industry partners; disadvantages include cost and complexity, possible conflicts of interest for network officers and researchers, and possible conflicts with universities.

Impact of federal NCE program management

Federal program management was seen as good to excellent for administrative matters (and having improved substantially over time), but less successful for access to policy advice and in terms of the perceived commitment and participation of senior management of the councils and Industry Canada. (Much of this discontent resulted from the impermanence of the program.) Networks certainly would not survive except in very limited fashion without federal funding; the impact of the federal management function is less clear, but there are some benefits to the coordination provided.

Impact of external factors on exploitation of network research

The program and the networks have little or no control over some basic university-industry technology transfer problems such as: lack of capital, lack of industrial receptor capability in some sectors and firms, strong international competition, the gap between the short time frame of industry and the long-term one of academe, and the difficulty of applying "Canada First" where there is no industrial interest or capability in Canada. In addition, the goals and methods of university researchers and industry are simply different — industry needs to pursue projects that are commercially-interesting but abandon those that aren't, while researchers need to pursue topics that are scientifically interesting irrespective of their commercial potential. Although the networks have succeeded to a limited fashion in reducing some of these barriers, it is unrealistic to expect the NCE to solve these underlying problems. It is also crucial to recognize that the success of NCE rests upon a continuing, strong, underlying base of support for fundamental research.

There are tensions beginning to arise between the networks and some of their university partners, especially at host universities. First, universities are increasingly unwilling to shoulder network overhead costs in cases where the provinces have not been supportive. At a few institutions this problem is becoming pointed. Second, there are some disagreements related to issues of IP ownership, contract negotiations, and revenue sharing from licences, royalties, and contract overheads. These may be regarded as signs of success since these issues would be unimportant if substantial economic benefits were not expected. These problems tend to be of lesser importance at universities where the inventors own the IP, and of greater importance where the universities own the IP. Third, the perceived pressure on the networks to act like corporations may in some cases create a conflict of interest for network researchers and may conflict with the universities' mandates for research, teaching, and publication. (This is especially true where networks are creating incorporated for-profit exploitation entities.) In essence, the universities have not been full partners to the program or individual networks — even though the universities have provided very significant support.

In a relatively minor point, if networks are intended to act like corporations, the program rules do not permit the networks to fully fund some aspects of commercialization, such as having the unrestricted ability to spend NCE funds for market studies, due diligence, patenting, and so forth. Although the program intends such costs to be borne by partners, they are not always willing or able to do so.

Evaluation Issue 3: What were the Consequences of the Phase II Program Reorientation?

All networks have become more applied in Phase II, partly due to the revised goals and policies, and partly through natural evolution as research results are exploited. The new networks are particularly applied (and are also probably more multisectoral and well-integrated than the renewed networks), but still have a significant fundamental research component. Industrial and government partners are well-satisfied with the current goals and policies, and many like them more than those in Phase I. The great bulk of respondents would prefer no changes for Phase III (if it occurs), although there is a small but vocal minority who would prefer the program to either focus strictly on exploitation of existing research, or to focus on fundamental research, with universities carrying out the technology transfer.

Evaluation Issue 4: What is the Value-added of the NCE Program?

Overview

Overall, the program adds marked incremental value through both its structural aspects and through the additional funding available through NCE and the partners. To the extent that it is possible to separate these factors, researchers would rate each as roughly equal in importance, with significant variation by individual scientist. From the picture painted by all data sources, our conclusion is that many impacts and outputs of the networks and the program would not have happened with equivalent amounts of traditional council funding. The value added comes in the form of substantial positive impacts on the nature of research conducted, the type of training provided, and the ability of the networks to provide knowledge exchange and technology transfer.

Value-added to Research

The program has had a marked impact on the type of research conducted. These impacts include especially the applied aspects of most of the networks and the existence of many specific research projects. Furthermore, network researchers think more about possible applications, the size of research teams is greater, there is more collaboration and interdisciplinarity within teams, there are more investigators from other institutions and sectors and more interactions among them, there are far more interactions across laboratories and across the country than before, there is a more integrated approach to solving large problems, and it is easier to support risky projects. Roughly half the researchers are more positive about both collaboration and applied research because of NCE; virtually none are more negative. There has been no significant impact on the scientific merit of the work done; rather, impacts are mainly on the nature of the research.

Value-added to Highly Qualified Personnel

Students and post-docs associated with the program are exposed far more than usual to other researchers and labs, to networking, and to industrial needs and concerns. Graduates are more interested in working in industry than was previously the case, and limited data suggest that they are also more comfortable with applied work and collaboration if they take academic positions. For companies, most respondents see the NCE as better than traditional programs at training students and in providing companies with access to highly-qualified university researchers in relevant fields.

Value-added to Knowledge Exchange and Technology Transfer

For knowledge exchange, the program has clearly increased the extent of collaboration among university researchers, and between many researchers and partners. (A limited amount of this collaboration has been retained, especially at the local level, among researchers at non-renewed networks.)

For technology transfer, all indications suggest that this program has the elements needed to be more successful at technology transfer and exploitation than is usual in most traditional council programs: there are many explicit formal mechanisms in place for this purpose, as well as many informal ones; most networks have specific committees and/or staff positions responsible for exploitation of their research; and the network structures and proposals show that most have taken the Phase II goals very seriously indeed. Furthermore, most partners believe the program is better at technology transfer than other council programs, especially with respect to the "bundling" of technologies (access to a whole suite of technologies built around a central discovery, as well as access to all the top researchers in the field across Canada). Almost all of the "big winner" projects that may lead to large economic, social, or health benefits would not have occurred, or would have occurred to a significantly limited degree, without the networks. Overall, the program is an excellent model for increasing the exploitation of university research results

Conclusions

Our general conclusion is that NCE is a very successful program. It has succeeded in all four of its objectives: to support excellent research, train and retain HQP, manage complex interdisciplinary and multisectoral programs, and accelerate knowledge exchange and technology transfer. Further, it fills a unique niche among Canadian university research programs. A very conservative partial benefit/cost analysis suggests that the program will provide substantial net economic benefits to Canadians, and there are many social benefits expected as well. The overall goal and objectives of the program are appropriate, as are the general administrative and management mechanisms associated with them. Such problems as exist are generally those associated with all university-industry programs, although issues of program funding uncertainty and the nature of network-university partnerships are specific to the NCE.

1. Introduction

1.1 Overview

The Networks of Centres of Excellence (NCE) program is intended to establish networks of university researchers and scientists across the country to conduct world-class research in areas crucial to Canada's competitiveness. The program is administered through a joint Steering Committee composed of the presidents of the Natural Sciences and Engineering Council (NSERC), the Medical Research Council (MRC), the Social Sciences and Humanities Research Council (SSHRC), and the Deputy Minister (or designate) of Industry Canada, whose Minister is responsible to Cabinet for the NCE program.

In Phase I of the program (1989/90 to 1993/94), the NCE supported 15 networks with a total funding package of roughly $240 million. For Phase II, (1994/95 to 1997/98), 14 of the existing networks reapplied to the program and 10 were renewed. In addition, four new networks were supported for 1995/96 to 1998/99. The total funding package for Phase II was about $197 million. Fuller details of the program are found in Section 3.

An Interim Evaluation of the NCE[1] was carried out in 1993 by The ARA Consulting Group under contract to the NCE Program Evaluation Committee (PEC). That study was mainly intended to focus on whether the program was "on the right track", and the conclusions were favourable at that time. In 1995, PEC carried out an evaluation assessment[2] that resulted in identification of key issues to be studied in a full evaluation, their availability, potential indicators, and a range of possible methodologies for pursuit in the full program evaluation scheduled for 1996. The full evaluation of NCE was subsequently done under contract by The ARA Consulting Group and is the subject of this report.

1.2 Evaluation Themes and Issues

The major evaluation themes and issues are shown below.

Evaluation Theme 1: To What Degree has the Program Achieved its Objectives?

- Issue 1: What has been quality and relevance of NCE research?
- Issue 2: What has been the impact on developing and retaining scientists and engineers in relevant fields?
- Issue 3: What has been the extent of management of multidisciplinary, multisectoral, integrated research programs?
- Issue 4: What has been the degree of acceleration of exchange of research results and technology transfer?

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1 *Final Report: NCE Interim Evaluation*, The ARA Consulting Group, February 1995.

2 *Networks of Centres of Excellence (NCE) Program Evaluation Assessment Report, Final Report*, NCE Program Evaluation Committee, December 15, 1995.

Evaluation Theme 2: What Factors Have Influenced the Achievement of Program Objectives?

- Issue 5: What has been the impact of program design on objectives achievement?
- Issue 6: What has been the impact of different network management styles?
- Issue 7: What has been the impact of federal NCE program management?
- Issue 8: What has been the impact of external factors on exploitation of network research?

Evaluation Theme3: What were the Consequences of the Phase II Program Reorientation?

- Issue 9: What effect did the Phase II reorientation have on the networks?

Evaluation Theme 4: What is the Value-added of the NCE Program?

- Issue 10: What value did the NCE program add to Canadian research?
- Issue 11: What impacts have occurred that would not have happened without the program?

2. Methodology and Analysis

2.1 Methodology

The project was carried out through a variety of data collection and analytic methods, intended to utilize a "multiple lines of evidence" approach. Major study activities are described below. Survey instruments and interview guides are found in Appendices N and O, respectively.

1. A review was carried out of relevant documents such as the renewed networks' Annual Reports, the renewed network's Transition Reports for 1994 (representing the networks' response to the changes between Phase I and Phase II of the program), proposals for the new Phase II networks, the reports of the Phase II Selection Committee, and the reports of individual reviewers for Phase II proposals. In addition, other documents were reviewed such as the overall program's Annual Reports, minutes of the meeting of network program leader and managers held April 2, 1996, and discussion notes prepared by PEC representatives of regional meetings between the NCE Directorate and university Vice Presidents (Research) and University Industry Liaison Office (UILO) officers at partner universities held in June, 1996.

2. Analysis was done of selected "appendix table" material provided by each network as supporting documentation for their Annual Reports. This analysis focused on changes over time in the degree of participation of universities, industry, and other partners; cash and in-kind contributions by partners; amount of collaboration; number of participants by type of organization; number and type of trainees; subsequent employment of network-trained individuals; and measures of innovation and dissemination of results.

3. Interviews were carried out with a census of network scientific leaders, network managers, and Board Chairs in renewed networks. Twenty-six individuals out of the total of 30 such officials were interviewed (one individual was seriously ill, two were too new to comment meaningfully, and one network chose to have the scientific leader comment for the network manager).

   Similarly, a census of scientific leaders and network managers was interviewed at the four new networks. A total of 9 people were interviewed (at one network there are two co-leaders). In addition, one Board Chair at a new network was interviewed.

   We attempted to interview all the scientific leaders, managers, and Chairs at non-renewed networks. We succeeded in contacting three of the five leaders, one of the managers, and three of the Chairs.

   Where possible, the interviews with network officers were carried out in person; in other cases they were done by telephone (sometimes over two or more sessions since many issues had to be covered).

4. Interviews were carried out with the Vice-Presidents (V-Ps) (Research, or equivalent) and/or UILO officers at universities which house the administrative centres of new and/or renewed networks. A total of 14 such VPs (Research) were interviewed. (Some universities have more than one network headquartered there and could therefore comment on more than one network, and some networks don't have their headquarters at a university. For the latter, representatives of universities having significant interactions with those networks were interviewed. All universities having new or renewed network administrative centres and/or significant network dealings were contacted.) In addition, 7 UILO officers (or equivalent) were interviewed (the VPs Research in some cases indicated they were familiar enough with technology transfer operations to comment for the UILO office; some officers could also comment on more than one network).
5. Interviews were carried out with an additional 15 V-Ps (Research) and/or UILO officers (or equivalents) at "node" universities (those institutions associated with one or more networks, but that do not house any network administrative centres).
6. The four NCE program officials responsible for the new and renewed networks were interviewed.
7. A census of network researchers at renewed and non-renewed networks was surveyed. In addition, a census of theme leaders at new networks was surveyed. Contact names and addresses were obtained from the NCE Directorate. Following a pilot test involving researchers at 7 renewed, 4 non-renewed, and 3 new networks, researchers were mailed a questionnaire. Survey instruments were available in both official languages. A follow-up was done with the assistance of the network managers: each manager was provided a list of non-respondents and was asked to help in encouraging their researchers to reply. The number of surveys mailed and returned (after follow-up) are shown below.

Researchers at:	Number Mailed	Number of Responses	Final Response Rate (%)
Renewed networks	680	207	30
New networks (theme leaders only)	33	13	39
Non-renewed networks	252	59	23
Total	965	279	29

8. "Significant" external network partners (e.g., private sector companies, hospitals, provincial government agencies, and Crown Corporations; but not including the participating universities) were surveyed. Contact names, addresses, and fax numbers were obtained directly from each network. For new and renewed networks, the networks were requested to provide contact information only for partners that had significant participation on the network Board or other committees, and/or that expected to obtain significant benefits from network participation. (The networks list all their external partners in the "appendix tables" provided yearly to the Directorate. However, these tables include some organizations who in reality have only very limited contact and participation with the network; e.g., companies which only provided very limited in-kind or cash support, donated small amounts of equipment, sponsored a graduate or post-doctoral position, etc. Asking only for significant partners was intended to exclude companies that had only minor contact.)

Where possible, the partners were faxed the survey in order to speed up and increase the response rate; where fax numbers were not available, the surveys were mailed. Surveys were available in both French and English. Two follow-ups were done for partners, one by ARA and one by the network managers. The number of partner surveys sent and returned (after follow-up) are found below.

Partners of:	Number Mailed*	Number of Responses	Final Response Rate (%)
Renewed networks	253	72	28
New networks	93	25	27
Non-renewed networks	7 (see below)	3	43
Total	353	100	28

* Note that a given partner may be involved with more than one network -- separate surveys were mailed if different individuals were listed as the main contact.

It had been intended to survey all partners of non-renewed networks, but contact information could only be obtained from the one network that has continued limited operations after termination of NCE funding.

9. Case studies were carried out of individual projects likely to be "big winners" in terms of providing economic benefits, and partial benefit/cost (B/C) analyses were done using those data. Networks were first asked to identify a preliminary list of possible projects fitting this criterion, as well as to provide initial information on types of impacts expected, likelihood of success, user groups, time frame for benefits, further R&D and testing required, and so forth. The selection process is shown below:

Total no. of projects suggested for analysis by networks	41
No. of projects selected by ARA for further investigation (using interviews with researchers and partners to assess likelihood of obtaining quantitative benefit estimates)	23
Projects for which quantitative estimates were initially obtained	8
Additional projects selected for quantitative analysis as a result of partner survey follow-up (selected from 10 possibilities)	1
Remaining projects for which qualitative analysis was undertaken	10

Details of the B/C analysis are found in section 4.5.

10. Fourteen case studies were carried out of individual projects likely to be "big winners" in terms of providing social benefits or health benefits. As for the B/C case studies described immediately above, the networks provided preliminary information on potential projects to investigate, types of benefits expected, user groups, further testing required, and so forth. Projects which were likely to produce substantial, quantifiable, economic benefits were investigated through the B/C case studies. The remainder were investigated through health/social benefits case studies — all remaining projects suggested by the networks were followed up on.

Wherever possible the principal investigator (PI), the industry partner, and two external experts (not part of the networks or the projects) were interviewed for each case. Interviewed were all 14 PIs (one from each project) and 12 industry representatives (two projects had no external partners, one partner declined to participate, and in one project two partners were interviewed, one from a company and one from a venture capital organization).

In addition, 22 external experts (not associated with NCE or the network) were interviewed. The experts were usually selected so that one could comment on the research aspects of the project, and one could comment on the project's impacts. Initial suggestions for experts were provided either by the investigator or the industrial partner. Experts were asked whether they were independent enough to comment on the project; none declined. Because of confidentiality issues, two projects declined to have their projects reviewed externally; no experts were contacted in those cases. In nine cases it was not possible to distinguish the reviewers' expertise in terms of research versus application, so the experts were asked questions relevant to both topics. In three cases only one reviewer was able to participate. Reviewers were sent a copy of preliminary information for the specific project as provided by the network, as well as additional abstracts, articles and/or impact descriptions provided by the researchers and/or industrial partners. It is important to note that in most cases the reviewers based their comments only on these brief descriptions and abstracts.

11. Follow-up interviews were done with a sample of the networks' external partners who responded to the mail survey. This was done to expand on responses regarding general evaluation issues, and also to identify projects that might lead to "moderate" economic benefits (i.e., those that were not identified as "big winners" in the main B/C analysis, but that still might contribute significantly to the program's net present value). We contacted all partners who: (1) completed the mail survey; (2) responded "Yes" to mail survey question #15: "For your organization, do any of the network research results have the potential to lead to significant revenues being earned, or significant costs being saved, relative to the investment you have made?"; (3) indicated on the survey that they were willing to be contacted for further information; and (4) had not already been contacted during the partial benefit/cost case studies of "big winners".

    Fifteen respondents were interviewed by telephone by the same consultant. During the discussion we took the opportunity to ask respondents to provide more information on general evaluation issues and to provide additional explanation of their survey responses.

    As a result of this follow-up, one additional project was included in the B/C analysis described above in point #9.

12. Case studies were carried out of the nature and results of the collaboration found in 10 specific network projects at nine of the renewed networks. In five of the case studies, the scientific directors or network managers were asked to recommend projects they considered particularly interesting in terms of the collaboration; e.g., because of the type of industry involvement, the achievement of critical mass, the extensive use of various disciplines and/or technologies, and so on. The other five case studies were chosen randomly: a random sample of theme leaders was asked to provide case study information

for "their project", or to recommend some other project from their theme. (No differences were found between the randomly-selected projects and those recommended by the networks; therefore the results are aggregated in the reporting.)

Within a case study, as many of the main investigators were interviewed as possible, resulting in interviews with:

- 56 people in total;
- 37 university or government researchers;
- 9 industry representatives; and
- 10 post-doctoral fellows or graduate students.

13. Interviews were conducted with 20 representatives of organizations that are not network partners, but "should be". Suggestions for these were obtained from the network managers and Board Chairs of new and renewed networks. Only one renewed network suggested any such organizations, while three of the new networks did so. Respondents were selected randomly from these suggestions, distributed as evenly as possible across the networks.
14. A workshop was held on November 1 1996 that included members of the ARA study team, PEC, and network officers to review the preliminary findings of the evaluation. Comments and suggestions made by participants regarding the results were incorporated into the analysis and/or the reporting.

2.2 Analysis and Presentation

Findings are organized approximately as per the major issues[3] identified in the Program Evaluation Assessment Report prepared by the NCE Program Evaluation Committee, although there are some findings that are reorganized slightly for ease of presentation.

Generally we present results separately for new, renewed, and non-renewed networks. Some results are presented by industrial sector for renewed networks:

- "Medical" includes responses for the Canadian Bacterial Diseases Network (CBDN), Canadian Genetic Diseases Network (CGDN), Inspiraplex, NeuroScience, and Protein Engineering Network of Centres of Excellences (PENCE);
- "Electronic" includes those in microelectronics, robotics, artificial intelligence, and telecommunications fields: Micronet, Canadian Institute of Telecommunications Research (CITR), and Institute for Robotics and Intelligent Systems (IRIS); and
- "Other" includes what might be termed engineering networks: Concrete and Mechanical Wood Pulps.

The term "sector" can be interpreted in two ways: in terms of industrial sectors as above; or in terms of the university, industry, and government sectors. There is no term that clearly

[3] We have called these "issue groups" as each is comprised of numerous individual questions.

distinguishes between the two meanings, so the distinction is discussed in the text as required (if it is not obvious).

Much more detailed information is available in the appendices for many results: the surveys of researchers and partners, the collaboration case studies, the overview of case studies of "big winner" projects for social and/or health benefits, the interviews of potential partners (who are not yet involved with the networks, but should be), and the "network case studies" (interviews with network officers, Board Chairs, V-Ps Research and UILO officers, and program officers). Detailed information is **not** presented here for case studies of "big winner" economic benefits as much of these data are confidential. Also, some of the individual case studies of social/health benefits are confidential and are **not** included.

Note that where percentages or proportions of responses or respondents are referred to, these are sometimes rounded off to approximate values where several data sources are aggregated. Readers interested in the exact figures may refer to the detailed appendix tables.

3. Program Description

3.1 Phase I: 1989/90 through 1993/94

3.1.1 Overview

The NCE program, as first announced, was intended "to establish networks of researchers and scientists across the country to conduct world class research in areas crucial to Canada's long-term competitiveness."[4] In particular, the networks were expected to achieve the following objectives:

- Stimulate the production of leading-edge fundamental and long-term applied research of importance to Canada;
- Develop and retain world-class Canadian scientists and engineers in technologies that are critical to future industrial competitiveness;
- Integrate Canadian research and technology development efforts into national networks with the participation of, and in partnership with, universities, the private sector, the federal government and the provinces, based on excellence as measured by international standards;
- Develop strong university-industry partnerships to accelerate the diffusion of advanced technological knowledge to industry.[5]

Details of the program were announced in May 1988, with the total funding set at $240 million. In June 1988, an Advisory Committee on the NCE was established to advise the Minister of State (Science and Technology) on the implementation of the program. On the advice of the Committee, the Minister decided on selection criteria, the schedule, and the rating system for the NCE competition. The competition was administered by an Inter-Council Program Directorate acting on behalf of the three granting councils and proposals were evaluated by an International Peer Review Committee (IPRC) on the basis of the following rating criteria:

- excellence of the science and of the people involved (50%);
- linkages and networking (20%);
- relevance to future industrial competitiveness (20%); and
- administrative and management capability (10%).

A total of 238 letters of interest were received, resulting in 158 formal applications. Fifteen networks in the areas of biotechnology, natural resources, telecommunications and microelectronics, infectious diseases, robotics and intelligent systems, protein engineering, neuroscience, space, advanced materials and processes, human genetic diseases, respiratory health and human ageing ultimately received funding and commenced operation in 1990.

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[4] Opening Address by the Prime Minister to the "National Conference on Technology and Innovation". Toronto, January 13, 1988.

[5] Canada, *Phase I: NCE Policies and Guidelines*. 1990, p.1.

3.1.2 Phase I networks

The Phase I networks and their level of funding are found in Exhibit 3.1. Note that the total federal government spending for Canadian university research in 1992 was about $839 million, and the total spending from all sources for university research was $2,527 million. On an annual basis, therefore, the NCE program accounted for about 6% of total federal government funding and 2% of total spending for university research.

Exhibit 3.1: NCE Grants Phase I and II

Network	Funding Phase I ($ millions)	Funding Phase II* ($ millions)
Phase I Networks — Renewed		
Canadian Bacterial Diseases Network (CBDN)	18.2	15.3
Canadian Genetic Diseases Network (CGDN)	17.5	15.1
Canadian Institute of Telecommunications Research (CITR)	14.7	12.7
Concrete Canada	6.4	5.5
Inspiraplex	12.3	10.6
Institute for Robotics and Intelligent 5ystems (IRI5)	23.8	20.5
Mechanical and Chemi-Mechanical Wood-Pulps Network (WOOD-PULP5)	14.6	12.6
MICRONET	10.8	9.3
Neuro5cience Network	25.5	22.0
Protein Engineering Network of Centres of Excellence (PENCE)	20.0	16.8
Phase I Networks — Non-renewed		
Canadian Ageing Research Network (CARNET)	5.0	Did not apply
Centres of Excellence in Molecular and Interfacial Dynamics (CEMAID)	18.5	Not renewed
Ocean Production Enhancement Network (OPEN)	23.9	Not renewed
Insect Biotech Canada (IBC)	9.5	Not renewed
Canadian Network for 5pace Research (CN5R)	17.0	Not renewed
New Phase II Networks		
Health Evidence Application and Linkage Network (HEAL-NET)**	Not applicable	8.6
Intelligent 5ensing for Innovative 5tructures (I5I5)	Not applicable	9.5
5ustainable Forest Management (5FM)	Not applicable	10.8
Telelearning Research Network (TL-RN)	Not applicable	13.1

* Projected funding for Phase II

** (75% MRC and 25% SSHRC)

Of the 15 networks, 13 were derived from university-led applications. Two were industry-led: IRIS originated with PRECARN Associates, a non-profit pre-competitive private sector research consortium of (at that time) 32 companies; and Wood Pulps was initiated by the Pulp and Paper Research Institute of Canada (PAPRICAN), an industrial research institute.

3.2 Phase II: 1994/95 Through 1997/98

3.2.1 Overview

In 1992, the government announced that the experimental program had been successful, and in 1993, Phase II was announced with a four-year budget of $197 million. Phase II of the NCE program was intended to build on the success of the initial four years of operation and move the program toward a stronger focus on multisectoral involvement in all aspects of the networks' activities to maximize the generation of social and economic benefits.

As outlined in the program policies and guidelines, the goal of Phase II of the NCE program is to mobilize Canada's research talent in the academic, private and public sectors and apply it to the task of developing the economy and improving the quality of life of Canadians.

This goal is to be accomplished by investing in national research networks that meet the following objectives:[6]

- Stimulate leading-edge fundamental and applied research, based on excellence as measured by international standards, in areas critical to Canadian economic development;
- Develop and retain world-class scientists and engineers in technologies that are essential to Canada's productivity and economic growth;
- Manage multidisciplinary, multisectoral research programs of nation-wide scope and develop partnerships that integrate the research and development priorities of all participants; and
- Accelerate the exchange of results within the network and facilitate the transfer of this knowledge to, and its absorption by, organizations in Canada that can harness it to advance Canadian economic and social development.

For the transition to Phase II, the NCE Selection Committee[7] evaluated the existing networks according to the Phase II selection criteria (see Section 3.2.2). In addition, the Selection Committee based its evaluation on the following sources of information:

- strategic plan applications for Phase II funding;
- site visit reports from the 33 month review process;

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[6] Program objectives have been reproduced from the program document, *Phase II Networks of Centres of Excellence: Policies and Guidelines*, July 1993, p.2.

[7] The membership of the Selection Committee was determined jointly by the granting Councils and Industry Canada, and was intended to provide the balance of expertise needed to assess proposals against all the selection criteria.

- evaluations of proposed strategic plans by site visit committees or other external reviewers;
- external review reports by economic reviewers[8]; and
- presentations by network representative(s) to the Selection Committee.

In 1994, after a peer-reviewed competition, 10 of the original 15 networks were selected to continue in Phase II of the program. These networks began the Phase II portion of their operations on April 1, 1994.

To extend the scope of the NCE program, $48 million of the $197 million Phase II budget was allocated to develop new networks in five specified, targeted areas of research. This targeted competition for new networks was a departure from the responsive model of the Phase I competition. The five target areas were: advanced technologies (materials, software engineering); environment; health research; technology-based learning; and trade, competitiveness and sustainability. In addition to meeting the five Phase II selection criteria, new networks were also required to demonstrate the relevance of their network to the research target area. The selection of four new networks was announced in July 1995, with new networks beginning in September 1995.

3.2.2 Changes between Phase I and Phase II

In addition to changes in the wording of the program objectives in Phase II, the selection criteria were also revised in Phase II. In Phase I, the selection criteria placed a greater emphasis on research excellence (weighted at 50%) than the other three criteria. In Phase II, successful proposals had to exceed a threshold of excellence for five equally weighted selection criteria:

- excellence of research program (20%);
- highly qualified research personnel (20%);
- networking and partnerships (20%);
- knowledge exchange and technology exploitation (20%); and
- network management (20%)

The networks also are required to continue to meet these threshold limits as a condition for holding the NCE grant.

The changes to the selection criteria, as well as the targeted competition for new networks, were intended to increase private sector involvement in all network activities, including the establishment of research priorities. One premise of the program is that strengthening the linkages between university, government, and private sectors will facilitate the exchange of information and technology, stimulating the private sector's ability to capitalize on frontier research and accelerating and commercalization of research results from the network.

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[8] Network applicants were sent to individuals/groups with expertise to evaluate the proposals within the Canadian economic context. Assessment received from these sources furnished background on the economic impact of the proposals for use by the Selection Committee.

3.2.3 Phase II new networks

In May 1994, the competition announcement was made for the support of new networks in priority areas of strategic importance to Canada in terms of economic, social and environmental benefits.

Sixty-five letters of intent were received of which fifteen groups were invited to submit full proposals. Two of the fifteen groups integrated their proposals, resulting in 14 applications going forward to the Selection Committee for review. Reports from Expert Panels in each of the target areas were provided to members of the Selection Committee to assist them in the evaluation process.

Four new networks were announced in July 1995: *Intelligent Systems for Innovative Structures (ISIS)* in the Advanced Technologies (materials) target area: *Sustainable Forest Management (SFM)* in the area of Environment; *Information-based Decision Tools in Health Care* in the health area and *Telelearning Network of Centres of Excellence* in Technology-based learning. Applicants in the fifth target area, Trade, Competitiveness and Sustainability did not meet the quality threshold required for recommendation by the Committee and no proposal in this area was supported.

3.2.4 Phase II funding

See Exhibit 3.1 for funding levels of new Phase II networks and existing Phase I networks that were renewed for Phase II.

3.3 Current Federal Program Management

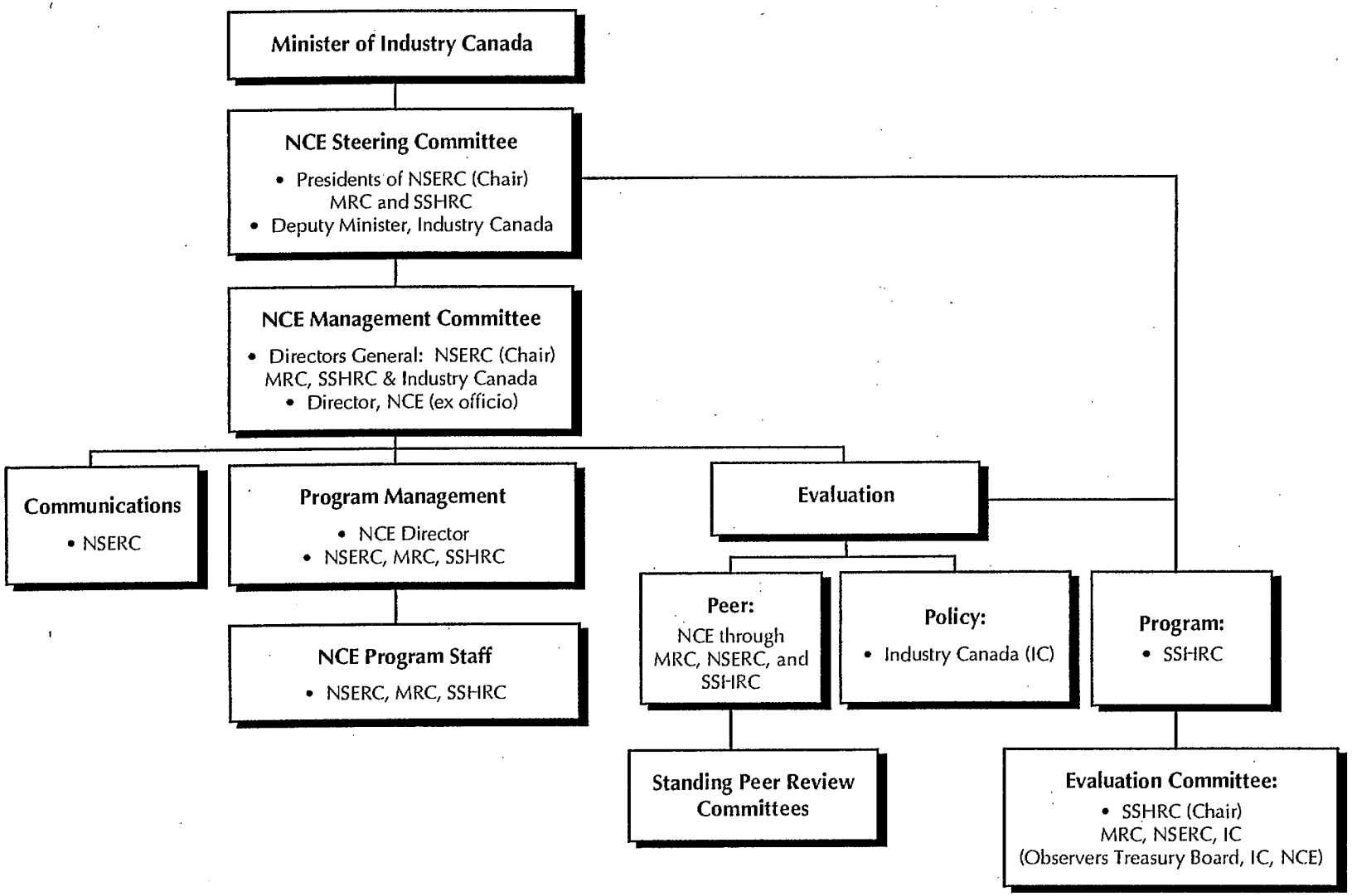
The administrative structure of the NCE program is shown in Exhibit 3.2.

The Minister of Industry Canada has overall program responsibility. The NCE Steering Committee is responsible for overseeing all aspects of the program, including direct responsibility for the program evaluation function. Responsibility for specific networks is assigned to the granting council most appropriate for the subject area in question

NCE program-related activities include network competition and selection, program management and administration, evaluation, monitoring, and guidance. Guidance may include activities such as granting council participation in the resolution of technical, financial or administrative difficulties; advice related to the interpretation of the NCE program's objectives, rules and guidelines; assistance with the coordination of the network's activities with those of other networks or of other government-sponsored initiatives; and diffusion of network achievements. Monitoring activities include reviews of network annual reports and participation on Boards of Directors meetings.

Evaluation consists of program evaluation organized by the SSHRC with guidance from the NCE program Evaluation Committee, peer review of the individual networks organized by the responsible Granting Councils, and policy review organized by Industry Canada as needed. SSHRC provides administrative reporting (e.g., on budgets) through the Management Committee, and functional reporting (e.g., accountability) through the NCE Steering Committee.

Exhibit 3.2: Administrative Structure of the NCE Program



The Management Committee was established in 1991 to oversee operations and coordinate activities related to administration, communications, and evaluation.

3.4 Network Organization and Management

The management approach to the establishment and operation of the individual networks is relatively flexible. Networks are given a fair degree of freedom to determine their individual management structures and styles of operation, although there are some mandatory requirements.

Each network is expected to have an administrative structure capable of managing a complex multidisciplinary, multi-institutional program. The particular structure will vary according to the needs of the individual network, but must be detailed by the proponents in their Internal Agreement and approved by the NCE Steering Committee. All networks have: a board of directors; a scientific committee to organize the research program; and, a network management team. Some networks have: an executive committee of the board for speedy decision-making and various types of industrial committees to organize links with the private sector. Some may also have committees or subcommittees related to training, intellectual property, communications, and so on.

Networks have been encouraged to consider incorporation, but the decision regarding incorporation is the responsibility of the individual network, and requires approval by their Board of Directors.

The organizations participating in a network must prepare and sign a separate agreement. This "Internal Agreement" covers such matters as the responsibilities, obligations, commitments and privileges of each organization, the arrangement and structures governing the management of the network, the distribution of funds, the internal reporting requirements, the interactions between the participants including corporate partners, the ownership and disposition of intellectual property, the publication of research results, conflicts of interest, title to equipment, insurance etc. The Internal Agreement must be consistent with the NCE program objectives and is subject to formal approval by the NCE Steering Committee.

The networks are expected to disseminate the results of their research activities through public sources (publications or otherwise) in a timely manner. The contributions of industrial partners to the network must, however, be recognized by allowing them preferential access to the commercial exploitation of intellectual property under terms commensurate with the extent and level of their contributions. Consistent with the program criterion on knowledge exchange and technology exploitation, the networks should make every effort to have the results of the network research exploited in Canada, for benefit of Canadians. This "Canada First" clause has significant implications for technology transfer and is discussed further in subsequent sections.

4. To What Degree has the Program Achieved its Objectives?

4.1 Overview

The program has been very successful overall, and has been successful in achieving all four of its primary objectives. The structural aspects of the program (e.g., the thorough external review of applications for Phase II) and of the networks (e.g., their various management mechanisms) ensure that the program goals are explicitly addressed. Some findings specific to each program objective are discussed below.

4.2 Quality and Relevance of Research

The results show the research is high quality and very relevant to users. (See also section 7 for a discussion of value added to research by the NCE program and by the network approach.)

- All data sources involving network participants (e.g., network officers, Board Chairs, university respondents, program officers) agree that high quality research is being carried out by high quality researchers. University V-Ps (Research) and UILO Officers agree.
- Where case studies of projects leading to "big winner" social and health benefits were reviewed by external experts, about 90% of the NCE research and/or the researchers were said to be the leading ones in the international field represented in that project, or that the NCE project was "unique", or the only one that had been successful world-wide to date. (Of course, by definition this was a sample biased towards projects most likely to be of high quality.)
- The NCE research is clearly in areas of high strategic importance, either because of existing Canadian industrial capability (e.g., in telecommunications), or in areas in which significant social, health, or economic benefits might be expected (e.g., in biomedical areas). This is self-evident from the nature of networks supported, but is also confirmed by the nature of the review carried out by peers and the selection committee for Phase II renewals and new applications, as well as by the results of the case studies of projects that will lead to major social, health, or economic impacts (see subsequent sections).
- Most elements of their network's research program were relevant to the partners' organization: understandably, relevance was higher for specific projects they were involved in, and lower for the network program as a whole. Partners of new networks, however, were more likely to find the entire network program was relevant:

	Partners of renewed networks	Partners of new networks
Relevance of overall research program to partner	34% said "high" 40% "medium" 12% "low"	57% "high" 26% "medium" 9% "low"
Relevance of network theme partner was most involved with	46% "high" 32% "medium" 3% "low"	61% "high" 26% "medium" 4% "low"
Relevance of specific projects partner was most involved with	61% "high" 21% "medium" 3% "low"	70% "high" 9% "medium" 0% "low"

4.3 Impact on Developing and Retaining Scientists and Engineers in Relevant Fields

Key results regarding the provision of training to develop or retain highly qualified personnel (HQP) are found below. (See also section 4.4 for a discussion of management mechanisms related to HQP, section 4.5 for a discussion of HQP issues for partners, and section 7.3 for value added to training by the networks.)

- The program is providing high quality training to large numbers of graduate students and post-doctoral fellows, 70% of whom take jobs in Canada after leaving the network and 45% of whom take jobs in Canadian industry. There is probably a small "brain gain" for Canada since only 60% of students and post-docs are Canadian, but 70% of the total stay in Canada.
- All networks train significant numbers of grad students and post-docs in network-related research. In a typical recent year, roughly 1,000 graduate students and 3 - 400 post-doctoral fellows are involved with the network, the average investigator's research team includes:

	Graduate students	Post-docs
Renewed networks	6.0	2.2
New networks	7.0	1.3

- Since joining the network, the average partner has recently hired about 3.7 Masters, Ph.D., or post-doctoral level people. Of these, about 35% received their training through the network. (These numbers probably only reflect new employees in the respondent's group.)
- Students contacted during the collaboration case studies were very satisfied with the training they received.
- There are some minor problems related to multidisciplinarity as there may be no related degree programs for students. (This problem is systemic to all multidisciplinary programs, not just NCE.)

- The program has a limited to moderate impact on attracting senior investigators to Canada, or retaining those already here:
- Most networks can point to a handful of senior investigators who were influenced to come to Canada, or to stay in Canada, because of the network or the network principal investigators (PIs). However, most network officers emphasized that many other factors affect such choices, including location, salary, and so on.
- Some scientific leaders reported that roughly half their senior researchers were being approached by recruiters of foreign universities at any given time. (Note that this is also an indirect measure of the quality of the network researchers.) This is roughly confirmed in the survey of researchers at renewed networks: about 37% have actively considered a non-Canadian research position since joining the network[9] — 42% said the existence of the network was a moderately important factor in their decision to stay here; 18% said it was very important.
- For researchers who moved to Canada (comprising about 10% of the researchers at renewed networks), the existence of the network was a moderately important factor in this decision for 14%, and a very important factor for 33%.

Results from the analysis of "appendix table" data

The tables below indicate that substantial numbers of Canadian graduate students and post-doctoral fellows are involved with the networks. In addition, the first jobs obtained by these individuals after leaving the networks are in Canada about 70% of the time — this indicates a small net "brain gain" for Canada, since only about 60% of the students and post-docs have Canadian citizenship.[10] These individuals are also highly likely to take positions in Canadian industry: almost half do so.

	Number of graduate students and post-docs involved in new and renewed networks*						
	Phase I				Phase II		
	90/91	91/92	92/93	93/94	94/95	95/96	96/97
Graduate Students							
NCE funds	326	538	570	No data	643	615	587
Other funds	67	415	515		246	435	468
Sub-Total	**393**	**584**	**1085**	**No data**	**889**	**1050**	**1155**
Post-Docs							
NCE funds	67	176	186	No data	194	185	212
Other funds	37	100	110		79	142	188
Sub-Total	**104**	**276**	**296**	**No data**	**273**	**327**	**400**

* PY equivalents

Note that graduate students are split roughly 50/50 at Masters and Ph.D. level, and roughly 60/40 as to Canadian/foreign citizenship.

Source: NCE Directorate (Annual Report "appendix tables".) Data are missing for the transition year from Phase I and Phase II.

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9 This figure was notably lower — about 18% — for respondents in the very applied engineering fields.

10 Such support of non-Canadian graduate students and fellows is common to most university training programs in most countries, not just NCE.

The table below shows that 58% of NCE graduate students and post-doctoral fellows eventually take first jobs in industry.

Post-Network Employment of Graduate Students and Post-docs — Phase II Totals for Renewed Networks		
Country	**Sector**	**No. in 95/96**
Canada		
	Industry	196 (46%)
	University	54 (13%)
	Government	17 (4%)
	Other	28 (7%)
	Total	**295 (70%)**
USA		
	Industry	37 (9%)
	University	16 (4%)
	Government	6 (1%)
	Other	5 (1%)
	Total	**64 (15%)**
Other		
	Industry	14 (3%)
	University	37 (9%)
	Government	7 (1%)
	Other	6 (1%)
	Total	**64 (15%)**
Grand Total		**423 (100%)**

Source: NCE Directorate (Annual Report "appendix tables")

As a matter of comparison, only 3% of holders of NSERC Post-Doctoral Fellowships go on to industry positions, while about 79% of NSERC Industrial Research Fellows do so.[11] At the graduate student level, about 69% of holders of NSERC Post-Graduate Scholarships take industrial positions after graduation.[12] Thus NCE is somewhere in between, as would seem appropriate.

[11] *Final Report Evaluation of the Scholarships and Fellowships Programs of the National Sciences and Engineering Research Council*; The ARA Consulting Group, March 1993.

[12] *Post-Graduate Survey — 1994*; NSERC, March 1995.

4.4 Extent of Management of Multidisciplinary, Multisectoral, Integrated Research Programs

The programs are being managed reasonably well, and they are indeed multidisciplinary and multisectoral (in the sense of involving universities, industry, and government), especially in new networks. The degree and quality of management and integration varies somewhat from network to network; this variation is more a function of individuals rather than the management model used.

Interview data

Some individual data from interviews are:

Network officers (scientific leaders and network managers)	Are mostly quite satisfied with their management. There are numerous specific examples of projects being terminated and/or researchers let go for not being in line with program goals (e.g., not enough external relevance), or for not collaborating enough. Research is probably managed somewhat better than technology transfer (partly because less is known about how to manage TT), and collaboration and networking are not so much "managed" as strongly supported.
Network Chairs of Boards	Are generally also satisfied with the management of their networks, although individual problems were often cited, particularly re: the adequacy of the Internal Agreements, conflicts with the universities, and the need for more management of technology transfer.
V-Ps of Research and UILO officers at partner universities	Reported a wide range of management effectiveness depending on network, from well-run, well-staffed, and well-organized; to disorganized and inefficient. The "average network" was seen to be moderately well run.
NCE federal program officers	Reported moderately good to excellent management, with variations more due to individual personalities than models employed. Some specific weaknesses in business knowledge were seen.

Results from the surveys of network researchers

- Half to three-quarters of researchers (depending on which aspect of management was being commented on) at renewed networks said their network had effective management mechanisms for various activities — the most relatively successful mechanisms were for communicating within the network and selecting integrated research themes; the relatively least successful were for selecting, reviewing, and revising individual projects, and for identifying research results with potential for commercial or social benefits (but these were still rated as OK).
- Researchers at new networks could mainly only comment on the mechanisms for selecting integrated research themes (other aspects were too new to tell) — this was found effective by about 75% of researchers (slightly higher than the equivalent 67% figure at renewed networks).

- Researchers at non-renewed networks were more likely to say their network had partial or no success at management — roughly 30-50% reported partial effectiveness, and roughly 15-20% reported no effectiveness at their networks.[13] The only mechanism that was highly rated was communications within the network; the relatively worst rated were related to individual project review, identifying possible commercial or social impacts, and transferring technology to users or increasing the technical ability of partners.

Results from the survey of network partners

- Roughly a third of partners of renewed networks reported being an active participant on the network Board, research committee, or committees related to technology transfer (e.g., TT committee, industry liaison committee, IP committee, etc.). The equivalent figures for partners of new networks were about the same for participation on most committees, except that far more respondents (70%) were active on the Board of Directors.
- Partners reported that they had a reasonable amount of input to network operations, were reasonably satisfied with the results of that input, and thought the network's management was reasonably effective. Partners of new networks tended to be more satisfied (this is consistent with their larger role in network proposal preparation):

	Partners of renewed networks	Partners of new networks
Degree of input to various aspects of network operations (*)	10-35% said "high" 25-35% "moderate" 30-50% said "low"	25-40% "high" 25-45% "moderate" 25-45% "low"
Satisfied with degree of input? (*)	65-70% said "yes"	60-85% said "yes"
Were network management mechanisms effective?	45-50% "yes" 10-30% "partially" 5-10% "no"	50-65% "yes" 15-40% "partially" 0-5% "no"

* Range represents answers to various types of input. No particular aspect of input to, or type of, network management was poorly rated, although communications were somewhat lower rated than other aspects of management.

- Many partners didn't know how effective the management was: about 20-35% of partners of renewed networks, and 15-25% at new networks.

Results from the analysis of "appendix table" data

These data bear partly on the issue of the success of networks at involving partners from industry, government, and health care organizations. The tables below show that the total number of partners has gradually increased over the lifetime of the program. (No data are available from the transition year of 1993/94 as network and program staff were overwhelmed with the transition process). As the footnote shows, these figures represent the number of network-partner agreements/involvements, **not** the number of separate organizations involved; i.e., if "Firm ABC" becomes involved with three different networks, this is counted in the

[13] The range in these and subsequent figures represents the range of responses regarding individual aspects of management.

table as 3 firms. Even where this may occur, these still represent partnerships in different research areas, and are usually between different individuals within the partner organizations. Overall, these data show a great deal of NCE involvement by universities and the private sector, as well as modest involvement by two levels of government, both of which have increased over time.

	Number of participating organizations* — Renewed Networks (signatories and non- signatories combined)					
	Phase I			Phase II		
	90/91	91/92	92/93	94/95	95/96	96/397
Universities	81	82	116	135	136	133
Firms	58	59	87	203	225	308
Hospitals	Not asked	Not asked	Not asked	48	47	40
Federal departments/Agencies	8	11	15	27	36	37
Provincial departments/agencies	8	8	13	32	32	48
Other	19	22	29	16	32	43

	Internal Agreement Signatories — Phase II Total for Renewed Networks*		
	Year		
	94/95	95/96	96/97
Universities	126	127	129
Firms	26	27	30
Hospitals	7	7	5
Federal department/Agencies	9	9	9
Provincial department/agencies	0	0	2
Other	7	10	10

* Note that the totals represents the number of individual network-partner agreements. Since most universities have signed Internal Agreements with more than one network, for instance, the total number of individual universities involved is substantially lower. Similarly, an individual firm or government agency may have agreements with more than one network.

Source: NCE Directorate (Annual Report "appendix tables"

	Internal Agreement Signatories — Phase II Totals for New Networks*
	Year: 94/95
Universities	79
Firms	31
Hospitals	0
Federal department/Agencies	3
Provincial Department/agencies	2
Other	11

* Note that the totals represents the number of individual network-partner agreements. Since most universities have signed Internal Agreements with more than one network, for instance, the total number of individual universities involved is substantially lower. Similarly, an individual firm or government agency may have agreements with more than one network.

Source: NCE Directorate (Annual Report "appendix tables")

The "appendix table" data also include information on the contribution of partners to the networks' research programs. The tables below show that cash contributions have been significant; industrial contributions in particular have been slowly increasing over time. In-kind contributions are even more significant, and have also been tending to increase over time. Note that the in-kind contributions were calculated by the networks, not the partners.

	Financial Support — All Networks to date ($ million)					
	90/91	91/92	92/93	93/94*	94/95	95/96
Cash Support:						
NCE Grants	62.3	54.6	54.0	49.5	53.4	45.1
Industry	0.4	2.1	3.6	0	4.4	7.7
Federal Agencies	0.9	6.4	9.7	0.4	1.4	1.2
Provinces	2.4	7.5	7.8	0	1.6	5.7
Universities	0.3	0.7	0.8	0	0.4	0.8
Other	0.8	0.2	2.9	0	3.4	3.1
Sub-Total	**67.1**	**71.5**	**78.8**	**49.9**	**64.6**	**63.4**
Administration Costs:	1.2	0.9	0.8	1.6	2.0	1.4
Sub-Total Cash	**68.2**	**72.4**	**79.7**	**51.6**	**66.5**	**65.0**
In-Kind Support:						
Industry	3.5	5.1	8.6	0.1	11.1	15.8
Federal	0	1.4	2.4	0	1.2	2.1
Provinces	0	0	0.2	0	0.6	1.1
Universities	4.4	5.5	6.0	0	0.4	1.1
Other	0	1.8	0.3	0	1.6	3.6
Sub-Total In-kind	**8.0**	**13.7**	**17.6**	**0.2***	**14.7**	**23.7**

Differences between sums and totals are due to rounding errors.

Source: NCE Directorate. Note that the Directorate's figures are assumed to be more complete and accurate than the data provided by individual networks presented in Appendix K, L, and M. Small expenditures in 1988/89 and 1989/90 are not shown.

* Data incomplete.

Overall, the appendix table data on numbers of external participants, as well as contributions in cash and in-kind suggest that there has been substantial involvement of such parties, and that this involvement has been increasing over the lifetime of the program.

4.5 Degree of Acceleration of Exchange of Research Results and Technology Transfer

4.5.1 General Findings

In general the study has found that:

- There is a tremendous increase in knowledge exchange among university researchers, with particular changes being found in inter-lab and cross-Canada collaboration and knowledge sharing.
- The networks have successfully increased the exchange of knowledge with users, and are better at this, on average, than other council programs. About 80% of partners expect the network to be highly useful or very highly useful to them in some way.
- There are many opportunities being actively explored for significant technology transfer through training of HQP; access to university expertise; access to new product/process ideas and/or IP (with consequent sales revenues or cost savings); changes to codes, standards, and regulations; and benefits to education, health, quality of life, the environment, and so on. Some of these opportunities may lead to truly substantial impacts.
- Some examples of applications that may result in economic and/or social benefits include: high-speed wireless access for all types of telecommunications equipment and services; testing and treatment of numerous bacterial diseases (e.g., tuberculosis, sexually-transmitted diseases); testing and possible future treatment of genetically-caused or -influenced diseases (e.g., breast cancer, Alzheimer's, retinoblastoma); development of higher strength, longer lasting, lower maintenance concrete for structural applications; non-polluting pulp whitening processes; reduction of childhood asthma; development of intelligent human-machine interfaces (e.g., for microsurgery or inspection of fish fillets); better decision-making in health care delivery; improvements to ability to design and use microelectronic devices; ability to re-grow severed nerves, or improve neural control of artificial limbs; protein-engineering-based drug delivery and treatment of infections; sustainable forest management practices that integrate social and economic priorities; better telelearning techniques for distance education; "smart" buildings that can monitor their own structural integrity over time. There are many others.
- The time frame for these benefits to be realized varies by sector: it is generally much shorter (e.g., months to a couple of years) for many results in fields such as telecommunications or telelearning; it is usually much longer for biomedical projects (often 5-10 years for those that must undergo clinical trials); and it may be quite long for projects affecting codes, standards, and practices (e.g., new construction methods may take a long time to infiltrate the industry).
- The networks have actively protected intellectual property through non-disclosure agreements, patents, and licenses in fields where these are relevant. This indicates that the networks are taking their technology transfer goals very seriously. This type of activity has mushroomed over the lifetime of the networks, reflecting and maturation

of the exploitation life cycle over time. In some other fields, access to highly-trained university researchers and potential new hires is most important.

- Networks have attempted a variety of creative mechanisms for dealing with limited receptor capability, including creating spin-off companies, developing R&D investment funds, incorporating "arm's length" commercialization entities, and so on. The best solutions are not yet known, but all networks for which product development is important are actively working on this issue.
- The partial benefit/cost analysis indicates the program is likely to **at least** cover its costs: economic benefits from just nine network "big winner" projects will cover **total** program and partner costs to date, as well as costs of commercializing the big winner projects in future. This is a very positive result for an R&D program of this type; in fact, it is the best result for any university-based research program that we know of. The analysis was conservative wherever possible: **all** NCE program costs to date, plus all industry cash contributions to date, were included in the "cost" ledger; costs also included all known future commercialization and production costs associated with the nine big winner case study projects; whereas the only benefits included were those associated with these nine big winner projects. **Not** included were benefits associated with all the many other network projects (most of these benefits cannot be foreseen at this time), benefits accruing to end users of the technologies, or valuations of difficult-to-quantify impacts such as those to health or the environment. Such non-quantifiable benefits are likely to be very significant indeed. In addition, where ranges of benefit estimates were obtained, lower bounds were used. Finally, an 8% discount rate was used for all costs and benefits over the entire life span of the case study commercial impacts.[14] (No adjustments needed to be made for incrementality as this was high or very high for all case study projects.)
- Significant hurdles still exist to technology transfer: see Section 5.4.
- Networks believe they are more successful at identifying and pursuing these opportunities than through usual programs; universities don't necessarily agree.

4.5.2 Findings Regarding Collaboration

Findings from the Researcher Surveys

Researchers report that during the NCE they did more applied research, and collaborated more than prior to joining the network:

- Regarding applied work:

	Average Per Researcher	
	Renewed	**Non-Renewed**
Proportion of work that is applied	35% prior to NCE 49% in NCE	30% prior 40% in NCE 36% after NCE

[14] Under the economic situation in 1996, an 8% rate may be slightly too high, but it is not unreasonable.

- Researchers reported considerably more collaboration of all kinds. Virtually none reported less collaboration since joining the network[15]:

	Proportion reporting "More or Much More" Collaboration since joining the network (*)	
Collaboration for various reasons with:	**Researchers at Renewed Networks**	**Researchers at New Networks**
Other university investigators	40-65%	60-75%
Industry	45-55%	40-55%
Government representatives	10-15%	30-45%
Hospital or health care workers	10-15%	10-25%

* The range represents collaboration for various individual purposes (planning, carrying out the research, and applying the results).

- At non-renewed networks, about half the researchers reported they still maintain collaborations with researchers at their own and other universities established while they were in the network (but about 40% reported fewer or no such collaboration, and the scientific leaders interviewed said that most national collaborations ended once the funding for them ended, leaving only local collaborations). About 30% maintain the same contact with industry as they did before, but about half either decreased such contact or now have none.

Findings from the Collaboration Case Studies

These ten case studies were carried out to investigate the specific natures of collaboration carried out in a sample of individual projects. The findings show that:

- Overall satisfaction of participants (researchers, students, industry) was high to very high in all but one case study, where it varied from low to very high among different participants. The most frequent reason for more lukewarm satisfaction was physical distance from the major collaborators.
- The collaboration provided benefits mainly related to access to different research perspectives, increased exchange of information, and exposure to new research areas and technologies. Student training and industrial relevance were also improved.
- Industry representatives in particular mentioned that the project was a good opportunity for them to stay abreast of state-of-the-art knowledge by being associated with university researchers, they were able to do work they couldn't do otherwise because of lack of in-house resources, and the training for students was especially useful in that it provided industry with suitably-trained potential employees.
- Almost half of the industry representatives reported that they had somewhat limited — but still quite satisfactory — input into the collaboration. They said that they did not

[15] Note that networks are not permitted to support researchers in government laboratories. This may have restricted the latter's participation.

want to control the research too tightly, instead preferring to express their concerns and interests and then allowing the researchers to proceed with their plans and research.

- A few industry representatives mentioned that they had anticipated problems (e.g., confidentiality issues and a perceived reluctance on the part of academics to do applied research), which did not in fact materialize.
- Almost all teams acted as true collaborative units.
- There was moderate to high collaboration outside the project (e.g., across network themes or with other networks) in all but one of the cases.

4.5.3 Findings Regarding Technology Transfer

Findings from the Researcher Surveys

Most researchers expect practical exploitation of their network research results to occur. The most common types of impacts expected were:

	Percentage of Researchers (**)		
Types of applications expected (*)	Renewed Networks	New Networks	Non-renewed Networks
No applications expected	0	0	17
New products, processes, or services	76	69	45
Increased industrial receptor capability, patenting, changes to private sector R&D focus, additional R&D investments being made, etc.	50-65	45-75	25-50
Better disease/injury diagnosis, treatment, etc.	41 (74 for medical workers)	23	13
Changes to policies of government agencies or industry	5-10	15 hospitals 55-60 gov't, industry	6 hospitals 25-35 gov't, industry

* See appendices for details on more types of applications. Varies by sector.
** Range represents different individual impacts.

- The time period in which these results will first occur is from the present to about 10 years from now. About 45% and 40% of researchers at renewed and non-renewed networks, respectively, indicated existing impacts.

Findings from the Partner Surveys

The partners of new and renewed networks reported that:

- The program is having a modest impact on increasing the receptor capability of partners in fields where it does not already exist:

	Partners of renewed networks	Partners of new networks
Existing receptor capability (*)	57% said "high" 35% "moderate" 5% "low"	55% "high" 35% "moderate" 10% "low"
Network's influence on receptor capability (**)	20% "high" 36% "moderate" 38% "low"	33% "high" 39% "moderate" 22% "low"

* This varied by sector: the most capability was reported in the medical sector.
** Highest for medical, lowest for electrical, for partners of renewed networks.

- About two-thirds of all partners said it was appropriate for the network to have a role in improving their technical capability. By sector this was highest among the partners in the electronics and telecommunications field; lowest in the biomedical field.
- The proportion of partners rating the network's usefulness as high to very high in some specific categories[16] is shown below. Note that usefulness is expected to increase over time:

	Percent of Partners			
	High or Very High Usefulness to Date		High or Very High Usefulness in the Future	
	Renewed	New	Renewed	New
Health benefits	27%	N/A*	38%	41%
Social benefits	25%	N/A	35%	83%
Influencing receptor capability	36%	N/A	55%	51%
Increased investments	30%	N/A	38%	77%
Sales revenues	45%	N/A	70%	78%
Jobs created or retained	28%	N/A	36%	59%
Policies of industry	19%	N/A	30%	50%

* N/A = Not asked

- The table immediately above is somewhat misleading, however, as an individual partner is likely to participate in the program to obtain only one or two of the types of benefits shown, not all of them. Such a partner might rate one type of impact as very highly useful, but all the rest as not at all useful. The table below shows that 82% of partners rated at least one network impact as highly or very highly useful, either to date or expected in the future:

16 Obviously these will vary by sector; see Appendices D and E. Here only overall results are provided.

Highest rating obtained for one or more type of network impact	Percent of partners of renewed networks
Not at all useful	2%
Low usefulness	2%
Moderate usefulness	15%
High usefulness	35%
Very high usefulness	47%

- Access to highly-skilled university network researchers was considered moderately or very important by about 80% of the partners of renewed networks overall, with little difference expressed by respondents in medical versus electronic sectors. Access to highly-trained students they might hire was found very or moderately important by about 70% of respondents, with a clear distinction between the "other" sector (87%), electronic (71%), and medical (42%).[17]
- About 70% of partners of renewed networks expect that some of the network's research results have the potential to lead to significant revenues being earned (or significant costs being saved), relative to the investments the partner made. The expected time frames for these revenues were mainly over the next five years, with a small proportion of respondents saying impacts had already materialized, or would occur over the next 6-10 years. Impacts in the medical and "other" engineering fields were more likely to be expected over a long term than those in the electronics/ telecommunications field.
- Significant social impacts from network results were also foreseen by just over half the partners overall: unsurprisingly, these were mainly in the medical field, in which three-quarters of the partners had such expectations.
- Where partners didn't find network research to have been highly useful so far, and didn't expect it to be highly useful in the future, the main reasons were lack of awareness of the research, lack of relevance to their organization, or (especially) the research being so long term that its usefulness wasn't yet known. Few respondents cited lack of quality or lack or their own receptor capability.
- Roughly half the partners of new and renewed networks said that some portion of the research would have been done by their organization without the network; however, they would have incurred significant costs to do so and there typically would have been a delay of 3 - 4 years.

Results from the analysis of "appendix table" data

The tables below show the amount of dissemination of research results, both through the "normal" academic routes of publications and presentations, and also through industrially-relevant routes of patenting, non-disclosure agreements, licencing, spin-off companies, and so forth. Although these data are incomplete (since some networks did not provide data), at least

[17] A possible explanation offered by the networks for the relatively low interest in biomedical training is that large pharmaceutical companies do most of their R&D outside Canada.

157 patents have been applied for by the networks, and at least 32 have been granted as of the time these data were obtained, in addition to at least 50 licence agreements and the signing of at least 158 non-disclosure agreements in Phase II alone. In some fields, patenting and licencing is not the normal route for technology transfer — for example, Concrete and Wood Pulps transfer technology mainly through other means, and the networks in the telecommunication and artificial intelligence areas work in pre-competitive areas — thus the number of patents, licences, and non-disclosure agreements is a lower bound on formal technology transfer from NCE. Note in particular that all forms of dissemination have been increasing steadily over time, as has the degree of collaboration shown in the publishing record.

	Dissemination of Research Results — Phase I Totals for Renewed Networks*		
	90/91	91/92	92/93
Peer-reviewed Articles with:			
one author	33	89	118
two authors	112	374	431
three authors	57	267	386
four or more authors	47	273	389
Other Articles	91	160	203
Books	4	15	16
Book Chapters	14	73	114
Other publications	33	201	398
Invited papers & lectures	188	615	763
Patents applied for	4	16	51
Patents issued	2	4	7
Copyright items registered	0	0	5
Copyright items unregistered	1	4	13
Exclusive technology licences	0	3	6
Non-exclusive technology licences	0	10	17
Other technology licences	0	1	2
Other	6	56	69

* No data for available 93/94.

	Dissemination of Research Results — Phase II Totals for Renewed Networks	
	1994/95	1995/96
Articles (Peer) authored from one research group	366	740
Articles (Peer) authored from two+ research groups	221	345
Other articles from one research group	167	380
Other articles from two+ research groups	79	164
Presentations authored from one research group	412	1208
Presentations authored from two+ research groups	196	374
Non-disclosure agreements signed	50	108
Patent applications filed	25	60
Patents issued	5	14
Copyrights	20	52
Licences under negotiation	17	47
Licenses granted to industry	4	37
Start-up companies	6	16

Source: NCE Directorate (Annual Report "appendix tables")

Note: The reporting format was changed between Phase I and Phase II.

Analysis of partner survey data by size of firm

The types of NCE impacts differ depending on the size of the firms involved. The following exhibit shows results of the partner survey analysis split by annual Canadian R&D investment:

- Small: less than $1 million
- Medium: $1-5 million
- Large: over $5 million

The detailed data are found in Appendix D.2 and generally do not show striking differences by size. Where differences exist, they tend to show that the networks have the greatest impacts for smaller firms. The differences between medium and large firms are not so great, and are less consistent in direction.

	Analysis by Size of Firm		
	Small (19 Respondents)	Medium (18 Respondents)	Large (22 Respondents)
Satisfaction with Phase II goals and policies	"highly" = 26%	"highly" = 11%	"highly" = 23%
Impact of changes in goals and policies from Phase I to Phase II:			
Satisfaction with network	"higher" = 44%	"higher" = 12%	"higher" = 37%
Willingness to join	"higher" = 38%	"higher" = 12%	"higher" = 26%
Expectation of useful results	"higher" = 38%	"higher" = 18%	"higher" = 21%
IWillingness to contribute cash or in-kind	"higher" = 18-21%, respect.	"higher" = 18%	"higher" = 11-26%, respect.
Relevance of network research program:			
Overall research program	"high" = 29%	"high" = 53%	"high" = 33%
Themes/groups most involved with	"high" = 44%	"high" = 41%	"high" = 62%
Projects most involved with	"high" = 65%	"high" = 65%	"high" = 57%
Internal technical capability	"high" = 61%	"high" = 71%	"high" = 33% (!)
Network's influence on internal technical capability	"high" or "moderate" = 67%	"high" or "moderate" = 53%	"high" or "moderate" = 43%
Should network have a role in improving partner's receptor capability?	71% "yes"	86% "yes"	67% "yes"
Usefulness of network to partner to date: The percentage of respondents saying "very high", "high", or "moderate"	Improving R&D ability = 75% Affecting R&D topics = 80% Job creation = 60% New products, processes, etc. = 76% Affecting gov't policies = 14%	Improving R&D ability = 75% Affecting R&D topics = 75% Job creation = 56% New products, processes, etc. = 69% Affecting gov't policies = 40%	Improving R&D ability = 58% Affecting R&D topics = 70% Job creation = 26% New products, processes, etc. = 68% Affecting gov't policies = 36%
Is there potential for significant revenues from network research being applied?	84% "yes", mostly in short term	61% "yes"	67% "yes", more in long term
If network research has not been useful, why not?	Medium-sized had least awareness of results (33%, vs 5% for small and 14% for large); otherwise NSD		
Would projects have been done without NCE?	53% "not at all"	12% "not at all"	36% "not at all"
HQP issues:			
Importance of access to highly skilled university researchers	50% "very imp."	53% "very imp."	36% "very imp."
Importance of access to highly trained students that might be hired	40% "very imp."	31% "very imp."	27% "very imp."
Benefits of network over "normal" programs:			
Access to university researchers	77% "more"	44% "more"	64% "more"
Access to highly-trained new staff	50% "more"	50% "more"	27% "more"
Technology transfer	71% "more"	56% "more"	46% "more"

4.5.4 Findings from the case studies of "big winner" projects providing social and/or health benefits

All of the 14 case studies investigated demonstrated significant potential (and in some cases, actual) social and/or health benefits. (Note that only renewed networks were considered for this analysis.) In a few cases, they represent the potential for true breakthroughs (e.g., neural regeneration). Most of these impacts are in the health arena, but there are also social benefits such as those related to improved education, reduced environmental damages, and so forth. Details of the types of impacts may be found Appendix H.

It should be noted that many other networks not included in these case studies will also provide significant social benefits of various kinds — these are not included either because they are less project-specific (e.g., those associated with training and development of HQP, as for Micronet) or more difficult to hypothesize (e.g., the eventual impacts of CITR's wireless communications research may be socially profound, but they are difficult to envisage in a manner concrete enough for our case study investigation).

Some key findings in the case studies were:

- The role of the network was seen as very important in almost all of the case studies. By far its strongest contribution was in fostering and encouraging the collaboration, providing academic contacts, and making it possible for collaborations to take place at all.
- The network had had a significant role in fostering contact between university researchers and industry in 12 of the 14 case studies, through mechanisms such as providing education and information on each other's needs, establishing the first contact between the two, carrying out project and contract negotiations, helping to bring in additional investment funds, and so forth. Where appropriate, the network had also had a significant role in IP protection (of course, for many projects in these case studies IP protection was irrelevant).
- Half of the projects would have taken significantly longer — usually on the order of several years — without the presence of the network.
- Almost half of the respondents said that the project would simply not have been undertaken without the presence or support of the network. Respondents mostly attributed this to their inability to collaborate in the same way in order to explore all the various aspects of the project work, or to their inability to gain access to the contacts necessary to do multicentered clinical trials.
- Almost half the respondents also said that their projects would not have had the same focus or degree of progress regarding commercial application without the network, or that (in one case) the spin-off company itself would not have been formed. Respondents said the network educated them and helped them focus on the application, provided the expertise, the venture capital interest, and so on that resulted in the potential application.
- External reviewers, with few exceptions, agreed with the opinions of the network and industry respondents as to size and likelihood of impacts. For example:

- Over half of the reviewers rated the likelihood and impact of the application as very high. A few were rated as high, two as medium and only the project in which the project's near-term company was considered to be unlikely to succeed was rated as low or low to moderate; even there, the other parts of the project (which involved more basic research and thus application in a longer time frame) were highly rated.
- Over half of the reviewers rated the projects as dealing with very important areas of research and application, with most of the remainder rating the projects as important.
- Without the network, the external experts mainly expected a lower degree of resulting collaboration — this was usually seen as quite a critical lack. Almost half of the reviewers felt the projects would not have been done at all without the network and several reviewers felt that the work would have gone significantly slower.

- The reviewers' opinions were sometimes limited by the fact that the necessary research has not as yet been completed; thus it was impossible to form an accurate opinion as to the efficacy or magnitude of the product. There were some concerns about various obstacles that would be faced and the need to overcome them; these would also affect what reviewers otherwise deemed to be large impacts.

4.5.5 Findings from the partial benefit/cost (B/C) analysis

Introduction

We used what is commonly referred to as a partial benefit cost (B/C) analysis[18] to evaluate the economic benefits that may result from NCE related research. (Note that only renewed networks were considered for this analysis.) This reviews benefits associated with a sample of "big winner" projects, but compares those benefits to **all** known program and partner costs. This is the best methodology available for research programs where many economic benefits have not been realized and where many important benefits (e.g., improvements to health or the environment) cannot be quantified. It is considered a very positive result if a program "breaks even" under this type of analysis, since total program costs are compared to the benefits from only a very few projects. Often, research programs do not cover their costs under partial B/C analysis. When this occurs the reader must estimate the likelihood that "non-big winner" projects will eventually result in large benefits, or consider whether the qualitative value of social, health, and environmental benefits are "worth" the program costs not covered by the big winners. See Appendix J for a complete discussion of methodology.

[18] Detail of standard benefit cost analysis may be found in E.J. Michan, *Elements of Cost-Benefit Analysis*, George Allen and Unwin Limited, 1972. This was modified for use in R&D programs by The DPA Group (now The ARA Consulting Group) in: The DPA Group, *Evaluation of the Cost/effectiveness of NSERC's Strategic Grants Program*, January 1988.

Project Selection

Exhibit 4.1 summarizes the project selection process. The networks were initially asked to provide project summary forms for those projects which had or were expected to provide significant economic benefits. Such forms were received from 8 renewed networks with information on 41 projects. These 41 projects were compared to produce a subset of projects based on the criteria shown. Note that attribution and incrementality of benefits to NCE had to be high for a project to be included. Follow-up with the researchers and the partner resulted in 8 projects which were initially included in the quantitative analysis. A ninth project was added after following up on the partner survey.

Other projects were excluded from quantitative analysis for a number of reasons. Primarily exclusion was due to the lack of information on the market size, timing of benefits, revenue generation or cost savings that may accrue from the application of the research.

Referent Group

The analysis compares the costs and benefits of a project or program from the perspective of society as a whole. The referent group used in the analysis is Canada as NCE is a national program, financed by tax revenues from across Canada. This concept is important in assessing the role of scientific research as it necessarily excludes those benefits which may be realized by non-members of the referent group (e.g., non-Canadian companies).

Economic Benefits

For the most part the analysis focuses on those benefits that are more often considered easily quantifiable (e.g. product sales revenues). The estimates of benefits could therefore be considered conservative. Additionally, we used lower estimates where ranges were given for variables such as market size, penetration, sales revenues, cost savings, etc. This also serves to provide a conservative estimate of economic benefits.

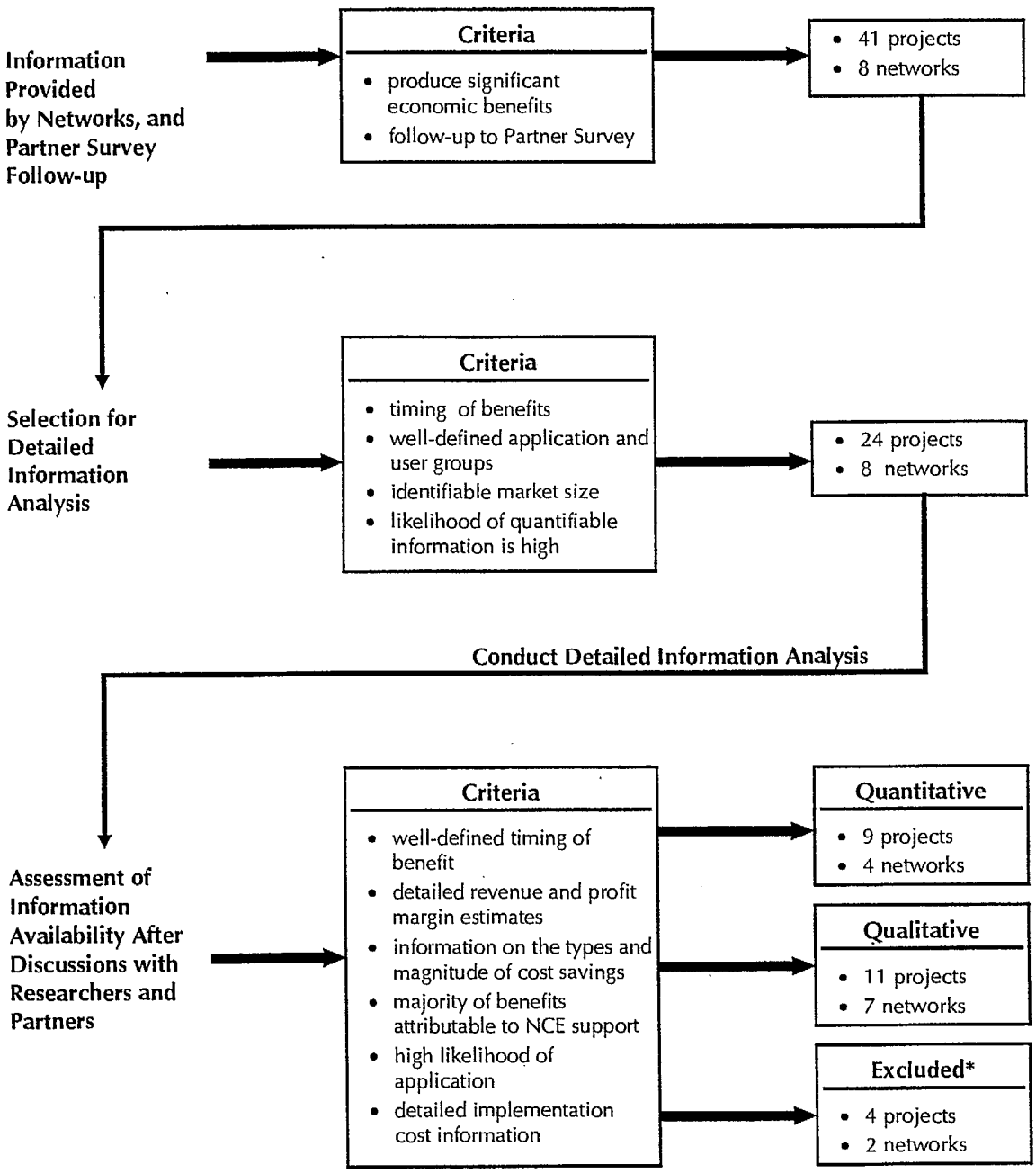
Increased Sales: Increased sales may flow from higher sales of an improved product or sales from a new product. Only increased sales garnered by Canadian companies are included in the analysis (although royalties paid by non-Canadian companies to Canadian entities are included).

It is also necessary to estimate the cost of production (capital, labour, and materials) to provide a net sales figure for the analysis. We have tried to be conservative in estimating the net sales (or conversely, liberal in estimating the cost of production).

Cost Savings: Cost savings applicable to the research carried out in some relevant NCE projects were also estimated. The definition of the market is extremely important in estimating total cost savings. This requires a clear understanding of the end users (including their location, industry or part of industry, and markets).

Royalties: Royalties represent the benefits received by the researchers and/or their institution. Royalty payments between Canadian entities are merely transfer payments and are excluded from the calculation of gross benefits. Royalty payments from non-Canadian entities to Canadian institutions, researchers, or companies represent an economic benefit to Canada and have been included in the analysis.

Exhibit 4.1: Project Selection and Summary



* Projects were excluded primarily due to our inability to contact those persons involved in research and commercialization

Economic Costs

Costs of Research: In partial benefit/cost analysis, total research program costs are used. The costs of research for NCE projects includes:

- the value of NCE program costs;
- the value of any other Canadian research grants and contributions directly supporting the NCE project research results (e.g., industrial support); and
- any administrative costs of the NCE network agencies.

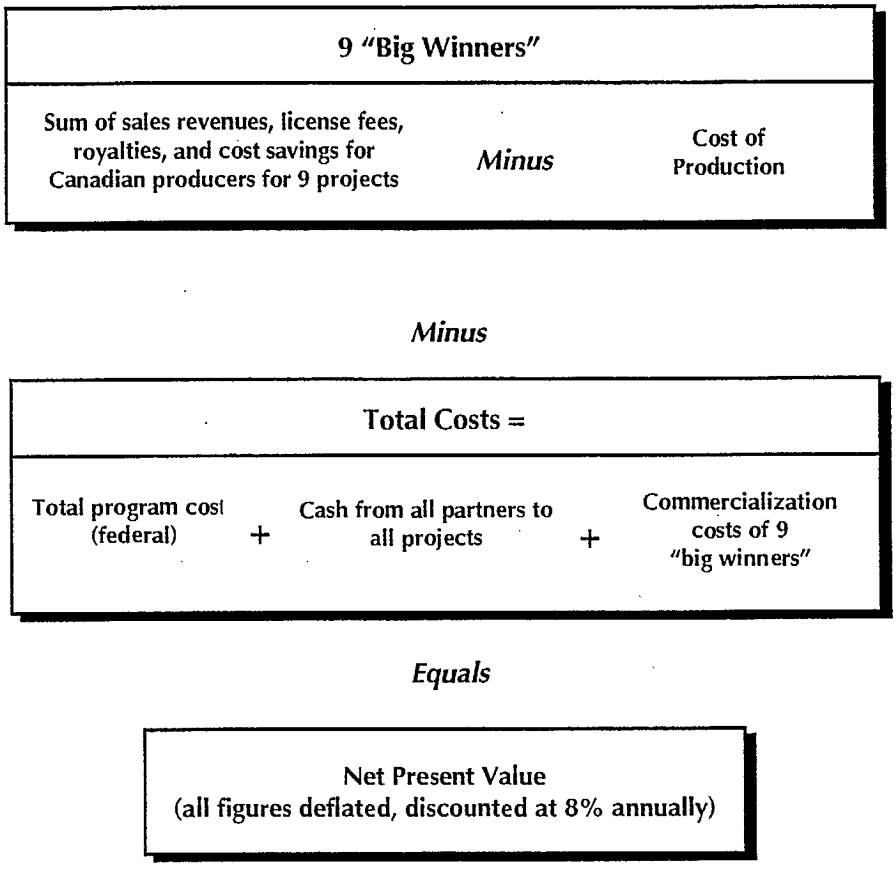
These program costs were obtained from NCE directly. For this analysis, we have included research costs from 1988-1989 through 1995-1996. Only cash contributions have been included in the research costs (e.g. in-kind contributions have not been included in the total program costs). Overhead costs to the universities have also not been included. Nor have earlier costs borne by other research grants programs been included — it is vital to remember that **all** NCE projects are founded upon research done earlier, often over decades. This situation also applies to the exploitation of any university research, not just NCE.

Implementation Costs: These costs include all costs incurred from the time the results leave the researcher until the benefits are reaped by the end user. The include such items as the cost of acquiring the research results, further R&D, marketing and promotion, and set up costs We used upper bound estimates for all implementation costs.

Incrementality: Incrementality identifies the degree to which benefits and costs are attributable to the NCE projects and the program overall. The key piece of information required in estimating incrementality is the degree to which the research results would have been available in the absence of NCE funding. A series of detailed questions were included in the interview guide to provide information on program incrementality. Generally, the incrementality of the economic benefits to NCE was very high.

Discounting: Costs and benefits for scientific research often occur at very different points in time. Discounting is used to calculate "present value equivalents" which are comparable. The present value equivalent is the dollar value which, if invested at a given interest rate today, would just equal that benefit or cost in the year in which it occurs. This analysis used a discount rate of 8% for all NPV calculations.

Exhibit 4.2: Calculation Methodology



Calculation Methodology

Exhibit 4.2 summarizes the calculation method used in partial BIC analysis. Note that the **total** program and partner costs are compared to the benefits from the nine "big winner" projects only.

The program costs were provided by NCE and subsequently adjusted to the 1996 base year. They include Phase I and Phase II grants and administration expenditures from 1988 -1995. They do not include in-kind contributions. Exhibit 4.3 summarizes these costs.

Exhibit 4.3 NCE Program Costs (Cdn 1996$)

Program Year	Grants/Administration Expenditures	Other Sources of Income	Total
1988-1989	$1 475 761	0	$1 475 761
1989-1990	$3 594 893	0	$3 594 893
1990-1991	$71 836 346	$5 321 967	$77 158 312
1991-1992	$59 399 329	$18 078 144	$77 477 474
1992-1993	$57 902 476	$26 189 708	$84 092 184
1993-1994	$52 950 464	$534 836	$53 485 300
1994-1995	$57 267 856	$11 570 947	$68 838 803
1995-1996	$47 095 892	$18 723 501	$65 819 392
Total	**$351 523 017**	**$80 419 103**	**$431 942 119**

Source : NCE Directorate

Economic Benefits: Quantitative economic benefits were calculated for nine NCE projects. These benefits are summarized in Exhibit 4.4. This table shows the categories of benefits that have been included for each of the projects. Detailed data cannot be shown as they are confidential for most projects. Most benefits have been quantified and included in the analysis except "other benefits" which have only been included qualitatively. Some cost savings were difficult to estimate and have also been excluded from the analysis. The exclusion of "other benefits" and some cost savings provides what could be considered a conservative estimate of the total benefits that may accrue from these nine projects.

Exhibit 4.4 Economic Benefits

Project	Past/Current Product Sales	Future Project Sales	Cost Savings	Other Benefits	Job Creation
Project A		✓	✓*		
Project B		✓	✓*		✓
Project C	✓	✓	✓*		✓
Project D		✓	✓	✓	
Project E		✓	✓	✓	✓
Project F		✓	✓*	✓	
Project G		✓	✓*	✓	
Project H		✓	✓*	✓	
Project I		✓	✓*	✓	

* Interviews indicated that these projects may provide significant end user cost savings. Information to provide quantitative estimates were not available and they have therefore been excluded from the quantitative analysis. If included, they could greatly increase the economic benefits of the projects examined.

Partial Benefit Cost Analysis Findings

Overall: The analysis uses the aggregated estimates of gross benefits and implementation costs from the individual project case studies. In evaluating the program, these "net project benefits" are compared to the total costs of NCE supported research for the whole program.

The NPV of **total** NCE supported research costs is estimated at approximately $611.9 million (1996$). A very conservative lower bound estimate of net economic benefit of the NCE program is indicated by the difference between the benefits of the nine quantifiable case studies (net of implementation and production costs) and the costs of NCE supported research.[19] Aggregate estimates are:

	Present Value (1996 $, millions)
Case Study Benefits (nine "big winners",net of implementation and production costs)	$611.9
Total Program Research Costs	$578.3
Lower Bound Estimate of Net Present Value (NPV)	**$ 33.6**

Based on revenues from only the nine case studies examined, we can conclude that the NCE program is likely to **at least** recover its costs and in fact will make a profit of at least $34 million. This is a very positive result for an R&D program of this type. For example, recent work using exactly the same methodology[20] for somewhat similar programs all yielded lower B/C ratios than NCE's 1.06:1. For NSERC's Strategic Grants program (which supports work that is relatively fundamental, but with strategic exploitation possibilities), the equivalent B/C ratio was about 0.37[21]; for the (then) Department of Communications research (which is a blend of fundamental and quite applied research in areas such as telecommunications and informatics, and for which individual projects often have specific industrial partners), the equivalent B/C ratio was 0.43[22]; and for the proposed KAON project of the University of British Columbia (which would have provided technology transfer to the industrial suppliers of this high-energy physics facility), the B/C ratio was 0.76[23].

Sensitivity to Assumptions: Overall, the analysis is very sensitive to factors that can either greatly increase, or greatly decrease, the NPV.

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19 Note that impacts such as taxes paid on revenues are **not** included, as these are not benefits to Canada as a whole, but merely transfers from one Canadian pocket to another.

20 Many economic impact studies use very different assumptions that greatly affect NPV and B/C results. We have seen many other reports, for instance, that **include** low incrementality projects or total company revenues (i.e., not just those attributable to the program under review), but that **don't include** costs to partners, future commercialization costs (which may be huge), or costs of production. Such studies often yield enormous B/C ratios, but they don't reflect the true return on investment to Canada. Readers attempting to compare NCE to other programs must carefully check that the analytic assumptions are equivalent.

21 *Evaluation of the cost-effectiveness of NSERC's Strategic Grants program*, The DPA Group (now the ARA Consulting Group); January, 1988.

22 This was a lower bound ratio. Much of the DDC work was confidential and data could not be obtained from the partners. *Final report for the study of the cost-effectiveness of the DDC research laboratories*, The DPA Group (now the ARA Consulting Group); August, 1989.

23 *KADN economic assessment final report*, The DPA Group (now the ARA Consulting Group); February 9, 1990.

On the pessimistic side is the very uneven distribution of the aggregated benefit estimate among the projects examined. For example, the benefits of the individual case study projects ranged from $2.5 million to $255.3 million. Three of the projects account for 86% of the aggregated benefit estimate. This distribution shows that the cost effectiveness evaluation would be altered considerably if just one of the examined projects experiences difficulties during the commercialization process. (Such an uneven distribution is common with research programs, however, and does not indicate anything unusual or problematic for NCE.) It also must be remembered that the economic benefits for each of the case studies represents forecasted benefits only. Unforeseen barriers during commercialization could result in some projects not reaching their intended market and these economic benefits remaining unrealized. At this point, it is impossible to state the magnitude of the economic benefit that will actually be realized from any or all of these nine projects.

On the optimistic side, all effort has been taken to provide a conservative estimate of potential economic benefits. Using upper estimates of revenues, cost savings, market sizes, etc. would have provided a larger estimate of benefits. Reducing the 8% discount rate might also be appropriate if current economic conditions persist over a long time frame.

In addition, this analysis has considered only nine of the many NCE projects supported, at least in part, by NCE funding, and even for these nine the end user benefits and/or cost savings, are, for the most part, not included. The many other network projects[24] are all at varying stages of development and commercialization but many of those not considered in the analysis will undoubtedly provide some economic benefit in the future. Additionally, it would appear that many of the projects considered qualitatively in this analysis will also result in potentially significant economic benefits. Even those that don't, provide significant social benefits. The estimates provided above should be viewed in light of this much larger collection of NCE projects that are highly likely to provide future economic and/or social benefits.

4.5.6 Other Network Technology Transfer Activities

Networks have attempted a variety of creative mechanisms for dealing with limited receptor capability, including creating spin-off companies, making seed investments in spin-offs, developing R&D investment funds, incorporating "arm's length" corporate commercialization entities, involving industry as co-leaders in projects, creating "top-up" funds to support projects with strong commercial potential, encouraging (or trying to require) their multinational partners to make new R&D investments in Canada, doing due diligence studies of market opportunities, carrying out demonstration projects, conducting workshops and seminars for training, hiring network business or commercial managers, having commercialization sub-committees of the Board, and so on. These are too numerous to list in detail, but see Appendix P for a summary of some of the more notable efforts. Note that new networks have had relatively little time to develop such mechanisms, but all have enjoyed substantial advice from the renewed networks.

[24] The exact number is impossible to quantify as each network specifies "projects" in a different manner. For example, one network has only three "projects"; another with a similar budget has dozens!

5. What Factors Have Influenced the Achievement of Program Objectives?

5.1 Impact of Program Design

5.1.1 Overview

The overall findings are that:

- The goals and policies are appropriate overall and are equally appropriate for all sectors, with the caveat that measurement of impact must take into account different external user needs.
- There is a strong desire on the part of network participants for a permanent NCE program, seeing it as a unique and valuable program with few design flaws. Most — but by no means all — university representatives would agree. While almost all of the latter group believe the NCE is a useful addition to council programs, a few see the program as unnecessarily complicated, and its technology transfer activities as overlapping with those of the UILOs.
- Program funding uncertainty has limited the commitment of some partners, researchers, and universities to individual networks, and also makes commitment to graduate students and post-docs difficult.
- The 10% carry-over rule (networks were not supposed to carry over more than 10% of their yearly funding into the next fiscal year) caused some difficulties, primarily due to forced short-term thinking; however the program made decisions on a case-by-case basis.
- "Ramping down" of network funding (federal funding to individual networks decreased over time) is not consistent with proper project management or corporate-type planning.

5.1.2 Findings from the Researcher Surveys

The majority of researchers are satisfied with the NCE program and their own networks:

	Proportion Very Satisfied or Moderately Satisfied		
	Renewed Networks	New Networks	Non-renewed networks
With the program	74%	85%	56%
With their network	92%	85%	73%

Researchers at renewed networks also found the Phase II goals to be appropriate for the program as a whole and their own network, while (not surprisingly) those at non-renewed networks didn't:

	Proportion Believing Goals Appropriate		
	Renewed Networks	New Networks	Non-renewed networks
For the program	61%	Not asked	27%
For their network	76%	Not asked	26% (if it had been renewed)

Most researchers at renewed networks believed their networks had achieved the program goals: roughly 75-90% said their network was moderately or very successful, depending on the goal (with least success for technology transfer and most for stimulating excellent research). Medical and "other" researchers were most positive about impacts on creating integrated multidisclipinary programs, while "other" and electronic networks were more positive regarding impacts on scientific excellence and technology transfer. There was no difference by sector re: HQP. A high proportion (about 40%) didn't know what the overall program success had been, but of those who did, almost all were positive.

Very few researchers had substantial suggestions for program improvements. If total federal research funding stays the same, most researchers are happy with the present NCE program budget:

	Proportion of Researchers	
	Renewed networks	New networks
More funding to NCE, less to other programs	17%	31%
No change	60%	39%
Less funding to NCE, more to other programs	16%	8%
Don't know	7%	23%

There was a small tendency for researchers in medical fields to prefer traditional programs; those in electronics and "other", to prefer the NCE.

5.1.3 Findings from the Partner Surveys

Partners were also generally satisfied with the program and their network:

	Proportion Very Satisfied or Moderately Satisfied		
	Renewed Networks	New Networks	Non-renewed networks
With the program	92%	90%	Few responses, but all were moderately satisfied
With their network	95%	95%	Few responses, but all were moderately satisfied

5.1.4 Findings from the Network Case Studies

There was some divergence of opinions depending on the type of respondent. Generally network officers and Chairs found the program goals and policies to be generally acceptable — with some reservations — while V-Ps Research and UILO officers had trouble with some aspects of the program and network designs. Overall our interpretation is that the program's goals and policies are appropriate, and that the changes for Phase II had the intended effect, but that issues of the program's funding uncertainty and network lifetimes need to be addressed.

Network officials

- The program's goals and policies are generally well-accepted by all networks, especially new ones. The main concern is that "relevance" not be measured by product sales alone, and there was some unclarity regarding selection criteria.
- The 10% carry over rule caused short-term thinking at some networks, and is not consistent with a business-like approach.
- "Ramping down" of funding is inconsistent with industry needs (most research investment is at the start; if commercialized, firms need to spend internally at a later date). Requiring cash from companies also encourages firms to want exclusive IP licences, which is inconsistent with pre-competitive nature of some networks.
- The funding uncertainty, and especially *program* uncertainty, makes it difficult to attract new partners and gain credibility with universities.
- The four year time frame is too short: networks spend a year gearing up after the award and a year preparing their renewal application; the network time span also doesn't fit with the time frame for applying research.
- Many networks have trouble with the "Canada First" rule if no obvious Canadian partner exists — flexibility within the spirit of rule is greatly desired, but the intent of the rule is well-accepted.
- The current program reporting methods and timing are much improved.

Chairs

- The program goals and policies were unanimously accepted, as were the changes for Phase II.
- The main concern is that the granting councils and federal government need to understand the long time frame needed to commercialize research: "Everyone understands the goals and objectives except the feds."
- There are significant and strong disagreements within the group of Chairs as to what the role of networks should be: from supporting basic research with an applied focus at one end of the spectrum, to acting as pure corporations with a completely business like focus at the other. Some of the Chairs are pushing for a much stronger business focus (but none discussed potential problems with student training, conflicts of interest among researchers, etc.)

- Two Chairs were concerned that the need for support of basic science was being lost.
- Chairs agreed that program funding uncertainty and "ramping down" had been problematical.

V-Ps Research and UILO Officers

- Overall, there was divergence of opinion as to the appropriate goals for the program — as for Chairs, while most respondents believed the current goals were appropriate, some V-Ps believed that Phase III should focus on the application of scientific results; others, on carrying out fundamental science. These opinions were often strong. To some degree they are connected to related concerns about the respective roles of the networks and the universities for technology transfer — see section 5.4.
- Several respondents indirectly confirmed that the uncertainty about program and network continued existence made them unwilling to put special effort into dealing with network issues — however, those who don't see much value to the program wouldn't see this as inappropriate.
- The Canada First rule needs to be adjusted so that it allows for more flexibility in cases when there is neither Canada receptor capacity nor an appropriate means to establish a spin off company. Respondents suggested that this be a guideline rather than a rule.

5.2 Impact of Different Network Management Styles

There is not a lot of useful information on this topic. There were not really large differences in satisfaction with the networks or network management by sector — since networks in the different fields tend to have rather different management model, this implies that the different models are roughly equally appropriate. (Data on effectiveness of, and satisfaction with, management, are found in section 4.4.) The general findings are that:

- Every network has a different model, and rightfully so. Each sector and individual group of partners has different needs as demonstrated by some of the case study and partner survey data presented earlier and in the appendices.
- Success may be as dependent on individuals as the models employed. We noted that where university or partner representatives mentioned problems with networks, these often related to dealing with specific individuals rather than program policies.
- Incorporation has pros and cons:
  - It provides benefits for networks that wish to act more like corporations. Most renewed networks have either incorporated, or have incorporated "arm's length" entities for commercialization, or are thinking about it. The advantages are increased credibility with industry, ease of dealing with IP and negotiation issues, ability to take equity in spin-offs and get product liability insurance, and so on. Small networks or those in areas where ownership of IP is unimportant don't see the need.
  - Incorporation introduces additional complexities and costs, possible conflicts of interest on the part of researchers (and especially network officers) if the focus on technology transfer is taken too far. For instance, there may be

conflicts with their responsibilities for research, teaching, and publication, (especially for students working on applied projects), and possible conflicts with their universities in the researchers' roles or as employees. There are also possible headaches for university partners such as legal and financial issues, conflicts with their research and teaching mandate, problems with overhead, IP ownership, revenue sharing, etc. (For-profit incorporation may be more problematic for universities than not-for-profit incorporation.) Still, most networks are moving towards incorporation.

5.3 Impact of Federal Program Management

This has been a relatively transparent process for almost everyone except the network officers (scientific leaders, network managers, business officers, Chairs etc.) Partners, university partners, and so forth had little or no information In sum, the federal management has been appropriate and useful, and has improved in quality — and decreased in complexity — over time. Other findings are that:

- There was unease and uncertainty within many networks as to what the councils, Industry Canada, Treasury Board, and Cabinet thought about the program and the networks. This was coupled with some disbelief that these agencies "weren't thrilled" with the program, seemed to be uncertain about the value of basic research, appeared unrealistic about the time frame for technology transfer, and seemingly didn't understand the value of the network approach to both research and exploitation. (We do not think these agencies in fact hold such opinions. Rather, there appears to be some lack of communication about these matters.)
- Federal management has been seen as good to excellent, especially for administrative and bureaucratic issues. Each of the federal program officers was given good marks for responsiveness, helpfulness, and flexibility.
- Respondents didn't find that they had good access to program policy advice or ability to influence policy. This was especially true over issues such as program continuation, Canada First, and technology transfer expectations.
- Some network officers and Chairs believe that more senior management level council and Industry Canada commitment and participation is required; this would satisfy the need for more policy advice and input.
- Most network officers believe their networks could exist without federal management, but there are some advantages of federal coordination of the networks — and more such inter-network coordination and collaboration would be welcomed. The Chairs generally believed that federal management and funding were both required.
- None of the networks would survive except in a very limited fashion without federal NCE funding. (Non-renewed networks retained limited local collaborative efforts, but little or none nationally.)
- Joint management by tri-council and Industry Canada has usually been transparent to networks, with the exception of the decrease in MRC funding being passed along to medical networks (but not similar decreases in NSERC and SSHRC budgets), and

perceived inconsistent application of the 10% carry-over rule (in fact this was applied on a case-by-case basis in what appears to have been an entirely appropriate manner).

- Financial accountability appears to be adequate in the sense that no improprieties or significant operational problems have surfaced. However, a few Chairs, university representatives, and partners commented that deciphering the network and university financial accounts was a daunting — and sometimes impossible — task.

5.4 Impact of External Factors

All data sources (as well as confirmatory information on some points from a number of studies of other university-industry programs) indicate that the networks are all subject to a variety of important external factors that affect their success:

- Some networks and their host universities work very well together, but some are experiencing significant tensions around issues of IP ownership, contract negotiations, revenue sharing from licences, royalties, and contract overheads. There may also be conflicts of interest among some network researchers, and conflicts with the universities' research, teaching, and publication mandates. It should be noted that not only networks are under pressure to "produce" — universities are under similar pressures. In the opinion of network participants, the universities tend to look for short-term pay-offs, or support spin-off companies with a very limited product line, therefore not maximizing Canadian value-added. Some university respondents would agree, others disagree vehemently. There is an opportunity for the program to improve the partnership and complementarity of the networks and universities. Overall, we regard these tensions as signs of success as they would not exist if there were no impacts of consequence to fight about.
- Universities are increasingly unwilling to shoulder the overhead costs associated with networks. At a few institutions, this problem is becoming pointed.
- The network impacts are affected by the health of the underlying research base — the program leverages not only funding from non-NCE sources, but also leverages the knowledge base in the field as a whole. Support to fundamental research must remain strong for NCE to be effective.
- A short list of hurdles to commercialization of network research includes: lack of Canadian receptor capability in some firms and industries; need for more seed capital, venture capital, mezzanine financing, etc.; long development and approval processes in biomedical fields; lack of funds for commercial activities such as patenting, marketing, market evaluations, etc.; impact of regulatory barriers; different timetables of industry versus academe, as well as different tolerances for risk; difficulty negotiating deals which provide a fair return to all parties; occasional conflict of interest between networks and universities, or between network partners and non-network companies dealing with UILOs; impact of federal and provincial R&D and tax policies; commercial and international competition; significant risks that some projects may "fail" in a commercial sense; lack of ability to follow "Canada First" where universities own the IP; possible "red tape" and associated delays when working through UILOs, but possible lack of expertise when dealing with network technology transfer units; and so on.

- Those factors related to their partners' receptor capability are referred to in section 4.5. In sum, each industrial sector has significantly different needs, expectations, and receptor capability; these drive the methods networks can use for commercialization or other exploitation of the research, and differ markedly from sector to sector, firm to firm, and project to project.
- Networks and the program have little or no control over the way Canadian industry operates; these problems are unlikely to be solved by the NCE. Lack of receptor capability continues to be a factor in some sectors, and it is unrealistic to expect any given network to have more than a small impact — especially given other problems such as the state of the economy, perceived lack of federal support for industrial R&D, strong multinational competition, and so forth. There is a strong conflict between the perceived need to have short-term economic impacts (which tends to lead to reliance on lower-risk, shorter-term solutions such as simple licensing of new technology), and the desire to produce the greatest long-term benefit to Canada (which tends to foster creation of start-up companies, many of which may not survive, or which will produce benefits only after 10-15 years even if successful). These strategies are also affected by industrial receptor capability.
- There is a basic conflict in the way university research is carried out, versus how industry R&D is done, that has been only partially resolved by the NCE program and individual networks. In particular, industry needs to follow through on specific projects when the results are encouraging commercially, but abandon those that don't have commercial promise or that don't fit into a firm's commercial strategy or product line. University researchers may wish to abandon projects that are of lesser interest scientifically, instead pursuing exciting but non-commercial research options that arise part way through the project. In essence, the two groups often have different criteria for continuing or terminating a given project. These problems are exacerbated by the short-term pressures on industry versus the long-term interests of university investigators. Finally, there are still conflicts between the university researchers' need to publish and the industry's need to keep some results confidential. These may result in industry being leery of committing to a network research program, or result in networks focusing on generic issues instead of proprietary ones.

  Having said this, we note that both "sides" (network researchers, and partners) indicated that each was more willing to address the other's concerns than had been expected. In addition, these problems are not a fault of the program or individual networks *per se*, so much as due to a fundamental difference in cultures and reward systems.

6. Consequences of the Phase II Program Reorientation

6.1 Overview

All networks have become more applied in Phase II, partly due to the revised goals and policies, and partly through natural evolution as research results are exploited. The new networks are particularly applied (and are also probably more multisectoral and well-integrated than the renewed networks), but still have a significant fundamental research component. Industrial and government partners are well-satisfied with the current goals and policies, and many like them more than those in Phase I. The great bulk of respondents would prefer no changes for Phase III (if it occurs), although there is a small but vocal minority who would prefer the program to either focus strictly on exploitation of existing research, or to focus on fundamental research, with universities carrying out the technology transfer.

6.2 Detailed Data

Findings from various data sources showed that:

- The change from Phase I to Phase II has affected the activities of roughly 40 - 50% of the researchers, especially in terms of having less focus on long-term fundamental research and more focus on research of interest to industry, government, or health care. Roughly a quarter of the scientists were more satisfied as a result; an equal proportion were less satisfied. Generally, investigators in electronics and "other" fields were more likely to be happy with the changes; those in the medical fields, more unhappy.
- Most partners were satisfied with Phase II program goals and policies, and were well-satisfied with them:

	Proportion Highly Satisfied or Moderately Satisfied		
	Renewed Networks	New Networks	Non-renewed networks
With goals and policies	71%	62%	Few responses

  Partners in the "other" engineering networks were especially satisfied. However, about a quarter of the partners of new and renewed networks didn't know what the goals and policies were.

- Most partners of renewed networks found that the program changes from Phase I to Phase II had either not affected their satisfaction with the program and their network, or had left them happier — very few (roughly 5%) were less satisfied. Partners in the "other" engineering fields were especially pleased with the revisions, generally followed by biomedical firms, and with electronics firms tending to be less affected by the changes.
- Network officials said that the split of effort between discovery versus developmental research changed from Phase I to Phase II: most "old" networks moved towards more developmental research; the new networks were already there. (Only one network

worried that the current split of effort is too far towards applied side.) There was less shift for networks that were applied to start with. Part of the shift is due to program reorientation; part is due to natural evolution of each network to meet relevance goal.

- Chairs noted that all networks save those already in very applied fields were seen to have adjusted their operation in response to the Phase II reorientation: there is now a more applied focus, more value-added approaches, termination of some projects, etc.
- VPs (Research) and VILO officials thought that the Phase II increased focus on application was appropriate, one individual calling it a "watershed" approach. Overall, most respondents felt the NCE program filled a valuable niche, but a few don't think it adds much compared to its cost and complexity. The necessity to keep the network focus on training and basic scientific knowledge for Phase III (if it happens) were also mentioned, while other respondents mentioned the need to build in industry funding for Phase III.

7. Value-Added and Incrementality of the Program Design

7.1 Overview

In some senses this is the most important issue of all. Given good researchers and reasonable funding, one would expect good research to be done. In addition, there are already significant pressures to collaborate and to exploit university research. Do the NCE and the networks add value because of their structural aspects — i.e., in addition to impacts simply because of the extra funding?

The discussion below shows that the program adds marked incremental value through both the structural aspects of the program and through the additional funding available through NCE. To the extent that it is possible to separate these factors, researchers would rate each as roughly equal in importance, with significant variation by individual. From the picture painted by all data sources, our conclusion is that the structural aspects are very important in providing added value, and we believe that many impacts and outputs of the networks and the program would not have happened with equivalent amounts of traditional council funding. These impacts include:

- The program has had a marked impact on the type of research conducted. These impacts include especially the applied aspects of most of the networks and the existence of many specific research projects. Furthermore, network researchers think more about possible applications, the size of research teams is greater, there is more collaboration and interdisciplinarity within teams, there are more investigators from other institutions and sectors and more interactions among them, there are far more interactions across labs and across the country than before, there is a more integrated approach to solving large problems, and it is easier to support risky projects. Roughly half the researchers are more positive about both collaboration and applied research because of NCE; virtually none are more negative. There has been no significant impact on the scientific merit of the work done; rather, impacts are mainly on the nature of the research.
- Students and post-docs associated with the program are exposed far more than usual to other researchers and labs, to networking, and to industrial needs and concerns. Graduates are more interested in working in industry than was previously the case, and limited data suggest that they are also more comfortable with applied work and collaboration if they take academic positions. For companies, most respondents see the NCE as better than traditional programs at training students and in providing companies with access to highly-qualified university researchers in relevant fields.
- For knowledge exchange, the program has clearly increased the extent of collaboration among university researchers, and between many researchers and partners. (A limited amount of this collaboration has been retained, especially at the local level, among researchers at non-renewed networks.)
- For technology transfer, all indications suggest that this program has the elements needed to be more successful at technology transfer and exploitation than is usual in "normal" council programs: there are many explicit formal mechanisms in place for

this purpose, as well as many informal ones; most networks have specific committees and/or staff positions responsible for exploitation of their research; and the network structures and proposals show that most have taken the Phase II goals very seriously indeed. Furthermore, most partners believe the program is better at technology transfer than other council programs, especially with respect to the "bundling" of technologies (access to a whole suite of technologies built around a central discovery, as well as access to all the top researchers in the field across Canada). Almost all of the "big winner" projects that may lead to large economic, social, or health benefits would not have occurred, or would have occurred to a significantly limited degree, without the networks. Overall, the program is an excellent model for increasing the exploitation of university research results

7.2 Impact on Research

Overall, the findings strongly confirm that the program adds significant value to the nature of research, although probably not to the absolute scientific merit or productivity.

Data from researcher surveys

The network funding provides a significant, but not overwhelming, addition to the research support of individual investigators. Thus it could reasonably be expected to have a significant, but not overwhelming, impact on the research that can be done. Note that no adjustment for inflation has been done in the following table:

	Approximate Average Change: Annual Funding*		
	Renewed networks	New networks	Non-renewed networks
Total research funding per investigator compared to same funding prior to investigator joining network	+47%	+38%	+52%
Change in total annual research funding per investigator after network terminated	N/A	N/A	– 16% (Compared to during network)
Proportion of total annual research funding per investigator from NCE	25%	26%	35% (while in network)

*Not adjusted for inflation, and excluding the small amount of NCE funding provided to some researchers at non-renewed networks during the network's end phase).

Some other selected results from the researcher survey are shown in Exhibit 12.1. This table indicates that the network has had significant impacts on the nature of research being done (and of course it has also increased funding to researchers.) Although there are many other factors affecting research, the program is definitely a significant one. Note particularly that researchers reported that structural features of the program (such as its focus on collaboration, network management, and training) are responsible for about half of the perceived changes to research, with the additional NCE funding being responsible for the other half. Thus while any type of additional research support can be expected to make an impact, the program is having an influence over and above this due to its specific goals and policies. From other researcher survey data, it appears that the most influential of these other features are the support for networking and collaboration and the support for HQP, with interactions of researchers with

external sources being somewhat less important, and network management having the least perceived impact.

Exhibit 7.1: Impact of the Network on Research: Data from Researcher Surveys

	Degree of Network Influence: % of respondents		
Type of Impact:	**Renewed networks**	**New networks**	**Non-renewed networks**
Influence on researchers total funding	57% said "major" 26% said "minor"	Not asked	56% said "major" 26% said "minor"
Influence on researcher's applied versus fundamental effort:	43% said "major" 28% said "minor" (35% of work was applied prior, versus 49% in NCE)	Not asked	23% said "major" 30% said "minor" (30% was applied prior, 40% in NCE, and 36% after)
Did network influence NCE research to be different from that done prior to joining network?	67% yes	69% yes	66% yes
Did network influence non-NCE portion of respondent's research program to be different?	75% yes	Not asked	Not asked
Change in attitude towards collaborative research due to network	49% more pos. 2% more neg.	Not asked	49% more pos. 4% more neg.
Change in attitude towards applied research due to network	49% more pos. 3% more neg.	Not asked	39% more pos. 6% more neg.
Number of people in research team in NCE compared to pre-NCE Total PIs at their university PIs at other universities Investigators from industry Investigators from government and hospitals	 +82% +49% +190% +216% +122%	 +39% +9% +274% +39% +50%	Total increased by 58% during NCE, and was 34% higher (compared to pre-NCE) after termination Current teams still include more PIs from other institutions and industries than pre-NCE.
Influence of the network on multidisciplinarity	43% "major" for NCE work 21% "major" for non-NCE work (54% of NCE work is multi., versus 48% of non-NCE work, and 40% of prior work)	80% "major" for NCE work 22% "major" for non-NCE (77% of NCE work is multi, versus 68% of non-NCE, work and 60% of prior work)	8% "major" 28% "minor" overall (40% of NCE work and 48% of non-NCE work was multi, versus 44% prior to NCE, and 47% afterward)

Exhibit 7.1: Impact of the Network on Research: Data from Researcher Surveys (continued)

	Degree of Network Influence: % of respondents		
Type of Impact:	**Renewed networks**	**New networks**	**Non-renewed networks**
Influence on scientific merit	No significant difference, even though there is more applied work.	Not asked	43% said merit of post-NCE work increased by NCE
Degree of risk of the NCE research compared to that supported through other programs	31% said "riskier" 20% said "less risky" 45% "NSD"	50% said "riskier" 25% said "less risky" 25% "NSD"	Not asked
What aspects of the network causes the impacts on research:			
The extra funding	54%	44%	70%
Other factors (networking, management, etc.)	46%	56%	30%

Data from the case studies of "big winner" projects leading to social and/or health impacts

The role of the network was seen as very important in almost all of the case studies. By far its strongest contribution was in fostering and encouraging the collaboration, providing academic contacts, and making it possible for collaborations to take place at all. Other impacts were in the ability to do multi-centred clinical trials, and in the initial choice of research area.

Network respondents agreed that:

- The big changes caused by the networks are much increased networking across different institutions across Canada and across different labs, more applied and market focus, better integrated programs that deal with all aspects of a problem through inclusion of more and different disciplines (one-stop shopping on research problem).
- The collaborative approach is new in some fields, amplified in others. The network is one important factor, but not the only one. In non-renewed networks, some local collaboration continued, but not Canada-wide, because of the costs involved.
- New Phase II networks show especially strong integrated, multidisciplinary approaches, but this is true of all networks, and there are signs of increased collaboration among networks.
- There is possibly more benefit of the network approach for younger researchers than established ones.
- Almost all networks found it easy to provide concrete examples of specific network results, or even complete research themes, that would not have occurred without the network — generally because of the increased breadth, collaboration, inclusion of more disciplines, and applied focus; but rarely because of additional funding. Some networks believed that virtually none of the applied portion of their network would have happened without the NCE.

- Only one network found its research program too diffuse to say whether specific topics would not have been investigated without the network; this network is intending to revise their program.

7.3 Impact on HQP

Data from the researcher surveys

Researchers were only asked about training for students. Overall, they believed that NCE provides similar or better training for graduate students and post-docs compared to non-NCE programs. Virtually none (2 - 3%) believed it was poorer. The major ways it was different (from most to least) were seen to be:

	Percent of Researchers at Renewed Networks			
	For Post-docs		For Graduate students	
Increases to:	NCE better	NCE similar	NCE better	NCE similar
Professional contacts and networking	66	13	72	20
Exposure to external users	63	16	70	21
Prestige and career	36	37	40	47
Ability to find a job	35	33	40	40
Experience with state-of-art equipment	33	44	40	50
Overall quality of scientific training	29	50	34	58
Involvement in research planning and management	21	53	26	60

The researchers from non-renewed networks had very similar opinions, although they were even more positive about the overall impact on scientific training, but less positive about the amount of additional exposure to external users.

Data from the partner surveys

Partners of renewed networks were asked about impacts on their own in-house technical capability, impacts in terms of the companies' access to HQP within the universities, and impacts on the capability and knowledge of new hires. For the first type of impact, please see section 4.5. For the latter two types of impact, the bulk of respondents said the network was better than other "normal" university programs. Very few respondents said NCE was worse:

	Percentage of respondents (excluding "don't know")			
	Partners of renewed networks		Partners of new networks	
	NCE is better	No difference	NCE is better	No difference
Overall technical capability of new hires	65	35	Not asked	Not asked
New hire's knowledge of organization's needs	59	41	Not asked	Not asked
Company access to relevant, high quality university researchers	64	32	78	12
Company access to highly-trained new staff	53	38	72	22
Technology transfer to organization	60	35	64	22

However, note that about 60% of the partners didn't know whether NCE-trained new hires were better than those trained in traditional ways (this is not surprising, since those completing the survey are unlikely to be those supervising new hires).

Data from the collaboration case studies

As part of the collaboration case studies, training for students and post-docs was investigated. The data from PIs, industry, and students were all similar: the networks were seen to provide significant advantages compared to traditional training in terms of:

- Students generally had far more active and meaningful collaboration than usual (including in project management and planning), and they were very positive about its impacts.
- Students had much greater access to other investigators and other labs, including those in other departments and other universities across Canada.
- There was a much greater degree of multidisciplinarity to the research.
- Students had better access to good equipment and training in how to use it.
- Students had significantly more involvement with industry.
- The experience caused the majority of students to be more positive about collaborating within academia, and some also felt the same about collaboration with industry and government.
- Most students became more positive about doing applied research, although some were now interested in the fundamental side since they saw that practical applications arose from basic research.
- Students were very positive about the training provided through the network, including that from special network courses, workshops, etc.

7.4 Impact on Knowledge Exchange and Technology Transfer

As has been seen in earlier sections, network researchers have larger teams, and have more collaboration, than prior to joining the network. The data generally show that:

- The research has a more applied focus than is usually the case.

- There is more collaboration among university researchers, with evidence of more collaboration than usual across different institutions.
- There is more interaction between university researchers and external partners, especially those in industry.
- There is more interdisciplinary research (more disciplines, and sometimes more people from various disciplines on individual research teams).
- There are significant attempts to try to transfer knowledge and technology for Canada's benefit through a wide variety of mechanisms (some of which vary by sector).
- There are a substantial number of projects that are expected to lead to significant economic and/or social benefits to Canada through application by the private sector, government organizations, hospitals, increases to the "public good"; where industry has been involved, the companies often would not have done the work at all, or in some cases would not done it as early, without the NCE.

At issue is what influence the network and the NCE program had on these aspects of knowledge exchange and technology transfer. There are several data sources:

Researcher survey	The network was said to be the most important factor in the increase in collaboration and networking by 46% of researchers at renewed networks, while 41%said that the network and other factors were about equal in importance. Very few respondents (7%) said other factors were more important.
Collaboration case studies	Most university respondents reported that they had become more positive about collaborating with industry, and about doing applied research.
Social and health "big winner" case studies	The network had an active role in fostering contact between university researchers and industry in almost all of the case studies; for example through providing information and education about industrial needs, establishing first contacts, carrying out negotiations, finding additional investment, obtaining IP protection, and so forth. Both the respondents involved with the network projects and external experts who reviewed the case studies agreed that, without the network, all the case study projects would have suffered to some degree. Roughly half probably wouldn't have been carried out at all, and the remainder would have had problems such as proceeding more slowly, having less collaboration, being of lower quality, or having less (or less likely) practical application.
Benefit/Cost case studies of "big winner" projects	Many researchers indicated that their work would not have been considered for commercialization in the absence of NCE. The networks were instrumental in fostering the interdisciplinary relationships necessary for product development and promotion. All primary NCE researchers were instrumental in transferring their findings to the commercialization process. Each worked very closely in all phases of product development and testing.
Network case studies	Most of the applied focus would not have occurred. Scientific leaders and network managers found it easy to provide examples of applications that wouldn't have happened without the network structure or NCE program.