Setting Priorities For Research In Canada

Partnership Group for Science and Engineering

APRIL 2000

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FOREWORD

The Partnership Group for Science and Engineering (PAGSE) is a cooperative association bringing together representatives of 25 major Canadian science and engineering societies. Individuals employed in the private sector, universities and government laboratories are active participants in these organizations. The Committee to Advance Research (CAR), an industry-university committee of PAGSE, addresses subjects including the establishment of priorities for research, modifying the university reward system, and enhancing university/industry synergy.

A principal objective of PAGSE is to ensure that Canada's capacity for research and innovation, and the subsequent industrial and intellectual outputs, are developed to their fullest potential for maximum economic and social benefit to Canada. Setting priorities for research in Canada is pivotal towards achieving our goals. Towards this end, CAR commissioned SECOR to conduct a study on the issue of setting research priorities. The analysis and conclusions in the report constitute an impressive document on research priorities in firms, universities, and federal government departments, which invest in in-house research and development, as well as the consideration of technology foresight activities.

PAGSE/CAR is indebted to the Canada Foundation for Innovation and the National Research Council for financial support of this study.

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SUMMARY

The Partnership Group for Science and Engineering (PAGSE) is a consortium of leading firms and associations involved in research and development (R & D). PAGSE has been active in addressing issues relating to the social and economic impacts of R & D in Canada. PAGSE established the Committee to Advance Research (CAR) in collaboration with industry.

PAGSE/CAR was concerned that:

- Canada seems to make little effort to identify and invest in areas of science and technology (S & T) that are of national importance for future job creation and wealth generation; and

- Funding for research appears to be insufficient to sustain Canada's competitiveness in the world economy.

PAGSE and CAR, decided to launch an investigation into the way that research priorities are set, to see if the concerns are justified and, if so, what could be done about them.

The Canada Foundation for Innovation (CFI) and the National Research Council (NRC) provided financial support to CAR in this initiative.

SECOR was given a mandate to carry out the investigation under the direction of CAR (PAGSE).

Work began in the summer of 1999. Surveys were used to collect information on R & D priorities. Three groups were investigated:

- 50 leading innovative firms;

- 12 leading research universities;

- All federal government departments involved in significant R & D programs.

The survey results showed that relatively few of the organizations contacted had a systematic approach to setting research priorities. The fit between the research priorities of the different groups was weak. Moreover, few mechanisms for collaboratively establishing priorities were available.

To better understand these problems, PAGSE:

- Carried out an analysis of technology foresight activities in other countries; and

- Analyzed economic indicators to assess the fit between research priorities and the contributions to GDP of the related industrial sectors.

Main Findings

Most organizations were simply not interested in how priorities ought to be established nationally. This message came through quite clearly from the surveys and related interviews. Moreover, Canada's capacity to define strategic research priorities based on concrete information was found to be very limited.

The data collected in this study demonstrated a poor fit between the research priorities of universities and those of firms. However, firms and universities shared similar views on the role of university research. Firms were not interested in having universities work on research problems of immediate concern to them. They wanted universities to conduct long-range research aimed at developing generic technologies and new methods.

Canadian universities place great emphasis on human molecular biology. The practical impact of much of this research is to develop new pharmaceutical products for the treatment of disease. Apart from a number of small and medium- size entrepreneurial firms, Canada has a pharmaceutical industry that is generally weak in innovation, although there are some genuine accomplishments in this regard. This frustrates the efforts of university researchers. They identified lack of industry receptor capacity and investment in R & D as factors that limit the applicability of their research.

University research in the life sciences is focused on research related to the pharmaceutical industry. This industry contributes 0.5% of GDP. By contrast, little research is carried out on the improvement of medical treatment outcomes, epidemiology and best practices, even though the delivery of health care constitutes 7% of GDP. With provincial medical insurance, Canada is ideally positioned to ”mine” health databases and to investigate practices that would help to optimize service delivery. The impacts of such work could be huge, since even small improvements translate into large financial and social effects.

The activities of the top 100 industrial R & D players are strongly oriented toward information and communications technologies, followed by health and aerospace. For example, the Canadian R & D expenditures of Nortel Networks exceed those of all Canadian pharmaceutical firms combined. The R & D interests of Canadian firms are poorly reflected by research activities at universities.

Although arguments in favour of the freedom of academic research would seem to resist any priority setting at universities, they overlook the fact that broad priorities are now set with little public debate. The basic split between the funding of university research in social sciences, life sciences and physical sciences is determined by government’s budgetary allocations to the three major Granting Councils. The decisions are not strongly supported by the analysis of technology trends or national needs, since such investigations have received minimal attention In Canada.

Government departments cite support of industry as a major research goal. Research in support of regulatory activities is given a lower priority. Health Canada, for example, which has a major regulatory mandate, has a relatively low research budget.

A good deal of activity across departments is oriented towards sustainable development. Little effort, however, has historically been made to coordinate sustainable development activities and to link them to university research. If Canada is to contribute important public goods for international consumption this would be an area where the nation could excel. The 2000 federal Budget takes an important step in addressing these concerns by providing additional funds for environmental technologies and practices, as well as the regulation of biotechnology.

Infrastructure Needs

The main infrastructure needs identified in this work were for "suites" of resources to support research projects. These included, for example:

- Additional laboratory space and analytical equipment; and
- Advanced computing equipment.

Respondents noted with some relief that universities have received increased funds for research and major facilities including those of national scope. However, this funding has not been matched by proportional increases in overhead, which has created enormous financial stress. Overall, the results suggest that the Canada Foundation for Innovation might want to allocate resources for both:

- Cohesive projects that aggregate a number of smaller investments; and
- The support of major facilities.

Technology Foresight In Canada

Countries such as Japan, US, Germany and the UK are leaders in technology foresight initiatives. All of these countries have well-organized teams leading foresight initiatives. The level of interest in future research directions is high. All stakeholders (industry, government and academia) are heavily involved in the process.

Canada's initiatives in this area were found to be modest compared to those of other western industrialized nations. To date, only four Canadian sectors have complete technology "road maps". Canada is now attempting to catch up. Unlike other countries, Canada's efforts have been primarily at the industrial sector level. Little effort has yet been made to create a national strategy by integrating the results from sector road maps.

Recommendations

Based on the findings of this work, PAGSE through CAR recommends that:

1. ***Government establish a foresight panel to identify the emerging technologies required for the country's future socio-economic needs and international competitiveness. Reviewing the directions of publicly funded research should be part of this activity. The panel should inform the political process of priority setting. It should provide recommendations to the Prime Minister's Office (PMO).***

2. ***Industry Canada support the work of the foresight panel by:***

- ***Improving its internal capability in technology analysis and foresight;***
- ***Undertaking technology foresight investigations for key industrial sectors using mechanisms that involve universities, firms and government laboratories; and***
- ***Benchmarking Canadian analyses against those of other countries such as the US, Japan and the UK.***

3. ***Government expand the support of research in sustainable development, advanced computer and information technologies for modeling and simulation, and medical treatment outcomes. Work carried out in each of these fields by industry, universities and government should be better coordinated to improve impacts.***

1 CONTEXT

1.1 CONCERNS ABOUT RESEARCH AND DEVELOPMENT IN CANADA

The Partnership Group for Science and Engineering (PAGSE) is a consortium of leading firms involved in research and development (R & D) and twenty-five key research-oriented associations. PAGSE has been active in addressing issues relating to the social and economic impacts of R & D in Canada. PAGSE established the Committee to Advance Research (CAR) in collaboration with industry.

PAGSE/CAR was concerned that:

- Canada seems to make little effort to identify and focus investment in areas of science and technology (S & T) that are of national importance for future job creation and wealth generation; and

- Funding for research appears to be insufficient to sustain Canada's competitiveness in the world economy.

PAGSE and CAR, decided to launch an investigation into the way that research priorities are set, to determine if the concerns are justified and, if so, what could be done about them.

The Canada Foundation for Innovation (CFI) and the National Research Council supported PAGSE/CAR in this initiative.

SECOR was given a mandate to carry out the investigation under the direction of the sponsors.

Survey Approach

Work began in the summer of 1999. Questionnaires were used to collect information on R & D priorities. Three groups were investigated:

- 50 leading innovative firms ;
- 12 leading research universities; and
- All federal government departments involved in significant R & D programs.

Statistically significant surveys could not be achieved easily, since the population base was too small. The survey approach was also complicated by the need to avoid constraining respondents. PAGSE did not want to limit the ways in which research fields and sub-fields were defined. Researchers, after all, should be developing and exploring completely novel fields. Questions relating to the definition of activities allowed free-form answers. In particular, R & D activities were not linked to industrial sectors, as defined by the standard industrial codes (SIC). These evolve slowly and tend to best represent traditional as opposed to knowledge-based industries.

Each sector had its own questionnaire. The three questionnaires are contained in the Appendix. The university and government questionnaires were similar. Universities and government departments were asked to define up to ten major research priorities. Firms were asked slightly different questions relating to their R & D needs in the short, medium, and long terms. The intention was to link R & D priorities to corporate strategy.

The survey results showed that relatively few of the organizations contacted had a systematic approach to setting research priorities. The fit between the research priorities of the different groups was weak. Moreover, few mechanisms for collaboratively establishing priorities were available.

To better understand these problems, PAGSE:

- Carried out an analysis of technology foresight activities in other countries; and
- Analyzed economic indicators to assess the fit between research priorities and the contributions to GDP of the related industrial sectors.

Despite some limitations, reasonable insights were obtained into the ways that firms, government departments and leading universities set research priorities. The findings are detailed in subsequent sections of this report. They prompted recommendations to government on the need for greater efforts to be made in technology foresight activities and in setting national research priorities.

2 RESEARCH AND DEVELOPMENT SPENDING IN CANADA

2.1 RELATIONSHIP OF R & D TO THE ECONOMY

The major research and development players in Canada are:

- Firms in a variety of industrial sectors
- Universities
- Federal government laboratories

Firms focus more in the “development” component of R&D while universities ederal government laboratories are involved in directed research.

Sustained R & D and industrial innovation are considered to be essential to the growth of advanced economies. Yet Canada lags behind its competitors in R&D investments.

2.2 IMPACTS OF RADICAL TECHNOLOGICAL CHANGE

Over the last three decades radically new technologies requiring large and sustained investment have had major impacts on industrialized economies. Examples of familiar and important technologies are shown in the table below.

Technology	Major Application	Example of Current and Future Uses
Space technology	Satellites	• Telecommunications • Broadcasting • Earth observation
Biotechnology	Genetic engineering Genomics	• Biopharmaceuticals • Enhanced agricultural crops • Understanding the genetic basis of disease • Patient-specific therapies
Information and telecommunications technologies	Compact computing devices Optical networks carrying digital data	• Improved productivity in all areas of the economy • The Internet • E-commerce

These technologies and most of their major applications were, in large part, seeded by visionary and sustained investment by the US government. Canada emulated the US example. With the possible exception of genomics, it has made sustained and important commitments to all of the fields above. Both Canada and the US have seized important competitive and economic advantage through these efforts.

Technological innovation and subsequent economic spin-offs have historically come in waves from the invention of writing, windmills, printing, steam engines, through to electrical power, the internal combustion engine, the transistor and the Internet. Being able to "ride the wave" confers huge competitive and economic advantage. PAGSE wants to ensure that Canada has the foresight and resolve to capture the benefits of emerging technologies.

2.3 SETTING RESEARCH PRIORITIES

The major players in R & D – firms, universities and government – are motivated by different drivers.

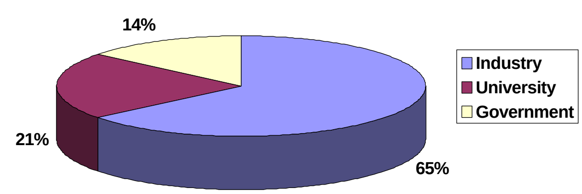
Player	**Important Drivers**
Firms	• Creating shareholder and employee benefits through profit and equity growth • R & D as a private good
Universities	• Training of qualified human resources • Research as a public good
Government	• R & D in support of: ➢ Regulation and standards ➢ Public goods, e.g. environmental quality ➢ Industrial development ➢ Policy development

The drivers described above intersect to a degree. Firms can benefit from human resources trained at universities. They can also benefit from the orderly establishment of government regulations and standards that define a clear framework for operations. All parties can benefit from research made available as public goods, since new knowledge allows the development of derivative technologies.

2.4 TRENDS IN RESEARCH AND DEVELOPMENT SPENDING IN CANADA

R & D spending in Canada amounted to $13.8 billion in 1997, representing 1.56% of GDP. The contributions by performing sector are shown in the pie chart.

R&D By Performing Sector, 1997



R & D spending by Canadian industry is low when compared to G7 countries. It has, however, increased by a factor of four over the last twenty-five years[1]. Over the same period, university research expenditures increased by less than 50% while those of provincial governments and the federal government remained more or less constant. While industry is increasing its R&D efforts, a small number of firms are responsible for most of R&D expenditures in Canada. These firms are mainly in the Information and Communications Technologies (ICT), aerospace and pharmaceuticals.

2.5 INDUSTRIAL EXPENDITURES

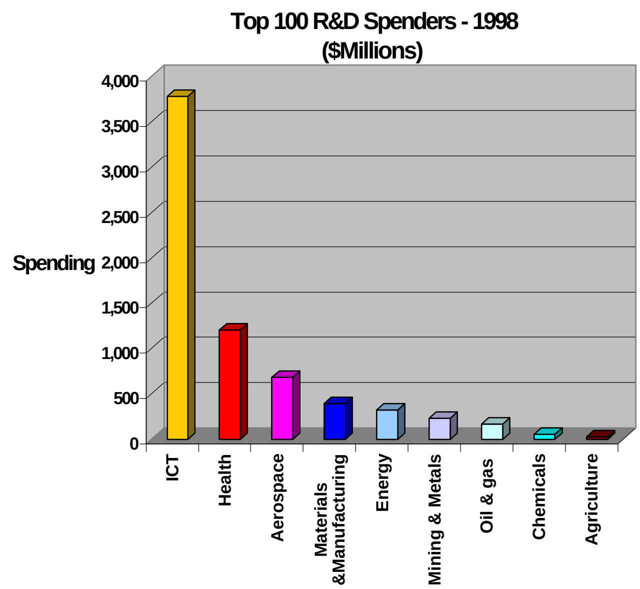
Industrial research and development expenditures in Canada represented 0.99% of GDP in 1997 – approximately $8.65 billion.

Expenditures by sector for the top 100 industrial spenders are shown in the bar chart[2]. R & D spending on information and communications technologies (ICT) is, by far, the greatest. In 1998, a single firm – Nortel – spent $1.9 billion accounting for 28% of this expenditure. Even when Nortel is taken out of the picture, research spending on ICT exceeds that in health.

[1] Data in constant 1992 dollars. Source: "University Research and the Commercialization of Intellectual Property" authors W. Gu and L. Whewell, a report prepared for the Expert Panel on the Commercialization of University Research of the Advisory Council on Science and Technology.

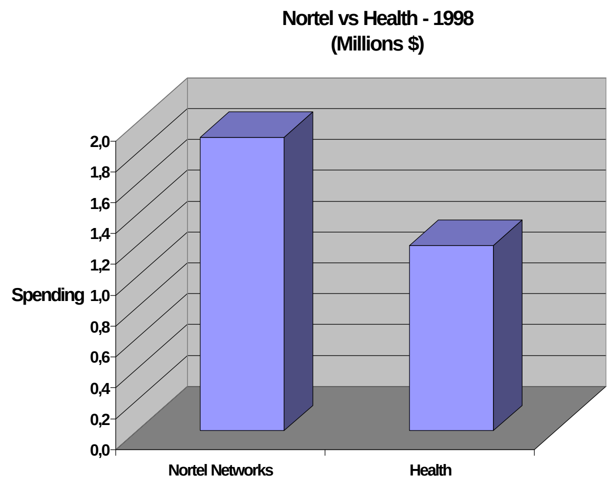
[2] Source: Evert Communications Limited, http://www.evert.com/top99sam.htm

Industrial expenditures on R & D in health are spent mainly on the conduct of clinical trials. Clinical R & D also includes "seeding" which encourages physicians to participate in aspects of clinical development so that they become used to working with a given manufacturer's drug. The "patented" pharmaceutical industry spends 11.5% of revenues on R & D.[3]



For comparison, R & D expenditures in Canada by Nortel alone exceed those of all the major pharmaceutical companies combined.

Aerospace is the third sector in importance among the top 100 industrial R&D spenders. Pratt and Whitney Canada is responsible for 60% of the expenditures.



In light of these industrial R & D patterns, PAGSE selected the following industry sectors for special focus:

- ICT
- Pharmaceutical
- Aerospace
- Materials and advanced manufacturing
- Chemicals
- Agriculture
- Environment

[3] Patented Medicine Prices Review Board, Annual Report 1998.

2.6 SUPPORT FOR INFRASTRUCTURE

During the early to mid-1990s, university funding was reduced as part of the government's deficit fighting strategy. Major investments in renewing university infrastructure were not made. In order to redress the problem, the federal government created the Canada Foundation for Innovation (CFI) in March 1997. The main objective of the Foundation is to strengthen the country's research infrastructure.

CFI received $800 million to invest in Canadian universities, hospitals and colleges. The Foundation granted $58 million in 1998 and is expected to award $420 million in 1999. In 1998, about 45% of the grants were awarded to the health sector.[4]

The 1999 federal Budget provided CFI with an additional $200 million. CFI is again expected to invest half of this amount in health.[5]

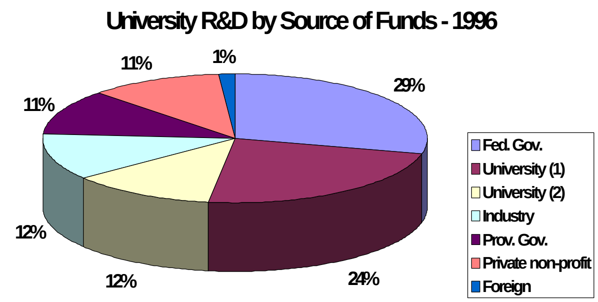
CFI co-funds the projects with other partners including the private, public and not-for-profit sectors. The Foundation usually covers 40% of the eligible costs.[6] CFI has provided a very important boost to research in universities. Infrastructure expenditures have to be made very carefully so that the capacity to provide overhead to support new initiatives is sustained.

2.7 UNIVERSITY RESEARCH GRANTS

University research amounted to $2.9 billion in 1997. This was equal to 21% of all research in Canada. In the US, the academic sector accounted for only 14% of the total. The sources of university funding are shown in the pie chart.

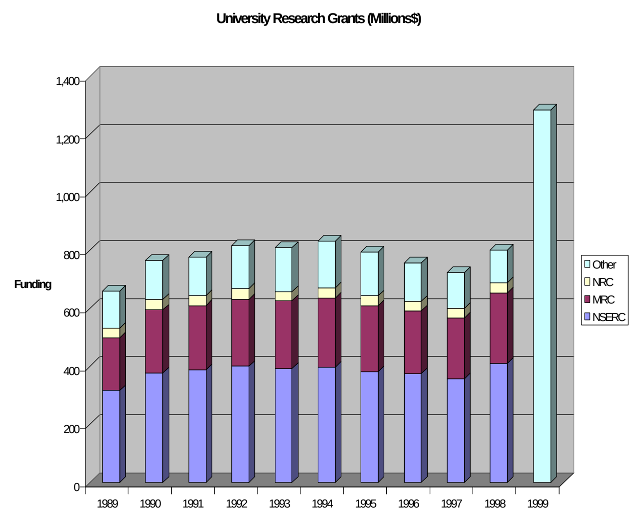
[4] 1999 Federal budget.
[5] CFI received five additional years of support in the 2000 Federal budget at a total level of $900 million. Part of the funds will provide infrastructure to support the new Canada Research Chair program. In addition, $100 million of the new allocation will be dedicated to an international joint venture fund.
[6] Canada Business Service Centres: www.cbsc.org

University research expenditures by sources of funds shown in the pie chart include research grants and the associated overhead required to support research programs. The overhead is probably in the order of half of the total amount. The contribution from provincial governments of 11% mostly supports overhead costs. Direct federal government support is in the form of research grants. University (1) represents government transfers while (2) represents other university funding.



The industrial contribution to university research at 12% is higher than the equivalent contributions in other G7 countries, which range from 2% (Japan) to 8% (Germany).

Direct federal support of university research comes mainly in the form of university research grants. These actually declined in the mid-1990's[7]. They were largely restored in 1999. Important new monies were provided to the Granting Councils and, in particular, to CFI. The precise amount that will be spent in the fiscal year 1999-2000 is uncertain because the CFI has the right to adjust the timing of its expenditures. The total amount could easily reach $1.2 billion.[8]



As indicated above, care must be taken in comparing university research grants with the total R & D expenditures of universities. Canadian grants cover only research supplies, equipment, together with post-graduate and post-doctoral researcher stipends. They do not cover the salaries of the principal researchers or university overhead. Total R & D expenditures include all costs. By comparison, most research grants awarded in the US provide for contributions to university overhead.

[7] Statistics Canada
[8] 1999 Federal Budget

The increase in contributions to university research by the federal government was warmly welcomed by the academic community, but are likely to stress the system. CFI grants require matching contributions in the order of 60% that are typically obtained from provincial resources. In addition, CFI funds and increases in grants from the MRC and NSERC make no provision for the overhead that universities must incur to support new research. Increased overhead needs could amount to as much as half a billion dollars over the next three to five years, depending upon the way that CFI investments are structured. This is a pressing issue that could undermine the benefits of the CFI capital program.

2.8 CREATION OF CANADIAN INSTITUTES OF HEALTH RESEARCH

In 1998, a task force of leaders in health research analyzed approaches to strengthen health research in Canada. They studied various issues including, for example:

- Connecting health researchers from all fields ;
- Encouraging collaboration between federal and provincial governments, universities, private sector and voluntary organizations; and
- Focusing resources on high priority health areas.

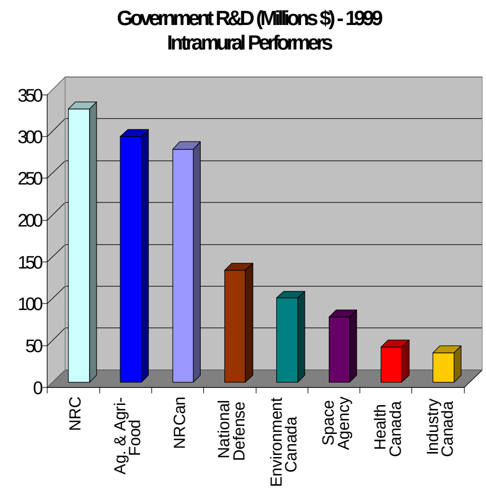
The task force recommended that the federal government create the Canadian Institutes of Health Research (CIHR). The new organization would integrate the operations of the Medical Research Council in 2000. The federal government welcomed this recommendation.

CIHR will act as a central agency that will bring together researchers by building networks. It will be composed of 10 – 15 health institutes. Each institute will specialize in a particular area, for example, cancer. In the 1999 federal Budget, the government provided $65 million for 2000-01 to support CIHR in its first operational year. This budget may increase to $175 million in the following year[9].

[9] Source: www.cihr.org/whatsnew

2.9 FEDERAL IN-HOUSE SPENDING

Federal government intramural R & D expenditures are illustrated in the bar chart[10]. The National Research Council, Agriculture and Agri-food Canada and Natural Resources Canada are the major players.



Research related to improving or sustaining the environment is an important activity for several government departments. Environment Canada, Agriculture and Agri-food Canada, Natural Resources Canada and the National Research Council are major participants. The Space Agency[11] plays a minor role.

Of the major departments involved in R & D, Health Canada has a surprisingly low budget given its responsibilities in regulating the production and use of pharmaceutical products, vaccines, blood products, and foods.

Most of Industry Canada's intramural R&D is carried out by the Communications Research Centre.

[10] Source: Statistics Canada
[11] The Space Agency contributes through its earth observation program based largely on the use of RADARSAT.

3 RESEARCH PRIORITIES AT UNIVERSITIES

3.1 CONTEXT

In general, the fruits of university research have been:

- New knowledge that is placed in the public domain; and
- A stream of highly qualified human resources.

The general assumption has been that the private sector will not produce sufficient of these "public" goods for economic growth.[12] Accordingly, universities as training and research institutions have generally been supported by public funds.

The distribution of funds for public research follows two basic models:

- The institute system; and
- The peer review approach.

The institute system is more common in Europe. In this model, funds are provided to support the activities of an entire institute that is often associated with a university. Researchers receive some or all of their funding from the institute. The system is more efficient in that researchers do not consume large amounts of effort in raising funding. The disadvantage is that institutes are often hierarchical. As a consequence, research is often directed by senior management, thereby reducing the flow of new ideas.

In North America, most university research is funded through the peer review system. The institute model is found, however, in agencies of the federal government.

The peer review system is very costly in terms of researcher effort. In the US, for example, a researcher may spend as much as 300 hours per year in developing grant applications. The system probably favours greater latitude in the development of new ideas. Even in a peer review system, however, researchers still have to "sell" ideas to colleagues and to adapt research to fit the expectations of important funding sources. In addition, the system has a

[12] Material for this section has been drawn from: "The Economics of Science", P. E. Stephan, Journal of Economic Literature, Vol. 34, page 1199 (1996).

built-in inertia, which tends to favour scientists that have been successful in the past.

The ideal of the scientist that is completely free to explore his or her ideas in the pursuit of pure knowledge is not readily attainable in the current system when the costs of the research involved are relatively high. Competition between researchers is also unlikely to go away. No objective measures are readily available as to how much research should be done at the public expense. The system, therefore, functions under a tension between the demands of scientists, which are only constrained by placing a limit of the availability of public funds.

Metrics are important to the success of the scientist in this competitive field. They include, for example:

- Numbers of publications; and
- Citations and awards.

The scientist must also be first to publish, since no rewards are available for those who place second or third. This leads to a focus on research niches. It sometimes engenders fierce competition and, occasionally, involves tacit agreements between researchers in the same field to avoid encroachments on each others' area.

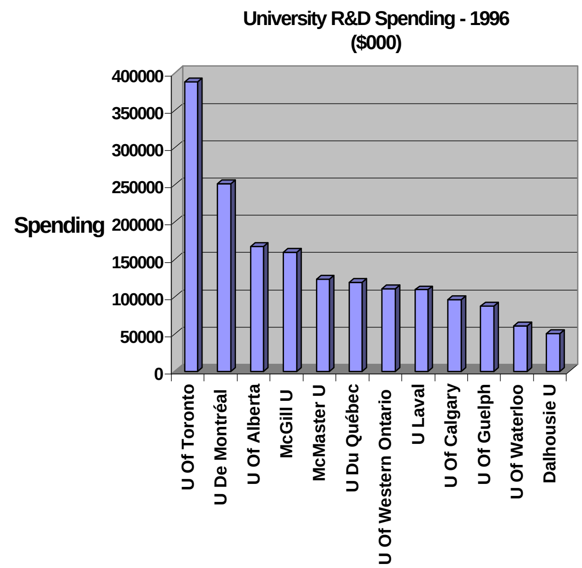
Recently, universities have been increasingly preoccupied with capturing private benefits from research. These are typically acquired through holding equity in spin-off companies, or by striking licensing agreements with firms. Two issues immediately arise and have not yet been settled:

- Are private goods more beneficial to the economy than public goods? and
- Should professors seek commercial benefit from publicly funded research?

These issues have also emerged in government departments and agencies. Despite increasing efforts to derive commercial benefit from university research, this report focuses on the main role of universities – delivering public goods.

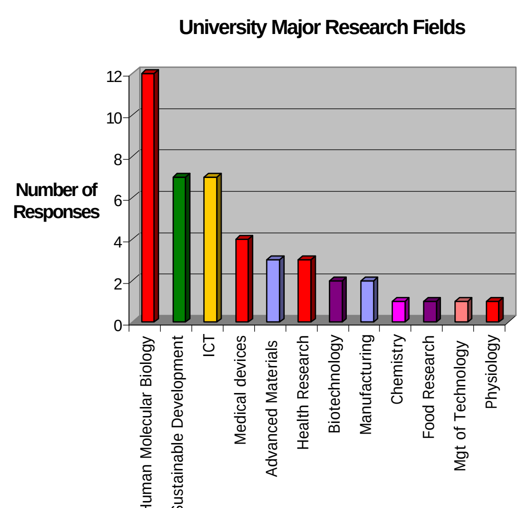
3.2 SURVEY OF LEADING UNIVERSITY PLAYERS

One of the most important objectives of this study was to obtain a representative sample of research priorities at leading universities. This was achieved by sampling major universities whose aggregate research expenditures represented an important fraction of the total. Those that agreed to participate in the study are shown in the chart.[13] In 1996, their research expenditures represented 68% of the total for all Canadian universities. Medical research constitutes a significant portion of the research in those universities with the highest research expenditures.



Research activities are reasonably well-focused in a few major centres. This focus is almost certainly appropriate. The cost of equipment required for modern research is high. In addition, critical masses of human resources are required to fully exploit them.

Responses from the universities were quite varied. Some universities identified more priority areas than others. Two suggested that the top priority was to restore funding levels so that research activities could be properly supported and staffed. In some cases, a single person responded to the survey on behalf of the university. In others, a number of respondents participated, each contributing information on his or her field.

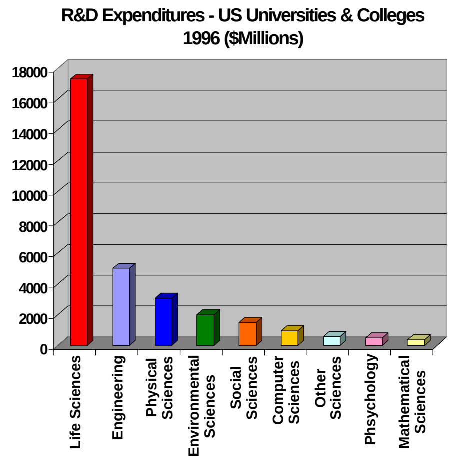


[13] Source: CAUBO, Financial Statistics of Universities and Colleges, 1996-1997, Report 3.1

3.3 MAJOR RESEARCH FIELDS

Universities were asked to identify as many as 10 of their top strategic research priorities. Responses covered a wide range of fields. Human molecular biology, sustainable development, health, as well as information and communications technology, were the dominant fields identified.

The strong focus on human molecular biology is, to a degree, understandable, given the enormous flux of new knowledge that is emerging in the field. For the first time in history, science may be able to unravel the molecular basis for many diseases. Individuals with a thirst for discovery will undoubtedly be drawn to this area whether or not practical benefits are immediately evident or attainable. The fit with economic priorities may be less of a concern for the individual researcher.



Arguably, molecular biology and life sciences in general require more publicly funded research because a substantial body of knowledge has to be developed before commercial benefits can be captured.

The data for US universities are shown in the chart[14]. If anything, US universities, and colleges have a greater focus on life sciences than their Canadian counterparts.

3.4 RESEARCH SUB-FIELDS

For each of the major research fields defined above, universities identified sub-fields, which more pointedly defined the research priority.

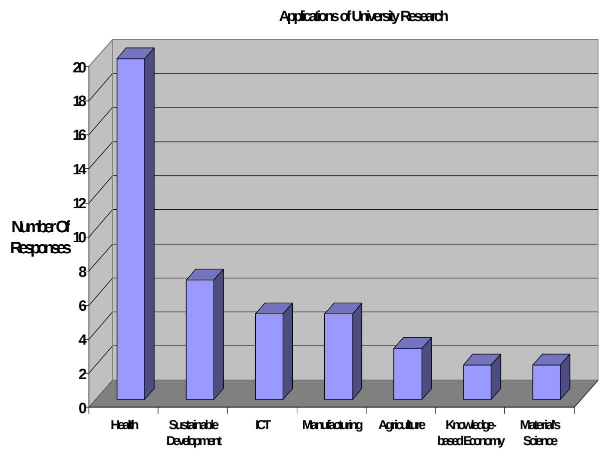
The range of research sub-fields was extremely diverse. Universities are conducting research in highly specialized areas. In the health area, however, research is focused on human genomics, proteomics and bioinformatics, i.e. on understanding the molecular basis of biology.

[14] Source: statistical Abstract of the United States: 1998, U.S. Census Bureau, the Official Statistics, http://www.census.gov/prod/3/98pubs/98statab/sasec20.pdf

Research sub-fields associated with ICT were oriented towards electrical engineering and computer science. The "other" category included a large number of sub-fields. This category accounts for over 50% of the responses.

The results indicate that university research priorities are not highly focused in specific fields.

3.5 FIELDS OF APPLICATION OF UNIVERSITY RESEARCH



Universities were asked to identify the major sectors of application for the research fields described as being major priorities.

Again, health was the main area of application. Within health, the overwhelming majority of applications were oriented towards the pharmaceutical sector. The pharmaceutical orientation is due to the fact that a great deal of research in human molecular biology is oriented towards understanding mechanisms of disease and their treatment through the development of new drugs. The pharmaceutical sector, however, represents 0.5% of GDP. On the other hand, ICT, a sector that represents 4.5% of GDP, received far fewer responses.

University research priorities and their fields of application are not aligned with the distribution of economic activities. For example, health as a whole represents 7.5% of GDP, but this includes all forms of medical treatment and care. Research activities associated with health as it factors into the economy would include, for example:

- Improving treatment outcomes by determining, for example, best hospital and surgical practices;
- Optimization of service delivery;
- Epidemiology; and
- Pharmacoeconomics.

These and related fields did not emerge in the survey as being priority areas. The result is surprising. Health care in Canada is publicly funded and administered provincially. Consolidated clinical information should be available, at least, on a province by province basis. Such research should be very valuable to the community.

In contrast, privately funded health care organizations in the US have been at pains to manage outcomes in order to reduce costs. Although critics may argue that the objective of cost reduction may have often overridden the optimization of healthcare practices, the US has been able to pursue health research in its broadest sense.

3.6 ADDITIONAL SURVEY FINDINGS

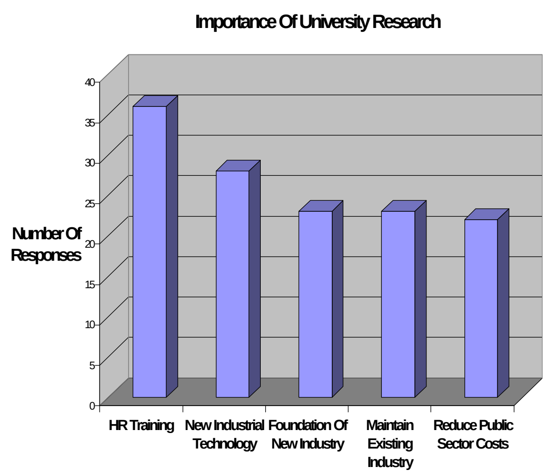
Implementation Time Frame

Respondents identified the time frame for implementing their research priorities. The majority - 64% of respondents - stated that the research priorities would need to be implemented in the short-term (within next two years). None of the respondents identified research priorities beyond a five-year time horizon.

This approach suggests that universities are focused on short-term funding priorities and have not generally developed long-range strategies for setting research priorities.

Importance of University Research

Respondents identified the main areas that will benefit from their research.
A high proportion of respondents selected the training of human resources. Other areas included industrial innovation and reducing public sector costs.



Negative Impacts of Failure To Invest

The universities were asked to identify the impacts of a failure to invest adequately in the research priorities they had identified. Lack of investment in research priorities could have major impacts on Canada's competitiveness. Most respondents stated that the quality of education, training, and knowledge advancement would be most affected adversely. Impacts on industrial innovation and quality of life, while important, were considered to be less significant.

Constraints On R&D Exploitation

Roughly half of the respondents identified industry's lack of investment in R&D as an inhibitor to successful university research exploitation. The finding is not unexpected. University research is heavily focused on activities related to pharmaceuticals, a sector in which Canada is relatively weak. On the other hand, the ICT industry is the lead R&D investor in Canada. While ICT is among the major research fields for universities, the level of effort is not proportional to the industrial commitment. The findings suggest that industrial innovation and university research are not well matched in Canada.

The argument has been made that human molecular biology currently requires a disproportionately high investment in university research in order to build a strong knowledge base. Such a base would then be the foundation for commercial and social development. This rationale could certainly be applied in the US given the strength of its pharmaceutical industry. Making the analogous argument for Canada is more difficult, given our industrial strengths and weaknesses. Setting broad priorities for university R&D is probably the best option.

Investment Required For Impact

Universities were asked to quantify the level of investment that would allow them to successfully accomplish each research priority in order to make a significant impact on the Canadian economy and quality of life. They all stated that their current levels of funding were not sufficient.

Improving Quality of Life

Respondents identified how the quality of life would be improved if the research priorities and goals were achieved. Again, as research in life sciences was a major priority, most respondents suggested that health would be improved as a result of pursuing university research priorities.

University Infrastructure Needs

Universities were asked to identify infrastructure needed to support their research priorities. The question was not formulated to cover all of the infrastructure needs of universities, such as a requirement for new buildings. In addition, the question did not cover projects of national scope such as digital libraries, major telescopes, particle accelerators and observatories. These important projects are typically conceived and supported by consortia involving many universities, provincial and federal governments and, in some instances, the private sector. They represent sustaining elements of national infrastructure that go beyond the needs of individual universities. Examples include the Sudbury Neutrino Observatory and TRIUMF.

In the main, universities did not ask for major facilities to support research priorities. Most respondents requested more space and equipment. Many asked for analytical equipment and spectrometers. The value of the items mentioned was typically from $0.1 million to $2 million. Approximately 40% of respondents asked for advanced computing equipment. A handful of respondents needed animal facilities for health-related experiments.

The collectivity of smaller investments made in a coherent manner would have a multiplier effect in advancing research and innovation. Investments in the range $1 million to $10 million would generally satisfy many space, equipment, or computing needs in priority research areas.

Canada's Relative Position

Respondents were asked to describe the strengths of each research priority, compared to competitor nations.

The general thrust of the university responses suggested that Canadian industry is poorly qualified to participate in the research priorities chosen by the universities. Interestingly, universities considered themselves to be at parity with competitor nations for the chosen research priorities, but never overwhelmingly in the lead.

Summary

The responses obtained from leading R & D universities suggest a mismatch between university efforts and industrial priorities. Many universities are focused on human molecular biology while the pharmaceutical sector in Canada lacks an adequate receptor capacity. This leads to a failure in deriving economic benefit from important research initiatives.

By contrast, much less effort is focused on the ICT sector, which is the major industrial R & D player in Canada.

4 FEDERAL GOVERNMENT R & D PRIORITIES

4.1 CONTEXT

The federal government directly funds about one fifth of the R & D performed in Canada. These expenditures include the financing of R & D undertaken in federal departments and agencies, as well as grants, contracts, and contributions for R & D conducted by industry, universities and private non-profit organizations.

In 1996, the federal government adopted a Science and Technology Strategy (Science and Technology for the New Century). That Strategy set out a set of national goals to which federal S & T resources should be directed:

- Sustainable job creation and economic growth;
- Improved quality of life; and
- Advancement of knowledge.

The federal review of science and technology that took place between 1994 and 1996 concluded that decision-making with respect to S & T priorities would continue to rest with individual Ministers. They have the capacity to direct their department's investment of resources and be accountable for the results. However, to reinforce the governance of S & T at the Ministerial level, the Economic Development Policy Committee of Cabinet was made responsible for formally reviewing the federal performance of S & T, and making recommendations to Cabinet on the government's S & T priorities. Coordination of S & T across the government is carried out by a committee at the level of Assistant Deputy Ministers.

Reduced program spending to reduce the federal deficit resulted in large decreases in expenditures of S & T following 1993 – 94. In recent federal Budgets, selected investments were made in S & T.

At the operating level, departments and agencies involved in S & T have advisory committees that assist in establishing investment priorities. As well, various mechanisms are being used by departments and agencies to identify industry research needs and priorities, as a basis for deciding on where to invest.

4.2 SURVEY APPROACH

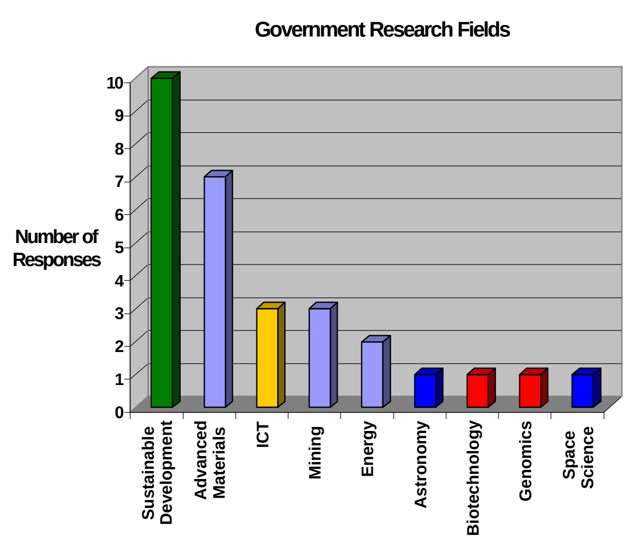
The government departments and agencies heavily involved in in-house R & D were surveyed. Health Canada was the only department that was unable to respond. Like universities, government departments and agencies were asked to identify up to 10 research priorities.

Thirty priority areas were identified. The data were probably skewed, however, by the heavy responses of three departments versus the modest responses of the remainder.

Department / Agency	Number of Priorities
NRC	10
NRCAN	10
Environment Canada	7
Agriculture and Agri-food Canada	1
Canadian Space Agency	1
Communications Research Centre	1

4.3 MAJOR RESEARCH FIELDS

For completeness, the responses of the government departments are recorded in the bar chart below. Readers should appreciate that they have limited statistical significance in light of the way that departments responded.



Despite the skewed sample, PAGSE had the opportunity to study the detailed responses of all the departments. These supported the conclusion that the major fields identified – sustainable development and advanced materials – provide a reasonable representation of the efforts that are high on the government's agenda. Natural Resources Canada intends to play a strong role in sustainable development research by investigating issues such as efficiency of fuel utilization, greenhouse gases, etc. Similarly, Agriculture and Agri-food Canada is interested in sustainable agricultural practices. The interests of Environment Canada in the field are evident and the work is highly focused. NRC plays an important role in sustainable development through its interests in fuel cell technology and environmental redemption. In addition, it is involved in many areas of advanced materials research. The federal government's 2000 Budget included new funding for a Climate Change Action Fund, Environmental and Sustainable Development Indicators, and a Sustainable Development Technology Fund. As well, there was funding for the Canadian Foundation for Climate and Atmospheric Sciences.

4.4 RESEARCH SUB-FIELDS

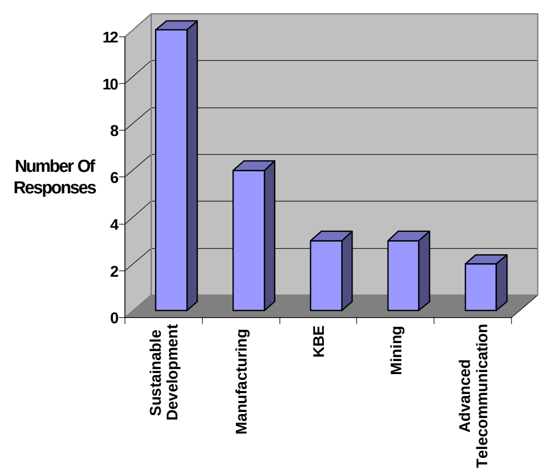
The survey asked respondents to identify the sub-fields associated with each primary research field of interest. As was the case with the universities, the sub-fields were diverse. No clear pattern emerged.

4.5 ADDITIONAL SURVEY FINDINGS

Applications of Government Research

Given previous responses, the fields of application of government research are not surprising. They focus on sustainable development and manufacturing.

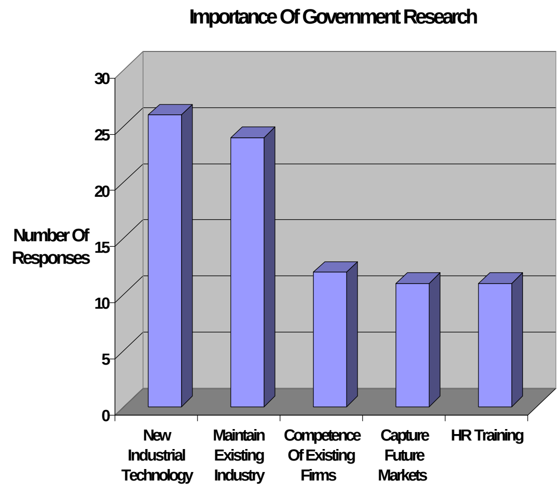
Applications Of Government Research



Implementation Time Frame

While government departments had some urgent priorities, the spread in the implementation time frame was much greater than that for universities. Government departments appear to be more adept in defining strategic research objectives and less pressured to find operating resources in the short term.

Importance of Government Research



When asked about the importance of government research, most respondents cited support for industry as being the main driver. Again, the results are probably biased by the nature of the sample. R & D in support of regulation was, surprisingly, not often cited as being an important activity. In part, this is a reflection of the fact that Health Canada was not in a position to respond to the survey questionnaire. However, research to support the development of regulations is an important role of the federal government, as evidenced by $90 million that was set aside on the 2000 Budget for the regulation of biotechnology.

Constraints on R&D Exploitation

Respondents identified the factors that constrain the exploitation of government R & D. The responses indicated that industrial receptor capacity is an issue. The continued growth of industrial R&D expenditures suggests that government laboratories need to do more than simply transfer technology. Some organizations such as NRC and CRC have, in collaboration with industry, been bringing together R&D capacity, capital, incubator facilities and other essential building blocks that stimulate industrial innovation (e.g. technology clusters in agricultural biotechnology in Saskatoon).

It should be noted that the government directly provides mechanisms to support industrial research through direct contributions and tax credits. In some areas, these may be more effective mechanisms than conducting in-house R&D.

Investment Requirement For Impact

Government research organizations were asked about the extent to which funding would need to be increased for priority projects, so that they would achieve their full impact. Most stated that their current levels of funding were not sufficient. It appeared that the needs expressed by some of the universities surveyed seemed to be more pressing than the needs expressed by some of the government organizations surveyed.

Improving Quality Of Life

Quality of life issues often include the environment, health, and safety. Responses to questions about the way that government research would improve the quality of life cited sustainable development as the main beneficiary, followed by health and education.

Government's Infrastructure Needs

The survey results suggest that government laboratories are somewhat better equipped than universities. Overall, government laboratories expressed a relatively modest need for additional space and equipment. Government research departments, however, emphasized the need for new major infrastructure to a greater extent than universities.

Canada's Relative Position

The extent to which government laboratories are leading, lagging or at parity with foreign rivals was also investigated in the survey. On the whole, departments were of the view that their research in priority areas was either at parity with, or lagged, those of other nations.

Summary

Government laboratories invest fairly heavily in sustainable development and energy-related research when compared to universities. Their space and equipment needs appeared to be less pressing than those of universities. However, they identify needs for major facilities and infrastructure that go beyond their own requirements.

Many of government's research priorities are oriented towards industrial development. Less emphasis is given to research priorities in support of regulation.

5 RESEARCH AND DEVELOPMENT PRIORITIES OF FIRMS

5.1 CONTEXT

Firms have obligations to shareholders to create profits and to build equity.

Firms use R & D in the following ways:

- Short term - to improve products and processes;
- Medium term - to gain competitive advantage from new innovations; and
- Long-term - to achieve strategic reorientation to ensure their viability.

In sectors where the results of R & D are codifiable, patents offer an important means of capturing commercial value from R & D. In the pharmaceutical industry, for example, patents are used extensively. Drugs are protected when their chemical structures are patented. In addition, pharmaceutical firms build fences around their original claims by patenting derivative structures and formulations.

Patents afford protection but also oblige the patentee to disclose the invention for the world to see. In some industries where novel technologies are used for in-house processing e.g. production of plastics, patenting may be avoided so as to keep information out of the public domain. Innovations may be protected as trade secrets.

In many industries, innovations are created through tacit knowledge that is passed between workers through training. The software-engineering sector is one in which tacit skills play an important role. Training and retaining a cadre of “high-tech” artisans is an essential part of being successful in business. In the telecommunications industry, for example, many acquisitions are motivated by the need to capture qualified human resources in a specific field of technology.

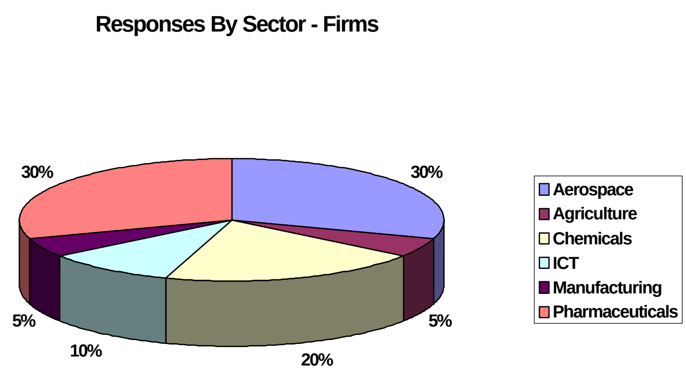
Firms do not engage in R & D under the same set of drivers as government and universities. Firms are not pressured to publish or to create knowledge as a public good. The absence of pressure to codify and publish knowledge in some sectors also allows firms to concentrate efforts on enhancing tacit skills in the workplace, and on developing trade secrets, when appropriate.

In contrast, universities develop tacit skills, particularly in graduate students. The relationship, however, is in the form of a short-term association.

5.2 SURVEY APPROACH

A careful analysis was carried out of leading firms in the seven industry sectors. The firms were investigated so as to identify those that are actively engaged in important research programs. Over 50 firms were sent the study questionnaire.

Responses were received from 40% of the firms or their subsidiaries. The breakdown of responses by sector is given in the pie chart.



5.3 GENERAL FINDINGS

Given the sample size and the sector diversity of firms, descriptions of main research fields and sub-fields cannot be aggregated in a meaningful way.

Most firms were able to define R & D activities on three time-scales. They defined those that are:

- Critical to solving current problems;
- Required for the introduction of new innovations that will maintain competitiveness; and
- Essential for providing the firm with long-range strategic options.

One exception was the pharmaceutical sector, where firms have a high degree of consensus on “next generation” technologies:

- Genomics;
- Bioinformatics;
- Combinatorial chemistry;
- High throughput screening; and
- Proteomics

5.4 AN IMPORTANT SHARED NEED

Although the remaining firms were involved in a wide variety of activities they shared, to a remarkable extent, a common focus on using advanced computer techniques for simulation and modeling. Almost universally, firms see great benefit in using high performance computing as a means of increasing R & D efficiency and reducing costs. Their ideal is, as far as is practical, to replace the physical experiment with calculation.

5.5 UNIVERSITY RESEARCH PRIORITIES

Firms were asked to specify their expectations of university research.

On the whole, firms are not interested in having universities work on research problems of immediate concern to them. They want universities to conduct long-range research aimed at developing generic technologies and new methods. For example, firms want universities to develop new approaches and methods in: high throughput screening, numerical modeling, the design of wireless networks, polymer technology, sensors etc.

Although firms were able to identify their needs of university research in a broad manner, they have little influence on the overall research agenda. Some participate by funding professorial chairs or by providing stipends to individual researchers. The Networks of Centres of Excellence provide a mechanism for companies to collaborate as partners in setting a Network's research agenda.

However, even modest industrial involvement is coming under increasing fire from the academic community. It regularly cites the statistic that Canadian firms provide roughly 11% of university research funds – an amount that is greater than the equivalent funding in other countries. The contribution is seen by some as being an intrusive means of influencing university research.

The approach actually used by firms is one of "cherry picking" opportunities. Industry does not have a significant voice that influences macro level decisions on university research, e.g. in the proportion of public funds that go to physical versus biological sciences.

5.6 TECHNOLOGIES THAT WILL TRANSFORM INDUSTRY SECTORS

Firms were asked to identify the new technologies that would assist in transforming their entire industry sector so as to make it more competitive. They were again fairly consistent in their replies. They identified:

- Advanced manufacturing technologies;
- Advanced materials;
- Surface science and catalysis;
- Process control including numerical simulation and sensor technology, and
- Advanced information and communications technologies.

Firms in the pharmaceutical sector generally identified technologies related to genomics, the use of robotics in combinatorial chemistry, and high throughput screening.

Firms called for university research funding to be increased in all of the areas described above. Although the sample size in this study was small, the results suggest that firms from a variety of sectors coalesce in their definition of priority research areas. Universities could play a very important role in support of industry by conducting long-range research in these areas to improve:

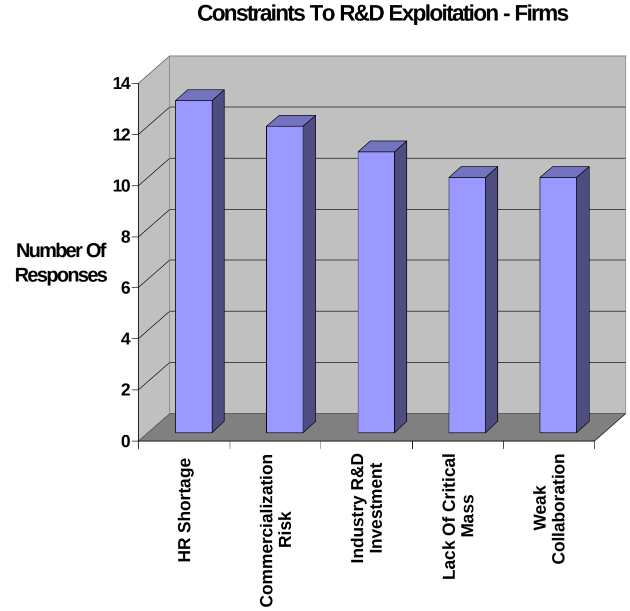
- The knowledge base – public R & D goods;
- The supply of qualified people; and
- The generic technologies on which firms could build innovations.

5.7 RESEARCH INFRASTRUCTURE

Overall, firms did not call for major pieces of infrastructure to be developed that would:

- Support university research and training needs; as well as
- Serve their own needs or those of their industry sector.

Among the few needs identified were an environmental test facility and a pilot plant for the production of advanced materials.



One or two small firms expressed a desire to have access to pieces of university analytical equipment such as NMR or mass spectrometers that typically cost $0.5 million to $1.5 million.

5.8 CONSTRAINTS TO R & D EXPLOITATION

Firms were asked to identify constraints to R & D exploitation that affect their entire industry sector. The five leading responses are shown in the chart. Firms cited human resource shortages as the main constraint to commercialization – an area where the universities have a critical role to play. Weak collaboration between firms and research institutions was fifth in the ranking of constraints.

5.9 NEGATIVE IMPACTS OF FAILURE TO INVEST

Firms were requested to identify the negative impacts that would accrue if firms in their sector failed to invest in strategic R & D priorities. The impacts were deemed to fall most heavily on knowledge advancement and innovation, followed by education and training.

5.10 CANADA'S RELATIVE POSITION

Finally, firms were asked to describe Canada's relative position for the performance of their industry sectors on a number of variables. The receptor and innovation capacities of firms were deemed to be weak, while scientific and technological capacities were considered to be up to international standards.

6 TECHNOLOGY FORESIGHT ACTIVITIES

6.1 ABOUT TECHNOLOGY FORESIGHT

Technology foresight activities are generally considered to be an essential part of setting research priorities. However, such activities are weak in Canada. Accordingly, PAGSE reviewed the level of foresight activities in other countries and compared them with the Canadian situation.

Technology foresight is "a systematic means for assessing scientific and technological development which could have a strong impact on industrial competitiveness, wealth creation and quality of life"[15].

Technology foresight activities help to establish a common vision for socioeconomic development and growth. From time to time major investments are made on the basis of foresight activities, even though benefits may not be clearly discerned at the outset. Examples include, space exploration and the potential human genome project. In general, however, most foresight activities focus on areas where the potential commercial benefits of a given technology are evident.

Technology road maps are a key component of technology foresight activities. They are usually developed as collaborative initiatives between industry, universities/colleges and government.

Technology road maps have important functions. They:

- Help large companies to plan for future investments in R&D and technology;
- Provide SMEs that are in supplier chains with a preview of the capabilities they will require to stay competitive;
- Provide a basis for inter-company collaboration to develop the needed technologies, thereby reducing costs and risk;
- Communicate research priorities to universities and government; and
- Reduce the probability that industry will be blindsided by changes in the competitive environment resulting from technological shifts.

[15] OECD, Technology Foresight and Sustainable Development Proceedings of the Budapest Workshop, December 1998

6.2 TECHNOLOGY FORESIGHT MODELS

Two methods have been widely used:

- The Delphi model; and
- The critical technologies model.

Delphi Model

The Delphi model involves an iterative process. Its objective is to project technological developments over a time horizon of up to 20 years.

Experts are asked to respond to a detailed questionnaire on scientific and technological developments in two or more rounds of surveys. At the end of every survey round, a summary of the findings is distributed to the experts. Based on the aggregate responses, experts are asked to re-assess their answers. They assess developments against set criteria, including their contribution to the country's economy and quality of life. They also determine the relative positions of different countries with respect to the technological developments.

Delphi surveys have been mainly used in Japan, Germany, France and the United Kingdom.

Critical Technologies Model

This model simply involves the creation and analysis of a group of technologies considered to be important to the future competitiveness of a nation over a 10-year horizon. The model was used recently in the United States, Germany, and France.

Irrespective of the methodology used, countries seem to share a common ground with respect to the main technologies being targeted. They focus on high-tech industries (life sciences, ICT, advanced materials etc). However, the specific research priorities and strategies vary from country to country.

6.3 INTERNATIONAL EFFORTS

Many countries appreciate the importance of setting research priorities for their future competitiveness. They invest accordingly. Leaders include, for example, Japan, Germany, the United Kingdom, and the United States.

Japan

Japan has the longest history in technology foresight. The National Institute of Science and Technology Policy (NISTEP) has been conducting Delphi surveys every five years since 1971. NISTEP conducted a survey in 1991 to assess the reliability of its first Delphi analysis (1971). Approximately, two-thirds of the predictions were realized, indicating the reliability of the Delphi technique. The fifth Delphi study (1991) was used by Germany and France as a model.

The most recent Delphi survey was conducted in 1996. It covered the period 1996 – 2025.[16]. The survey studied Japan's competitive position compared to the US and Europe. It showed that the US is in the lead in most areas, especially in life sciences, health and information technologies.

Germany

Germany has conducted two Delphi surveys and another mini-Delphi survey in collaboration with Japan. The first Delphi survey was conducted in 1992 and the second in 1998. The first was modeled on the Japanese Fifth Delphi. Germany made small changes when topics did not fit well with the German context.

The responses to the German and Japanese surveys were similar, with a few variations due mainly to cultural differences. The following table summarizes those variations[17].

[16] Environment in Technology Foresight, Science and technology policy division, directorate for science, Technology and Industry, OECD

[17] http://www.astec.gov.au/astec/future/intepers/section1.html

Aspect	Japan	Germany
Time frame for research priority	Focus on long-term priorities	Focus on short to medium-term priorities
Application of new technologies, in particular information technology	More favorable	Less favorable
Important technological areas	• High priority given to: Cancer, computer technology, health care robots, decision-making processes of the human brain and nuclear power.	• High priority to: energy and environment • Low priority to healthcare robots, decision-making processes of the human brain and nuclear power.

Germany conducted a critical technology study along with the first Delphi survey. The objective of this study was "to identify technological trends and their possible commercial application in the time horizon of ten years".[18]

United Kingdom

The Office of Science and Technology launched its Foresight Programme in 1993. The program was implemented in three stages:

- Pre foresight (1993) – a steering committee was formed and details of program were outlined.
- Main Foresight (1994 –1995) – 15 sector panels were formed. Each panel consisted of 15-20 people. Every panel thoroughly examined its respective sector.
- Post foresight (1995 onwards) – results were analyzed and integrated into government decisions on research priorities, funding etc.[19]

United States

The US National Critical Technologies Panel has been active in setting research priorities since 1991. Studies are conducted every two years.

The 1995 critical technologies study, for example, covered seven main fields and 27 sub-fields. The table on the following page illustrates the competitive positioning of the United States compared to Japan and Europe. [20]

[18] Environment in Technology Foresight, Science and technology policy division, directorate for science, Technology and Industry, OECD
[19]Foresight for SMEs: implications for Policy and Practice http://imru.bham.ac.uk
[20] http://www.whitehouse.gov/WH/EOP/OSTP/CTIformatted/execsum/execsum.html

The study demonstrates that the United States mostly leads other competing countries. However, this lead was declining in areas such as communications and computer systems.

National Critical Technologies
Technology Position and 1990-1994 Trend

US Technology Position Relative to:
Japan ▷, ○, or ◁
Europe ▶, ●, or ◀

1990–94 Trend
Improved ▷
Declined ◁
Maintained ○

	Lag: Substantial	Lag: Slight	Parity	Lead: Slight	Lead: Substantial
Energy					
Energy Efficiency			▶	○	
Storage, Conditioning, Distribution, and Transmission			●	○	
Improved Generation			●	○	
Environmental Quality					
Monitoring and Assessment				◁ ◀	
Pollution Control			○ ●		
Remediation and Restoration			◀	◁	
Information and Communication					
Components			▷	●	
Communications				●	◁
Computing Systems				●	◁
Information Management					▷
Intelligent Complex Adaptive Systems*			○	◀	
Sensors			▷ ▶		
Software and Toolkits				●	▷
Living Systems					
Biotechnology				○ ▶	
Medical Technologies				▷ ●	
Agriculture and Food Technologies				◁ ▶	
Human Systems				▶	▷
Manufacturing					
Discrete Product Manufacturing				○ ●	
Continuous Materials Processing*			○ ●		
Micro/Nanofabrication and Machining			▷	●	
Materials					
Materials				◁ ●	
Structures				●	◁
Transportation					
Aerodynamics				●	◁
Avionics & Controls				◀	◁
Propulsion & Power				◁ ●	
Systems Integration				●	○
Human Interface*					▷ ▶

*based on limited information

In 1998, the RAND Corporation published a study "New Forces at Work: Industry Views Critical Technologies". This work was carried out for the Science and Technology Policy Institute in Washington (formerly the Critical

Technologies Institute, created by Congress in 1991). This major study obtained, from industry, the technologies that leading companies consider critical to their own competitiveness and that of their sector. It also assessed U.S. efforts in relation to those in other countries and considered the respective roles of industry, universities and governments in contributing to, and sustaining, the U.S. technology base.

A key finding of the report is that many important technologies did not show up on previous critical technology lists because they are systems and know-how, or they exist at the intersection of various technologies.

6.4 CANADIAN EFFORTS

For each of the industry sectors studied, PAGSE reviewed the literature to identify those that have been the subject of technology road maps or similar initiatives. Although industry technology road maps have become commonplace in the United States, few are to be found in Canada.

Four were identified that are related to the industry sectors covered by the present study:

- Canadian Aircraft Design, Manufacturing and Repair and Overhaul;
- Forest Operations In Canada;
- Wood-Based Panel Products; and
- Geomatics and Virtual Technologies.

Industry Canada is constructing another three technology road maps. They cover:

- Electrical Power;
- Medical Imaging; and
- Metal Casting.

The Aircraft Design technology roadmap is probably the most extensive of its kind in Canada. It was co-sponsored by the Ontario Aerospace Council and was led by Ontario aerospace companies in partnership with Industry Canada, the National Research Council and the Department of National Defence.

In the microelectronics sector, the Micronet Network of Centres of Excellence has identified the medium and longer-term industrial technologies needed in Canada, as well as the pre-competitive research themes to meet those needs. In developing its Strategic Plan for Manufacturing Technologies that will guide the work of its Manufacturing Technology Group, the National Research Council engaged in technological forecasting for innovative materials, advanced processes, and modeling and simulation.

By and large, industry associations in Canada have not engaged in setting research and technology priorities, even when the sector they represent is science and technology based. By way of example, the Canadian Agri-Food Research Council (CARC) has a mandate to coordinate and act as a catalyst for research prioritization in Canada. Its paper on Canada's National Strategy for Agri-Food Research and Technology Transfer (1997-2002) does not contain research priorities.

6.5 CONCLUSION

Countries such as Japan, US, Germany and the UK lead in technology foresight initiatives. All of these countries have well-organized teams focussed on these initiatives. The level of interest in futures research seems to be high. All stakeholders (industry, government and academia) are heavily involved in the process.

On the other hand, Canada's initiatives are modest compared to those of other western industrialized nations. To date, only a few sectors have complete technology road maps. Canada is behind other countries with respect to technology foresight and is now attempting to catch up. Unlike other countries, Canada's efforts have been at the industrial sector level. Little effort has yet been made to create a national strategy by integrating the results from sectoral road maps.

7 CONCLUSIONS

7.1 ISSUES OF INTEREST TO PAGSE

PAGSE is interested in six important questions related to research priorities in Canada:

- Do the major research players share a sufficient common purpose to establish research priorities?
- Do mechanisms exist to allow them to define priorities and act upon them?
- What are the strategic technology priorities of Canada, based upon inputs from academia and industry?
- How do these priority areas fit with the current level of funding invested in them within the university system?
- What gaps exist in current and planned university research and training, in the priority areas identified by industry? and
- What specific priorities for increased public sector investments in the university system will address these gaps and remove barriers to innovation?

The results of this investigation reveal that these questions anticipate a much higher level of research priority setting in Canada than actually exists. Most organizations are skilled at determining their internal priorities. However, with only a few exceptions, most are simply not interested in the broader dimension of how priorities ought to be established nationally. This message came through clearly from the information collected. Moreover, Canada's capacity to define strategic research priorities or even to discuss the subject based on concrete information is very limited.

7.2 THE EXTENT OF COMMON PURPOSE

With some exceptions, the three major players in Canadian R & D do not share a common purpose in defining research priorities. They have quite different motivations.

- Firms want to maximize shareholder value. They also want to ensure long term survival by carefully plotting and executing R & D strategies.

- Universities build prestige often by focusing on key areas of technology and by building constellations of research stars around them. Once established, grants and students gravitate towards the constellation. Individual stars need to publish first, be cited extensively and be respected by peers.

- Government departments have research mandates relating the public good. They support regulation, standards and best practices. Some departments have mandates to support industry.

The drivers described above suggest that the strategies of the major players will not necessarily gravitate towards synergy except in the cases where:

- Government departments/agencies have mandates to provide industrial support;
- Government is developing regulations and standards in new fields of technology being practiced by Canadian firms; or
- Special mechanisms are put in place, such as the Networks of Centres of Excellence Program.

7.3 MECHANISMS TO DEFINE PRIORITIES AND TO ACT UPON THEM

Mechanisms that would prompt the players to work together to define strategic research priorities are:

- Financial – making the research funding of the players interdependent; and
- Social and economic – establishing shared goals.

Some financial interdependence already exists. For example, Agriculture and Agri-food Canada has a Matching Investment Initiative. Under this program, private and public sector resources are matched one-for-one to launch collaborative research projects with commercial applications. In 1998-99, 954 such agreements were signed.

Some grant programs for universities involve contributions from firms. The tendency of some academics is, however, to reject this trend on the basis that firms should not have the capacity to limit academic freedom. Firms will generally encourage the pursuit of academic research so long as it has a strategic fit with the areas of technology of interest to them. This is equivalent to defining the general field of research, but leaving the academic with freedom to operate within that field.

In reality, constraints are broadly applied to university research, but in a somewhat arbitrary way. The federal Budget process, de facto, defines the amounts of money going towards university research and the basic split between health, physical and social sciences. Once these decisions are taken, the various Granting Councils have elaborate advisory committee and peer review structures that divide the funds. The basic allocation is, however, defined in a political process.

Extensive lobbying influences that political process. Metrics, such as the number of worthy university researchers in a field who do not receive funding, are used as ammunition but the process is not heavily influenced by analysis of socioeconomic needs. The debate is essentially one between the government and university leaders. It does not heavily engage the public or industry.

Technology foresight activities could be used to bring additional information and perspectives to the debate. These activities can be carried out at two levels:

- Micro-analysis – how are science and technology likely to evolve in a given field;
- Macro-analysis – what broad research activities would fit best with the socioeconomic priorities of the country.

One school of thought would reject this line of thinking out of hand. It believes that science will best advance if creative researchers are given the needed resources and left to their own devices. It overlooks the fact that macro-level decisions are already being made through a political process about the distribution of scientific funding.

Canada has no well-established mechanisms for globally reviewing the fit between publicly funded research activities and socioeconomic needs. The data collected in the present study suggest that setting research priorities in Canada would benefit from a macro-analysis that looked at the fit between publicly funded research, socioeconomic goals and emerging technologies. In the US, for example, such systems are already in operation. Expert advisory bodies research technology foresight issues and report to senior political levels. The body of expert opinion forms a platform on which the political debate can ensue in an informed manner.

1. ***It is recommended that Government establish a foresight panel to identify the emerging technologies required for the country's future socio-economic needs and international competitiveness. Reviewing the directions of publicly funded research should be part of this activity. The panel should inform the political process of priority setting. It should provide recommendations to the Prime Minister's Office (PMO).***

7.4 SETTING STRATEGIC TECHNOLOGY PRIORITIES IN CANADA

The data collected in this study demonstrate a poor fit between the research priorities of universities and those of firms, as evidenced by the sectors in which industry conducts most of its R & D.

Canadian universities place great emphasis on the bio-sciences. The ultimate practical impact of much of this research will be to develop new cures for diseases based on pharmaceutical approaches. However, Canada lacks sufficient private sector receptor capabilities for university research. Universities also identify the generally low level of industry investment in in-house R & D as limiting the applicability of their research. To a degree, this frustrates the efforts of university researchers.

In the US, the disparity between the R & D effort in life sciences and other sciences seems to be even more pronounced. However, the US has a much stronger pharmaceutical and agricultural biotechnology industries than does Canada. Its bet on the future importance of life sciences research may have better odds of achieving commercial success.

Crudely speaking, the Canadian university system emphasizes human molecular biology research while firms are interested in information and telecommunications technologies, advanced materials and advanced manufacturing techniques. Whether the model is right or wrong is actually a secondary issue. The primary concern is that the strategy is ad-hoc. We have not asked the appropriate questions.

One way of dealing with the issues would be to use the proposed expert panel system to review the problem. The panel could investigate whether:

- The public goods produced by taxpayer investment in research should fit with the economic needs of the country;
- Publicly funded research activities should be linked to industrial sector priorities; and
- The appropriate investments are being made in research for social benefit.

In order to function effectively, an advisory panel would need solid inputs from stakeholders and reliable analyses.

Industry Canada has Branches responsible for monitoring and promoting specific industry sectors. These groups could gather and analyze information on strategic priorities. They could be involved much more in technology foresight. At present, the research and technology information available on key sectors is limited. Government could be assisted by industry associations, universities, and by representatives of major firms.

In technology forecasting exercises, Canada should establish benchmarks that take into account the relative size of the economies. Useful countries to benchmark against would be:

- The US – since we mostly follow the US model of R & D and industrial innovation;
- Japan – in the business of technology forecasting for two decades, but less involved in entrepreneurship and radical innovation through R & D;
- The UK – heavily involved in technology foresight activities, but with less of a life sciences bias in its R & D.

2. It is recommended that Industry Canada support the work of the foresight panel by:

- ***Improving its internal capability in technology analysis and foresight;***

- ***Undertaking technology foresight investigations for key industrial sectors using mechanisms that involve universities, firms and government laboratories; and***

- ***Benchmarking Canadian analyses against those of other countries such as the US, Japan and the UK.***

The involvement of government processes in setting research priorities is often criticized as being a process of "picking winners". However, this criticism ignores the fact that government is already heavily involved in such activities. It is "picking winners" through the way that it organizes:

- Programs such as TPC;
- The distribution of funds to Granting Councils; and
- Budget allocations to government departments involved in research.

The recommendations flowing from this study seek to bring more information and insight into a process that is already ongoing.

7.5 POTENTIAL NICHES FOR RESEARCH

Three potential niches that merit expanded research beyond recent government initiatives emerged in this study. They are:

- Research on improving the outcomes of medical treatment and epidemiology;
- Advanced computing and information technologies for modeling and simulation; and
- Sustainable development.

University research is strongly oriented towards life sciences, but the major emphasis is on research that could contribute to the pharmaceutical industry. Insufficient research is being carried out on medical treatment outcomes, epidemiology and best practices even though the delivery of health care constitutes 7% of GDP, notwithstanding the good work of the Health Evidence Application and Linkage Network of Centres of Excellence (Heal *Net*).

With provincial medical insurance, Canada is ideally positioned to "mine" health databases and to investigate practices that would help to optimize service delivery. The financial and social impacts of such work could be huge, since even small improvements translate into large effects.

All of the respondents in this work cited the importance of using advanced computer methods for simulation and modeling, e.g. using the computer to simulate:

- Research experiments;
- The industrial processes; and
- The physical behaviour of prototypes and products.

A greater emphasis on the development of techniques and qualified people would be of considerable advantage to many R & D players. Universities in particular noted that more advanced computing equipment is required to support research efforts.

Finally, government research institutions and universities are heavily involved in research related to sustainable development. If Canada is to contribute important public goods for international consumption, this might be an area where we could excel. Canada is the steward of enormous natural resources in:

- Forestry;
- Oil and gas;
- Minerals; and
- Fresh water.

The experience gained from a national interest perspective in managing these resources effectively could easily be transferred to other nations.

Canadians have strong interests in climate change and the control of atmospheric emissions. Canadians are:

- High per capita users of energy;
- Custodians of fragile ecosystems in the Prairies and the north that could be greatly impacted by even modest changes in temperature;
- Leaders in international protocols aimed at bringing forward global improvements (Montreal - chlorofluorocarbons, Kyoto – greenhouse gas emissions); and

- Pioneers in ecosystem definition and management.

3. ***It is recommended that Government expand the support of research in sustainable development, advanced computer and information technologies for modeling and simulation, and medical treatment outcomes. Work carried out in each of these fields by industry, universities and government should be better coordinated to improve impacts.***

7.6 INFRASTRUCTURE NEEDS

The main infrastructure needs identified in this work were for “suites” of resources to support research projects. These included, for example:

- Additional laboratory space and analytical equipment; and
- Advanced computing equipment.

Respondents noted with some relief that universities have received increased funds for research and major facilities including those of national scope. However, this funding has not been matched by proportional increases in overhead, which has created enormous financial stress. Overall, the results suggest that the Canada Foundation for Innovation might want to allocate resources for both:

- Cohesive projects that aggregate a number of smaller investments; and
- The support of major facilities.

7.7 SUMMARY

The data obtained in this study suggest that setting national research priorities is not a subject that has attracted much attention in Canada. This situation should be reversed. Priority setting should be the subject of informed public debate. Technology foresight activities need to be improved. The extent to which university research should be linked to the country’s socioeconomic needs should be objectively assessed and acted upon.

APPENDIX – SURVEY QUESTIONNAIRES