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THE ROLE OF R&D CONSORTIA

IN TECHNOLOGY DEVELOPMENT

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O C C A S I O N A L P A P E R

THE ROLE OF R&D CONSORTIA IN TECHNOLOGY DEVELOPMENT

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EXECUTIVE SUMMARY

Technology consortia are technology alliances among business firms, universities and governments. They are formed to share increasingly rising costs and risks associated with undertaking basic or precompetitive research and development (R&D). The alliances are both vertical and horizontal and can include both domestic and foreign companies. In most cases, they are found across such high-tech industries as electronics, computer, aerospace and pharmaceutical sectors. Technical alliances have become an important part of the corporate competitive strategies of high-tech industry leaders such as IBM, Hewlett-Packard, Northern Telecom and Texas Instruments. Technology consortia are also found in traditional industries such as the textile and automobile sectors.

This study analyzes the role of R&D consortia in technology development. We have primarily focussed on the growth of technology consortia in the United States, the participation of Canadian companies in those consortia, and the institutional barriers to Canadian membership in American R&D alliances.

In business literature, there is no formal definition of a technology consortium. Various authors have used different definitions in their research. We have adopted the following definition: a consortium is a co-operative research effort among business firms, governments and universities, that helps the participating companies maintain leadership or gain a competitive edge over their international competitors in a particular industry. A technology consortium is a stronger alliance than a trade association, yet more loosely coupled than some other forms of joint ventures. A technology consortium includes direct competitors whereas most other corporate alliances do not. Moreover, an R&D consortium often has lower equity and other inputs from each member than is the case in other alliances.

The literature on technology consortia suggests that the motives for establishing them vary widely. Each member perceives their benefits in a different way. In general, a member company considers

one or more of three strategic objectives when it joins in co-operative research:

- horizontal diversification into new product lines;
- backward and forward vertical integration; and
- leapfrog competition within existing product lines.

Some companies emphasize other advantages of consortia such as minimizing the cost of developing new technologies by reducing unnecessary duplication of research efforts, sharing the risks of undertaking R&D, getting immediate access to new technologies, new markets and cheap production sources, and making otherwise big and complex research projects possible.

Many technology alliances are cross border and established by multinational enterprises that are based in the Triad—the European Community, Japan and the United States. They are mostly observed in core or strategic technologies: information technologies, biotechnology and advanced industrial materials. Japan and the European Community have longer experience with technology alliances while the United States and Canada are new to this form of industrial organization. Japan improved the international competitiveness of its semiconductors by establishing the consortium of semiconductor producers while the European Community improved its computer industry by forming the consortium of computer manufacturers. In the United States, large increases in the growth of technology consortia, mostly horizontal, occurred only after 1984 when Congress implemented the *National Cooperative Research Act* (NCRA). This law allows American firms in the same industry to establish consortia that conduct precompetitive R&D.

The general factors driving the growth of R&D consortia are the globalization of the world economy, technology trends and the greater role of government in shaping a nation's comparative advantage. The global marketplace has now become much more interdependent, and international linkages among countries, or among global firms based in different countries, have increased over the last four decades. Multinational enterprises act as a prime agent of globalization. They organize their operations from manufacturing and sourcing, through marketing and sales, to R&D, on a worldwide scale. By rationalizing their operational activities worldwide, global firms benefit from economies of scale and scope in R&D and production operations. Moreover, the generation of new technologies is much more expensive at the frontier. This is attributable to shorter product life cycles and the fusion of various technologies; thus, a cross-fertilization of several technical and scientific disciplines is required to advance technologies. The increasingly rising cost of undertaking R&D and the need for complementary specialized skills to generate new technologies have encouraged international networking among multinational enterprises, such as cross-border R&D consortia.

Finally, it is generally recognized now in advanced countries that a nation's comparative advantage is determined more by active industrial, and/or technology, policies rather than by factor endowments. Both Japan and the European Community, for example, have used active industrial policies to improve the international competitiveness of their strategic industries such as the semiconductor industry and the commercial aircraft industry. Now, both the United States and Canada are encouraging the formation of technology consortia through their new or expanded technology programs, such as the US Commerce Department's Advanced Technology Program (ATP) and the Strategic Technologies Program (STP) administered by Industry Canada.

After the implementation of the NCRA, technology consortia have increased substantially in the United States. There are now about 350 technology consortia involving about 1,200 American and 50 foreign firms. As indicated above, they predominate in high-tech industries. The Microelectronics and Computer Technology Corporation (MCC), the Semiconductor Research Corporation (SRC) and the Software Productivity Consortium (SPC) are examples of co-operative research ventures that involve companies in similar markets.

To prepare the profile of US R&D consortia we conducted a telephone survey of 15 leading American consortia and interviewed technology policy analysts in Washington, DC. Our findings included:

- Nine out of 10 consortia are initiated by the private sector in the United States; only one out of ten consortia is initiated by the government.
- The primary goal of most consortia appears to be precompetitive research, and the secondary goal is product development.
- Eighty percent of US consortia have less than 100 members.
- The funding for technology consortia is mostly provided by government–industry shared programs; only four in 10 consortia are funded solely by the private sector.

Over the next decade or so, the number of government-funded co-operative R&D projects will grow very rapidly in the United States. Canadian companies are wondering whether they will be allowed to participate in these consortia. This question is very important in the light of our history of close economic relations with the United States and our desire to keep channels open to new technologies from all sources. Canada is concerned with the growth of protectionism in the United States as evidenced by some barriers to technology sharing between Canada and the United States. For example, Canada was surprised that it was not invited to participate in the Super Car consortium even though Canadian and American automobile industries are very closely integrated.

Canadian companies do participate in American R&D consortia although the participation is relatively small. Our sample survey indicated that only one out of 60 consortia members is a Canadian firm. More important, except in particular circumstances, Canadian firms are not allowed to participate in large consortia funded by the US federal government. Canada, for instance, is restricted from participation in co-operative R&D projects supported by the National Institute of Standards and Technology's Advanced Technology Program and the Semiconductor Manufacturing Technology (SEMATECH). If the Collins and Manton restrictive amendments had been accepted by the US Congress and included in the *National Competitiveness Act* 1993, Canadian companies would have been completely barred from participation in federally funded technology consortia. Canada is quite concerned about the development of a protectionist sentiment since federally funded consortia will proliferate under the Clinton Administration, which has planned to increase significantly the number of technology consortia under the two expanded technology programs—the Advanced Technology Program and the Advanced Research Project Agency. Some technology policy experts in Washington DC believe that the doors are almost closed to Canadian companies wanting to participate in these programs. The Clinton Administration has adopted a new technology policy that will encourage co-operative R&D to improve economic performance of American industries and thus their competitiveness in the global marketplace. We expect that the US government will become increasingly more protectionist and that it will ask for reciprocal relations when sharing new technologies with other nations in the future.

In our interviews with consortia and government officials, three more barriers to Canadian participation in American consortia were indicated. First, there is a standoff on an umbrella intellectual property agreement between Canada and the United States. The US government wants to sign a bilateral agreement that sets out general guidelines about sharing the intellectual property results from collaborative research. Second, it appears that Canadian companies are less interested in American consortia because they do very "advanced R&D" which Canadian firms find difficult to translate into products quickly. Canadians are more interested in applied research with quicker commercial results. Third, Canadian companies find that membership fees of American technology consortia are too high. For instance, SEMATECH requires a minimum annual fee of $1 million, and full participation could cost the member as much as $25 million.

In March 1994, Industry Canada consulted with the Canadian research community by holding two workshops, one in Toronto and the other in Montréal. The participants were from Canadian companies, research institutes and universities. At the workshops, the discussions focussed on three broad themes:

- the reasons why the Canadian firms' participation in foreign technology consortia, especially the American ones, is low;
- the barriers, legal or institutional, Canadian companies face in participating in foreign technology consortia; and
- the role the government should play in promoting technology consortia.

Several participants at the workshops indicated that Canadian participation is low only in precompetitive technology consortia. This is mainly attributable to the fact that Canada does not have the culture of doing precompetitive R&D. However, Canadian companies are often small- and medium-sized enterprises that specialize in market niches. They form technology alliances to undertake "near-market" or applied research and market alliances to compete effectively in the global marketplace.

It was generally agreed at the workshops that there are real barriers to Canadian participation in American, European and Japanese technology consortia. Barriers are even stronger in Europe and Japan than in the United States where barriers are not insurmountable. If Canadian companies or American subsidiaries operating in Canada have expertise in some technology and possess strong R&D infrastructure, they can be invited to join in government-funded technology consortia in the United States. For example, Northern Telecom has strong R&D capability and is playing an active role in a number of US consortia. Similarly, Pratt & Whitney Canada possesses expertise in the manufacturing of small aircraft engines and has been invited to participate in technology consortia funded by the US government.

Some participants suggested that Canada does not have specific programs for encouraging technology consortia. Before worrying about Canadian participation in foreign consortia, Canada should first gain experience and credibility in building technology consortia of domestic firms. The few domestic technology consortia we do have are not operating very well. Their focus is on short-term gains and on near-market rather than precompetitive research. Consortia members often cannot decide what technologies should be developed through joint research. Therefore, the Canadian government can play an important role by designing new policy initiatives that will promote joint precompetitive research among domestic firms.

INTRODUCTION

During the 1980s and 1990s, a new type of industrial organization in the form of strategic alliances has been gaining prominence in the global marketplace. These alliances among business firms, which are alternatives to mergers and acquisitions, have appeared for sales, production and core business joint ventures, product swaps, production licences and technology development consortia. The strategic alliances are both horizontal and vertical and can involve both domestic and foreign firms. The partnerships are found across all the leading new industries such as the electronics, pharmaceutical, computer and aerospace sectors. Linkages are observed even in such traditional industries as the automobile and textile sectors. In most cases, they are a vital part of the competitive strategies of some industry leaders such as IBM, Hewlett-Packard, Northern Telecom, and Texas Instruments.

This study analyzes the growth of technology alliances, also called research and development (R&D) or technology consortia. A consortium implies a co-operative research effort among companies, universities, trade associations and/or governments. In most cases, technology consortia are established among companies of major industrialized countries, for example, the United States, the member countries of the European Community and Japan. To some extent, Canadian companies are also actively involved in some foreign R&D consortia, especially US-based ones.

This study focusses on the development of R&D consortia in the United States and the extent and the nature of participation by Canadian companies in those consortia. We examine the barriers, legal or institutional, that Canadian companies face in increasing their participation in US technology consortia, particularly in those financially assisted by the US government. Based on a sample survey of leading American R&D consortia, we have developed their profile and the role the government plays in supporting them. And we look at the extent of participation by foreign companies in American consortia.

We have also developed the profiles of Canadian and other foreign (European and Japanese) consortia and considered what lessons Canada can learn from the experience of foreign consortia. Some European countries and Japan have much longer experience in establishing and managing R&D

consortia than the United States. In March 1994, Industry Canada carried out consultations with industry by holding workshops in Toronto and Montréal. The participants in these workshops came from Canadian companies involved in foreign technology consortia as well as from the rest of the Canadian research community. The main objective was to share information about the legal or institutional bottlenecks Canadian companies were encountering in their participation in these consortia.

This report is organized as follows. In Chapter 1 we define R&D consortia, we review the typology and benefits of this new organizational form and show how it differs from other forms of co-operative research.

In Chapter 2, we discuss the growth of technology consortia in the global marketplace and the role of government in promoting R&D consortia. We consider the role R&D consortia in the United States within the context of structural shifts in a new American technology policy designed by the Clinton Administration. In addition, we examine the underlying causes for the rapid growth of R&D consortia during the 1980s.

Chapter 3 presents the empirical findings of our sample survey of 15 leading US consortia including a discussion of the growth of consortia activities in the United States, a profile of R&D consortia and the factors leading to their success.

In Chapter 4, we deal briefly with the growth and profile of our domestic technology consortia, a subject that will be developed substantially in the forthcoming study on the growth and experience of technology consortia in Canada.

Chapter 5 looks at the extent of participation by Canadian companies in the United States and the barriers they face in extending their participation in American technology consortia.

Chapter 6 deals with the growth of technology consortia in Europe and Japan. Chapter 7 provides the results from our consultation with Canadian research companies and draws some policy implications for Canadian science and technology policies.

1. R&D CONSORTIA

Co-operative Research: Some Forms

Heightened competitive pressures, shrinking profit margins, skyrocketing capital requirements for long-term product development and manufacturing capacity, and the worldwide scope of both technology and market have compelled many firms to establish new co-operative arrangements which sometimes result in challenging current organizational forms. Even the largest players in the global marketplace are teaming up with their competitors to help share costs and risks. Thus, these partnership arrangements act as a means of improving innovation, technology transfer and competitiveness.

Alliances take many forms based on different needs and criteria. There follow a few ways through which a firm can choose to develop new technologies:[1]

- Informal alliances are the most widely used means of sharing technologies among companies. Scientists from different companies discuss their research projects in an informal environment, such as conferences, and thus exchange technical ideas and information. Here the risks are small because of the low transaction costs involved and the flexibility in structuring the nature of the exchange and the type of knowledge to be shared.

- Government-sponsored university research programs provide funding to specific departments of a university, and the outcome of each project is transferred to the private sector for further development and commercialization.

- A corporate-sponsored university research program is an alliance between a university and the industry, where the university initiates the research project and the industry funds it.

[1] This discussion does not include approaches to acquire a technology such as licensing or acquisition.

- A R&D limited partnership (RDLP) is a partnership between a general partner who co-ordinates the undertaking of the research and receives the funding, and limited partners who invest but have limited liability and no role in the partnership's management.

- A research joint venture refers to the formation of a new organization, jointly controlled by at least two parent firms, whose only purpose is to engage in research and development activities. A joint venture is an equity-based relationship, and can take two forms:

    - joint ventures of limited duration set up by a small number of firms to conduct research on a specific project with well-defined characteristics;
    - longer lasting joint ventures with large membership to conduct more generic research or research aiming at the maintenance, upgrading or setting up of the technological infrastructure.

Technology consortia fall under the second group of research joint ventures, and are formally defined below.

R&D Consortia: Definition

Literature has numerous discussions about consortia, but there is no explicit formal definition of a consortium. Kanter (1990) has described consortia as multiorganizational service alliances where a group of organizations with a similar need, often in the same industry, band together to create a new entity to fulfil their collective need. It is a group formed to take an enterprise beyond the resources of any of its members and provide benefits to all of them.

Smilor and Gibson (1991) describe a consortium as often being composed of companies (i.e., shareholders) that seek mutually beneficial co-operative research while remaining competitors in the marketplace.

In summary, a consortium connotes a co-operative research effort among companies, universities, industries and/or government, typically aimed at helping the participants maintain their leadership position or gain an edge over their international competitors in a particular industry. This definition advanced by Lee and Lee (1992) seems to be more practical since it includes research organizations other than private firms.

R&D Consortia Versus Other Co-operative Alliances

There are specific differences between a technology consortium and other co-operative research ventures. Technology consortia, for example, are stronger versions of the weaker alliances (such as trade associations) that companies in the same industry form to conduct research or take action at the industry level. A technology consortium normally has more strategic significance. Unlike a trade association where the mandate is to work for generalized or abstract benefits for the industry as a whole, a consortium is expected to produce specific benefits for specific companies. The stake is higher here, and participation in governance is thus a more significant issue.

When compared to joint ventures, a consortium is close to one end of the spectrum. It maintains the lowest degree of joint commitment by the members. Most joint ventures are formed by two companies while most consortia have more than two sponsors; many of these sponsors are direct competitors. An R&D consortium tends to have less focussed goals than conventional joint ventures where members set specific goals and responsibilities. The equity and other inputs from members of a consortium tend to be appreciably less than those invested by each member of other types of joint ventures. An R&D consortium tends to be a more loosely coupled organization than a conventional joint venture with two sponsors.

There is a fine-line distinction between a consortium and another organizational form, termed a "centre of excellence," or "industry and university co-operative research centre," that is gaining prominence. As do R&D consortia, these centres also bring together companies to fund, at least partially, research projects. Companies also provide direction to the centre’s programs and evaluate its progress. Unlike consortia though, these centres are initiated by universities, and universities have a substantial input into how they operate. Their initial funding is from government until they can sustain themselves. In an R&D consortium, even though a part of the research is contracted out to universities, the industry members retain control.

In summary, some distinguishing features of an R&D consortium are as follows:

- An R&D consortium tends to be more loosely coupled than other forms of alliances.
- It includes direct competitors, while most other alliances do not.
- The equity and other inputs from each member of a consortium tend to be substantially less than those invested by each member of other alliances.
- The research might be conducted at a university, but the industry members retain control over how the research is conducted.

Typology of R&D Consortia

Classification of technology consortia can be based on structure, technology emphasis, degree of co-operation and interdependence, and the type of integration among members. Evan and Olk (1990) divided consortia into two broad types by structure. The first is a free-standing body in which research is conducted in-house. The second type of consortium serves as an administrative body that co-ordinates research at universities or at member-company sites. They may also have outside consultants.

Another perspective of classification is based on technology emphasis or the motives for forming alliances related to different phases of the product cycle (Mody, 1992). This classification includes precompetitive, product-development and standard-setting consortia. In a precompetitive consortium, firms pool such resources as capital, scientists, engineers and their specialized knowledge in particular areas to conduct basic research. The participating firms then try to commercialize the work on their own. These ventures are precompetitive because the joint research is not related to specific products but rather to generic technologies.[2]

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[2] Precompetitive co-operative R&D has appeared in a variety of formats. For example, some technology consortia are primarily university based, although they may be financed by associated business firms, with or without government

[2] (cont'd) support. This kind of technical co-operation involves more fundamental research, which is somewhat closer to basic R&D. In another example, some consortia represent strictly government–industry technical collaboration. They concentrate on developing those technologies that are generic, enabling and synergistic. The Strategic Technologies Program of Industry Canada, for example, promotes the latter kind of technology consortia.

Product development consortia are formed either to produce new products, to add new features or to customize products according to customer requirements. Firms share their complementary capabilities at different stages of a product life cycle.

Consortia are also sometimes formed to create alternate standards in the industry. Established during the transitional period when both product and price competition prevail, these alliances challenge the standards set by a few dominant firms. They also help the co-operating firms increase their market share.

Another scheme of classification of R&D consortia, proposed by Souder and Nassar (1990), suggests the following 10 types of consortia: R&D sponsor pool, basic research co-operative, equity joint venture, non-equity joint venture, university research centre, R&D limited partnership, industry R&D institute, trade and industry association, industrial development co-op and government–industry program.[3] Each model represents different degrees of organizational interdependence and co-operation.

R&D consortia are both horizontal and vertical. Horizontal technology consortia are formed by firms that are competing with each other in the same industry. For example, the Semiconductor Manufacturing Technology (SEMATECH) in the United States has 11 competitive firms from the semiconductor industry. Similarly, the Strategic Microelectronics Consortium (SMC) in Canada involves almost all of the Canadian microelectronics companies in the country. On the other hand, vertical consortia are established by those companies that do not operate in the same industry and, therefore, are not competitors, but may be linked indirectly, for instance, through customer–supplier relations. For example, in the United States, the members of the Semiconductor Research Corporation (SRC) represent semiconductor manufacturers, users, equipment, materials and software suppliers, federal laboratories and government agencies. Similarly, the members of the Gas Research Institute (GRI), another American consortium, represents distributors, pipeline and gas producers, and municipalities. Although we cover both kinds of consortia here, our focus in this study will remain on horizontal R&D consortia.

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[3] Many of these have been discussed in the preceding text. More details can be found in Souder and Nassar (1990).

Perceived Benefits of R&D Consortia

The motives for forming consortia vary widely:

- To achieve economies of scale and scope in areas where no one firm can realistically afford to do research alone. Small- and medium-sized firms, in particular, are able to carry out larger and more complex R&D projects through technical alliances. Thus, consortia offer scale benefits through resource pooling. Each member gains some of the benefits of a large scale organization while still retaining its independence with respect to every other activity (Kanter, 1990; Evan and Olk, 1990; White, 1985; Niosi and Bergeron, 1992).

- To reduce duplication of efforts (White, 1985; Ouchi and Bolton, 1988; Lee and Lee, 1992; Souder and Nassar, 1990).

- To spread the risks of accelerated technical change in new technologies among several firms. These technical alliances, thus, are a way of coping with such problems which consume a large amount of money and time without always achieving the desired results (White, 1985; Niosi and Bergeron, 1992; Lee and Lee, 1992; Evan and Olk, 1990; Souder and Nassar, 1990).

- To make otherwise formidable research projects possible as collaborative research ventures by capitalizing on the complementary abilities of the members' scientific staff in a way individual companies cannot (White, 1985; Lee and Lee, 1992).

- To achieve standardization in terms of developing uniform industry-wide product standards, standard testing procedures and standard prototype technologies. To set a standard for new technology firms on which to collaborate so that they can build, from the start, products with compatible characteristics (Niosi and Bergeron, 1992; Ouchi and Bolton 1988; Evan and Olk, 1990; Souder and Nassar, 1990).

- To achieve synergistic effects of cost. Joint use of resources can result in a decrease of fixed costs (Lee and Lee, 1992; Gemunden, Heydebreck and Herden, 1992).

- To provide a buffer for members against such threats as pending legislation and foreign competition (Souder and Nassar, 1990).

- To reduce development time for new generations of products and processes (Ouchi and Bolton, 1988).

- To provide an opportunity to learn more about new technologies, i.e., a forum for technological learning (Souder and Nassar, 1990).

- To obtain immediate access to new technologies, new markets and cheap production sources (Lee and Lee, 1992).

- To improve existing technologies with regard to health, safety and the environment (Souder and Nassar, 1990).

- To facilitate technology transfers among members. Alliances provide an integrative environment that brings users and performers of R&D together. They also provide an opportunity for members to develop, sell, license or trade ideas and by-products of their own research efforts (Souder and Nassar, 1990).

- To improve networks—for example, partners can be mediators or serve as references, thus improving sales opportunities (Gemunden, Heydebreck and Herden, 1992).

- To increase opportunities for management training and to build managerial experience (Souder and Nassar, 1990).

In summary, firms, wanting to go into co-operative research consider one or more of the following three strategic objectives: horizontal diversification into new product lines, vertical integration (backward and forward), and leapfrog competition within existing product lines (Link, 1990). The proponents of consortia emphasize the advantages of minimizing the cost of developing technologies, spreading the risks of research and development, reducing unnecessary duplication of research efforts, obtaining immediate access to new technologies, new markets and cheap production sources and making otherwise formidable research projects possible.

2. R&D CONSORTIA IN THE GLOBAL ECONOMY

Growth of Consortia

Many technology alliances are cross border and are negotiated by multinational corporations based in the Triad—the United States, Japan and the European Community. As well, technology collaborations are mostly found in core and strategic technologies, such as information technologies, biotechnology and advanced industrial materials. Over 90 percent of worldwide technical co-operative agreements in core technologies have taken place between companies from and within the Triad (Hagedoorn and Schakenraad, 1990). IBM, for instance, has established technology alliances with Toshiba of Japan to develop Liquid Crystal Display, with Siemens of Germany to develop 64 MBit DRAM, with its competitor Microsoft in the United States to develop joint software and with Ferranti of the European Community to install its PCs in Ferranti computers (Krubasik and Lautenschlager, 1993). These alliances have important implications for international trade, the flow of foreign direct investment and international technology transfer.

Since 1980 there have been rapid increases in the formation of new co-operative agreements in strategic technologies. In 1989, MERIT-CATI Data Bank counted about 4,600 technical co-operative agreements in all three core technologies in the world (Hagedoorn and Schakenraad, 1990), 90 percent of which took place during the 1980s. About 60 percent of these agreements were in information technologies, 26 percent in biotechnology and 15 percent in new materials. The preponderance of agreements in information technologies is not surprising since this field has a wider application, ranging from telecommunications to microelectronics. Although the other two technologies still have relatively fewer uses, their importance in the production process is now expanding.

Japan and the European Community have greater experience with technology consortia. Japan was able to improve the international competitiveness of its semiconductors by forming the technology consortium of semiconductor manufacturers, and the European Community increased the competitiveness of its computer industry through the establishment of a technology consortium of computer producers. In the United States, a major boost in the growth of technology consortia, in particular the horizontal ones, came only after 1984 when Congress passed the *National Cooperative Research Act* (NCRA). This legislation permits American companies in the same industry to form consortia that undertake precompetitive R&D. The legislation was extended in 1993 to include joint ventures for production. It is now called the *National Cooperative Research and Production Act* (NCRPA).

General Factors Driving the Growth of Technology Consortia

The apparent reasons for the growth of technology consortia in the United States, Canada and other major industrialized nations are related to the leveraging of scientific and engineering expertise and of financial resources and the pooling of risks attached to undertaking R&D at the technological frontier. In fact, the factors driving the formation of technology consortia are deeper, more subtle and more permanent. The three forces influencing technology consortia in the global marketplace are globalization of the world economy, technology trends and industrial policy that advocates a greater role of government in shaping a country's comparative advantage. These forces are not mutually exclusive but often overlap and reinforce each other. From a technology perspective, they have engendered two contradictory phenomena. They have encouraged the establishment of cross-border technology collaborations but, at the same time, they have made major trading nations more protectionist about their technology-based competitive advantage.

Globalization of the World Economy

Over the last four decades, the global marketplace has become much more interdependent. International linkages among countries have passed through three phases, increasing substantially and becoming more complex. The first phase was driven by international trade liberalization under successive GATT rounds during the 1950s and 1960s. With the dismantling of trade barriers by GATT members, worldwide trade expanded considerably. The second phase was initiated by financial integration during the 1970s and accelerated during the early 1980s as a result of deregulation, privatization and the revolution of communication and information technology. In the 1980s and the early 1990s, the world economy entered the third phase called globalization. This phase is driven by a rising volume of foreign direct investments (FDI) and by accelerating technological change and technology transfer.

The prime agent of globalization is the multinational enterprise (MNE). MNEs have adopted global strategies to enhance efficiency and profitability along their entire production chain. The global firms organize their operations—from R&D for process and product innovation, through manufacturing and sourcing, to marketing and sales—"as an internationally integrated ensemble" (Vickery, 1992/1993). They acquire their inputs from the cheapest sources, produce goods and services in the lowest-cost countries, and obtain and develop technological expertise and skills wherever they are available in the interlinked global economy. As communication and information costs decline and the world transportation infrastructure improves, global firms locate "their operations wherever they can best use complementary assets to maximize their corporate positioning" (Cowhey and Aronson, 1993). These global firms are commonly found in high-technology, high-skill and high-capital-intensive sectors such as the electronics, computer, aircraft and chemical industries. By rationalizing their operational activities worldwide, they benefit from economies of scale and scope in R&D and in production operations. As a result, during the 1980s, the FDI flow grew much faster than world merchandise trade and world output (Economic Council of Canada, 1992).

Technology Trends

One important factor pushing globalization is the increasingly rising R&D costs required in the race for the technological frontier in the leading edge sectors (Ostry, 1991). New generation technology is much more expensive to invent. Because of shorter product life cycles, greater speed of new product introduction and cross-fertilization of several technical and scientific disciplines required to advance technology at the frontier. For instance, it used to take 10 or 15 years before old products were replaced by new ones. Now it takes only four or five years for a product to become obsolete (Rosow, 1988). In the computer industry, obsolescence sets in much faster: personal computers or computer chips become obsolete within two years or less. Therefore, very large capital funds are required to introduce new products quickly, especially in the high-tech industry and the capital goods sectors. In the aircraft industry, for example, even for the largest producer—Boeing—the introduction of a new product "requires more financial resources than the company's entire equity base" (Krubasik and Lautenschlager, 1993).

The high cost of R&D and the need for complementary specialized assets to invent new technologies have stimulated a wave of international mergers and takeovers and created a phenomenon of technoglobalism. This, in turn, has generated new forms of international networking among global firms, such as cross-border technology alliances and R&D consortia. Global companies are finding "that the critical complementary resources. . .are available only through global sourcing" (Cowhey and Aronson, 1993).

Since the early 1980s, the pattern of international trade has changed substantially. Over the last decade, rapid growth in trade has occurred in manufactured goods. And within the manufacturing sector, a higher proportion of trade among industrialized countries has been observed in high value-added high-tech manufactured products produced by MNEs in imperfectly competitive international markets. Furthermore, powerful new players have entered the global marketplace such as Japan and newly industrialized countries (NICs) such as South Korea, Taiwan and Hong Kong. These developments have greatly enhanced international competition, and the fights among large firms to maintain or to increase market shares in high-tech trade have become much more fierce. Technology becomes a critical factor in the race to maintain or enhance the competitive edge, which puts greater pressure on global firms to do more R&D and, thus, stimulates further technoglobalism with more technology alliances and consortia.

The Role of Government and National Comparative Advantage

It is widely recognized now that in today's developed economies, national comparative advantage is determined by active industrial or technology policies rather than merely by factor endowments. "Man-made comparative advantage replaces the comparative advantage of Mother Nature (natural-resources endowments) or history (capital endowments). . . . Global market economies of scale and scope are open to everyone—even if they live in relatively small countries" (Thurow, 1992). When comparative advantage depends on the skills of management and labour and on innovations, it can be "shaped by government policy" (Lipsey, 1993). This view has been discussed in the economics profession under the umbrella of strategic trade policy.

Comparative advantages in certain industries are not necessarily attributable to differences in endowed primary factors of production. Instead, they are "often created through a positive feedback" (Krugman, 1992). This feedback process refers to the generation of external economies as a source of international competitiveness. For instance, improving the competitiveness of a domestic high-tech industry through an industrial policy will create two kinds of external economies: market-size effects and pure information spillovers. A strong national industry, by providing an extended market for specialized labour, encourages workers to attain higher skills and so builds high-skilled labour pools in various industrial sectors and in the national economy. Similarly, it also builds up a stronger supplier base that provides higher-quality intermediate inputs and capital equipment. The knowledge base available to the domestic industry improves. In turn, the spillovers from the improved knowledge base further strengthen the industry, make it internationally competitive and complete the loop. The external economies create self-reinforcing advantages, through positive feedback effects for the particular industry, for the industrial sector in which the industry is positioned and for the national economy as a whole.

Both Japan and the European Community have followed active industrial policies to bolster the international competitiveness of their strategic industries such as the semiconductor industry and the commercial aircraft industry. During the 1960s and early 1970s, the United States was a leading player in the semiconductor industry in the global marketplace. Since the industry had large economies of scale, significant learning effects and large external economies, Japan's Ministry of International Trade and Industry (MITI) decided to improve the competitiveness of its semiconductor industry through a Four Year Very-Large-System Integration (VLSI) Program (1976-1979). The MITI supported the industry by providing R&D funds, technical training and education, and preference for government procurement by imposing restrictions on foreign access to its domestic market and by setting production and product targets. As a result, during the 1980s, the Japanese semiconductor industry became a formidable foe to the American counterpart. The Japanese industry gained a substantial market share in the US market. The VLSI industrial policy was indeed a great success. The story is the same with respect to the development of Airbus Industry by a consortium of nine European nations. They provided the industry with large subsidized R&D funding, export financing and other assistance in the manufacturing process. In consequence, by the mid-1980s, Airbus Industry eroded significantly the global market positions of Boeing and McDonnell Douglas.

To recapture market shares lost to Japan, the American semiconductor manufacturers established SEMATECH, a government-subsidized consortium, in 1987. Over the last seven years, the US government has spent over $900 million, with SEMATECH members contributing the same. This experiment in industrial policy by the United States did indeed work successfully. By the early 1990s, the US semiconductor manufacturers regained their leadership in the American chip market (Hafner, 1993). Furthermore, SEMATECH made strong contributions to the performance of the semiconductor equipment industry. SEMATECH indicated in October 1994 that it will not require any federal financial assistance in 1997. Other industries in the United States hold up SEMATECH as a technology policy model to be followed by the Clinton Administration for restructuring industry–government relationships in technology development.

The American aerospace industry, increasingly threatened by competitive pressures from the European airbus consortium, has proposed a new consortium called Aerotech whose structure is modelled on that of SEMATECH. Similarly, US textile manufacturers have formed, with government assistance, a consortium called Amtex. And the Big Three auto companies recently established a new consortium with government partnership with the objective of designing a fuel-efficient "super car."

The new American government has overhauled its technology development programs and expanded the role of technology consortia. The Clinton Administration considers SEMATECH "a model for federal consortiums funded to advance other critical technologies" (Clinton and Gore, 1993). The Commerce Department's Advanced Technology Program (ATP), established in 1990, has been expanded significantly to share the costs of undertaking R&D in precompetitive generic technology. It also sponsors co-operative research between private industry and federal laboratories such as the National Institute of Standards and Technology (NIST). Further, all US laboratories run by NASA, the Department of Energy and the Department of Defense should devote "at least 10-20 percent of their budgets to R&D partnerships with industry" (Clinton and Gore, 1993). All US agencies are directed to encourage Cooperative R&D Agreements (CRADAs) and industry–lab co-operation through other policy instruments.

Thus, over the next decade, the number of US government-funded co-operative R&D projects will grow very rapidly in the United States. Canadian companies are wondering whether they will be allowed to participate in these consortia. This question is very important in the light of our historically close economic relations with the American economy and our desire to keep open the channels of receiving new technologies from all sources. Canada is concerned that with the growth of protectionism in the United States, these channels are getting weaker or disappearing. We will return to this important issue in Chapter 5.

3. GROWTH AND PROFILE OF R&D CONSORTIA IN THE UNITED STATES

Growth of Consortia

Collaborative R&D activities in the United States are not new.[4] Development of the computer and the integrated circuit, for example, can be traced to research sponsored and co-ordinated by the US government during the 1950s and 1960s. The US space program and biotechnology research are other examples of collaborative efforts. However, before the 1970s, collaborative industrial efforts that were not supported by government occurred among companies in vertical sectors. Such was the case with automobile manufacturers and petrochemical firms collaborating to develop ceramics for use in auto bodies, for example. There is ample evidence that before 1984, the US antitrust laws seemed to scare high technology companies away from entering into co-operative research agreements with their competitors. The spectre of liability for triple damages if found guilty of anticompetitive practices has plainly dampened much enthusiasm for such ventures. The limited horizontal R&D collaboration among firms in the same industry was most often carried out, informally, under the sponsorship of a trade association.

Since the implementation of the *National Cooperative Research Act* (NCRA) of 1984, technology consortia in the United States have proliferated.[5] By the middle of 1993, over 350 consortia, involving more than 1,200 US and 50 foreign businesses, had registered with the US government under this Act. In spite of some criticism of the Act, it seems to have fostered a co-operative research environment among competitors to the extent that consortia are growing at a rate of almost two per month.[6]

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[4] A brief overview of co-operative R&D efforts in the United States is given in Fusfeld and Haklisch (1985) and Alice (1990).

[5] The *National Cooperative Research Act* of 1984 (NCRA) stipulates that joint research and development ventures" must not be held illegal per se. In addition, the NCRA eliminates the availability of treble damages, provided the parties in the co-operative research arrangement first register their alliances with the Department of Justice.

[6] Critics of the NCRA advance two major objections. First, they say it protects only co-operative research efforts, excluding manufacturing and commercialization consortia. And second, they claim that the rule of reason standard offers only vague guidelines, thereby

Today, R&D consortia involving manufacturers in horizontal business sectors, such as semiconductors, chemicals, advanced materials and telecommunications are increasing. The Microelectronics and Computer Technology Corporation (MCC), the Semiconductor Research Corporation (SRC) and the Software Productivity Consortium (SPC) are examples of collaborative ventures that bring together firms in similar product markets.

The Profile of US R&D Consortia

What follows is a profile of American technology consortia, developed on the basis of information obtained from a sample survey of 15 consortia in the United States. As can be seen in Table 1, most respondents are leading or prominent members of the Council of Consortia CEOs. Most consortia in the sample are large and therefore reflect the profile of US consortia with reasonable accuracy. For example, in all, about 2,500 firms participated in 350 US consortia; our sample of 15 consortia has 50 percent of those firms as members. We gathered information on the consortia's structural characteristics such as size, type of membership, prime initiators, duration, funding levels and research facilities, technology emphasis, organizational structure and decision making, and other operational characteristics such as fee structure, ownership of intellectual property and policies related to conducting research.

Structural Characteristics

There are a number of different ways of structuring consortia. For example, in terms of population, almost one half of the consortia have more than 50 members each. As shown in Table 2, three consortia (20 percent) even have more than 100 companies on their membership roster.[7] Since the formation of each consortium, 80 percent (eight out of 10 who were able to provide us with growth estimates) were growing. Two reported more than a 100 percent growth rate while the other six had a growth rate between 10 and 55 percent.

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discouraging, or at least not encouraging, co-operative ventures. For details see Lee and Lee (1991).

[7] The mean number of memberships is an inappropriate statistic since most consortia in our sample are the leading ones. In another study (Evan and Olk, 1990), the mean number of companies per consortium was about seven, and the range extended from 2 to 150. Seventy percent of consortia had memberships within the range of three to 20 companies.

Table 1
US R&D Consortia Interviewed

1.	MCC: Microelectronics and Computer Technology Corporation
2.	NCMS: National Centre for Manufacturing Services
3.	NIF: News in the Future
4.	IAP: International Affiliates Program
5.	OAI: Ohio Aerospace Institute
6.	SPC: Software Productivity Consortium
7.	PRF: Plastic Recycling Foundation Inc.
8.	Bellcore: Bell Communications Research
9.	SEMATECH: Semiconductor Manufacturing Technology
10.	National Science Foundation–Industry University Co-operative Research Centre (Alfred University, New York)
11.	The Consortium for Advanced Manufacturing International
12.	International Magnesium Development Corporation
13.	Chemical Specialities
14.	The University of Massachusetts Polymer Science Program
15.	The Consortium for Plant Biotechnology Research Inc.

Table 2
R&D Consortia Membership Range in the United States, 1993

Membership Range	Absolute Number	Percentage
1 to 50	8	53
50 to 100	4	27
Over 100	3	20
Total	15	100

Source: Derived from a sample survey of R&D consortia.

No set pattern of membership classification was reported by the consortia. Different types of membership offered by these consortia were full membership, associate membership, small business associates, supporting affiliates and shareholders. The majority (11 out of 15) offered full membership.

Who took the initiative in forming the consortium? As shown in Table 3 the consortia in our sample were primarily initiated by the private sector. Only two were promoted by the government and two by the universities.

Table 3
R&D Consortia Sponsors in the United States, 1993

Sponsors	Absolute Number	Percentage
Government	2	13
Private Sector	10	67
Government and Private Sector	1	7
University	2	13
Total	15	100

Source: Derived from a sample survey of R&D consortia.

The duration of the consortium was another aspect we investigated. All consortia were open ended, without time limits. Only one consortium mentioned that it renewed its membership on a staggered basis every five years.

Most consortia in our sample have high funding levels. One quarter (25 percent) of the consortia we examined have budgets of over $50 million. Another 16 percent run on a budget between $11 and $50 million. Therefore, almost 60 percent of the consortia have budgets between $1 and $10 million. MCC and SEMATECH are at the high end of the spectrum. A significant proportion, almost 40 percent, are privately funded; one consortium is purely federal and state funded; and the majority (54 percent) share costs between government and the participating companies.

Research facilities were also explored in our sample. One third of the consortia in our study have their own laboratories. About 14 percent use member-owned facilities, i.e., project members conducting the work within their own companies. Most consortia (53 percent) contract out the research, mainly to universities. The proportion of work allocated to each of these options is not accounted for in this survey.

Technology Emphasis

Most consortia are involved in more than one phase of research. The major focus of consortia activity in the United States, however, seems to be on precompetitive research, as can be seen in Table 4. Firms pool their resources to do basic research not related to specific products but rather to generic technologies. The collaborating firms then expect to develop marketable products on their own. An example of such an alliance is SEMATECH. Precompetitive alliances are funded substantially by the government. It appears that R&D consortia engaged in precompetitive research are perceived by the United States as being critical to the country's competitiveness.

Product development seems to be the second most popular focus, supporting the notion that companies are comfortable with collaborating on activities other than precompetitive. About 33 percent of the consortia, including the two largest consortia in our sample, indicated this goal to be their prime emphasis. None of the respondents indicated that it is working toward the commercial end of the spectrum or is working toward developing standards.

Table 4
Primary Goal for the Formation of R&D Consortium
in the United States, 1993

Primary Goal	Absolute Number	Percentage
Precompetitive	9	60
Product Development	5	33
Others*	1	7
Total	15	100

* Creation of alternative standards, cost cutting or any other.
Source: Derived from a sample survey of R&D consortia.

Organizational Structure and Decision Making

Developing consensus among a large number of consortium members is a challenge. To address this challenge, almost all consortia in our sample have a board of directors and one or more technical advisory boards within their organization structures. The former is required to develop overall policies and directions and to oversee the operations of the consortium while the role of the latter is to work with the consortium staff to make sure that the ongoing projects have the right technical capabilities and focus. The composition of these boards and their decision-making processes vary from case to case. What is common is that the decisions are influenced by input from all the members but tend to favour those who have a direct interest in the decision or who have a greater investment in the consortium.

Operational Strategies

Most consortia we studied have an initiation fee as well as an annual project contribution. The type of the membership, the size of the participating firm and the extent of involvement with the project are some of the factors that dictate the fees which ranged from $2,000 to $25 million per year. While some consortia encourage companies to participate by keeping a very low initiation fee, others tend to be very selective. MCC, for example, allows companies to have non-voting participation in particular projects at reduced rates. Small companies can get involved in MCC for as little as $5,000, which can be paid with stocks, provided they become members of at least one of the research projects. The associate membership fee is $25,000. A full equity share in MCC could cost as high as $250,000, plus additional annual dues for particular projects. On the other hand, SEMATECH requires a minimum annual fee of $1 million and full participation could cost a company as much as $25 million. In another model, PRF has three levels of membership: directorate ($50,000/year), associate ($25,000/year) and supporting ($5,000/year). Member companies may also contribute technical knowledge by contributing researchers, equipment/machinery and, occasionally, new technological processes. For example, Owens-Illinois contributed the basic recycling technology to PRF. In all, it is clear that those who contribute more tend to have more input into the decision making.

Where to conduct research is another frequent dilemma for a consortium's management. Rather than fight the natural tendency to keep one's best people at home, MCC and SEMATECH are following SRC's lead by assigning much of their development work to member sites. This helps solve personnel problems, encourages rapid transfer of technology, and promotes industry co-operation by allowing members to play host to suppliers and even forcing competitors to work on areas of common interest. As a senior official of a prominent consortium said, "Frankly, that's a great way for consortia to work; let the work be co-ordinated by the consortia but done by the members.

The ownership of the intellectual property generated by consortia is dealt with in many different ways. In 40 percent of the consortia (six cases), the intellectual property is the common property of all the members involved in the project. The second most frequent arrangement (33 percent) was that ownership of the intellectual property was retained by the consortium which then licensed it back to the members on a variety of schedules. A third approach was a variable but mutually agreed arrangement between member firms and universities. In one case, a consortium retained the right to ask the university to license the patent to its participating members either free of charge or for a small royalty fee.

Generic Problems and Critical Variables of Success

Consortia managers do not support the views that the concept of precompetitive research is too ill-defined to achieve meaningful results, that the consortia participants do not assign their best people to the venture, or that competitors in domestic markets do not co-operate. The real problems seem to be different. Some of them, apart from the obvious day-to-day management or financial problems, are as follows:

- Technology transfer is the most critical issue suggested by most of our respondents. The consortium members tend to treat technology transfer in a cavalier way so that often technology lies fallow after it becomes available to members. Technology transfer should be seen as a continuum of interrelated processes that starts even before formal research begins.

- Too much communication creates inflated and unrealistic participant expectations.

- There is a risk of placing "longer time horizon" research in direct competition with commercial sources of the same technology.

- Conflict between university goals and industry goals sometimes slows the pace of research.

- Excessive turnover in the membership dampens the momentum of a consortium. Disagreement over consortium operations and a change of one member's R&D strategy are possible reasons for a company to leave a consortium.

Another empirical study by Souder and Nassar (1990) suggests five major disadvantages to R&D consortia. These, in decreasing order of importance, are the loss of proprietary opportunities, the loss of control, the loss of flexibility, the increase in bureaucracy and the slowing of response time in various situations.

What needs to be done to make a consortium successful? Werner and Bremer (1991) have identified five lessons for success: maintain a coherent strategic vision, choose research problems that have significant payoffs, optimize communication with members, make technology transfer a continual process and strengthen membership commitment.

Lee and Lee (1992) studied the experiences of two American R&D consortia and one United States–Japan co-operative venture in the United States and concluded that to establish a successful consortium, it helps to have participation and support from the industry's leading firms; a common set of goals, or problems, shared by all participants; an exceptionally strong motivation to succeed, such as the protection of national security; well-defined goals that are not too broad and that do not involve too many participants; the support of upper level management; and the assurance of flexible antitrust laws.

What is common to the above studies and our discussions with consortia managers is that the success of any research consortium hinges on how effectively and efficiently the resulting technology is adopted by its participating members. The irony is that often the participating firms allocate inadequate resources for transferring the technology into mainstream use. A consortium must:

- encourage definition of technology use at the outset of consortium research;
- establish incentives for successful adoption;
- budget resources for technology demonstrations, support, testing and enhancement; and
- use internal company communications to inform potential users of the availability of the technology.

Smilor and Gibson (1991) suggest that shareholders and the consortium management can accelerate the technology transfer process by developing an infrastructure that focusses on increasing interactive communication and motivation for technology transfer while decreasing physical and conceptual distance and technological equivocality.

4. R&D CONSORTIA IN CANADA

In a Canadian context, collaboration research has become more and more a way of doing business for industry. This section presents, in brief, the growth of R&D consortia in Canada and the role of government programs in promoting them. A detailed analysis of Canadian R&D consortia is forthcoming in a separate study on technology collaboration in Canada.

Growth of Consortia

R&D consortia have been a part of the technology landscape in Canada for decades. As early as 1925, Paprican, a consortium of Canadian pulp and paper companies, began conducting joint R&D. In the late 1940s, Atomic Energy of Canada, Ontario Hydro and Canatom formed a large consortium, which included several electrical equipment suppliers, to design and build the Candu reactor. Since 1980, the growth of technical alliances in general, and technology consortia in particular, has been rapid. Initially, technical alliances in the form of consortia were formed in a few industries, such as communications and information technology, but now more and more industries are participating in such collaborative efforts.

Unlike in the United States, there seems to be no one source for information about Canadian consortia. Table 5 contains some examples of Canadian R&D consortia, and detailed descriptions of some of these consortia are given in Appendix 1.

To judge from these examples, most industrial research consortia in Canada are in the high technology sector. Their focusses and objectives may be diverse, but they all have been formed to extend new technologies. There is a vast scope for developing this new organizational form of co-operative research in more traditional, low technology industries.

Table 5
Some Examples of Canadian R&D Consortia

1.	**CARC:** Canadian Audio Research Consortium
2.	**CANARIE:** Canadian Network for the Advancement of Research, Industry and Education
3.	**FORMTECH:** Advanced Engineering for Metal Stamping
4.	**ICST:** Institute for Chemical Science and Technology
5.	**OP-CON:** Opto-Electronic Research
6.	**PRECARN:** PRECompetitive Applied Research Network
7.	**PROGERT:** Projet de Recherche pour l'Observation et la Gestion des Ressources Terrestres
8.	**SIMCON:** Software for Integrated Manufacturing Consortium
9.	**SMC:** Strategic Microelectronic Consortium
10.	**SSOC:** Solid State Optoelectronic Consortium
11.	**TCC:** Telecommunication Consortia of Canada
12.	**Vision 2000:** Advanced Personal Communication
13.	**VOLVOX:** Large Scale Environmental Management

Source: National Research Council of Canada, and others.

Government Role and Programs

A number of initiatives, many of them very successful, are in place in Canada to support co-operative research. To the benefit of Canadian industries, co-operative R&D has become a target of government spending in the last decade; government at all levels (federal, provincial and municipal) has used this idea of partnership as a policy tool to improve industrial competitiveness by accelerating technology creation and dissemination, with the particular focus on "critical" technologies.

Canadian programs range from the creation of centres of excellence at universities for the development of technology in key areas and the training of students, to the formation of industrial consortia in specific technology domains. Many provincial and local governments sponsor technology institutes at universities to develop university–industry links and to strengthen high technology companies in their areas of expertise.[8] Funding, regulation and information dissemination are the three areas in which government can play a catalytic role in consortia activities. In Canada, most funding for research partnering programs is contributed by government, although the industry does sometimes contribute itself in kind or in cash. This can be seen as the role of government: to help offset the technical risk run by companies participating in precompetitive R&D and to fulfil its responsibility in the domain of university education. Government also offers tax breaks to research consortia. Sometimes, when both federal and provincial levels of government contribute to the same consortium, there is an agreed-upon "stacking rule" whereby the total government contribution cannot exceed 75 percent of the total funding for the project. To the best of our knowledge, most if not all consortia in Canada are partially government funded and very few have foreign partners.

The Strategic Technologies Program (STP), launched in 1989 by the then Industry, Science and Technology Canada, is most popular and is rapidly gaining importance. It is aimed at improving Canadian industry in three strategic technologies—biotechnology, materials and information technology. The three parts of this program are the research and development alliance, the technology application

[8] Some examples of centres of excellence are the Canadian Institute for Telecommunications Research (CITR), the Institute for Robotics and Intelligent Systems (IRIS) and the Microelectronic Devices, Circuits and Systems for Ultra-Large Scale Integration (ULSI). The Ontario centres of excellence program has lead to a number of ventures such as the Information Technology Research Centre (ITRC) and the Telecommunications Research Institute of Ontario (TRIO). Similar examples are the British Columbia Advanced Systems Institute (BCASI), which is jointly supported by the Canadian and British Columbian governments to the tune of $8 million over five years and the Centre de Recherche Informatique de Montréal (CRIM) which gets support from the Quebec government. The Ottawa-Carleton Research Institute (OCRI), an example of a local government supported venture, is a consortium of post-secondary academic institutions, government and industry. Thomson (1992) provides the detailed objectives of the above programs.

alliance and the feasibility study.[9] Some examples of projects funded under the STP are Gentec Inc., Centre de Recherche Informetrique de Montréal (CRIM), VOLVOX and Pre-Competitive Applied Research Network (PRECARN). The other federal programs that support co-operative networks in research and development are the Technology Outreach Program, the Industrial Research Assistance Program (IRAP), and the Japan Science and Technology Fund.[10]

Since most government policy in this area was designed before the concept of research partnerships was developed, regulations for research partnerships tend to be on an ad hoc basis.[11] We now need coherent definition and regulation of such areas as the law, taxation, R&D innovation, intellectual property and funding.

Another area that needs some attention is the dissemination of information about consortia activities both in Canada and around the globe. Often, industry, specifically in low technology sectors, is not aware of the trends, success stories and benefits of co-operative research. There seems to be a lack of awareness of government programs, for example, the STP, and the relevant regulations. Small- to medium-sized companies in particular may find it hard to exploit joint R&D opportunities and make use of government support.

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[9] A research and development (R&D) alliance involves a Canadian-based company working with one or more companies, universities or research institutes on precompetitive R&D to develop the knowledge base needed for a range of new or improved products or processes. A technology application alliance involves both developers and users of the technology in question. Again, a Canadian-based company works with other companies, universities or research institutes on the precompetitive development of a product or process. A feasibility study involves one or more Canadian-based companies, universities or research institutes that undertake preliminary studies and analyses to resolve a wide variety of questions prior to the launch of a project.

[10] The Technology Outreach Program funds co-operative networking to promote technology acquisition and diffusion. The Industrial Research Assistance Program supports, on a cost-sharing basis, firms intending to conduct collaborative R&D with other industry and federal research organizations. The Japan Science and Technology Fund, which is managed by the Department of Foreign Affairs and International Trade, promotes bilateral collaboration with Japan in science and technology, including research, standards setting and initiatives to facilitate exports to Japan.

[11] See Thomson (1992).

5. CANADIAN AFFILIATES' PARTICIPATION IN US CONSORTIA

Eligibility Criteria

The issue of foreign, including Canadian, participation in federally funded technology consortia was addressed in the *American Technology Preeminence Act* of 1991. This legislation imposes certain eligibility criteria on US-based Canadian companies; essentially, these companies can participate in the consortia if it is in the economic interests of the United States. Two kinds of conditions are applied in order to judge the economic interests: performance and reciprocity criteria. Canadian affiliates can participate in federally funded R&D consortia provided they have already invested in R&D and manufacturing in the United States, they contribute significantly to employment in the United States, they agree to use technology resulting from the consortia in manufacturing in the United States and they agree to procure parts and materials from competitive suppliers.

The reciprocity conditions are linked with Canadian foreign investment policies. Our affiliates in the United States can participate in the technology consortia if Canada provides market or investment opportunities to US-owned companies that are comparable to those provided to other companies, allows US companies to participate in any joint venture under conditions that are comparable to those offered to Canadian companies in the United States, and protects adequately and effectively the intellectual property rights of the US-owned companies.

In summary, it is evident that the US government, through the above stringent eligibility criteria, has imposed barriers to foreign participation in federally funded co-operative R&D projects. Further, Canadian firms are restricted from participating in collaborative R&D projects supported by the National Institute of Standards and Technology's (NIST's) Advanced Technology Program and SEMATECH.

Current Extent of Participation

Canadian (or foreign) participation in US consortia is limited. It is also apparent from Table 6 that most foreign firm participation in the United States is in larger consortia: all three large consortia (with a membership of over 100) have foreign or Canadian participants. On the other hand, almost two thirds of small consortia (with a memberships of less than 50) do not have any foreign or Canadian firms.

Table 6
US/Foreign Member vs. Membership Range in American Consortia, 1993

Member Countries	Number of Consortia	Membership Range
Only US Members	6	1 to 50 = 33% 50 to 100 = 7%
Only US and Canadian Members	2	50 to 100 = 7% Over 100 = 7%
US, Canadian and Other Foreign Members	7	1 to 50 = 20% 50 to 100 = 13% Over 100 = 13%
Total	15	

Source: Sample survey of R&D consortia, 1993.

Table 7 demonstrates that not all US consortia are closed to foreign members. In our sample survey of 15 consortia, 60 percent had foreign members. Further, 40 percent had Canadian members, which might give the impression that Canadian companies are doing well. However, this notion is erroneous. In fact, Canadian participation in US consortia is almost insignificant. Smilor and Gibson (1991) found that of the 902 consortia members sampled, 843 (93 percent) were US companies, 42 (less than five percent) foreign firms and the remaining 17 (two percent) were state and federal government agencies, and US and foreign universities.[12] Also, there are only four Canadian companies participating in 12 consortia formed by NIST; these 12 consortia have a total membership of over 100. And finally, our study shows that there are less than 20 Canadian member firms in our sample of 15 consortia which have a total membership of over 1,200.

[12] These data are taken by Smilor and Gibson (1991) from the consortia data base of the IC2 Institute at the University of Texas at Austin.

Table 7
Composition of R&D Consortia, United States, 1993

Member Countries	Number of Consortia	Percentage
Only US Members	6	40
Only US and Canadian Members	2	13
Only US and Other Foreign Members	3	20
US, Canadian and Other Foreign Members	4	26
Total	15	100

Source: Derived from sample survey of R&D consortia, 1993.

Northern Telecom Inc. (NT) is perhaps the most aggressive Canadian company participating in US consortium. It has recently agreed to join IBM, MCI Communication and nine universities in developing technology to improve the performance of the US national data highway.[13] NT will donate $5 million to the non-profit Advanced Network and Services formed three years ago with the help of MCI and IBM to create and manage a high-speed data network called NSFnet.[14] Allen Weis, the president of Advanced Network and Services, feels that Northern Telecom will bring valuable engineering skills in high-speed switching technologies that are needed to increase the speed of data sent on the upgraded NSFnet.

When we asked our sample US consortia without foreign members their reasons, some of the responses were as follows:

- no foreign firm approached them (three);

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[13]"Northern Telecom joins data highway alliance," *Ottawa Citizen*, November 4, 1993.

[14] NSFnet is a crucial component of a collection of computer networks known as the Internet which connects more than two million computers and has more than 15 million users including students, researchers and businesses. The National Science Foundation is set to award another series of contracts to upgrade the performance of NSFnet to what is to be called the Very High Speed Backbone Service.

- the purpose of the consortium is to promote the competitiveness of American industry (four);

- the consortium functions only as a regional entity (two); and

- the dilemma of allowing one foreign country and having to deny others (two).

Most consortia who have at least one foreign member claim that these members, once in, are treated on an equal footing with Americans. They have voting rights (eight of nine respondents) and full access to information on the project in which they are involved.

Interestingly, the US industry viewpoint regarding foreign participation is very positive. John Wilson, while summarizing the views expressed in a workshop on research consortia held in March 1991, writes:

> As participants noted, it is increasingly difficult to distinguish between U.S. and foreign companies. Just as U.S.-based firms have subsidiaries overseas, foreign corporations have operations in the United States that employ U.S. workers and provide federal and state tax revenues. Some public and private sector representatives at the workshop suggested that if a foreign-owned U.S. subsidiary pays taxes in the United States, it should be eligible to participate in government supported R&D collaborations. It was also noted that foreign participation in collaborative research can benefit U.S. companies. In many key areas, workshop participants said, foreign firms are at the forefront of technological knowhow. To be competitive, U.S. companies must draw on these repositories of expertise.[15]

Even some US officials were very supportive of Canadian participation in the US co-operative. Some unsolicited comments from these officials included "NAFTA should help," "getting the Intellectual Property Right Act (between the United States and Canada) through will create an even more congenial environment," and "it is the industry which must speak out."

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[15] *The Government Role in Civilian Technology—Building a New Alliance*. Washington DC: National Academy Press, 1992, p. 175.

Rising US Protectionism

The US Congress was planning to make the American R&D consortia eligibility criteria for Canadian companies even more stringent. The Collins and Manton amendments to the House's bill of the 1993 *National Competitiveness Act* (H.R. 820) were alarming. The Collins amendment required "that no funds made available under H.R. 820 shall provide direct financial benefit to any person that is not a US citizen or national. This amendment would have bar any company, Canadian or American, with foreign shareholders, to participate in government-funded technology consortia."[16] Almost all companies whose stock is traded at American stock exchanges have foreign shareholders.

The Manton amendment also stipulated stringent eligibility criteria. In addition to the eligibility criteria required under the 1991 *American Technology Preeminence Act*, the US affiliates who wish to join the technology consortia would have had to agree "to promote the manufacturing within the United States" of products resulting from consortia research. And the affiliates would also have had to agree "to procure parts and materials. . .from competitive United States suppliers." The Manton amendment had also added a general, somewhat ambiguous, criterion: the parent country should have "a standards development and conformity assessment process that is open and transparent, and that results in standards that are fair and reasonable and do not discriminate against the United States products and production processes." This test can be applied to any national policy such as trade, foreign investment, taxation and so on.

The Senate version of the 1993 *National Competitiveness Act* (S–4) did not have provisions that are similar to the Manton and Collins amendments. Even US industry and business associations, such as the National Association of Manufacturers, the Organization for International Investment and the Industry Coalition on Standards and Trade oppose these amendments. These associations believe that if the amendments were to be included in the *National Competitiveness Act*, they would violate the national treatment obligations under the GATT, and this will invite retaliatory actions from US trading partners. The Clinton Administration did not support the amendments either. However, there is still cause for

[16] Indicated in letters addressed to Congress by the Organization for International Investment, National Association of Manufacturers and European-American Chamber of Commerce.

concern as the protectionist sentiment in the U.S. is not expected to vanish in any way in the near future.

6. THE GROWTH OF TECHNOLOGY CONSORTIA IN JAPAN AND THE EUROPEAN COMMUNITY

Japan is a leader in promoting technology collaboration among business firms, and co-operative research between companies is an important feature of the Japanese industrial structure. Since Japanese firms undertake relatively more basic and fundamental R&D, technology collaboration becomes a major mechanism of accessing such specialized research. Furthermore, unique business organizations, such as the Keiretsu, encourage technology consortia, especially vertical ones. The Keiretsu comprises a large number of big, diverse firms that are interlinked by mutual share holdings. They include well-known groups such as Mitsui, Mitsubishi and Sumitomo. The Japanese also have a cultural and business ethic that promotes co-operation rather than competition. This qualitative factor encourages extensive business linkages between companies.

In Japan, technology consortia have become an important instrument of government support for R&D, especially in the promotion of the basic research. About 80 percent of all government research loans are given to co-operative research. The Japanese government believes that the formation of technology consortia, because it helps companies pool resources and share risks, leads these companies to undertake larger and more ambitious technology projects at the technological frontiers.

Technology consortia in Japan are established by the formation of engineering research associations (ERAs) of business firms. The structure of the ERA is based on the British system of co-operative research associations, created after World War I to prevent the erosion of British technological leadership in the global economy. In the initial stages, ERAs focussed more on collaborative research among small- and medium-sized firms, but the focus gradually shifted toward large firms. Now, most of the active members of ERAs are large firms.

The ERA often conducts research at the members' own facilities, covering such diverse fields as polymers, aircraft jet engines, microelectronics, fine ceramics and biotechnology. Furthermore, they also promote research in enabling technologies that extends to a whole industrial sector. Firms rarely join an ERA joint research project just to get subsidies from the government. Specifically, they might participate in a project:

- to enhance operational efficiency by solving common technology-related problems;
- to obtain important technology information;
- to gain intelligence on research in other firms and in universities;
- to gain access to expertise in emerging new fields and to other ERA members' research facilities and equipment; and
- to participate in industry–government consultations through ERAs.

The Japanese ministry of international trade and industry plays a pro-active role in promoting technology collaboration between companies; ERAs are largely financed by government funds and are also encouraged by favourable government procurement programs, by favourable tax and regulatory policy and by accelerated depreciation on scientific equipment. ERAs receive about 50 percent of government research subsidies that provide "critical stimulus" to private R&D spending. In addition, the government uses several other policy instruments to increase the access of Japanese consortia to public laboratories.

The Japanese government has also established an independent Key Technology (Key-Tec) Centre whose function is to fund joint research proposals submitted by companies, usually basic research. The Centre provides equity capital to R&D companies that are engaged in co-operative research, loans to private joint venture R&D companies and basic infrastructure to collect and distribute technical information. The Key-Tec Centre provides 70 percent of funding and the remaining 30 percent comes from private companies. To obtain funding from the Key-Tec Centre, at least two firms must establish a joint research project.

We believe that the Japanese programs to promote technology collaborations have contributed significantly to their international competitiveness and have also encouraged the United States and the European Community to set up similar programs to stimulate joint research. In particular, American and EC programs to promote collaborative R&D arose in response to Japan's Fifth Generation Computer System Program.

The European Community has used various programs to stimulate technology collaboration. Two well-known programs are ESPRIT (European Strategic Program for Research and Development in Information Technology) and European Research Coordinating Agency (EUREKA). ESPRIT, launched in 1984, fosters precompetitive R&D collaboration in microelectronics, information processing systems and software, advanced business and home systems, and computer integrated manufacturing and engineering systems. It also sets standards and components to improve the international competitiveness of European information technology (IT) companies. The projects financed by ESPRIT must be sponsored by firms located in at least two EC member countries, and the level of financial support provided amounts to 50 percent of costs for companies and 100 percent for universities and research institutes. ESPRIT-supported research projects were valued at over C$5 billion from 1984 to 1992.

Several researchers have evaluated the technology collaboration projects supported by ESPRIT. They agree that the program has been successful and that it has had positive impact on the competitiveness of European information technology companies. Mytelka (1991) has shown that ESPRIT made the following contributions to European companies by:

- sharing costs and risks in R&D collaborations;
- encouraging further networking of European firms and extending the applications of existing or emerging technologies across various industries;
- increasing the technology knowledge base of small- and medium-sized companies;
- stimulating long-term basic research in technology collaborations with universities; and
- improving information about market trends and, thus, reducing market uncertainty.

The EUREKA program is a pan-European technology collaborative initiative. It was started in 1985 and includes the 12 EC members, the six EFTA countries and Turkey. EUREKA promotes collaborations in "market-oriented" research by focussing more on the introduction of new products, production processes and services. It supports R&D projects in sectors including communications, energy, environment, information technology, lasers, medical/biotechnology, new material, robotics and production automation. The level of financial support to collaborative research projects ranges from one third to one half of costs. EUREKA-supported research projects were worth C$12 billion dollars from 1985 to 1991.

Again, public funding is not the primary motive for companies to participate in the EUREKA program. They take advantage of this research collaboration opportunity in order to benefit from the cross-fertilization of research ideas.

Foreign-owned companies in the Europe Community and Japan do not usually get equivalent treatment in government-supported technology collaboration. Therefore, foreign (including Canadian and American) participation in Japanese or European Community technology consortia is low (Dodgson, 1993). For example, although IBM is a major R&D performer in several European countries, it was not easy for IBM to join the ESPRIT program. It presented over a dozen research proposals to ESPRIT, but was only accepted with some hesitation. "If IBM were to be included, then the EC would be supporting a US firm's research, and allowing it access to European research results." (Dodgson, 1993, p. 114).

7. CONSULTATION WITH CANADIAN RESEARCH COMPANIES

In March 1994, Industry Canada carried out consultations with the Canadian research community through two workshops, one in Toronto and the other in Montréal. Participants came from Canadian companies, research institutes and universities (their names appear in Appendix 2). At the workshops, discussion revolved around three broad themes. First, the reasons why Canadian participation in foreign technological consortia, especially American consortia, is low. Second, the barriers, legal or institutional, Canadian companies face in participating in foreign technology consortia. Third, the role the government should play in promoting technology consortia. To this end, a few case studies where Canadian firms are participating were presented.

Several participants in the workshops expressed the view that Canadian participation is low only in precompetitive technology consortia. This is mainly attributable to the fact that Canada does not have the "instinct" or culture of doing precompetitive R&D. Canadian companies, for the most part, are small-and medium-sized enterprises, and they specialize in market niches. They often form technology alliances in order to undertake "near-market" or applied research and market alliances to compete effectively in the global marketplace. If the scope of this study were to be extended by focussing more on the formation of alliances other than precompetitive technology consortia, Canadian performance in the field of strategic alliances would be seen to be remarkable. Several participants, therefore, recommended that this research study on technology consortia be extended to focus more on Canadian SME activity in the formation not only of precompetitive technology consortia but also of joint ventures, strategic alliances, and shared R&D and production contracts.

It was generally felt at the workshops that there are real barriers to Canadian participation in American, European and Japanese technology consortia, although barriers are stronger in Europe and Japan than in the United States. If Canadian companies or American subsidiaries operating in Canada have expertise in some technology and possess strong R&D infrastructure, they are often invited to join in government-funded technology consortia in the United States. For example, Northern Telecom has strong R&D capability, and is playing an active role in a number of US consortia, while Pratt & Whitney Canada, with its expertise in the manufacturing of small aircraft engines, has been invited to participate in technology consortia funded by the US government.

Divergent views were expressed about the role of government policy in encouraging the formation of technology by various participants at the workshops. Some people suggested that the Canadian government should encourage domestic technology consortia by providing direct subsidies or by providing favourable government procurement. On the other hand, other participants indicated that the government should avoid giving direct subsidies or tax benefits to members of Canadian technology consortia because it might cause Canadian companies to become dependent on government handouts. In their view, the government should confine its intervention to providing stronger R&D and university infrastructure or to facilitating the formation of horizontal consortia that emphasize basic research, thus playing a catalytic role in consortia activities. The latter was a more common view at the workshops.

Some participants suggested that Canada does not have specific programs for encouraging technology consortia, and that before worrying about Canadian participation in foreign consortia, Canada should first gain experience and credibility in building technology consortia of domestic firms. At the moment, Canada does have a few domestic technology consortia but they are not operating very well. Their focus is on short-term gains and on near-market rather than precompetitive research, and consortia members often cannot decide what technologies should be developed through joint research. It follows that the Canadian government can play an important role by designing new policy initiatives that will promote joint precompetitive research among domestic firms.

8. CONCLUDING REMARKS

In this paper we have discussed the profile of US technology consortia and the extent of Canadian participation in them. The profile was developed after our survey of 15 leading American consortia. There have been rapid increases in the formation of R&D consortia after the 1984 *National Co-operative Research Act*. Now, about 350 consortia operate in the United States, predominantly in high-tech industries, with most initiated by the private sector (only one out of 10 consortia is initiated by the government). The primary goal of most consortia is precompetitive research and the secondary goal is product development. The majority of US consortia have fewer than 100 members (only one in five consortia has more than 100 members) and consortia funding is mostly provided by government–industry shared programs, with only 40 percent of consortia funded solely by the private sector.

Although the participation is relatively small, Canadian companies do participate in American R&D consortia. In the sample survey, we observed that only one of 60 consortia members is Canadian. More seriously, Canadian firms are not allowed to participate in key leading consortia that are funded by the US government. Canada, for instance, is restricted from participation in collaborative R&D projects supported by the NIST's Advanced Technology Program and SEMATECH, and also from those research projects undertaken by the National Centre for Manufacturing Sciences. If the Collins and Manton amendments had been accepted by the US Congress and included in the *National Competitiveness Act*, Canadian companies would have been completely barred from participation in US government-funded R&D consortia. We are quite concerned about the development of a protectionist sentiment since federally funded consortia are expected to proliferate under the Clinton Administration, which plans to increase significantly the number of technology consortia under two expanded technology programs—the Advanced Technology Program and the Advanced Research Project Agency. It appears that the doors are almost closed for Canadian companies to participate in these two major technology programs. The Clinton Administration has adopted a new technology policy that is concerned with how government and industry can co-operate to harness innovation and improve economic performance (Burton, Jr., 1993). We expect that the US government will become increasingly more protectionist and that it will ask for reciprocal relations when sharing new technologies with other nations.

In our interviews with consortia and government officials, three additional barriers to Canadian participation in American consortia were indicated. First, there is a stand-off on an umbrella intellectual property agreement between Canada and the United States. The United States wants to sign a bilateral agreement that sets out general guidelines about sharing the intellectual property results from collaborative research. Second, it appears that Canadian companies are less interested in American consortia because they do very advanced R&D which Canadian firms find difficult to translate into products quickly. Canadians are more interested in applied research with quicker commercial results. Third, Canadian companies find that membership fees of US consortia are too high.

APPENDIX 1
Overview of Some Selected R&D Consortia

PRECARN (PRECompetitive Applied Research Network)

Year of establishment:

1987

Purpose:

To develop a better awareness and competence within Canadian industry of current and future potential of "intelligent systems" of all kinds.

Highlights:

PRECARN is a non-profit organization.

It promotes long-term, precompetitive research in the area of robotics and artificial intelligence.

It brings together industry, governments and universities.

It also brings together both the users and producers of new technologies.

PRECARN established IRIS in 1990 under the federal Network of Centres of Excellence Program. As outlined in the proposal, PRECARN is charged with the general management of the IRIS Network.

Membership:

Every member of PRECARN is afforded full briefings on research as it is performed and access to all resulting technology.

Members make an annual donation to the program and participate actively in the management of the projects. Larger member companies contribute to the research effort itself.

Members and their affiliates are entitled to the use of intellectual property arising from a research agreement for work carried out with or on behalf of PRECARN in accordance with the licensing policy of PRECARN.

Non-confidential publication of research results will not be permitted until six months after they have been made available to members on a confidential basis, and then afterwards only on approval of PRECARN. Advance approval may be granted by PRECARN in special circumstances. Ownership of any intellectual property rests with PRECARN.

PRECARN has 39 members including: Alberta Research Council, Alcan International Ltd, Asea-Brown Boveri Inc., Atomic Energy of Canada Ltd., BNR, Canadian Institute for Advanced Research, Spar Aerospace, Hewlett-Packard, Shell Canada, Ontario Hydro, Petro-Canada Resources and Xerox Research Centre of Canada. Associate members include the Department of Natural Resources, National Defence and the National Research Council.

Projects:

Its approved projects are:

APACS: Advanced Process Analysis and Control Systems
ARK: Autonomous Robot for a Known Environment
TDS: Telerobotic Development System
IGI: Intelligent Graphic Interface

Its approved feasibility studies are:

MAP: Mining Automation Project
CORFFA: Control of Robots for Future Applications

PRECARN will receive $23.8 million over four years for the support and management of 22 university-based research projects that make up IRIS, including: Computational Perception, Knowledge-Based Systems and Intelligent Robot Systems.

PRECARN is also conducting a feasibility study for a new project slated for 1994 called TIPS (Team-based Intelligent Productivity Systems).

SMC (Strategic Microelectronics Consortium)

Year of establishment:

1991

Purpose:

To assist the Canadian microelectronics industry achieve sales greater than $1 billion by the year 2001.

To support the development of high-density packaging techniques such as hybrid technology, multi-chip modules, PCMCIA cards and smart cards.

To support the development of ultra-low power RF and digital circuitry for applications in personal communications.

To support the development of low-cost fast-response prototype IC manufacturing using direct write systems.

To increase the competitiveness of its members through the TQM program leading to ISO 9000 certification.

To raise capital for members by making their requirements known to sources of investment capital.

To create alliances between regular members and associate members to enhance their designs for world markets, and to enhance services, equipment and software.

Highlights:

SML is a non-profit corporation.

It is a consortium for new product/process development that has immediate or mid-term revenue generation capability.

Membership:

SMC's total membership is 21. A regular member is defined as a company engaged in the design, development and sale of microelectronic components or technology for the open market. Benefits offered to regular members are:

- networking opportunities through regular meetings of the SMC;
- access to fast-growing new areas not currently being served by existing microelectronic R&D activities; and
- alliance agreements enabling new products and processes to be developed at a lower cost.

Some prominent members are: ATI Technologies Inc., C-MAC Industries Inc., Creation Technologies, Epitek Microelectronics, IBM Canada, LSI Logic Corp. of Canada Inc., Mitel Semiconductor, Newbridge Micro Systems Inc. and Northern Telecom,

Funding:

Funding through the IC's STP and MSDP programs covers project costs up to 50 percent with the balance of funding coming from project members.

Projects:

Projects include: Low Power Projects, High Density Packaging, Video and Multimedia, General Microelectronics and Quality Improvements.

SIMCON (Software for Integrated Manufacturing Consortium)

Year of establishment:

1990

Purpose:

To pool the resources of industry, the NRC and universities to develop prototypes of products that demonstrate integrated solutions to manufacturing problems. Industrial partners receive a royalty-free licence to exploit the technology commercially. By sharing costs and resources, companies can lower their individual risk factor and leverage a much broader base of skills, experience, and capital assets.

Highlights:

SIMCON is a non-profit organization.

It conducts precompetitive research.

It is based at the labs of NRC's Institute for Information Technology.

Membership:

Although the aim is to have 10 corporate members, SIMCON's current membership is three. They are Electronic Data Systems Canada Ltd. (EDS), which offers information processing services; Interfacing Technologies Corp. (ITC), which specializes in integrated manufacturing information systems and CIM solutions for small- and medium-sized manufacturers; and Phoenix Systems Synectics Inc., which is involved in a broad range of real-time and object-oriented systems engineering.

Each company pays an annual fee of $5,000 and dedicates one full-time engineer to consortium work. NRC matches the number of engineers committed by the industrial side and provides the combined R&D team with computers, equipment, office space and administrative support.

The cost to corporate members is being kept to a minimum through contributions from NRC and anticipated support from the Strategic Technologies Program of Industry Canada which has already contributed $100,000 toward a feasibility study. An application will be submitted requesting further assistance to reimburse the corporate partners for up to 50 percent of their expenditures, a contribution that is expected to total about $6 million over three years.

Projects:

At present, there are three projects under way: Manufacturing Data Integration, Enterprise Modelling and Assembly Management Information systems.

VISION 2000

Year of establishment: 1989

Purpose:

To accelerate the implementation of advanced personal communications systems and technologies in Canada.

To facilitate co-operation among companies to provide Canadian industry and individuals with the best tools in advanced personal communications systems. The result will be an expansion of the Canadian market and the restoration of Canada as a key player in international personal computer and information technology markets.

Highlights:

Vision 2000 is a non-profit corporation which is a partnership of industry, government and academia.

It works closely with government agencies.

It is concerned with the stages of feasibility, development, trial and implementation of a product/project but not precompetitive research.

Projects:

Vision 2000 has identified seven key focus areas that would benefit from an integrated industry strategy approach: a national public system for the interchange of messages, text, data and images; mobile/remote personal terminals; multimedia data bases and networks; desktop video; personalization of the network; secure integrated communications networks; and bandwidth of the future. The time frames for the projects range from two to 16 years.

Project selection criteria are as follows. Will a project:

- provide a benefit to the user by moving forward toward the integrated advanced personal communications world of the future?
- consist of technologies suitable for Canadian development?

- provide an expansion of market opportunities for the participants?
- provide a clear path for policy evolution by government?

Membership:

The total membership is 43. Some well-known members are: IBM, Ernst and Young, Mitel, Motorola Canada, Canada Post Corporation, BCE Mobile Communications Canada, Canada Marconi Companies, NRC, SPAR Aerospace, Unitel Communications Inc., Sotham Inc., University of Manitoba and University of Toronto.

Regular (full voting rights) and associate (non-voting) memberships are available. For associate members, there is a flat fee of $1,000 (+GST), while for regular members the fee varies based on the annual revenue of the member company. The fee range is from $1,000 (for less than 5 million annual turnover) to $28,000 (for more than $200 million annual turnover).

There is no requirement that all of the members of a sub-project consortium be members of Vision 2000. Members are therefore free to invite any entity to join them in a proposed venture. However, only members are invited to participate in focus project planning activities.

The operation of sub-projects has to be autonomous except for the commitment to report to the focus project on major schedule milestones and critical dependencies, and on technical issues relating to system functions, cost and interface compatibility.

Funding:

The funding of sub-project activities is the responsibility of consortium members. Vision 2000 assists in the preparation and presentation of sub-project funding proposals to the government on request.

SSOC (Solid State Optoelectronics Consortium)

Year of establishment:

1988

Purpose:

To create a Canadian capability in integrated optoelectronics research, and to establish an environment and infrastructure which will enable Canadian industry to achieve leadership in the economic introduction and profitable exploitation of systems and products based on this technology.

Highlights:

SSOC is incorporated as a federal non-profit research corporation.

Its core research program is based at the NRC's Institute for Microstructural Sciences.

The SSOC consists of three parts:

- the SSOC/Member Program, funded by SSOC members and contracted to NRC, universities and companies;
- the SSOC/NRC Program, funded by NRC and performed at NRC by NRC staff; and
- the NRC-Related Program which is part of the regular programs of the Institute for Microstructural Sciences that relate to optoelectronics.

Membership:

SSOC has members (industrial) and research affiliates (non-industrial). There are three classes of industrial memberships: principal, senior and associate membership.

The consortium also taps the expertise of universities that deal with solid state optoelectronics. Five universities invited to participate in SSOC programs are McMaster University, Queen's University, University of Toronto, University of British Columbia and the Technical University of Nova Scotia. Its research affiliates are the National Research Council

(NRC), the Communications Research Centre (CRC) and the National Optics Institute (NOI). Its members are BNR, Digital Equipment of Canada Ltd., EG&G Optoelectronics, ITS Electronics Inc., Lockheed Canada Ltd., MPR Teltech, TR labs and Spar Aerospace.

Projects:

Current projects include: GaAs devices, PIn devices, electronic devices and international review.

CARC (Canadian Audio Research Consortium)

Year of establishment:

1990

Purpose:

To conduct precompetitive research in order to develop a new generation of adaptive loudspeakers.

Highlights:

CARC is a non-profit organization.

There is a collaborative agreement between the consortium and NRC. Projects are conducted in the NRC labs where scientists from industry and NRC work together.

Membership:

The membership fee is same for each member. Its four members are Global Audio Products International, PSB Inc., Paradigm Electronics Inc. and State of the Art Acoustiks.

Project:

Its main project is called ATHENA.

APPENDIX 2

List of Participants in Workshops in Toronto on March 24, 1994, and in Montréal on March 28, 1994

Benoit Amar	Focam Technologies	Montréal
Louis Berlinguet	Conseil de la Science et de la Technologie	Montréal
Jean Bourbonnais	Alis Technologies Inc.	Montréal
Sarah Bradshaw	Ministry of Economic Development and Trade	Toronto
Gilbert Drouin	École Polytechnique	Montréal
Simon Dyer	Conseil national de recherche du Canada	Montréal
David Edwards	Strategic Microelectronics Consortium (SMC)	Toronto
Philippe Eloy	Ministère de l'industrie, du commerce, de la science et de la technologie	Montréal
Jacques Germain	Hydro-Québec	Montréal
Christiane Grignon	Applied International Economics Inc.	Montréal
David Heaslip	ORTACH	Toronto
Roger Heath	Industry Canada	Toronto
Allan Kennedy	Telecommunication Consortium of Canada (TCC)	Toronto
David Kinsley	Industry Canada	Toronto

John Knubley	Industry Canada	Montréal
Real L'Archeveque	Agence spatiale canadienne	Montréal
Laval Lavallee	Applied International Economics Inc.	Toronto
Marie Lavoie	Département de génie industriel Polytechnique	Montréal
Sunder Magun	Applied International Economics Inc.	Toronto
Gilles Mcdougall	Industrie Canada	Montréal
Stephen Oikawa	Bell Canada	Montréal
Ross Preston	Industry Canada	Toronto
Someshwar Rao	Industry Canada	Toronto
Marie-Josée Roy	Département de génie industriel Polytechnique	Montréal
Serge Roy	Hydro-Québec	Montréal
Mukerjee Sidhahartha	Ministry of Economic Development and Trade	Toronto
André St-Pierre	Industrie Canada	Montréal
André Vaillancourt	Bell Québec	Montréal
Peter Wysoski	Ministry of Economic Development and Trade	Toronto
Tsukasa Yoshinaka	Pratt & Whitney Canada Inc.	Montréal

APPENDIX 3
QUESTIONNAIRE

Name of the Consortium

Name of the Contact Person

Address and Phone #

Purpose

1) To understand the U.S. Consortia with respect to their purpose, structure, policies etc.

2) To determine the extent of Canadian participation in the U.S. Consortia.

I Who initiated the Consortium?

- i Government
- ii Private Sector
- iii Others

II i When was this Consortium formed?

ii What is the time-frame for the Consortium?

a Open-ended

b Limited time-frame Time span

III What is the purpose (primary goal) for the formation of this Consortium?

i Pre-competitive (i.e. mainly for basic research) ii Product development (i.e. for producing new products, adding new features to the products etc.)

iii Creation of alternative standards

iv Cost cutting by sharing process technology or achieving economies of scale

v Any other reason

IV What is the total current budget for this Consortium?

V How is the Consortium funded?

i Private funding

ii Federal/State funding

If Federal/State funding, then how does it influence decisions with regards to Foreign/Canadian firms participation in the consortium?

VI Membership

i Total membership?

ii How has the membership grown over time?

iii Out of these members, how many are

a Canadian members?

b Other foreign members?

iv List of Canadian members

Name of the Firm	Name of the Firm	Name of the Firm
Contact person	Contact person	Contact person

VII What are the reasons for not having Foreign/Canadian Firms?

i No Foreign/Canadian Firm approached to participate

ii Firms approached but could not be allowed because:

a

b

c

VIII What type of foreign/Canadian firms can become members of the Consortium?

i Subsidiaries of foreign parent firms that are incorporated in the U.S.

ii Firms having no operations in the U.S

iii Any other type of firms

IX What type of membership is offered to the participants?

	American firms	Canadian firms	Others
i Shareholders			
ii Full-membership			
iii Associate-membership			
iv Small Business Associates			

X Do you have a membership fee? YES / NO

If YES,

i Fees for American firms

ii Fees for Canadian firms

iii Fees for other foreign firms

XI Do foreign firms have voting rights? YES / NO

If YES, What is the basis?

i Membership fees?

ii Technical strength of the applicant firm?

iii Any other reason?

XII Do foreign/Canadian firms have full accessibility to all the information? YES / NO

If NO, What are the reasons?

i

ii

iii

XIII What is the R&D arrangement?

i Consortium has its own R&D Lab

ii Firms share their R&D

iii Any other reasons

XIV What is the arrangement for ownership of the intellectual property?

	American	Canadian	Others
i Common property to all members			
ii Each firm remained the owner of its own R&D results i.e. firms just traded their R&D results			
iii All intellectual property belonged to the lead firm			

XV Have you taken any patents? YES/NO

If Yes, How many?

XVI What are the problems faced in effective working of the Consortium?

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