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A CONCEPTUAL FRAMEWORK FOR ASSESSING LINKS BETWEEN GOVERNMENT PROGRAMS AND INDUSTRIAL NEEDS

Prepared for Industry Canada

SECOR

May 1994

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INTRODUCTION

- Groupe Secor received a mandate from Industry Canada to formulate a conceptual framework for assessing links between government programs and industrial needs.

- The framework was developed by using:

  - findings that Secor has gathered in numerous interviews with innovative firms in Canada and in other industrialized countries;

  - literature review;

  - input from industry specialists within Industry Canada;

  - interviews and discussions with Industry Canada staff.

- The findings were delivered in two presentations. The first was conducted with senior managers of Industry Canada and the second with a larger group of sector specialists. The report captures comments that were made at both meetings. In addition, Industry Canada staff reviewed a draft version of this report and provided written comments that were used to refine the text.

- While Industry Canada staff contributed to this document, the opinions expressed are those of Groupe Secor and are not necessarily those of the department.

- This document contains copies of the overheads that were used in the presentations together with explanatory notes on numbered pages that follow each overhead. The notes are intended to flesh out the content of the overheads so as to make the entire package more readable and comprehensible.

- We would like to thank the Director General and members of staff of the Science Strategy group for their generous help, support and encouragement in this project and the specialists who contributed their expert knowledge of industrial sectors.

PROJECT GOALS

- The objectives of this study are :
  - to show broadly how firms' approaches to innovation vary by industrial sector.
  - to identify some of the factors that differentiate strong and endangered firms.
  - to devise a framework to assist the design and application of tools relevant to Industry Canada.

Overhead #1

- Approaches to innovation vary according to industrial sector. For example, the pharmaceutical sector depends upon basic research in order to develop new drugs while the pulp and paper industry often acquires innovation that is embedded in new machinery.

- Various facets of innovation have been described in the literature by looking at some of the behavioral characteristics of firms and by grouping like firms across industrial sectors. While the results of such studies are valid, the results do not easily lend themselves to the construction of a model that is simple, logical and has some predictive power.

- We have found that the innovative behaviour of firms can be readily understood by considering the position in the R & D spectrum at which they begin their innovation. For example, firms that begin their innovation with basic research behave in much the same way. Others that are production-oriented such as food processors and metal refiners share a common behaviour that is quite different to that of the research-oriented firms but is nevertheless readily comprehensible in terms of the model. We have applied this model in a study on National Systems of Innovation conducted for the National Research Council and in a study of the biotechnology industry for the Premier's Council of Ontario.

- This simple model, based upon starting points for innovation, will be used in the development of the conceptual framework that establishes links between government programs and industrial needs.

Strong and endangered firms

- An important component of this project is to identify some of the factors that differentiate strong and endangered firms and to see the extent to which these vary according to industrial sector. Endangered firms are not necessarily beyond redemption so long as they recognize their situation and are motivated to save themselves. Chrysler is an example of a firm that achieved a last minute reprieve.

- Vulnerable firms lie between the strong and endangered. Such firms sometimes falter by failing to recognize an impending shift in technology, e.g. typewriter manufacturers at the dawn of word-processing or horseshoe makers at the advent of the automobile. Most often, deficiencies in management rather than shifts in technology lead to untimely demise.

- Industrial development and its links to innovation are complex phenomena that give rise to a number of important questions:

  - Why are some firms more innovative than others and is this an important success factor?
  - Should all industrial sectors be committed to a basic research effort?
  - Is value-added a good guide to the innovative capacity of firms?
  - Is the proportion of knowledge-based employees in the workforce a good indicator of successful firms?
  - Why do industrial statistics fail to produce much in the way of useful information to guide industrial policy?
  - Why do most firms have such inordinate difficulty in interacting with university researchers?
  - Why does economics have so little to say about innovation?
  - Why do some firms collaborate through trade associations, others through strategic alliances and some through industrial consortia?
  - What makes some firms focus on extremely refined technology for years and then suddenly explode into a broad diversification strategy?

- Why do technologically oriented firms agglomerate around big cities and why are some cities renowned for certain industrial specialities?
- Are capital intensity, numbers of patents, or R & D expenditures good indicators of firms that are likely to succeed?
- Is it important to sustain a world-view or can firms survive by focusing on their local regions?
- What differentiates weak and strong firms and are these factors sector-specific?

- In this document we present a simple framework that attempts to answer these and other questions.
- The framework is based on our finding that the behaviour of firms can be easily understood by looking at the point in the R & D spectrum where they begin their innovation. In general, this starting point is sector-specific.
- We believe that the framework can be a useful tool in the design of government programs.

INDUSTRIAL ECONOMIES ARE UNDERGOING RADICAL CHANGE

- **Key sources :**
  - Technological revolution - computers operating in real time.
  - Highly efficient communications.

- **These lead to :**
  - Knowledge-based production.
  - An information revolution based on fast data transmission and analysis.

A radical change in mechanisms for wealth generation is taking place.

Overhead #2

INDUSTRIAL ECONOMIES ARE UNDERGOING RADICAL CHANGE...

- This radical change :
  - Affects all sectors of the economy
  - Redefines competitive advantage
  - Changes market power
  - Demands technological restructuring

Overhead #3

- The nature of structural shifts in the economy have recently been discussed in presentations to Industry Canada by Richard Lipsey and Marcel Côté. Both economists agree upon the impact of the technological revolution brought about by computers operating in real time.

- Lipsey identifies technological change over the last century as the agent that has produced the very high standard of living that the industrialized world now enjoys. In addition to the role of computer technology in shaping the world economy, Lipsey identifies the steady reduction of transportation costs as a powerful influence in determining where goods are produced.

- While concurring with Lipsey's general thesis, Côté argues that computer-induced change leads to short-term upheaval especially in employment. He likens the impact of the computer-based revolution to that which took place when mass production of the automobile was introduced. That technological revolution created suburbs, drive-in movies and allowed easy delivery thus changing patterns of production and distribution.

- The automobile led to the elimination of many traditional jobs. These were not replaced by emergent new industries for more than a decade. By analogy, computer-based technology is deemed to be an important factor in today's structural unemployment.

- New industries based on the computer will emerge. Many workers such as architects and engineers will need extensive retraining. Not all new jobs will be extremely advanced. The computer age will have its equivalent to the gas-pump attendant.

- Few sectors have escaped the impact of the computer operating in real time. Automobile engines and microwave ovens are regulated by microprocessors. Aircraft fly "by wire". Drugs are designed with the help of computer modelling of protein structures. Retailers place orders with wholesalers based on automatic inventory control thanks to the presence of laser readers at cash registers.

- In a competitive environment, computer-based technology offers another tool through which a firm can gain advantage over its rivals.

- Market power is increasingly captured through the rapid accumulation of knowledge about consumer expectations and the positioning of rivals.

- Above all, those who fail to exploit computers operating in real time will be disadvantaged with respect to their rivals. Restructuring to take advantage of computer and information technologies will be a key success factor for firms over the next decade.

IMPACT OF CHANGE

Change	Example
Product and process innovation increasingly science-based	Biotechnology
Product life cycles dramatically shortened	Automobile production
Up-front costs for product development increasing	Pharmaceuticals, complex microprocessors
A global market place is emerging	24-hour financial trading
Productivity increasing rapidly	Banking

Overhead #4

- Change based upon the rapid dissemination of new knowledge has caused process and product innovation to be increasingly science-based.

- Biotechnology, for example, is being used to produce remarkable health-care products such as human insulin, growth hormones, blood factors for haemophiliacs, vaccines for hepatitis B and cytokines for cancer treatment. It is also used to immobilize enzymes on solid surfaces for cheese and yoghurt production. A Canadian firm hopes shortly to sell a genetically engineered yeast to be used in the fermentation of champagne.

- The interrelationship between new technologies and computers is illustrated in a biotechnology case that has been supported by Industry Canada - the Human Genome Project. The genome is now being deciphered at the rate of tens of thousands of bases per day. The most pressing problem that scientists now face is how to store and analyze the information.

- Reduction of product life-cycles reflects the ability of firms to engineer new products extremely rapidly thanks to computer assisted design tools and simulation. The computer also captures and interprets consumer preferences and translates them into production. In Japan, for example, customers specify all of the options they want on a new car and have it delivered to their door within three weeks. This is customized mass-production.

- The increased investment in knowledge required for innovation and production has, concurrently, increased the up-front investment necessary for many products. A single new pharmaceutical product requires an average investment of $300 million before it reaches the marketplace.

- Rapid computer-based communication systems have also led to the emergence of global financial markets. Twenty years ago, traders on the London Metal Exchange could make a healthy income by arbitraging copper between London and New York by using telex, pencil and paper for calculation, and the telephone. Now the arbitrage game in stocks is played on-line and with immense complexity by trading options on shares and share indices. The ambitious trader need never sleep. He or she can move with the sun from market to market around the world, trading from the keyboard of a computer.

- This massive introduction of computer technology is leading to dramatically increased productivity - the supermarket checkout being a prime example. Voice recognition by personal computers will lead to a further quantum leap in productivity within the next three to five years.

- Lay-offs in Canadian banks, and in major industrial firms generally reflect productivity gains rather than any demise in their financial fortunes.

REACTIONS TO RESTRUCTURING

- Firms react to technological change by :
  - reducing costs of development and production
  - marketing more effectively
  - redeploying activities into new markets and methods of production
  - innovating, which takes longer and is often an incremental activity

Reducing costs, marketing and redeploying improve performance in the short-term.

Innovation is most important
and leads to long-term growth.

- Reducing costs of development and production, marketing more effectively or redeploying into new markets and methods of production are obvious and short-term responses to the impact of technological change.
- The best response to changing technology is to exploit it through innovation. By innovation we mean the successful introduction of a new product or process into the marketplace.
- Innovation is generally carried out in small increments. Radical innovations occur infrequently.
- Innovations are often developed in response to problems. The transistor was developed to satisfy Bell Telephone's need for a solid state amplifier to replace the vacuum tube.
- In numerous interviews, we have found that firms with above average performance for their sectors are those that are committed to innovation. In production-oriented sectors they may carry out little research but may buy the ability to innovate from suppliers of equipment. In research-based sectors, innovation may be generated within the firm. Although successful firms in different sectors develop innovation in different ways, their commitment to innovation is always strong.

PERSPECTIVES ON INNOVATION

Innovation is the successful introduction of a new product or process. It is :

- mainly conducted by firms, not research institutions, universities or government;
- concentrated in large urban areas rich in human resources and supplier networks;
- driven by external pressure from competitors and internal pressure within firms from entrepreneurs and champions of innovation;
- carried out differently according to industrial sectors and the sizes of firms;
- a social phenomenon influenced by long-term relationships between firms, their suppliers and customers.

Neoclassical economics says little about innovation. It can only describe the economy in terms of fairly stable states that are regulated by price-sensitive equilibria.

Innovation leads to radical change in economic states. Relationships between key players tend to be price insensitive. Trust, loyalty, confidence are important factors.

Overhead #6

- Since innovation involves the successful introduction of a new product or process into the marketplace, it is almost always conducted by firms.

- Government funded infrastructures that seek to support innovation have been described in many studies as "national systems of innovation". The term is something of a misnomer. When formulating policy to promote innovation, it is vital to focus on firms and their industrial sectors. Modern studies of systems of innovation are of limited value when they fail to maintain this essential focus.

- Clusters of firms in a given industrial sector are frequently found in major cities, e.g. computers (Boston), telecommunications (Ottawa), pharmaceuticals (Montreal), biotechnology (San Francisco).

- Clustering has occurred throughout history, e.g. violin making in Cremona, Italy. It depends mainly upon high concentrations of knowledge-based workers that occasionally transfer their allegiance from one employer to another or that decide to form their own firms.

- The phenomenon of clustering reflects the importance of the apprenticeship style of learning as a means of transferring knowledge.

- Clusters also attract competent suppliers and often rely initially upon local consumers.

- In Canada, much of our population is concentrated in a few major cities as are many knowledge-based industries. For example, the biotechnology, pharmaceutical and space industries are concentrated in Montreal, Toronto and Vancouver.

- Regional development policy often seeks to embed new industries in centres of low population. Important niche industries in smaller centres of population do spring up, e.g. software engineering in Halifax and Fredericton. These particular examples have been seeded by a flow of highly qualified university graduates from local universities. However, when regional development policy attempts to build new industries in small centres of population it is attempting to buck an important social phenomenon. As such it should be executed with considerable care, foresight and planning or should not be attempted at all.

- Innovation is driven by competition from rival firms and client demand. Frequently, the innovation that results from these drivers is incremental in style.

- Greater leaps in innovation are often driven by renegades or impatient pioneers. These are either entrepreneurs that form their own firms or champions of innovation in larger firms.

- The role of the champion has been well documented in the literature. These tenacious individuals stubbornly stick to an innovative idea until they manage to overcome the inertia of the companies for which they work so that development takes place. In some instances, employees fail to motivate their firms to develop their chosen process or product. When this happens, employees often leave to form their own companies creating a "spin-off". The former employer is generally the first customer of the new off-spring.

- Innovation is carried out differently by firms in different sectors. Numerous examples abound. Design and the use of new materials are the essential components of innovation in haute couture while research skills in cellular biochemistry are keys to success in the pharmaceutical industry.

- The importance of social phenomena in innovation cannot be overlooked. Relationships between firms their suppliers and customers are often fairly price insensitive. Trust, confidence, quality of product tend to be important sustainers of these relationships. Quality rather than price-oriented relationships lead to new innovation.

- A classic example of variations in these kinds of relationships is found in differences of behaviour between North American and Japanese car manufacturers in the nineteen eighties. The North American firms tended to be vertically integrated following the model of Henry Ford. Roughly, 20% of parts were supplied from outside the firm. Suppliers competed vigorously on price, often by sacrificing quality in manufacture. By contrast, firms like Toyota purchased 80% of their components from suppliers. Two or three suppliers for a given range of components were selected. Delivering components on time and to exacting quality standards was more important than price. Generally, Toyota held some equity in its supplier firms. Japanese cars produced under these conditions typically had one third as many defects as their North American rivals.

  The same practice has been applied by Japanese car assembly plants in Britain. The approach has led to dramatic improvements in the efficiency and technical skills of British parts suppliers who are now capturing important markets in the rest of Europe.

- Neoclassical economics fails to capture the significance of these relationships. As a starting hypothesis, it assumes that supplier-customer relationships are at arms length and completely price sensitive. It, therefore, has very little to say about innovation which is intrinsically a social phenomenon.

- Neoclassical economics treats states of the economy by using equilibrium models. It says little about the way in which radical changes occur between states as may be caused by the introduction of a pervasive new technology.

- During our discussions with Industry Canada sector specialists, the question arose as to whether a new management technique represented an innovation. For example, most felt that the production line approach developed by Ford was indeed an innovation. There was less consensus as to whether Japanese "lean-production" was innovative. Some experts viewed the statistical approaches to quality management in the Deming style as simply a means of reducing waste while others felt that it was truly innovative. At their inception, these techniques allowed Japanese firms to gain competitive advantage. Now that they are well understood, they offer new converts a means of catching up with the leaders but not of surpassing them. In this sense, the approach was innovative at the outset but has now fallen into the realm of best practice.

WEAKNESSES OF CLASSICAL INDICATORS OF INNOVATION

Examples of Classical Indicators	Limitation
Patents	Used mainly by certain sectors, e.g. pharmaceutical; by contrast, innovations of most industries are protected by other means, e.g. trade secrets, marketing.
Capital intensity	Many firms now invest more in the knowledge of their workers than they do in plant and equipment.
R&D expenditures	What constitutes R&D varies greatly between sectors, e.g. car manufacturers often classify redesign work as R&D.

The limited usefulness of classical indicators represents a major problem for the development of policy instruments.

Reliable measurements of the worth of intangible assets have yet to be established. This hinders the financing of modern innovation.

- Classical indicators of innovation are frequently unreliable guides and should be used with great care in the formulation of policy instruments. Patents are a good case in point.

- Patents are used to protect intellectual property by firms that begin their innovation with fairly fundamental research such as drug companies. Beer makers and food processors have extremely limited ability to protect innovation through patent since their products are readily emulated and their patents are easily circumvented. In these fields, innovations are protected through aggressive marketing and trade names.

- Capital intensity is also an unreliable indicator. The computer-based technological revolution has also led to a situation where the value of products often reflects the knowledge of the workers that designed and built them. The low cost of the material content but high selling prices of most electronic products serve as good examples.

- Capital intensity, i.e. the investment in plant and equipment is an equally poor indicator of innovative capacity. Many firms now invest more in the knowledge of their workers than they do in plant and equipment.

- Investment in knowledge is causing a major headache for the banking and investment industries which find it very difficult to evaluate assets in technology-based companies and are now wrestling with these issues.

WHO INNOVATES?

- Studies of innovation that trace the successful introduction of new products or processes to their origins have rarely been carried out.

- Those studies which have been conducted show that :
  - 50% of innovations come from small or medium-sized firms with less than 500 employees;
  - 50% of innovations result from technology transfer between firms.

- Government can be an important driver of innovation through procurement, e.g. in transportation, civil engineering, health care, aerospace and by setting standards.

Overhead #8

- The literature contains many studies on innovation. Rarely have these been carried out by looking at the introduction of an important new product or process and by tracing it back to its source.

- A careful study that traced innovations to their origins revealed that small and medium sized firms were responsible for roughly 50% of them.

- The study also revealed that about half of all important innovations are exchanged between firms, e.g. when embedded in equipment or through technology transfer.

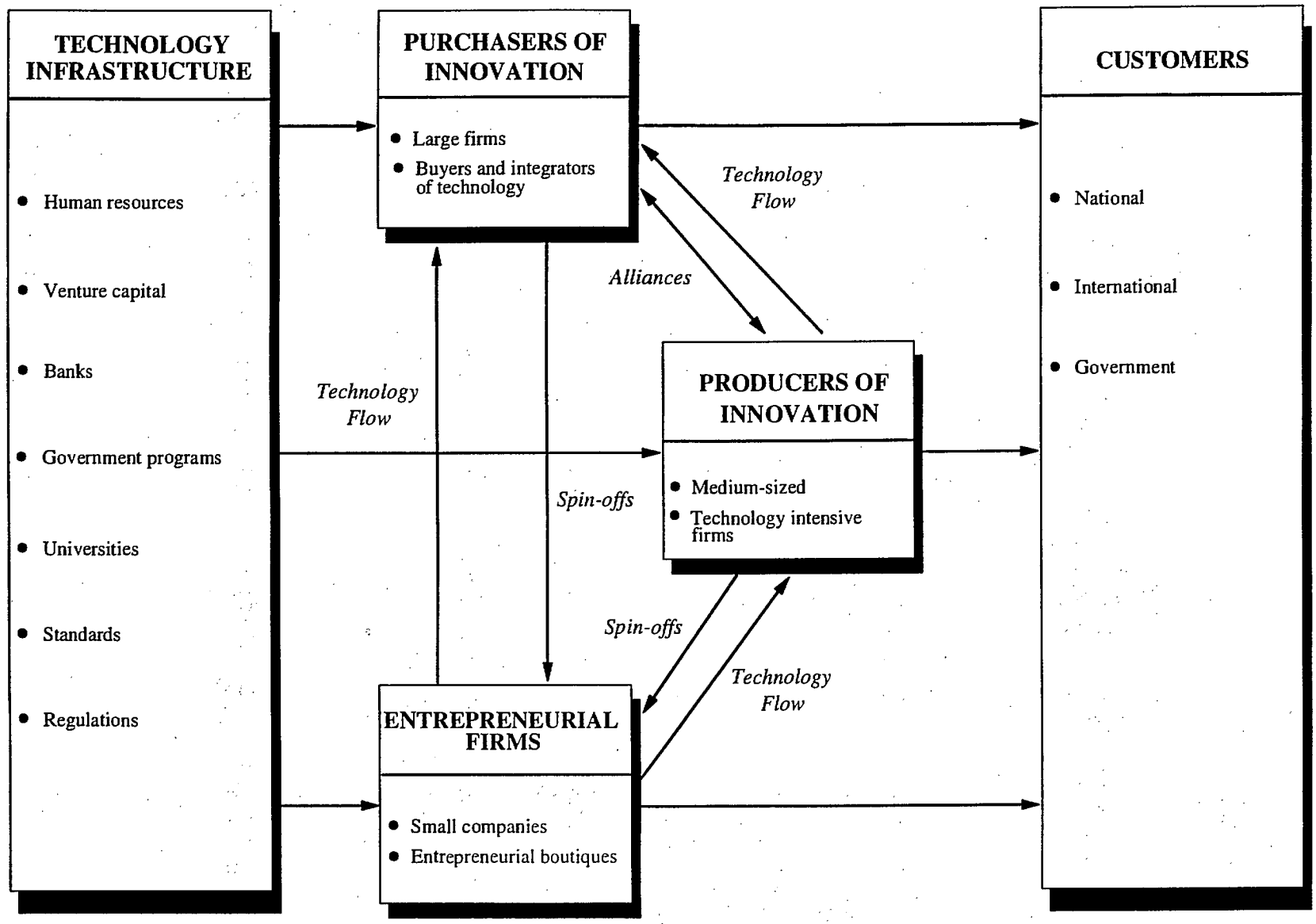
- Government can also be an important driver of innovation. The focus of policy has been upon the creation of infrastructure, programs and incentives that support firms. Examples include, Western Economic Diversification, the Industrial Research Assistance Program and the Atlantic Canada Opportunities Agency. However, government as a purchaser of products and services has an important role to play in innovation particularly in areas such as defense, communications and transportation.

- In interviews with firms, we have found that government assistance through programs such as the Defense Industry Productivity Program (DIPP) has allowed many firms to develop important innovations which they then translate into product lines that have wider commercial application. We have seen, for example, DIPP money used to build signal compression products for telecommunications and highly sophisticated optical detection equipment that was subsequently sold in space and industrial applications.

- Governments role in setting standards can also be a powerful driver of innovation. However, for a country like Canada with a small domestic market formulating regulation and standards internationally with our trading partners is of paramount importance. Idiosyncratic and provincial regulation can do much to inhibit the competitive and innovative abilities of firms.

- Excellent examples of Canada adopting a lead or highly participatory approach have been in:
  - the formulation of the Montreal Protocol on the atmospheric release of chlorofluorocarbons (Freons);
  - setting standards for flight simulators thus ensuring continued access to international markets for world-leader, CAE;
  - collaborative review and simultaneous approval of two anti-AIDS drugs by the Drugs Directorate of Health Canada with the US Food and Drug Administration.
- A poor example is the current disarray surrounding regulation and intellectual property rights for biotechnology.

INNOVATIVE FIRMS



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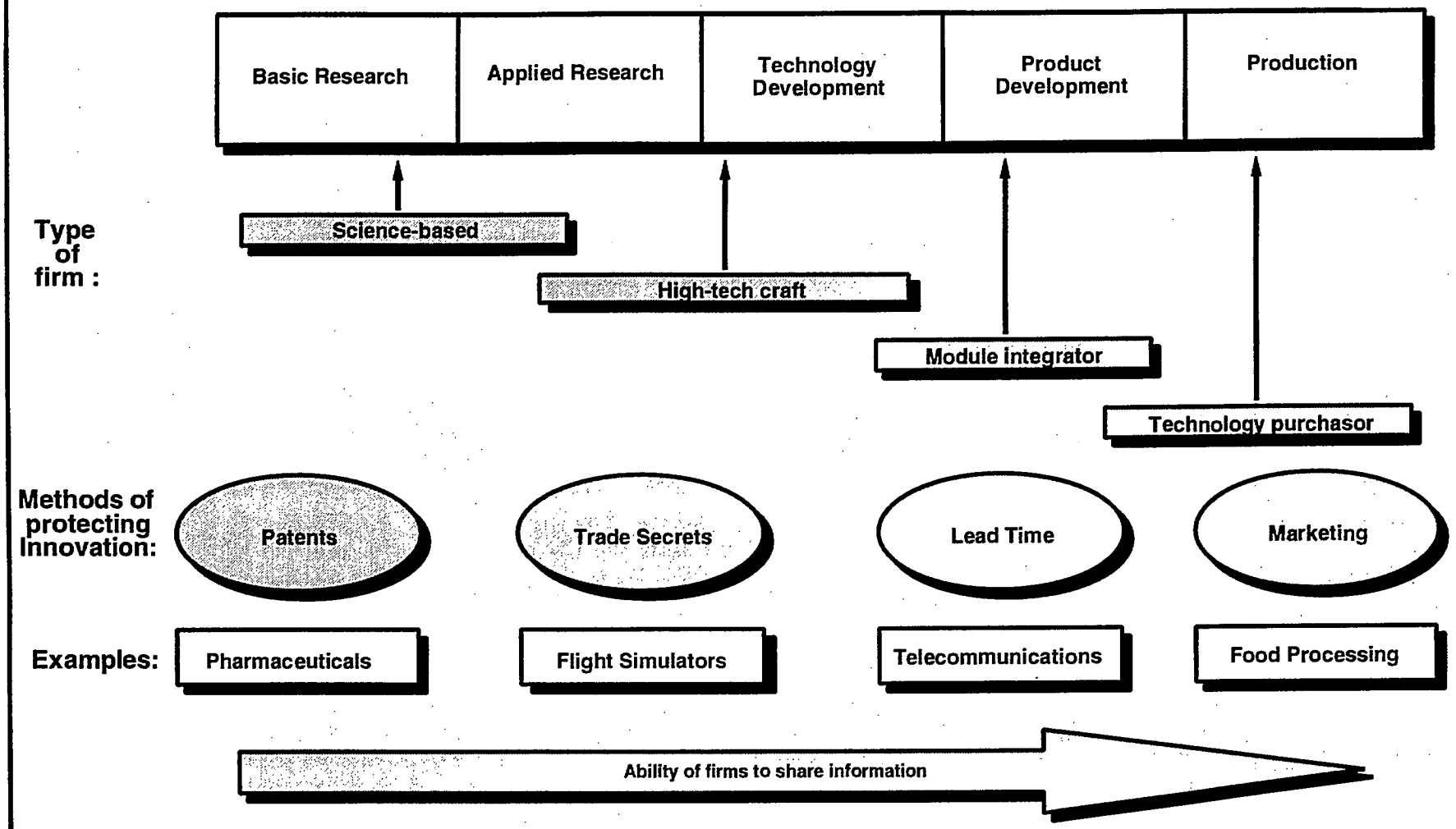
- The schematic on innovative firms shows relationships between firms, technology infrastructure and clients.
- Firms are classified as three groups, small entrepreneurial firms, medium-sized firms that depend upon continuous innovation for their existence, and large firms that often purchase innovation from the smaller fry.
- Bombardier is an example of a firm that progressed through all three levels and which now acquires innovation through the purchase and integration of subsidiaries and from technology oriented suppliers.
- Com Dev of Cambridge, Ontario which has roughly 70% of the world's market in multiplexer switches for satellites started life as a spin-off from a major firm. Its first products were radio frequency filters. As a medium-sized firm and producer of innovation, it has ascended to the second level.
- Interestingly, many firms that are highly oriented towards technology development in a niche market face an enormous challenge when the seam of technology that they are mining runs out. Agile firms typically foresee technological dead-ends and respond though a rapid diversification strategy.

WHERE FIRMS BEGIN THEIR INNOVATION



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TAXONOMY OF FIRMS

Type of firms	Industrial Sector	Mode of Innovation Protection	Culture
Science-based	Pharmaceuticals	Patents	Highly secretive, participate in R&D races.
High-tech craft firms	Flight simulators	Tacit skills kept within firms	Highly introspective, sustain technical superiority, often world leaders.
Systems integrators	Tele-communications	Lead-time	Respond to market opportunities and client demands with rapidly developed niche products, interact with other firms and consortia.
Flexible technology purchasers	Food processors	Marketing	Fairly open, purchase technology from competent suppliers, and highly production/market oriented.

Overhead #11

- The schematics describing innovative firms were applied by Secor in a study of the National Research Council's role in Canadian innovation.

- Innovations do not begin with research and end in production. As Rosenberg pointed out, aeroplanes flew and steam engines chugged before the sciences of aerodynamics and thermodynamics were born. Indeed, these cases innovations gave birth to the science.

- Innovation is not a linear process. It may begin with technology development, move to production and then jump to basic research for refinement and elaboration. However, we can say that firms in specific sectors tend to begin their innovation at different positions in the R & D spectrum.

- For example, pharmaceutical firms tend to begin with basic research. They are science-based, protect their inventions by patenting and are extremely secretive. The up-front investment costs in new products is huge.

- We have defined another group as "high-tech craft firms". These firms typically custom-make highly specialized products for individual clients. Examples of firms in this category are CAE and Com Dev whose activities were described above.

- Like all craft firms throughout the ages, the high-tech variety are fairly introspective since they are typically more skilled than any other group in the world in their particular line of business. Learning is conducted in an apprenticeship mode, products are protected through trade secrets.

- These firms begin innovation with applied research or technology development. Information on relevant basic research comes from universities. In our experience, high-tech craft firms often have links with university professors who, in some instances, are participants in the company.

- We thank members of NRC's Corporate Planning and Evaluation Team for helpful discussions about the model and the nature of its fit to the Council's experiences with its most successful institutes.

- High-tech craft firms are sometimes criticized for not doing basic research. Such criticism is frequently misdirected since basic research is often not an essential part of their business.

- In such firms the craft skills required to build the product are so demanding that would-be emulators cannot enter the field through techniques such as reverse engineering.

- Module integrators are what their name suggests, purchasers of components that are integrated into the final product. Examples include firms in the telecommunications field who buy electronic components and signal compression software from craft suppliers.

- Module integrators challenge the custom built approaches of the craft firms since they try to mass-produce products.

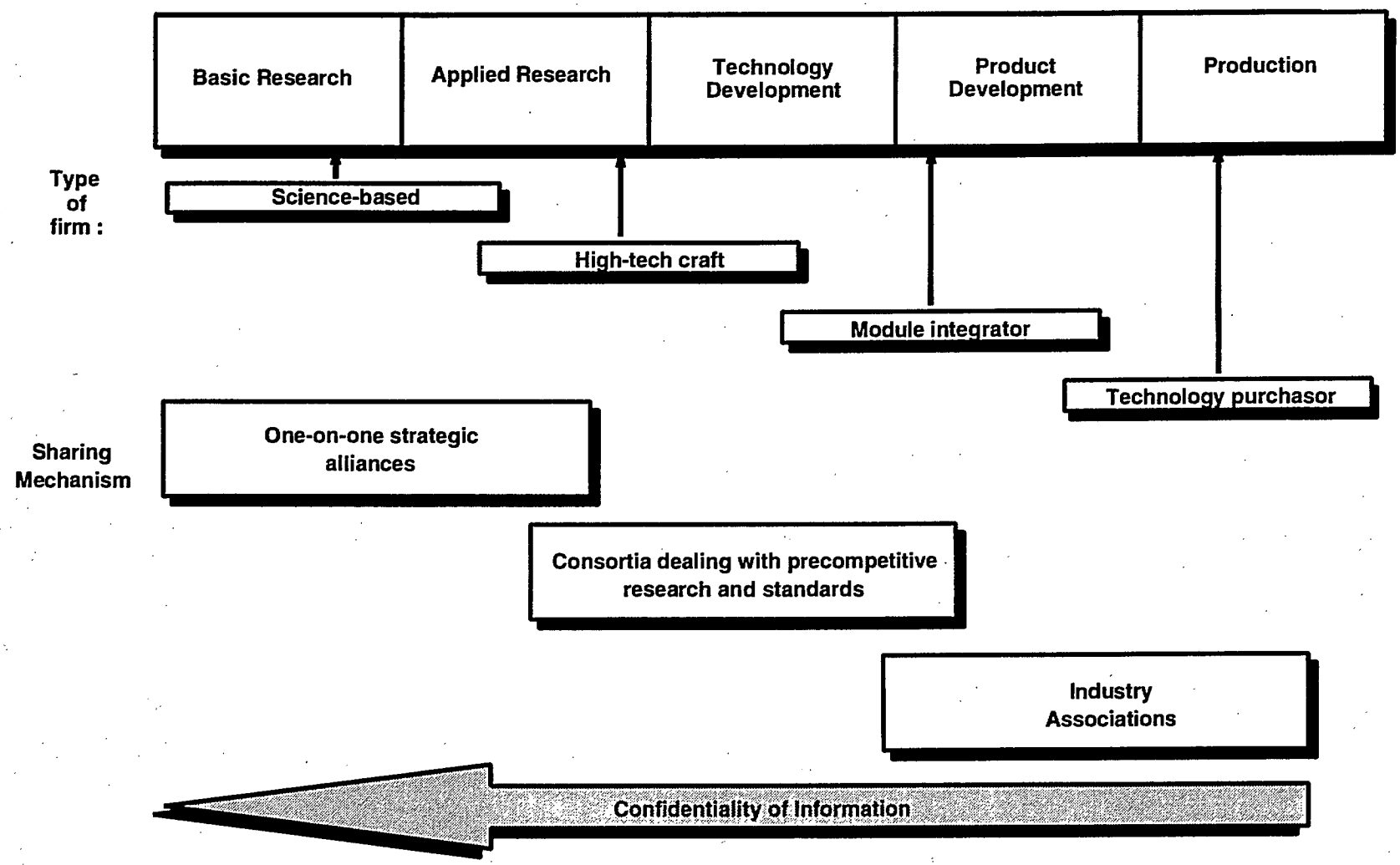
- Before Henry Ford, automobile production was entirely a craft activity. Now the only craft firms remaining in the sector are companies such as Rolls Royce, Jaguar, Aston Martin and Mercedes-Benz. As usual, they are being challenged by mass-produced "up-market" cars and a number of them owe their survival to merger with or acquisition by the mass-producing, module integrators.

- The final group of firms in our taxonomy are the technology purchasers. They innovate at the production stage. Examples of such firms include food processors and brewers. The ability to innovate is embedded in production equipment or in recipes, formulations or specific processes that are specified by the technology integrator and are supplied by small specialist firms. Firms in this category protect their innovation through marketing and can sustain their advantage by developing a solid trade name, e.g. Aero chocolate, Labatts Blue.

- Our thesis is that the behaviour of firms in any sector can be inferred by considering to which part of the taxonomy they belong, i.e. science-based, high-tech craft, module integrator or technology purchaser.

- Once the firm is classified, the position in the R & D spectrum where it begins its innovation, its style in protecting intellectual property and its ability to share information automatically follow.
- In the following pages we explore many other characteristics of firms that depend upon their position in the taxonomy.
- We will argue that in the design of programs and policy instruments firms cannot be treated as a homogenous group. Their behaviour is related to the position in the R & D spectrum at which they begin innovation and will, at a minimum, be sector-dependent.

MECHANISMS FOR SHARING KNOWLEDGE



Overhead #12

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- In the following pages, we explore some facets of the model and how they can be used to probe the benefits of government program or initiative.

- Some government programs are predicated on the assumption that firms have an interest in sharing knowledge, e.g. Technology Outreach Program (Canada), Sematech (USA), Centre for the Exploitation of Science and Technology (UK).

- In fact, mechanisms for sharing knowledge are complex - a factor not always considered in program design. For example, firms that begin their innovation with basic research tend to be highly secretive. At best, they share information with other firms through tight strategic alliances often based on the transfer of knowledge in exchange for financial support.

- Canadian biopharmaceutical firms have formed one-on-one strategic alliances for this very purpose - Biochem Pharma, with Glaxo, Biomega with Boehringer-Engelheim, Allelix with Glaxo and Quadra Logic Technologies with American Cyanamid.

- While most of these firms belong to their trade association, they do not expect it to promote exchanges of scientific information or technology diffusion. The Pharmaceutical Manufacturers Association of Canada acts as a lobbyist on behalf of its members in areas of regulation, patent lifetimes and so on.

- Firms that begin their innovation with technology development can participate in consortia to look at precompetitive research. This is because they differentiate themselves through the application of a given technology rather than through the technology itself.

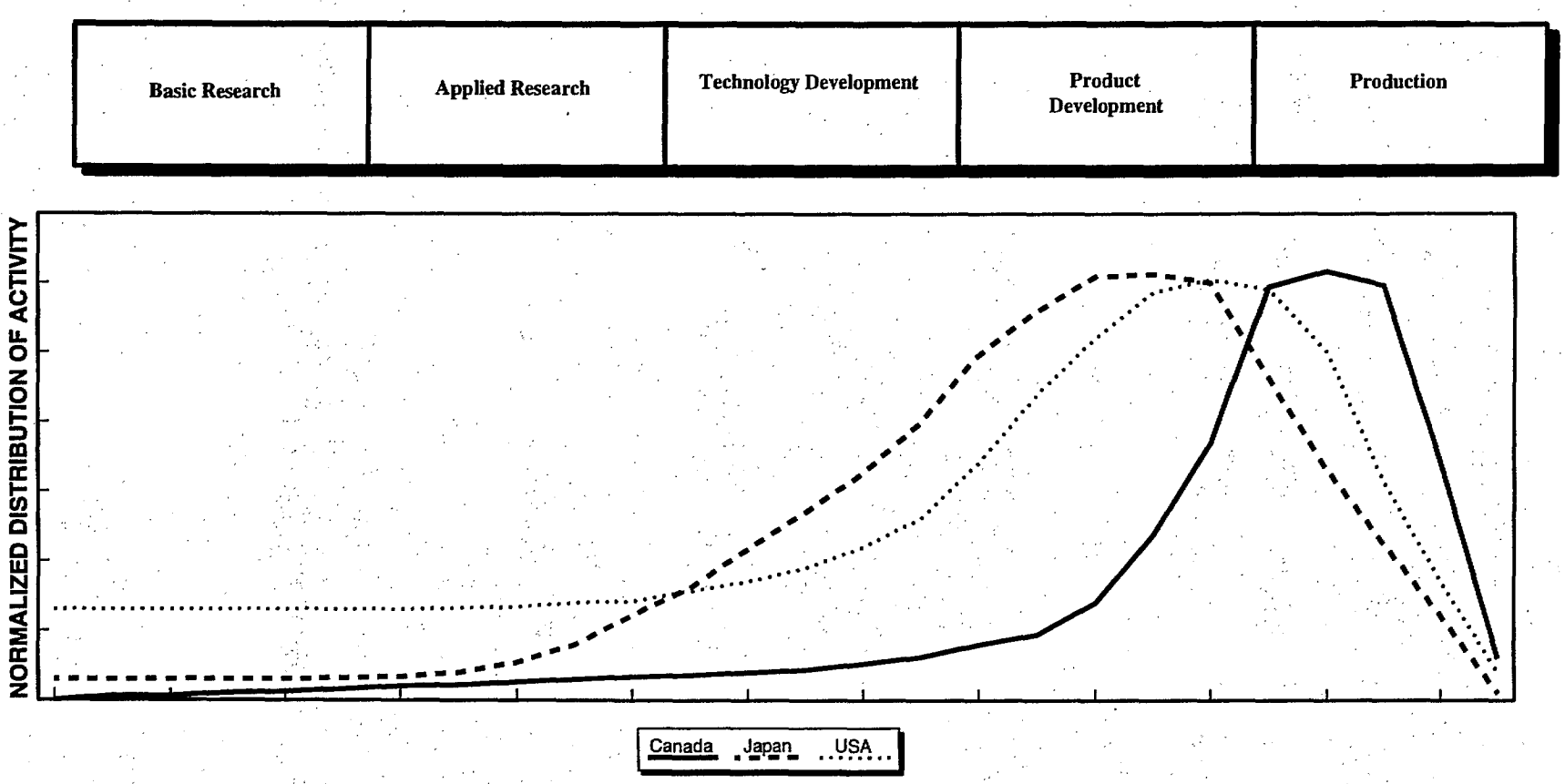
- Participating firms in Sematech in the USA can share advances in the area of microelectronics simply because they apply these advances in fairly distinct products. Similarly, the Canadian Software Engineering consortium which is one of the TOP programs can act as a vehicle for establishing norms and standards for software code simply because the practitioners differentiate products by using software in different applications.

- For firms that begin their innovation at the production end of the spectrum, trade associations can act as agents for sharing knowledge. For example, member firms of the Pulp and Paper Association of Canada actually jointly fund a research laboratory to look at production problems. The results are shared by all members who differentiate themselves mainly through customer services. Steel makers are a group that behave in similar fashion.

- As an example of the way in which the model can be applied, we would say that the TOP program is most useful to firms that begin their innovation with technology development since they can share a certain amount of precompetitive information. TOP will be of little use to firms that begin their innovation with basic research, since they are unable to share knowledge with rivals. For firms that begin their innovation with product development or production, TOP will be of value in sectors where best practices are changing rapidly. In slower moving sectors, TOP would be of less value and would compete with suppliers and trade associations as sources of technical knowledge.

- In the following pages, we explore the relevance of a broad range of government programs that aim to encourage innovation in Canada.

REPRESENTATION OF CONTRIBUTIONS TO GDP ACCORDING TO THE STARTING POINTS FOR INNOVATION OF INDUSTRIAL SECTORS



- Canada's economy is not strongly dependent upon firms that begin their innovation with basic research.

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Overhead #13

- During the course of this study, we attempted to breakdown contributions to GDP by sector and to plot the results according to the positions in the R & D spectrum where firms in those sectors typically begin their innovation.

- Unfortunately, data from Statistics Canada are categorized in ways that makes this exercise very difficult to achieve. However, the information that we gathered showed that the bulk of manufacturing firms in Canada begin their innovation in product development or production areas of the R & D spectrum.

- We have attempted to represent our perceptions of the situation for Canada in the preceding figure and have traced scenarios for the US and Japan.

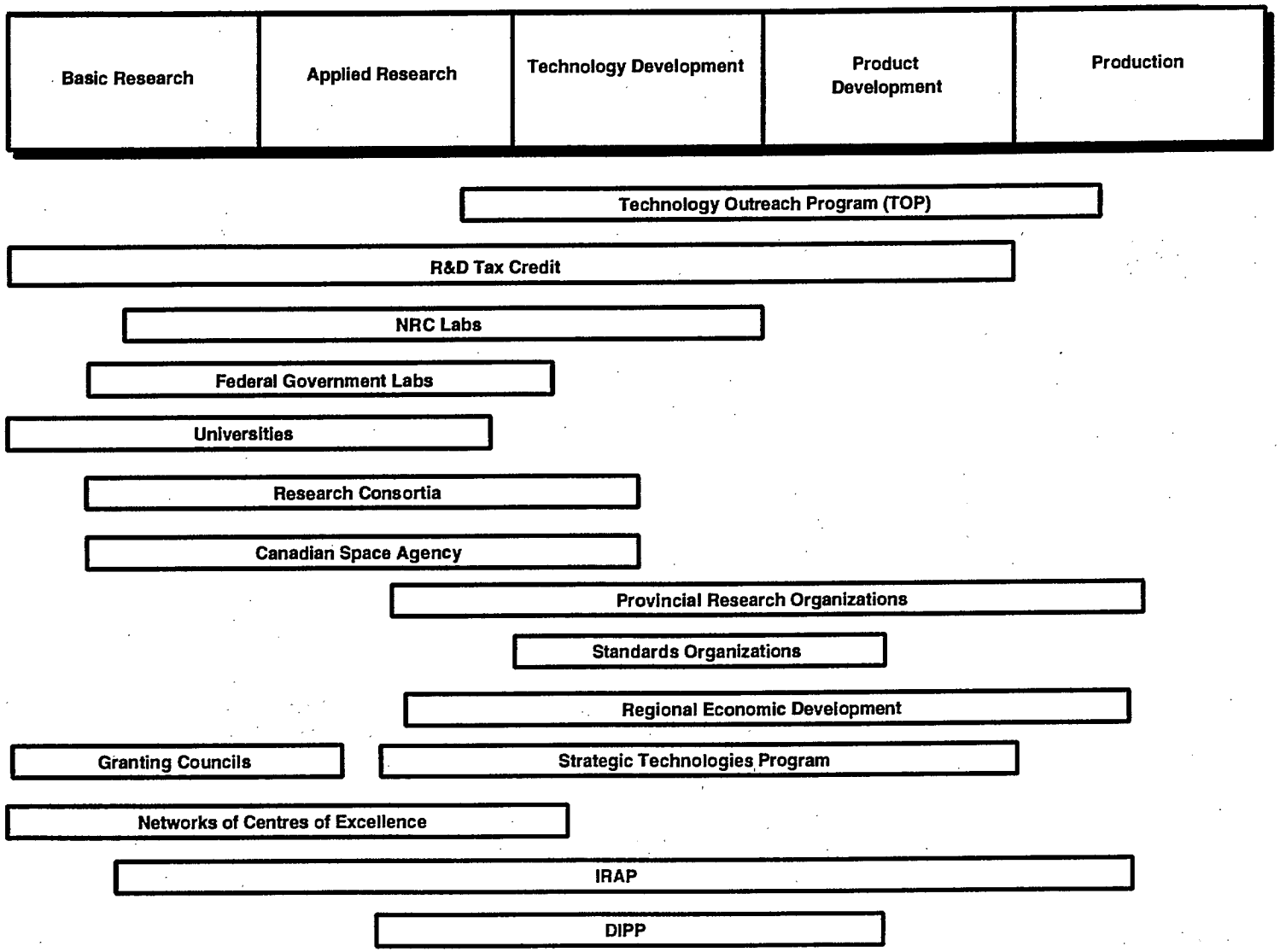
- Japan's strengths in fields such as microelectronics and optics mean that firms which begin their innovation with technology or product development will contribute fairly strongly to the economy. Japan is, however, quite weak in areas that depend upon basic research such as the pharmaceutical sector.

- By contrast, the US may be somewhat weaker in technology development than Japan but it is certainly much stronger in industries that depend upon basic research.

- The Canadian profile in terms of the sophistication of its manufacturing sector is much more that of a developing than developed nation. The bulk of our manufacturing sectors begin their innovation in the area of production.

- Nevertheless, many government funded mechanisms that are intended to encourage innovation are oriented towards the basic research end of the R & D spectrum and are disconnected from the needs of most firms. Examples include support for federal government laboratories and some grants for university research

GOVERNMENT'S SUPPORT FOR INNOVATION



Overhead #14

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GROUPE SECOR

- Many highly funded government programs for R & D are used to support activities at the basic and applied research areas of the spectrum, far away from most industrial needs. Examples include, university grants, Networks of Centres of Excellence, and the work of federal government laboratories.

- In our experience, technology transfer from government programs and laboratories is most efficient when the technology is taken across the R & D spectrum to the point where firms normally begin their innovation, i.e. they match the capabilities of the recipient.

- The large spectral gap between many government programs and the starting points for innovation of the bulk of firms means that the programs are not well-tuned. Scientists in universities and federal laboratories decry the lack of technology "receptors" in industry, while industrialists find academic and government research to be of interest but seldom related to their needs.

- This dichotomy between industrial needs and government programs is cultural in origin. In the fifties and sixties, Canada's economy was relatively wealthy. Academic research flourished, often spearheaded by European immigrants. These researchers drew their culture and inspiration from European and US style research aimed at fairly pure science.

- As the economy has waned this orientation has been increasingly challenged. In response, organizations such as the National Research Council have restructured their programs to target wealth generation. Universities have, on the whole, been less agile.

- In Canada, some take the view that academics should have close links with industry and do much to support industrial innovation. In formulating the Networks of Centres of Excellence Program, the ultimate economic impact of the work to be conducted was an important selection criterion.

- Many academics argue in favour of academic freedom and stress the primary research and teaching roles of universities. This is a perfectly valid view. In Japan, for example, universities concern themselves with education and training and have very little to do with supporting industrial innovation. Canadian universities, meanwhile, consume 26% of the nation's R & D expenditures.

- Canada needs to clarify its goals. If government intends that universities and government laboratories should provide useful support to industry, e.g. in precompetitive research, development of standards etc., then the centre of gravity of their research activities must shift somewhat away from the basic research end of the R & D spectrum and towards the technology development and production end.

- If, on the other hand, we do not intend that university research should support wealth creation directly, we should state this clearly.

- The tendency, in Canada, has been to try and cover all of the bases in the absence of clearly stated policy directions. Thus, the Natural Sciences and Engineering Research Council funds both basic research and "strategic" research. It also provides a large number of modest grants that sustain research in small regional universities even though researchers often lack the infrastructure necessary to use the funds to advantage.

- If research programs are to mix academic and industrial goals then methods for planning and evaluation need to be refined. Methodologies used to evaluate federal government programs, for example, have typically maintained the status quo since they are highly retrospective and do not explore prospective options.

- Frameworks of the kind developed in this paper can, we believe, be used as guides to program development. In the notes that follow, we provide an example of the application of the framework to the Networks of Centres of Excellence program.

- The framework suggests that a Network of Centres of Excellence (NCE) working on problems of relevance to the pharmaceutical industry could not ultimately function as a true network with fairly free exchange of information. According to our model, firms in this field begin their innovation with basic research and are highly secretive. Any arrangements that they make with university researchers will be one-on-one and "networks" in this field will function as brokerages selling individual projects from individual researchers to firms.

- NCE's conducting research in fields relating to microelectronics will be able to function as true networks since the firms that begin their innovation with applied research and technology development are able to share precompetitive information since they differentiate their products by the applications to which the technology is put.

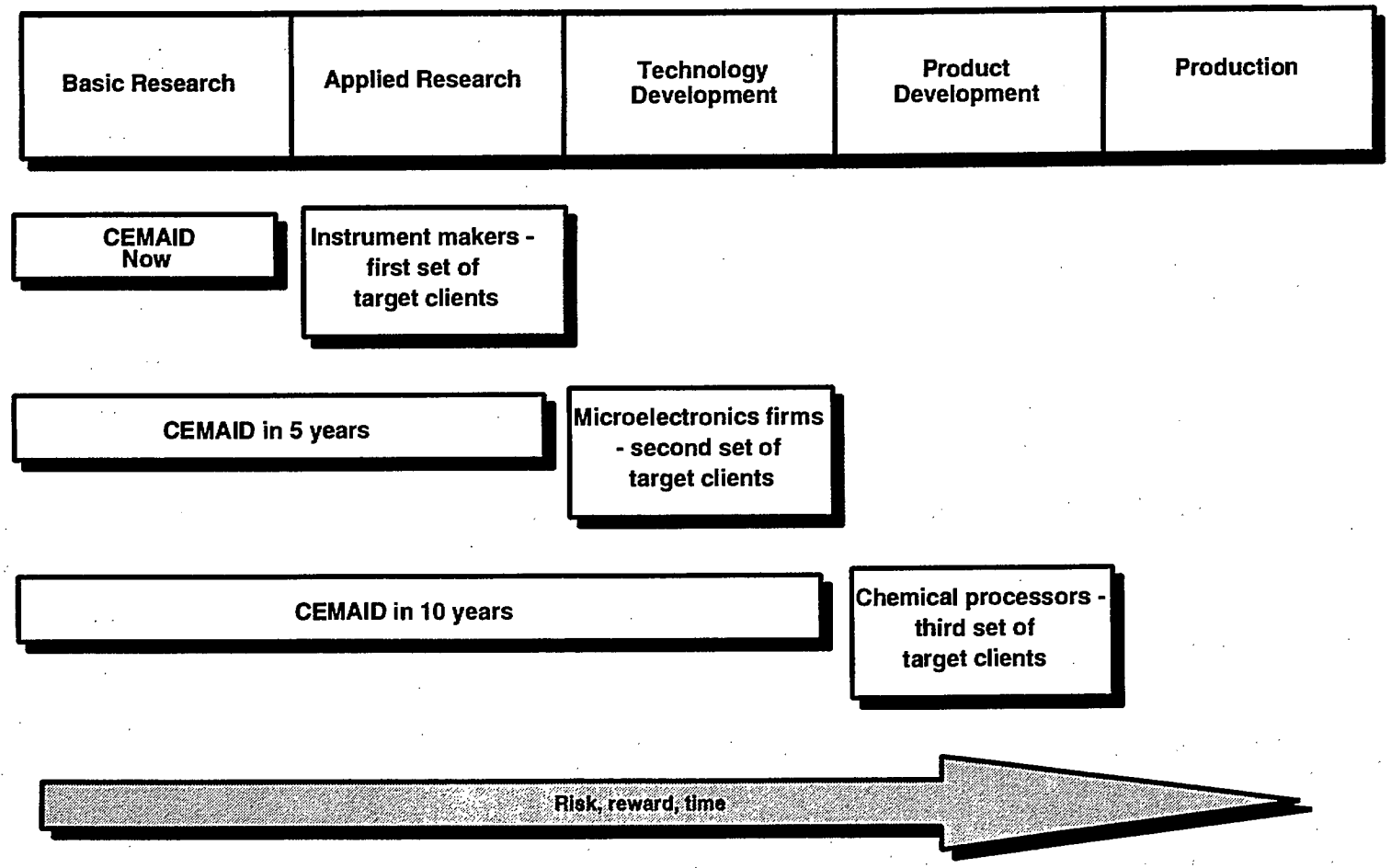
- If networks conduct basic research that aims to support firms which begin their innovation much further down the R & D spectrum, then these networks must carry the work forward to the point where firms are actually capable of adapting it. This approach has been applied in CEMAID, the Centres of Excellence for Molecular and Interfacial Dynamics. CEMAID conducts research on molecular structures related to nanotechnology, microelectronics and catalysis. Its planned development is described in the following overhead. A key success factor for such a network will be its capacity to drive research across the R & D spectrum. The actual quality of the research may not be quite as critical[1].

- At the very minimum, the application of simple criteria derived from the model can provide a simple checklist which would help to ensure that programs are properly designed and evaluated.

[1] *Funding for CEMAID was cancelled while this report was being developed.*

THE MODEL APPLIED TO A NETWORK OF CENTRES OF EXCELLENCE

Position where collaborating firms begin their innovation



Overhead #15

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GROUPE SECOR

DIFFERENCES BETWEEN FIRMS

- We use the following classification of firms :
  - strong - high value-added, export-oriented worldview.
  - vulnerable - lower value-added, regionally-oriented, lack awareness of competition.
  - endangered - low value-added, locally-oriented, significant under performer.

- Underlying the business performance of these firms will be their :
  - style of innovation
  - ability to innovate
  - the extent to which they feel pressure to innovate.

- An important element of this project was to establish some of the factors that differentiate strong from endangered firms.
- We began by briefly describing three groups strong, vulnerable and endangered.
- Industry Canada sector specialists then provided detailed information on the characteristics of these groups by responding to a brief request for information (Appendix).

GATHERING INFORMATION

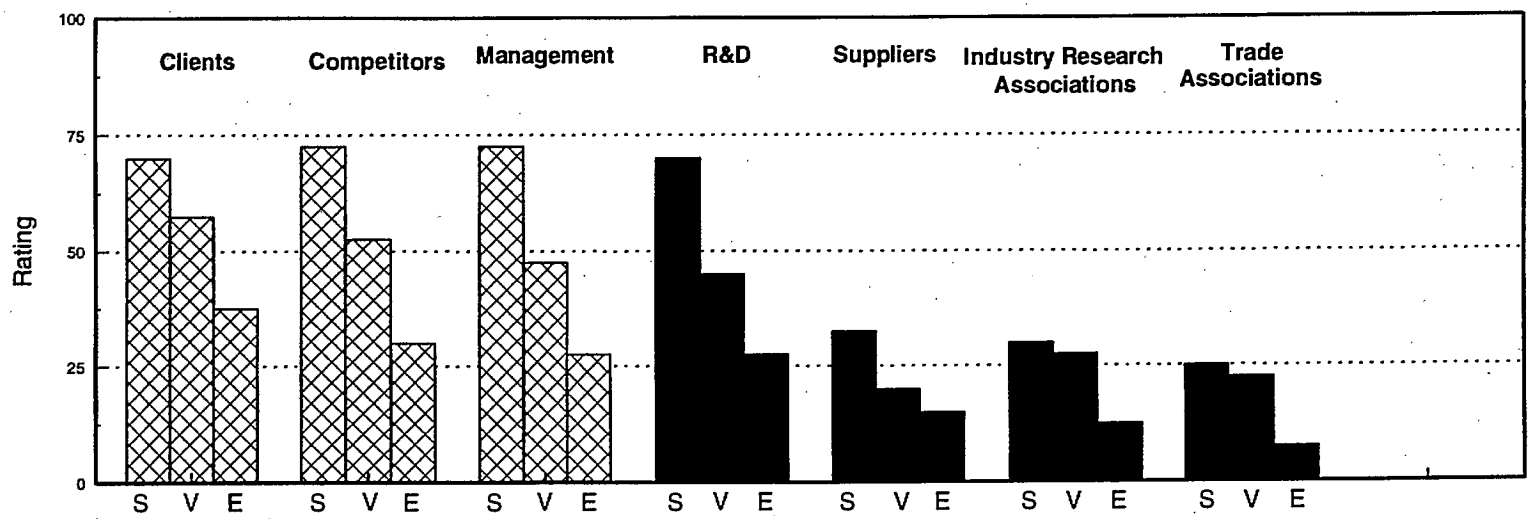
- A brief request for information was circulated to 9 Branch Sector Heads in Industry Canada:
  - Software Products and Informatic Services
  - Auto Components and Tires
  - Defence Electronics
  - Industrial Equipment
  - Apparel and Footwear
  - Biotechnology
  - Airframe Systems
  - Computers and Suppliers
  - Telecommunications and Microelectronics.

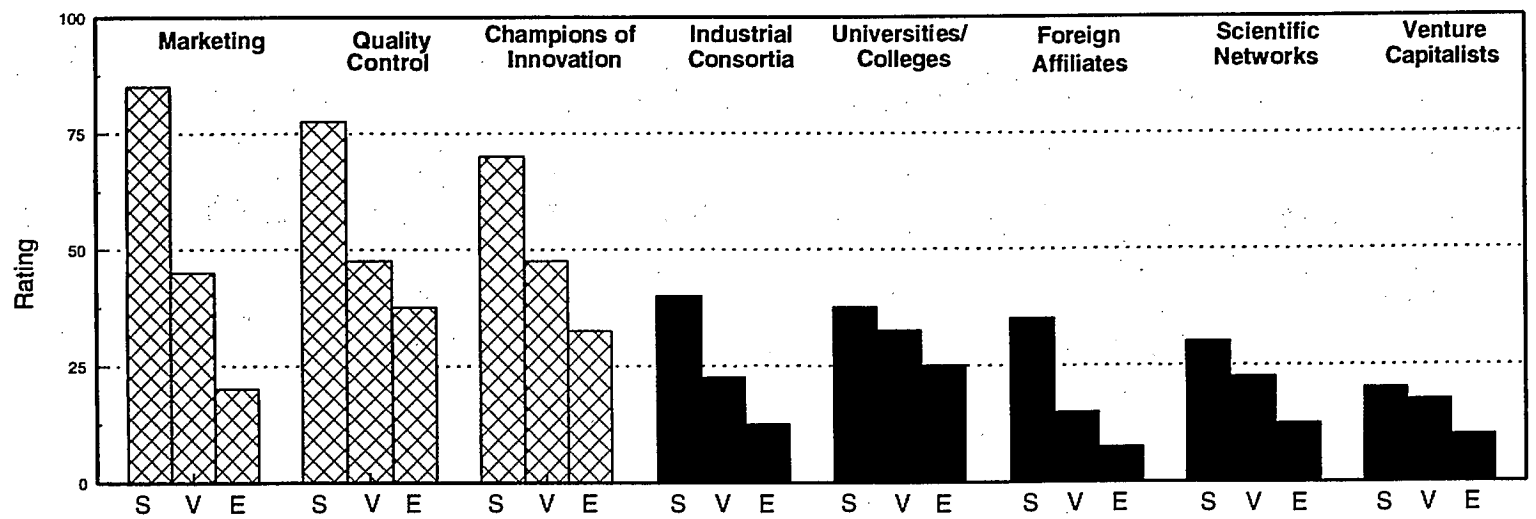
GATHERING INFORMATION...

- The questions were divided according to :
  - private sector drivers or sources of innovation
  - government tools.

As expected, private-sector drivers provide the primary impetus for innovation. Government tools are of secondary importance.

SOURCES OR DRIVERS OF INNOVATION (PRIVATE SECTOR)





S - Strong V - Vulnerable E - Endangered

Shading indicates sector-dependent factor, hatching indicates sector-independent factor

Overhead #19

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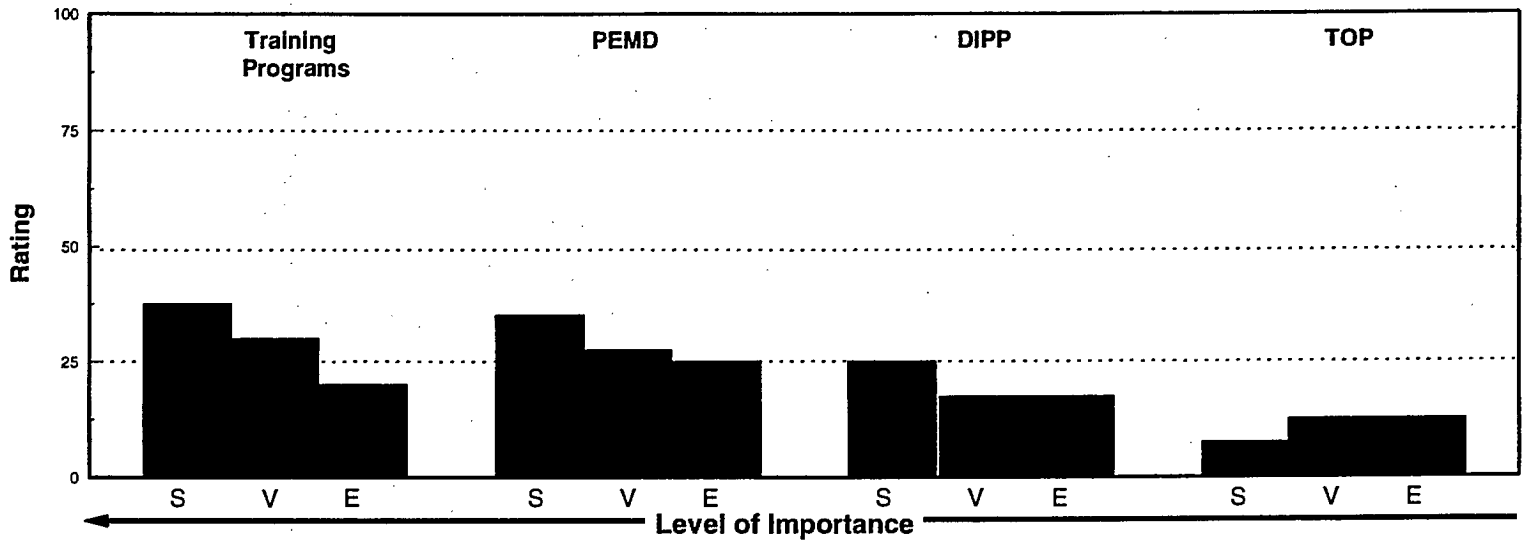
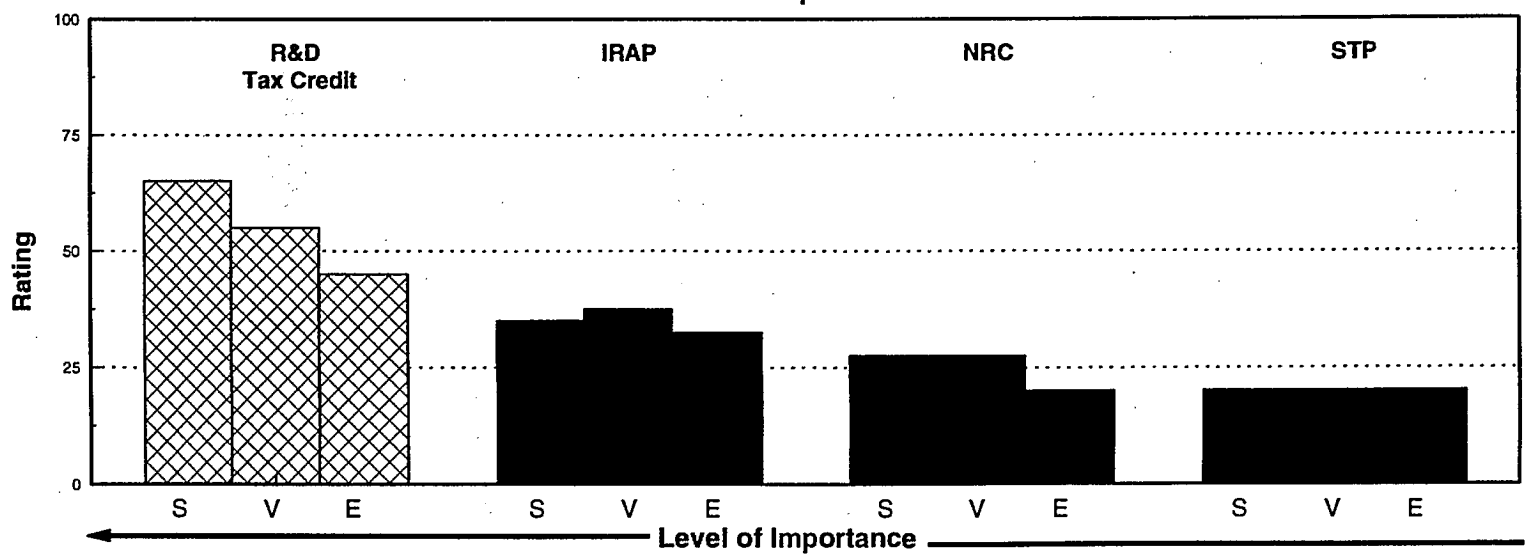
GROUPE SECOR

SOURCES OR DRIVERS OF INNOVATION (GOVERNMENT TOOLS)





S - Strong V - Vulnerable E - Endangered

Overhead #20

Shading indicates sector-dependent factor, hatching indicates sector-independent factor

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GROUPE SECOR

- The responses of sector specialists were analyzed to see if there were sector-dependent variations.
- Questions on the importance of R&D, suppliers and trade associations, as sources of drivers of innovation produced sector-dependent responses.
- Replies about the importance of clients, competitors, management were sector independent, i.e. they were deemed to be important sources or drivers of innovation in all of the sectors examined.
- Quantitatively, the results are very crude. We simply summed ratings assigned by sector specialists (see Appendix A).
- In areas where the ratings are low, such as the importance of government tools, error limits are such that differences between strong, vulnerable and endangered firms are not significant.
- To avoid misinterpretation, we stress that the low ratings assigned to government tools versus private sector drivers or sources of innovation do not represent an implied criticism. If government turned out to be the primary driver of innovation in Canada, there would be cause for alarm.
- By and large, the results obtained from the industry sector specialists fit almost perfectly with responses that we and others have obtained by collecting data from firms.
- The fact that the sector specialists are government rather than private sector employees did not seem to colour responses in any area where we were able to make comparisons.
- By far, the most important data that resulted from this mini-study come from replies about differences between strong and endangered firms.

- The literature is very weak in this area. Everyone, including academics, likes to work with winners. As a consequence, studies of the weak and feeble are few and far between. In our experience, this natural tendency is manifest in the application of government programs and should be thrown open to question.

- The sector specialists noted that no matter which factor is examined as a driver or source of innovation, endangered firms always under perform the strong and vulnerable.

- If correct, this is an extremely important result. One might have imagined that endangered firms in one or more sectors might be competent in all areas of innovation except, for example, that they might lack capital. Alternatively, they might be good at marketing and quality control but weak in design. This is not the view of the sector specialists. They suggest that the endangered are less able than the strong in everything that they do. The result implies that vulnerable and endangered firms simply have poor management when compared with the strong.

- The finding is striking. The sector specialists report that endangered firms are less able to respond to client demand, less sensitive to competition, less aware of market forces, less able to acquire innovation through R&D, trade associations, universities or from suppliers. They are universally poor and are not simply weak in one or two areas of competence.

- To summarize, the specialists note that some drivers or sources of innovation are more important to some sectors than others. These include R&D, trade associations, suppliers, etc. This result fits precisely with the framework that we developed earlier in the text. The responses of the sector specialists support the model in all of its detail. This is because the model was based upon information from firms and the specialists responded in much the same way as firms.

  The specialists identify a number of sector-independent sources or drivers of innovation. The weighting that they give to these fit well with opinions gathered from the private sector.

  The experts suggest that no matter which driver or source of innovation is considered, vulnerable and endangered firms are less able to take advantage of it than the strong.

Note of caution :

- The results about differentiation between endangered and strong firms are difficult to confirm simply because of the paucity of data in this area.
- The findings were based upon responses from a very small group of experts from within Industry Canada.
- The design of the request for information (Appendix A) could have influenced the replies. This is because experts were asked to assign a numerical rating to the importance of a source or driver of innovation. Having assigned a score to a strong firm there may have been a psychological tendency to assign lesser scores to vulnerable and endangered firms.
- The results are of sufficient importance to warrant further investigation.
- Identifying endangered and vulnerable firms is difficult. Databases such as Industry Canada's BOSS compilation of firms favour the strong who tend to offer themselves for inclusion. The National Research Council's database of firms that have participated in the IRAP program may be a better starting point.
- We encourage Industry Canada to establish the correctness or otherwise of this result in a broader investigation since it has profound implications for the design of policy and programs.

SOURCES OF INNOVATION

- The most important drivers of innovation are :
  - Client demand
  - Competitors
  - Champions of innovation
  - Management that encourages change
  - High standards of quality control

- The most important sector-dependent drivers of innovation are :
  - Strong R&D capacity
  - Industrial consortia
  - Universities/colleges
  - Foreign affiliates

- Government tools are far less important drivers of innovation, as would be expected in a market-driven economy such as Canada's

COMMENTS ON THE RESULTS

- The relative importance of sources of innovation identified by some IC staff closely corresponded to the results of studies on :
  - highly innovative firms (SECOR)
  - a broad spectrum of firms (Premier's Council of Ontario)

- Government supported programs and research were not thought to be very important.

According to the IC staff consulted, weakness of a firm in a given sector is characterized by deficiencies in all areas of the firms' activities.

STRONG FIRMS

- Characteristics of strong firms :
  - Export outside local region.
  - Produce higher value-added goods than competitors.
  - Innovate and feel pressure to innovate.
  - Gather intelligence internationally.

- Important drivers of innovation in most strong firms :
  - Clients;
  - Competitors;
  - Management that encourages change;
  - High standards of quality control;
  - Strong R&D capacity;
  - Internal champions of innovation;
  - Participation in industrial clusters.

STRONG FIRMS...

- Overall, the R&D tax credit is the most popular government tool for improving innovation. Consultations with industry specialists indicated that it was the most highly rated. Its effectiveness has, however, been challenged from time to time.

Vulnerable and threatened firms are simply less able in all of the above.

INTERPRETATION OF THE FINDINGS

- The findings are most easily understood by using :
  - ability to innovate = ability to solve problems.

- Strong firms can solve large problems while the threatened can solve only small problems.

- The style of problem solving (innovation) is sector dependent.

If government is to assist industry, it must :

- respect sector-dependent mechanisms for problem solving;
- help firms to solve problems of different magnitudes according to their ability.

- Dealing with the ability to innovate is conceptually difficult. An alternative is to describe firms in terms of their ability to solve problems. Ability to innovate and ability to solve problems are, to a large degree, two sides of the same coin.

- We will use the notion of ability to solve problems as a means of further extending the conceptual framework.

- Strong firms are typically able to define and solve important problems. They have the ability to listen to client needs, to recruit help from appropriate suppliers, to respond to competition, to sense market demand and to manage the quest for solutions.

- If the survey findings are correct, then the ability to solve problems will be vested in strong firms irrespective of industrial sector. The style of problem-solving will, however, vary by sector.

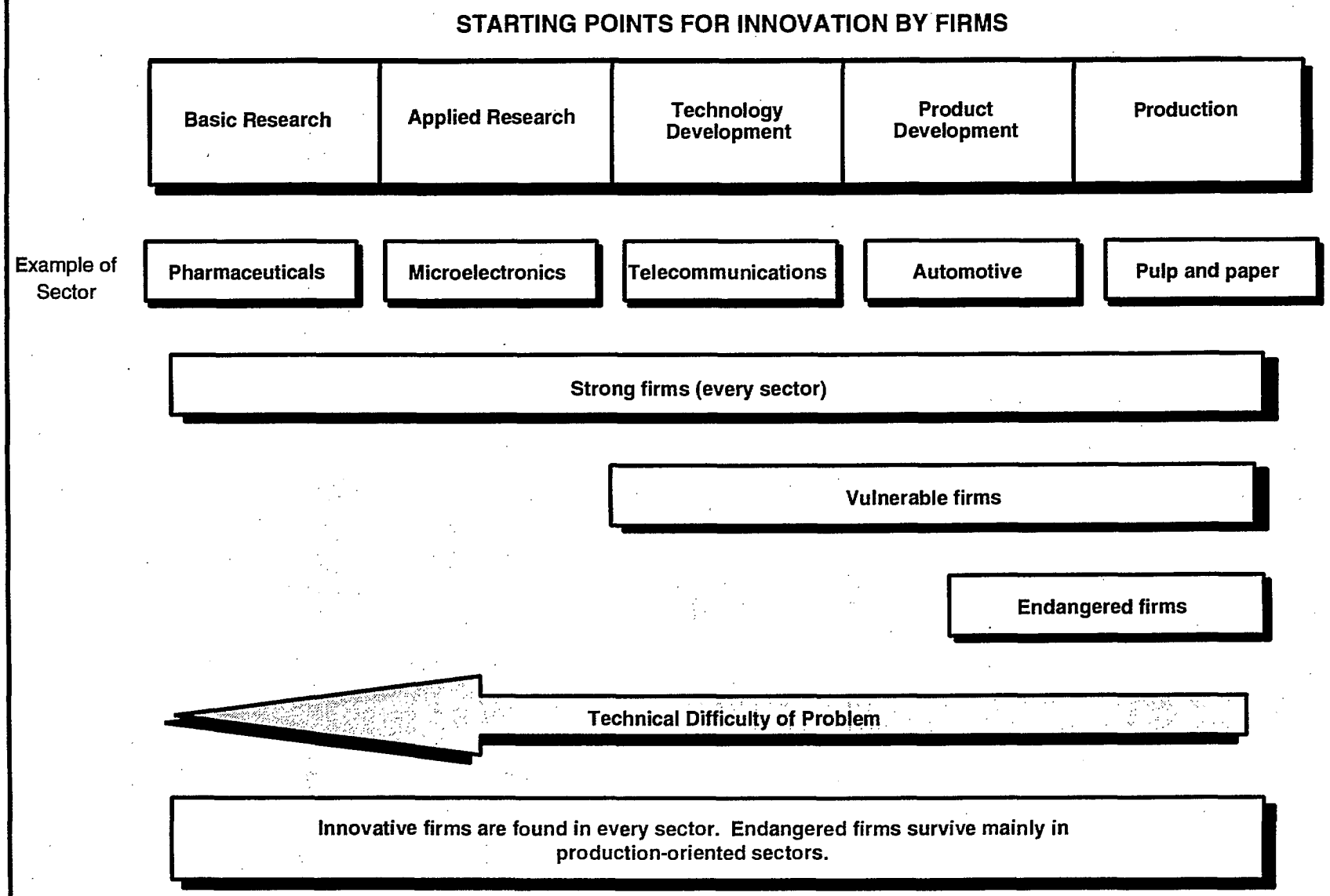
- If government is to help firms then it must respect the different approaches to innovation or problem solving that apply in each sector. Programs that blanket all industrial sectors are likely to be extremely crude instruments with many deficiencies.

- In addition, government must recognize that firms have different capacities to solve problems and must tailor programs accordingly.

- Programs that are strongly oriented towards basic and applied research are well suited to helping stronger firms but are inappropriate aids for vulnerable and endangered firms which simply do not have the capacity to utilize the high-level scientific output.

- Too many government programs are oriented to helping the strong while few are well adapted to support vulnerable and endangered firms.

DISTRIBUTION OF FIRMS BY ABILITY TO SOLVE PROBLEMS



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- In developing this framework, we have consistently categorized firms by using the points in the R & D spectrum where they begin their innovation. For example, telecommunications firms tend to begin their innovation with technology development whilst pulp and paper firms begin their innovation by looking at production processes.

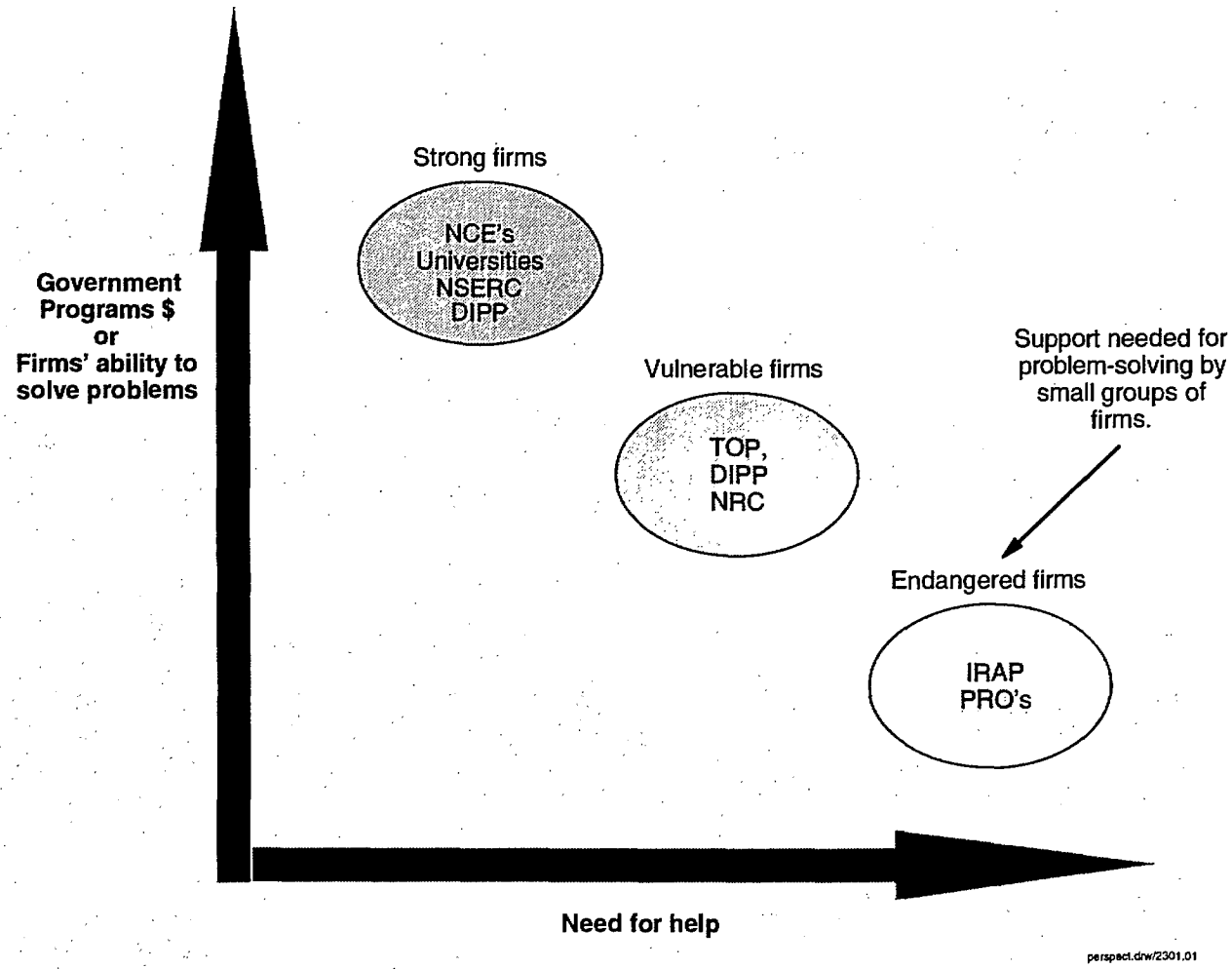
- The hostility of the environment in which firms find themselves is not uniform across the spectrum. Firms that begin their innovation with basic research, such as pharmaceutical firms, tackle problems of great scientific difficulty and technical complexity. This is the High Arctic of the world of innovation. Vulnerable and endangered firms quickly perish. Only the strong survive.

- Firms that begin their innovation with technology development or product development find themselves in more temperate zones. The environment is somewhat forgiving. Thus, the failing automobile manufacturer can escape a sorry end by improving quality of production or design. The keys to survival are not as technologically complex as they are for firms that begin innovation with basic research. Of course, strong firms can be found in this zone as can the vulnerable but the endangered quickly disappear.

- Firms that begin their innovation with production find themselves in the innovation equivalent of a tropical rain forest. They can survive in a small microenvironment based upon supply to local markets. Predators are kept at bay simply because it is often too much trouble to penetrate the zone for limited bounty. Traps and pitfalls such as trade barriers and often keep out undesirables. All firms can survive in this zone. The strong venture out of their microenvironment and so, to some degree, do the vulnerable. The endangered remain cloistered in their small region and feed off of local markets.

- Strong firms can be found in all sectors, the vulnerable in a few, and the endangered in those that are predominantly oriented towards production. If government programs are to target endangered firms, they must be aimed increasingly at those that begin their innovation in the production area of the R & D spectrum. Moreover, they must be designed to help endangered firms improve in small increments that reflect their limited capacities to solve problems and to innovate.

A PERSPECTIVE ON GOVERNMENT PROGRAMS



The role of IC is far greater than the provision of support for technical problem solving.

Overhead #27

- The current distribution of government programs is not well suited to helping vulnerable and endangered firms. Government expenditures support instruments that are designed to help firms make major technological advances. Only strong firms with powerful capacities to solve problems and to innovate can make use of these programs.

- Vulnerable firms have a greater need for help but have access to less support. National Research Council laboratories do help firms that are vulnerable but yet which are still capable of taking new technology on board. Programs such as DIPP and TOP offer some help for these firms.

- Endangered firms have few resources on which they can draw. The best of the basket available to them is the National Research Council's highly regarded IRAP program. They may also access provincial research organizations for help with hands-on problems.

- In previous work carried out for Industry Canada, we have found that endangered firms often cite the need to solve problems of low technical complexity in small groups. Some of the projects that firms wanted to tackle in groups were to improve heat recovery in paper mills, to find alternatives to toxic paint primers, and to work out improved management practices for shared forest resources.

- In work carried out for the Canadian Space Agency, we have seen the dramatic improvements made by firms that have introduced better management techniques to improve quality in manufacturing. We are convinced that such simple and inexpensive measures can have profound impacts on the overall performance of firms.

- We have focused on programs that aim to help firms innovate. Industry Canada's role is, however, much broader than this and in formulating industrial policy it uses a much broader range of tools. Some of the key variables that relate to innovation or problem solving and their relationships to these instruments are shown in the overhead that follows.

PROBLEM SOLVING BY FIRMS

KEY VARIABLES	EXAMPLES OF SUB-VARIABLES	SOME ROLES OF GOVERNMENT
Style of problem solving	Size of firm	Control of acquisitions
	Industrial sector	- procurement - STP
Pressure to solve problems	Entrepreneur (small firm)	Tax incentives
	Champion (large firm)	Tax incentives
	Exposure to competition	Strategic intelligence
Ability to solve problems	Technical competence	NRC, IRAP
	Scientists and engineers	Education system
	Access to capital	Venture capital
	Quality of management	Standards programs
	Quality of equipment	Tax incentives

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WAKING-UP VULNERABLE AND THREATENED FIRMS - SOME OPTIONS

Building pressure to solve problems through innovation :

- Expose firms to competitive pressure through trade agreements.
- Promote entrepreneurship through tax incentives, local action.
- Gather strategic intelligence through IC and Foreign Affairs and International Trade - use secondments from industry to fill key positions.

WAKING-UP VULNERABLE AND THREATENED FIRMS - SOME OPTIONS

Helping to solve problems through innovation

- Shift the centre of gravity of technological support programs towards the production region of the innovation spectrum.
- Improve management systems and production quality through standards programs, e.g. ISO 9000 series.
- Use TOP or IRAP to build mini-consortia of firms to deal with specific problems.
- Improve the flow of qualified human resources by encouraging colleges and universities to set curricula in collaboration with appropriate firms.

Overhead #30

- In the notes that follow, we have attempted to offer some practical suggestions on methods of promoting innovation without the need for radical change.

Building pressure to solve problems through innovation

- Trade agreements provide an important mechanism for exposing firms to competitive pressure. For firms in sectors that are currently sheltered, exposure must be developed at a rate that allows sufficient time for adjustment. The Ontario wine industry, under the free trade agreement with the US, has shown how competitive pressure can lead to a dramatic burst of innovation and quality improvement. Canadian poultry and dairy producers should be subjected to similar pressures in a controlled manner.

- Promoting entrepreneurship through tax incentives is both useful but not necessarily costly. At present, small businesses assume the risks of entrepreneurship and take on a heavy administrative load in collecting taxes and complying with regulation. Federal and provincial sales taxes, corporation taxes, income taxes for employees, health taxes, CPP and UI are among the large number that are administered by firms. In addition, firms trading across Canada often have to deal with a complex web of provincial regulations. All this for a Canadian market that is probably smaller than that of New York City and its environs.

  At present, the bureaucratic burden sends a negative signal about government's attitude towards entrepreneurship. Only the capital gains tax break that is achieved on the sale of a business offers any tangible compensation. A modest fiscal signal to the operators of small businesses, such as an improvement on the dividend tax credit, would provide some confidence about government policy in this area.

- Local action to promote entrepreneurship should equally be encouraged because of the importance of clusters in the innovation process. Provincial governments are taking an increasingly active role in this area, notably in Quebec, Ontario (through Premier's Council initiatives) and New Brunswick. The initiatives are often province-wide in principle but focus on major metropolitan areas in practice. These approaches are entirely consistent with cluster building.

- Greater use of strategic intelligence is extremely important. In numerous case studies, we have found that strong firms adopt a world view of their businesses. Senior executives are typically global deal makers. Alliances are sometimes struck simply as a means of tapping into technological infrastructure in other countries. Vulnerable and endangered firms tend to be far less able at gathering the intelligence necessary to pilot their affairs over the medium to long term.

- Intelligence gathering by IC and Foreign Affairs and International Trade would be more effective if firms were to second their employees to work as trade commissioners or analysts for limited periods. This model is used by some European countries. It puts people with hands-on industrial experience into key positions. The advantages are self-evident. The mechanism is limited by the fact that only large firms will be easily able to participate.

Helping to solve problems through innovation

- The importance of shifting the centre of gravity of government support programs towards the production region of the R & D spectrum has been discussed in some detail. This is the region where much of Canadian industry begins its innovation and where the weakest firms are to be found.

- Firms that begin their innovation with product development or production receive little support from government programming. (We use the word "support" in its broadest sense and do not equate it with direct financial aid.) Ensuring an adequate supply of suitably qualified workers, eliminating inter-provincial trade barriers, defining sensible standards and regulations that pull technology rather than constraining it are all examples of legitimate and appropriate industrial support roles of government.

- Government has an important role to play in ensuring that Canadian standards and regulation conform to good international norms and must be a proactive player in the international fora where these are defined. "Made in Canada" regulation is extremely destructive and inhibits firms from tackling international markets. Moreover, poorly coordinated regulation can inhibit the import of raw materials necessary for Canadian production.

- The benefits of international harmonization in regulation and the methods for going about this have been promoted by the Regulatory Affairs Group within the Treasury Board. However, winning converts seems to have been a difficult battle.

- The input received from Industry Canada specialists showed that vulnerable and endangered firms generally suffer because of weak management. Moreover, these firms are generally not capable of major leaps in innovation or problem solving.

  One gentle way to improve management and production processes is through the introduction of techniques that improve quality and diminish waste reduction. These come in a variety of guises. "Total quality management" is the name given by the US Navy to the Deming's approach to industrial management. It is generally only useful if it is tied to sensible measures aimed at improving product quality, e.g. those based on the statistical analysis of defects in production. The Japanese "Kaisan" approach to continuous improvement is almost the same and is often associated with "just-in-time" inventory control. Japanese car firms have been very effective in introducing these approaches amongst their suppliers in any countries where they have established operations.

  In order to encourage the adoption of these approaches, government has to encourage rather than criticize firms. Japanese car manufacturers have introduced quality techniques amongst suppliers by using the approach, "we'll buy from you if...." where the "if" speaks much more about quality than price. Government has some "if" cards to play itself - "we'll give you a DIPP contract if you upgrade....." or "we'll give you the IRAP grant if you commit to improving.....".

The implementation of the ISO 9000 series of standards would help firms considerably and may soon become an important entry ticket into certain markets. Conforming to the standard is not easy and may represent too formidable a first step to weak and endangered firms. However, some less onerous packages that show firms how to upgrade would be a very useful starting point.

- In many respects, the measures described above are designed to bring weak and endangered firms up to best practices for their industrial sectors. This is a sensible first step for such firms and is the key to their immediate survival.

- Encouraging firms that are production-oriented to innovate is a more subtle problem. This is because the means of innovation are often embedded in new machinery and because the goals are often defined by clients. In addition, protecting innovations requires a strong marketing effort because they tend to be easy to emulate.

- Prompting firms to be sensitive to the needs of their clients, to be aggressive marketers or to keep a watchful eye on new technologies is more difficult than, for example, setting-up a network to help technology-oriented firms conduct generic research. Nevertheless, production-oriented firms do encounter technical problems that can be solved in groups. Solving these problems can create an appetite for innovation.

- We have found that vulnerable and endangered firms are often interested in solving problems of modest technical complexity in small groups in much the same way as strong firms in certain sectors form consortia to deal with major technical challenges. We also discovered that the sums of money required to facilitate these initiatives are quite small and could easily be handled by programs such as IRAP or TOP. We would encourage these programs to develop mechanisms where small and relatively informal consortia of vulnerable or endangered firms can collaborate on specific technical issues. These initiative would give firms a taste for innovation through problem-solving.

- Linking firms more closely to colleges and universities is a means of ensuring that the education system trains people appropriately for the workplace. In addition, it sensitizes firms to the value of recruiting young engineers and scientists. These young people are very inexpensive in proportion to the innovative power that they deliver to firms. In technically advanced fields such as circuit design, microelectronics and software engineering very young scientists and engineers are often the lifeblood of the corporation.

CONCLUSIONS

The nature of innovation

- Innovation is the process by which new products or processes are developed and are successfully introduced into the marketplace.

- Innovation is the sustaining driver of economic growth. It is conducted by firms and is best understood through social analysis and microeconomics.

- Innovative firms are found in all sectors of the economy and can be classified in a taxonomy or framework in which the primary variable is the point in the R & D spectrum at which the firm typically begins its innovation.

- For example, firms that begin their innovation with basic research such as those in the pharmaceutical industry, are highly secretive, protect their inventions by patent, are R & D intensive and generally add high value to their products. They seldom work in consortia and favour one-on-one strategic alliances. Their trade organizations tend to act as political lobby groups and not as diffusers of technology or best practice. The technical complexity of innovation in their sectors tends to be extremely high. Only the strongest firms survive.

- Firms that begin their innovation with production processes such as those in the food and beverage industries, protect their inventions by aggressive marketing. They generally function as intelligent purchasers of technology and buy innovations embedded in new machinery or contract with specialized suppliers to fulfil their needs. They have low R & D intensity and typically do not add high value to their products. The technical complexity of innovation is fairly modest but the rate at which new innovations are introduced can be high. Firms that are slow to innovate can survive, at least temporarily, in sectors that are production-oriented by focusing on their local markets.

- These differences between the behaviours of innovative firms are related to the nature of their industrial sectors. They tend to undermine the usefulness of classical indicators of innovation such as R & D expenditures and capital intensity that governments have traditionally relied upon to formulate policy.

- Highly innovative firms across the industrial spectrum need to be characterized by different criteria. They typically:

  - have above average growth and profitability for their sectors;
  - are able to compete effectively in international markets
  - sustain a world view;
  - are highly sensitive to the needs of their clients and the potential of their suppliers.

Imperfect matching of public investment and industrial needs

- Canada's economy is in a developmental phase. Most of our manufacturing industries are oriented towards product development and production. We are comparatively weak in sectors that rely upon technology development and applied or basic research for innovation.

- Canada has made very strong investments in publicly funded research in both universities and government facilities. However, these have not been translated into substantial economic benefit.

- First, much of the effort has been disconnected from the needs of industry. It has been weighted towards the research end of the R & D spectrum while most firms are concerned with product development and production.

- Second, mechanisms for creating new firms from this technology investment have been very weak as evidenced by the paucity of firms that have been created around major research centres.

- Third, and more importantly, firms have not been able to absorb the knowledge generated because it is too distant in terms of from their immediate needs. Firms best improve their abilities to innovate through incremental processes rather than through quantum leaps.

- The disconnection between public investment and industrial need has persisted throughout the post-war period. It was tolerable when the economy was rich. Now that Canada's economic position is weakening, the conduct of the nation's science and technology policy urgently needs improvement.

- An example of the magnitude of the problem in exploiting technology investment can be found in the University of Toronto which, with its associated hospitals, boasts the largest medical faculty in North America. Yet only four biopharmaceutical firms of any substance can be found in its region and these are largely disconnected from the university's research.

- It is a US firm that has acquired the rights to commercially exploit the university's pioneering research in human genetics. Weakness in "selling" technologies on the part of the university, in the scientific understanding of the investment community and smallness of Canada's reserach-active biopharmaceutical and pharmaceutical firms have all contributed to the problem which has been exacerbated by a poor fiscal climate for entrepreneurship.

The need for readjustment of the publicly funded technology portfolio

- On the whole, the distribution of public investment in research should be shifted so that its centre of gravity is moved somewhat away from the basic research end of the spectrum. Such a shift would help to allign public's investments with the needs of industry. This would require, for example, the Natural Sciences and Engineering Research Council to reexamine, and partially redistribute its research grants.

  Notable shifts in orientation achieved at institutes of the National Research Council such as those responsible for research in construction, microelectronics, biotechnology and industrial materials could be used as examples of what might be done in terms of restructuring programs.

- In areas where Canadian research is of exceptionally high quality and where public investment is relatively large, such as in hospitals and related university institutions, greater effort should be made to commercialize promising technologies. What is missing in the Canadian context is the transition in which researchers become entrepreneurs - a model that is prevalent in the US. This is an area that demands greater attention with respect to access to intellectual property rights and the entire climate for entrepreneurship.

- Government intervention in industry through programs such as IRAP, TOP and DIPP needs to be constantly validated and fine-tuned in response to their mandates. These programs tend to help firms that are involved in technology and product development. Assessing the interest of firms as measured by their own commitment of resources must be an essential yardstick of relevance.

Useful technology diffusion mechanisms - consortia

- For firms involved in technology development, industrial/university consortia for the generation of precompetitive knowledge have been used with considerable success especially in Quebec. Such consortia tend to be most successful when driven by firms. On the whole, firms do not drive the Networks of Centres of Excellence program suggesting the need for readjustment.

- It is obvious that consortia and networks can only work well when players are able to share precompetitive information. This is almost impossible in some areas such as pharmaceutical research. This emphasizes the importance of carefully considering mechanisms of innovation before industrial assistance programs are put into place.

- A key component of government's in-house research is its role in developing norms and standards. If these are well constructed they can be important drivers of industrial quality and innovation. "Made in Canada" standards are not particularly useful because of the smallness of our domestic market. Putting a Canadian bias on internationally harmonized standards is the best course of action.

- Regulations must be approached in the same way by stressing international harmonization. Development of regulation must be based on a sound assessment of risks and benefits. Responsiveness to lobby groups and fragmentation of regulation in areas of provincial jurisdiction tend to undermine innovation and reduce competition. Examples, of these effects have been seen in Canada's transportation, construction and biotechnology industries.

Helping Weak and Endangered firms

- Our analysis showed that weak and endangered firms are mostly to be found in sectors that are oriented towards product development and production. They can survive in these areas because the technical complexity of innovation is not high. In addition, they are sheltered from international competition when they are able to focus on local markets.

- Government programs focus more on the more technologically advanced areas of the economy and afford little help to such firms. Moreover, weak companies can only easily adapt to incremental improvement. Radical cures will often kill the patient.

- The simplest approach to incremental improvement in manufacturing is through improvements of standards and quality control. Firms that target lean production approaches, statistical methods of quality improvement and general quality standards such as those of the ISO 9000 series or AQAP can improve their competitiveness in incremental fashion. Again giant strides should be avoided. These include the wholesale application of total quality management approaches which require a massive devolution of decision-making and authority and demand a highly educated workforce. Such approaches should be introduced incrementally.

- Government can help weak firms to achieve best practices. Delivering programs requires dealing with a large population of firms. To support weak and endangered firms government will need to focus on incremental improvements to quality in manufacturing and of human resources. Such programs must be delivered in large volume and at low unit cost, possibly through distance-learning formats.

Many government programs are not geared to helping production-oriented firms. Most are not adapted to suit large numbers of weaker firms. Changes in both program positioning and delivery mechanisms are required if these firms are to be targeted.

APPENDIX

Name: _____
Sector: _____

REQUEST FOR INFORMATION

A. Description of Firms in the Industry.

1. **How well do the following characteristics describe the firms in your industry sector?**

Please circle the number that best represents the strong, average and weak firms in your sector. (1 - very significant, 2 - rather significant, 3 - significant, 4 - somewhat significant, 5 - not significant)

We do not want to restrict your definition of strong, average or weak firms. However, we offer the following guide:

Strong firm - has above average growth in revenue (excludes start-up firms) compared to other firms in the industry sector;

Average firm - has average growth in revenue; and

Weak firm - has below average growth in revenue.

	Firm		
Characteristic	Strong	Average	Weak
Sells outside home province	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Produces a higher value-added good/service than other firms in the sector	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Innovates (adds a new product/process/service to maintain or increase market share)	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Capable of introducing major changes in product/processes/ service	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Feels pressure to innovate	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Has a world view of development in its field	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

Characteristic	Firm: Strong	Firm: Average	Firm: Weak
Has a cadre of young engineers & scientists	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Meets international standards and certifications	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Other factors (please specify)			

B. The Innovation System.

1. **Innovation is the introduction of a new product, process or service. How important are the following players in helping firms innovate?**

   Please circle the number that best represents the strong, average and weak firms in your sector. (1 - very significant, 2 - rather significant, 3 - significant, 4 - somewhat significant, 5 - not significant)

	Firm: Strong	Firm: Average	Firm: Weak
Suppliers	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Demands of clients	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Competitors	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Foreign affiliates	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Firms in industrial consortia	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Industry research associations	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Trade associations	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Universities/colleges	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Scientific networks	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Venture capitalists	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

	Firm		
	Strong	**Average**	**Weak**
Management that encourages change	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Strong marketing force	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
High standards of quality control	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Strong R&D capacity	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Has people that drive innovation	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Government programs:			
NRC	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
IRAP	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
TOP	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
TIP	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
DIPP	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
STP	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
PEMD	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
R&D tax credit	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Training programs	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

Others (please specify)

2. **In what areas of R&D and innovation are the best firms in your industry sector most active?** (1 - very significant, 2 - rather significant, 3 - significant, 4 - somewhat significant, 5 - not significant)

	Firm		
Activity	**Strong**	**Average**	**Weak**
Basic research	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Applied research	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Technology development (prototypes, testing)	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Productive development	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
Production	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5

C. How Strong Firms Innovate.

1. **Briefly describe the industry sector for which you are responsible.**

2. **Briefly explain how the best firms in your industry sector innovate.**

   Questions to consider include:

   - Is it an expensive process (e.g. relative to revenue)?
   - How is the process funded?
   - What organizations, programs, tools are available to help strong firms innovate?
   - Are government programs (e.g. IRAP, R&D tax credit, training programs, other) useful? Why or why not?
   - Are industry associations helpful? Why or why not?

Thank you for your cooperation.

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