Industry, Science and Technology Canada
Industrie, Sciences et Technologie Canada

PRODUCT AND PROCESS DEVELOPMENT IN THE CANADIAN AUTOMOTIVE SECTOR

Canada

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IN THE
CANADIAN AUTOMOTIVE SECTOR

Automotive Directorate
Industry, Science & Technology Canada
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FORWARD

The purpose of this paper is to establish a consensus concerning the state of product and process development in the automotive industry, focussing on problems and challenges faced by the Canadian industry. The paper was first circulated in July, 1989. This version incorporates comments made by industry and governments, and presents a generally accepted view of issues facing the Canadian automotive industry as it adapts to technological change.

A Research and Development Sub-Committee was established in July 1989, reporting to the Minister of Industry, Science and Technology Canada's Automotive Advisory Committee, to advise on technology development issues. ISTC is coordinating a workplan, involving industry, other government departments and provinces, to examine issues raised in more depth. Topics being examined include R & D tax incentives, technology transfer, availability of capital, and availability of human resources.

It is anticipated that most of the work plan will be completed by mid-1990, to be followed by a strategy paper outlining actions taken and future directions for the industry. This paper will also reflect views expressed in an industry forum held in February 1990. The result of this process should be a clear and realistic assessment of what role Canada can expect and plan to assume in technology development in the automotive industry of the 1990s.

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SECTION ONE: INTRODUCTION

Canada's automotive sector is a major generator of wealth and employment, with 1988 vehicle production of $27 billion, parts production of $14 billion, and employment of 154,000. Trading in a fully rationalized North American market under the Auto Pact, $36 billion of automotive products were exported in 1988, producing a trade surplus of $4 billion.

In contrast to this strong performance, the automotive sector is one of Canada's largest underperformers of research and development relative to sales, with a research intensity of only 0.3%, one tenth that of other automotive producers. Compared to the OECD average intensity, underspending is estimated at close to one billion dollars. Total R&D expenditures equalled $92 million in the sector in 1987, including $40 million by assemblers and $52 million by parts producers. In contrast, R&D expenditures of GM, Ford and Chrysler equalled almost $8 billion (U.S.) in 1987.

Low levels of R&D in the industry reflect the centralization of activities around Detroit, and high degree of foreign ownership in the sector. Despite low levels of indigenous R&D, Canada has benefitted from technology transfer from foreign parents, performing well by several key indices of technological innovation. Productivity growth in the sector has surpassed that of the United States during the 1980s, and outperformed the Canadian manufacturing average, while investment and adoption of technologies such as Statistical Process Control (SPC) and Computer Aided Manufacturing (CAM) have increased rapidly. Canada has a disproportionately large share of assembly and parts plants awarded superior quality ratings by assemblers. Fully one third of General Motor's suppliers are located in Ontario, and once new capacity becomes operational, Canada will have 25 percent of North American assembly capacity.

However, while reliance on technology transfer has been successful in the past, it is becoming a less and less viable strategy. A basic change has occurred in the competitive environment, led by the Japanese. The Japanese are making management of the innovation process the key competitive issue of the 1990s, as they did cost and quality in the 1980s. Not only have Japanese expenditures on automotive technology increased, approaching American levels, but the Japanese have been more successful than their competitors in turning these expenditures into innovative products and processes. Patents registered by Japanese producers in the United States now exceed those registered by American companies, while product development time of Japanese producers averages three to four years, compared to up to seven years for American and European producers.

As a result of the Japanese example, and consumer demands for increased quality, reliability, safety and performance, three fundamental changes have occurred to the innovation process in the North American automotive industry. Firstly, the automotive industry is becoming more technologically intensive, with greater value added due to R&D activities. Vehicles of the 1990s will be constructed of advanced composites, and incorporate up to $2,000 of electronics, performing functions such as emission control, anti-lock braking and active suspension.

Secondly, the organization of the R&D function is being transformed, as simultaneous engineering and continuous improvement techniques are introduced. Thirdly, the relationship between suppliers and assemblers is changing, with recognition that suppliers must be given a greater role in the development and application of technology, leading to the development of Tier 1, or fully capable suppliers, and lower tier suppliers. The best suppliers will provide expertise in a specific technology, as well as modular assembly capability. These expectations are in sharp contrast to previous decades when assemblers controlled all technology and design functions.

These changes have several profound implications for the Canadian automotive industry, offering both threats and opportunities. As the industry becomes more technologically intensive, and the parts industry stratifies in tiers, Canada risks losing its share of value added operations. As emphasis on product and process engineering increases, both assembly and particularly parts plants must increase basic engineering capability, to provide, at the least, process engineering skills. Failure to do so will mean an attrition of basic manufacturing capability, as assemblers will see no reason to source from a high wage country unless significant value added is provided.

Significant barriers exist to increasing product and process design and engineering functions of both assemblers and parts companies in Canada. Assemblers cite the traditional centralization of these functions by parent companies, and large investments in existing facilities in the United States and Japan. Shortage of trained personnel, particularly automotive designers, is also a constraint. Suppliers point to a shortage of risk capital and trained personnel, and also cite uncertainty of commitment by assemblers and difficulty in recovering development costs.

At least three scenarios exist:

One is that Canada's position as a lower level manufacturer will be re-enforced, with assemblers continuing to centralize product and process activities in Detroit, and suppliers becoming sub-contractors to Tier 1 producers in the United States. Given existing levels of technology, Canada would simply be another commodity producer, losing ground to low cost countries such as Mexico and Korea.

A second scenario is that, in order to succeed against emerging competitors of commodity products, Canadian operations build on existing strengths to achieve a world class process development capability. An opportunity exists to define a niche of expertise in incremental process development, an area in which the Americans and Europeans are weak. To do this however, Canadian firms must develop engineering capability, and change organizational structures to make continuous incremental improvement possible.

A third scenario is that Canada will gain greater control over product development and greater value added, as some parts producers develop into Tier 1 operations. A handful of firms already operate on a Tier 1 level, albeit on a smaller scale than our major competitors. A possibility also exists that assemblers could expand product and process responsibilities in Canada, to benefit from simultaneous engineering and exploit Canadian expertise in areas such as alternate fuels. If these possibilities are to be realized, considerable initiative will be required by Canadian operations to convince assemblers of their potential, as well as high risk investment in equipment and personnel.

The solution to low levels of technology development in the Canadian automotive industry must be both supply and demand driven. Assemblers have a role to play in increasing in-house engineering and scientific activities in Canada, for both process and product development, and in developing suppliers' capabilities. Suppliers must acquire product and process engineering skills, and Tier 1 suppliers, in particular must develop leadership in their area of technology.

The low level of technology development in the automotive industry in Canada is of concern to the federal government. ISTC has begun to address these issues by introducing the Automotive Components Initiative (ACI) sector campaign, which supports companies to hire experts to assess their process technology. The Minister of Industry, Science and Technology Canada (ISTC) has requested that industry and labour examine the issue, considering the roles of all parties, and develop a possible course of action. The challenge now is for industry, labour and government to address the broad question of automotive technology development and develop an agenda which will lead to increased levels of activity in the sector, positioning Canada as a high value added, knowledge intensive producer.

SECTION TWO - INNOVATION THEORY AND R&D ACTIVITY IN CANADA

2.1 THE INNOVATION CYCLE

In the automotive sector, as in most manufacturing sectors, research and development is restricted to development, occurring near the end of the innovation cycle. Innovation includes all activities required to transfer technical ideas into new products or processes. Development of any new product passes through an innovation continuum, usually defined as:

Pre-competitive Research:	-	basic research
	-	applied research
Development:	-	exploratory development, which may involve design scheduled development (prototypes, pilots)
Production:	-	commercial manufacturing
	-	marketing

(See Annex 1 for Research Pyramid).

Strong basic research, in itself, does not guarantee development of competitive advantage. The critical link is how companies use this research to develop new products and processes. Recent evidence (eg. Made in America , Massachusetts Institute of Technology) suggests that downstream skills in product design and manufacture are as important, if not more important, than basic research, accounting for the Japanese success in producing high quality, high value, manufactured products. It is also clear that in the best companies, the stages of the innovation continuum overlap, rather than being conducted in a linear fashion, resulting in shortened product development time, and rapid commercialization of innovation. Such is certainly the case in the automotive industry. (Section Four)

2.2 LEVEL OF R&D ACTIVITY IN CANADA

While the automotive sector is one of Canada's largest underperformers of research and development, the R&D performance of the Canadian economy as a whole is poor, as measured by most indicators. Canada ranks second from the bottom of the G-7 countries, devoting 1.4% of expenditures to R&D as a percentage of GDP (GERD) in 1987, compared to 2.27% in France, 2.81% in Germany, 2.86% in Japan, 2.69% in the United States, 2.36% in Great Britain, and 1.27% in Italy (1987 data).

Performance reflects both low expenditures by industry and government; however, when military expenditures by government are excluded, underperformance by industry is particularly evident. R&D funded by industry in Canada is the lowest of the G-7, at .71% of GDP, compared to 1.97% in Japan, 1.82% in Germany, and 1.27% in the United States.

While industry is the single largest funder of R&D in Canada, accounting for 42% of total expenditures in 1987, industry in Japan, Germany and Sweden funds 69%, 65% and 64% of R&D respectively. Industry's contribution to R&D in the United States and France is consistent with that in Canada, at 47% and 41% respectively, however large military expenditures by government skew ratios in these countries.

Government contribution to R&D in Canada was .59% in 1987, compared to 1.38% in Germany, 1.28% in the United States and 1.17% in Britain. The Japanese government devotes only .62% of GDP to R&D, while Italy devotes .76%. When defence expenditures are excluded, the American government spends only .40% of GDP on R&D, while the British spends .58%. Only expenditures by the German and French governments remain high, at .96% and .91% respectively. The federal government contributes approximately 11% to total business R&D expenses in Canada, consistent with Germany and Sweden, and exceeded only by the large defense spenders - the United States, Britain and France. (see Section 7)

Consistent with other indicators, total research and engineering graduates (RSE) per thousand labour force in Canada lag behind G-7 countries. Canada employed 4.3 RSE per thousand labour force in 1986, compared to 8.1 in Japan, and 6.6 in the United States. Germany and Sweden employ approximately 5.2 and 4.5 respectively (1985 data), but perform much better than Canada when total R&D personnel is compared (8.0 for Canada, v.s. 14.3 for Germany, and 11.1 for Sweden) (1985 data).

Somewhat surprisingly, Canada's production of advanced degrees in science and engineering is in the middle ranks, surpassing Germany and Sweden, and not far behind Japan. Even accounting for repatriation of foreign students, the problem would seem to be absorption of these graduates by industry, an outcome of low levels of R&D by industry.

The most commonly cited reasons for low levels of industrial R&D in Canada are reliance on resource based industry, foreign ownership, lack of defense spending, and a small domestic market. The Canadian Institute for Advanced Research (CIAR) questions the continuing validity of these premises. The CIAR notes that resource based industries such as forestry and agriculture are becoming more technology intensive, while multinationals need not develop all technology in a central location, but will invest where skills are available at a reasonable cost.

IBM, Pratt and Whitney and Xerox all provide examples of the decentralization of research facilities.

While Canada's GERD/GDP ratio remains low, it should be noted that the GERD has an exponential relationship to GDP: the larger the economy, the greater the percentage of resources devoted to R&D. ISTC estimates that for a free-market economy with Canada's GDP, the GERD/GDP ratio should be about 1.7 per cent, or approximately .4 per cent greater than the existing GERD/GDP ratio, rather than the 3% being approached by Japan and the United States.

Further, increasing the GERD/GDP ratio presents a moving target, as even if R&D expenditures increase, the ratio will decrease if GDP increases even faster. Such has been the case in the past year in Canada. Preliminary estimates show the ratio decreased from 1.40% in 1987 to 1.35% in 1988 and 1.28% in 1989, despite a nearly $1 billion increase in GERD in this period ($7.4 to $8.3 billion), as GDP increased even more rapidly, by nearly $100 billion, during the same period.

Increases in the GERD and the portion of activity funded by industry are encouraging. The share of the GERD financed by Canadian industry, while low, increased 45% from 1974 to 1985. Significant change will only come, however, when underperformance by certain key sectors, such as the automotive industry, is addressed.

SECTION THREE - AUTOMOTIVE INDUSTRY IN CANADA

3.1 CANADIAN INDUSTRY

The automotive assembly and parts industry is a major contributor to GNP, exports and employment in Canada, accounting for $41 billion of production, exports of $36 billion, a positive trade balance of $4 billion, and 154,000 jobs (1988 data). Automotive activities accounted for some 16 per cent of total Canadian shipments of manufactured products in 1986, and 44 per cent of manufactured exports to the United States.

The industry consists of the assembly of vehicles, trucks and buses, and manufacture of parts, with production of approximately $27 billion and $14 billion, respectively. Unlike many other Canadian industries, the sector does not suffer from lack of economies of scale or market access, as production has been rationalized under the Auto Pact, reinforced by the Canada-U.S. Free Trade Agreement.

The industry is dominated by multinationals. In the assembly sector, General Motors (GM), Ford and Chrysler have been recently joined by Toyota, Suzuki, Honda and Hyundai. Parts production is dominated by "in house" operations owned by GM, Ford and Chrysler (45 per cent), with other American companies owning 38 per cent of capacity, and Canadian companies 17 per cent. The Canadian owned sector is composed of a handful of larger firms, (sales in excess of $100 million), with most considered small to medium sized.

Approximately 425 companies are primarily engaged in the manufacture of automotive parts, with another 1500 involved in the sector. The auto parts sector is a microcosm of the entire manufacturing sector, with engines and drive trains accounting for 31 per cent of production, followed by metal stamping (15.5%), plastics (8%) wiring harness (2.5%) and electronics. Major subassemblies consist of exterior stamping and trim, interior trim, seating, engine and drive train, door systems, suspension and steering, and heating, ventilation and cooling systems.

3.2 RESEARCH AND DEVELOPMENT ACTIVITIES IN THE CANADIAN AUTOMOTIVE INDUSTRY

Technological innovation is usually measured by inputs devoted to R&D, the number of intermediate outputs, such as patents, and the amount of inputs required to produce end products (i.e. productivity). The Canadian automotive industry performs poorly in terms of inputs and intermediate outputs, but well by productivity measures, reflecting the degree of technology transfer in the sector.

Inputs

Research intensity, or expenditures as a per cent of sales, is the lowest of any industry in Canada, at 0.3%, compared to 3.5% in low intensity sectors such as business machines, and 18% and 14% in high intensity sectors such as telecommunications and aerospace. In contrast, in 1980, the OECD reported a research intensity of 3% in the American automotive industry, 2.3% in the Japanese, and 3.2% in the German. If Canada were to match OECD average intensity, an additional billion dollars of expenditures would be required.

The automotive industry also ranks near the bottom of manufacturing industries in Canada in terms of absolute expenditures. Expenditures of $92 million in 1986 were surpassed by telecommunications ($831 million), aerospace ($501 million), business machines ($330 million), electronics ($305 million), chemicals ($202 million), petroleum ($142 million), drugs ($127 million), and non-ferrous metals ($104 million). In contrast, in 1984, the OECD reported official R&D expenditures in the automotive sector of $4.8 billion in the United States, $2.7 billion in Japan, and $3.2 in Europe, for a total of over $10 billion.

Assemblers

Of the $92 million, $40 million was spent by assemblers, representing a negligible percentage of sales. Assemblers maintain small engineering staffs in Canada, primarily to test vehicles for cold weather conditions, and to adapt vehicle designs to meet Canadian regulations. In contrast, General Motors spent $4.36 billion (U.S.) in 1987, Ford $2.5 billion (U.S.), and Chrysler $798 (U.S.), ranking first, second and twelfth respectively in rankings of private research conducted by American companies.

Parts sector

$52 million was spent by the parts sector in Canada in 1986, representing 0.49% of sales. Of approximately 425 parts firms operating in Canada, Statistics Canada reported 33 R&D performers in 1986:

Engine and parts	2
Wiring assemblies	1
Steering and suspension	1
Wheel and brake	3
Plastic parts	5
Fabric	3
Other	18

Twelve companies had programs in excess of $1 million. A majority employed less than 500 employees, while five employed over 1000. Canadian owned firms, while accounting for only 17 percent of shipments in the parts sector, and approximately 6 percent of overall automotive shipments, conduct 46 percent of total automotive R&D.

Companies performing technology development include ABC Plastics, Woodbridge, Waterville, the Narmco Group, Long Manufacturing, Siemens and Magna International. Most companies emphasize process technology, although emphasis on product technology is increasing, as assemblers demand full product design from Tier I suppliers. (Section Four)

Design house

In addition to assemblers and parts supplies, a small design house sector exists in Canada. The existence of design houses in Canada is fairly recent and generally unrecognized. For example, Hawtal Whiting employs approximately 100 automotive designers and engineers in Windsor.

Skilled personnel

Inputs also include employment of skilled personnel. A total of 1175 scientific and engineering personnel were employed in the automotive sector in 1986, representing less than one percent of total employment in the industry. The majority of professional staff had bachelor' degrees.

Patent activity

As well as inputs, another critical measure of the degree of innovation in a sector is patent activity, usually measured as patent registrations in the United States. Canadian patents registered in the United States are negligible in comparison to those registered by Japan, Europe and the United States.

Productivity

The industry fares better with measures of productivity and use of intermediate technologies. Productivity in the Canadian automotive sector grew 13% faster than that of the American during the 1980s. Growth rates of 7.3% remained well above the Canadian manufacturing average of 4.7%. Productivity increases can be attributed to the introduction of new process technologies, such as Computer Aided Design and Manufacturing (CAD-CAM) and Statistical Process Control (SPC). The transportation sector, comprised primarily of the automotive sector, leads Canadian industry in the use of CAD (60% adoption rate); CAD/CAM (37%); numerical control (48%) and flexible manufacturing techniques (32%). Up to 80% of automotive companies use Statistical Process Control. Adoption of these technologies has been driven by demands of assemblers for improved quality and lower costs.

Conclusion

The overall picture presented of R&D performance in the automotive sector is that of substantial underspending by assemblers, and strong activity by a handful of Canadian owned parts firms. Surveys by Industry, Science and Technology Canada (ISTC) have shown that both assembly and parts producers concentrate on process engineering, in response to customer demands. Technology is acquired primarily from equipment suppliers, with little or no interaction with universities, government laboratories, or technical centres, severely limiting the sector's ability to conduct truly innovative activities.

SECTION FOUR - CHANGING ENVIRONMENT

The structure of the industry has not favoured the development of technology intensive automotive companies in Canada. Traditionally, assemblers designed and engineered all aspects of the vehicle body and componentry in Detroit, giving complete specifications to parts producers to manufacture. Assemblers did not demand product innovation from suppliers, but rather low cost production. The "build to print" era demanded minimal technical knowledge of suppliers, limited to minor design modifications and process engineering. A.E. Little, examining Canadian automotive technology capability in 1979, commented that most companies saw no need to perform R&D, instead specializing in responding quickly to needs of the assemblers for process and tooling modification.

With assemblers dominating all aspects of automotive engineering, centralized in Detroit, it is not surprising that development of automotive technology in Canada has been minimal. However, the nature of the automobile and the design process is changing rapidly, in response to increased competition, primarily from Asian countries, and more sophisticated consumer demands. Just as the North American automotive industry has begun to catch up to Japanese manufacturing techniques, the Japanese have introduced a dynamic system of research and development, which has overtaken both the European and American, as measured by product development time and patent activity. This dynamic system is changing the degree of technological intensity of the industry, the way in which the R&D function is carried out, and the relationship between suppliers and assemblers. These changes have fundamentally altered responsibilities assigned to suppliers, and the nature of the engineering process itself.

4.1 TECHNOLOGICAL INTENSITY

Motor vehicles should not be considered mature products, but are in fact at the forefront of applications of new technologies, primarily electronics and advanced materials. The automotive sector is considered an R&D intensive sector, along with chemicals, electrical and electronics, and aerospace, with expenditures by assemblers averaging from 3 to 6 percent of sales. The level of activity in the sector is demonstrated by patent applications in the United States. Four of the top ten fastest growing patent classes in mechanical engineering in 1984 were in the automotive sector, as was one of the top ten electrical and electronic classes.

Introduction of these technologies was initially driven by the need for greater fuel economy, leading to the use of electronic controlled fuel systems and substitution of materials such as plastic and aluminum for steel. Import competition and consumer demands for increased reliability, safety and performance have further pushed the development of electronic controls, such as anti-lock braking systems, and active suspension, and use of high performance materials which resist corrosion. By the year 2000, each vehicle will contain an estimated $2,000 in electronic components, and hundreds of pounds of advanced composites.

The push for increased technological intensity is being led by the Japanese. The Japanese have greatly increased spending on R&D in the last ten years, catching up to European levels and approaching American. Japanese spending per vehicle, at $370, remains below the German level of $540, and the American of $450. However, on a company basis, Honda, at $700 per vehicles, stands well above GM, Ford, Toyota and Nissan, at $400, and Chrysler, VW and Fiat, at $300.

Apart from increased expenditures, what is most worrying to their competitors, however, is the ability of Japanese companies to maximize benefits from their

R&D investments. While the increase in R&D activities of the Japanese was initially devoted to absorbing European and American technology, they are now at the leading edge of automotive technology. Toyota, Nissan and Honda have overtaken GM and Ford in the number of patents granted in the United States. Japan now leads in patents related to engines and automotive electronics, while the Europeans lead in brakes and clutches, and process equipment. The Americans hold their own with the Japanese and Europeans only in patents relating to motor vehicle bodies.

Not only have the Japanese established the lead in the application of technologies, but are becoming trend setters in styling and design. Mastery of technology provides increased design possibilities, exploited through the use of design houses in California and Europe.

The key to the Japanese success in translating R&D expenditures into patents and commercial success lies in the organization of the R&D function. The two outstanding characteristics of this system are the introduction of multidisciplinary product teams using simultaneous engineering, and the role of component suppliers:

4.2 SUPPLIER ROLE

Much has been written about the "Tier 1" parts supplier in Japan, charged with complete design of a component, from the concept stage of the vehicle, the sub-assembly of a component module, and supply of the module on a just- in- time basis to the assembler. Assemblers source up to two thirds of components from suppliers, who account for fully two thirds of the patents registered by Japanese companies in the United States. Close ties exist between parts manufacturers and assemblers, nurtured through equity relations and long term contracts.

In contrast, the North American supply system evolved as a highly vertically integrated system, with independent suppliers used as expendable providers of low technology components at the lowest possible price. General Motors produces fully two thirds of components in-house, while Ford sources up to 50 percent. In-house operations could have evolved as Japanese Tier 1 suppliers, but protected from competition, tended to develop as high cost producers.

In the mid-1980s, observers confidently predicted a widespread adoption of the Japanese model. However, a great deal of confusion and uncertainty has occurred in the last two to three years, and will continue in the foreseeable future, as American assemblers attempt to redefine the role of the supplier. The result will be a critical determinant of where and how product and process development is conducted.

Early predictions of a wholesale adoption of the Japanese model have not been realized. In the short term, American assemblers are compelled by union agreements to maintain captive parts operations. Further, it now seems clear that, rhetoric aside, American assemblers are not immediately willing to relinquish control of vehicle design and sub-assembly, despite the advantages of technical specialization and increased flexibility. Suppliers are being asked to demonstrate full product design and sub-assembly capability, yet assemblers are often unwilling to guarantee purchase of completed modules in advance, or guarantee recovery of development costs.

Individual examples of assembler-supplier co-operation exist. The G.M. Saturn project and Ford Tauras project involved suppliers from the early development stages. So far, however, outsourced components have usually been low value, low technology products with high labour content, such as brakes, wheels, soft trim, seats, fabric, small stampings and wiring. G.M. appears to have reversed a policy to increase outsourcing due, in some measure, to union pressure, and is attempting to make in-house operations more efficient. In these circumstances, how widespread will outsourcing become in North America?

Obstacles to the contrary, most observers agree that, in the long run, a tier structure will emerge in North American, in what Richard Lamming of MIT's International Motor Vehicle Program refers to as the "Post-Japanese model". In this model, fewer, larger, more capable suppliers will exist, growing through acquisition. Assemblers seeking Tier 1 capability expect suppliers to have more than $250 million in sales, and to devote 5% of sales to R&D, representing expenditures of $12.5 million, with development staffs of 1,000 or more. To reduce overhead, assemblers will deal with fewer suppliers, and will assist them to develop new technologies. The Tier 1 suppliers will provide collaborative R&D and component technology at the pre-competitive stage, expertise in CAD, and manage sub-contractors. Tier 1 suppliers will need to be present in more than the automotive sector, to provide required technological expertise.

The lower tier suppliers will supply the Tier 1 assembler, and while having relatively low value added, will have expertise in process design. This group will contain many commodity producers of plastic parts and metal stampings. For both Tier 1 and lower tier producer, competitive advantage will continue to rest on best practice world class manufacturing methods.

Auto analyst Maryanne Keller reinforces these views, commenting that "the requirements of successful companies include engineering and process capabilities, materials technology, and process controls to achieve high quality requirements... suppliers that can take in grey box design and engineering assignments will have an advantage... The assembler will work with a select few who have demonstrated capability to design and manufacture... the producer with broad materials and manufacturing knowledge will have an advantage over the company that is tenuated in scope."

This concept is far from realization. Recent surveys of North American suppliers reveal a fundamental distrust of assemblers. Suppliers are left in a position of having to demonstrate capability, but not enough to challenge assemblers' control.

4.3 SIMULTANEOUS ENGINEERING

The second major area of change is the integration of product and process engineering, aided by CAD/CAM systems and new organization structures, permitting quicker product development time, and improved quality.

Increasingly, product lead time is seen as a measuring stick of performance. Recent research indicates that the average development time of a vehicle in the United States is 60 months, compared to 59 months in Europe and 46 months in Japan. The Japanese spend an average of 1.7 million engineering hours on each new platform, compared to 3.0 in Europe and 3.1 in North America. Die lead time is 13.8 months in Japan, compared to 26.8 months in the United States.

These differences reflect fundamental differences in organization and management, as well as different approaches to the use of new computerized engineering tools. Traditional design systems progressed in a batch, or sequential fashion, beginning with styling, passed on to engineering, and then to manufacturing. Frequent transformations were required from geometry to formulae, analogue to digital, drawings to models. Clear decision points often did not exist, and senior management intervened at late stages to change direction. This system resulted in constant compromises, errors, re-design, re-tooling, multiple prototypes and consequent delay.

The system used by the Japanese, now being adopted by GM, Ford, and Chrysler, is an integrated, or overlapping process, using a team approach, and integration of all functions through computer tools. A team from all elements of the organization (design, manufacturing, marketing) is responsible for vehicle design and engineering. Production problems are minimized by designing for manufacturability. Most cost and quality losses originate not in manufacturing, but in the design stage: in fact, when 15 to 25 percent of development is completed, 75 percent of production costs have been committed. In a world class operation, process engineering starts within three to four months of initial concept, compared to 34 months in traditional operations. (See Annex 4 for GM Design Process.)

Integration of functions is made possible by computer integrated manufacturing techniques. Integration, rather than greater speed, is seen as one of the major benefits of CAD/CAM. CAD systems allow all parties to see proposed changes simultaneously. Rather than simply capture basic information in a computer format, analysis, drafting, design, testing and manufacturing can now all be controlled through a digital data base, shared by assemblers and suppliers. Use of expert systems will prevent re-solving of problems, and reduce errors. Conceptual design, formerly done on paper, can be produced by holograms. Product design using CAD/CAM uses cost, manufacturing and process data concurrently; analysis and drawings are a by-product of this process. Soon, with the addition of solid modelling, structural analysis, and aerodynamics, the designer will know instantly if the design is viable. Increased accuracy reduces the number of prototypes required, and prototypes are used not to solve problems, but to validate design.

New design methods rely on CAD/CAM, but, most fundamentally, represent organizational and operational changes. Design engineering is characterized as a highly political function, with high uncertainty, time pressures, interdependence between groups, conflict and negotiation. The technical specialist is now required to take a broader view, as part of a project team; the team leader is probably an engineer, but is required to rise above his technical specialization to integrate marketing, design, production and engineering concerns. Finally the new system involves senior management in early stages of a project, to define strategic goals, and make decisions at clearly defined milestones, but reduced involvement in operational decisions.

Simultaneous engineering has profound implications for assemblers and suppliers. If American assemblers are to match the Japanese, product design must occur closer to the place of manufacture, with integration of product and process engineering. Suppliers must be prepared to participate in the design process from the concept stage, working with both the platform team and central engineering staff. Such participation will require appropriate engineering staff, equipment, and knowledge of the design process of each assembler.

4.4 GLOBALIZATION OF R&D FUNCTIONS

A final impact of competitive changes in the automotive industry is a tendency towards increased centralization of R&D activities. In a series of interviews on three continents, Roger Miller found that assemblers viewed centralization as essential to maximize economies of scale, and systematically coordinate activities with other corporate functions. Economies of scope as well as scale are required to apply generic technologies across product lines, and to master technologies in depth. Proximity to experimental process facilities is also a necessity.

Smaller technical and styling centres will be established in foreign divisions, to deal with parts suppliers, adapt design to local markets, and learn from local design trends, particularly in Italy and California.

This view of increasing centralization is borne out by the experience of Canadian assemblers and parts producers. Parts producers must establish product design facilities in Detroit if they are to develop a Tier 1 presence with American assemblers. Assemblers confirm, that, despite modern data transfer methods, and advantages presented by local expertise, lower costs, or more flexible, smaller operating units, major development work will continue to be centralized.

A few exceptions exist to this general rule. First is the need to integrate product and process design. While simultaneous engineering can be conducted using prototype assembly plants, some process work must be conducted on-site. A second, and related need is that of establishing capability to ensure effective transfer of technology to local operations. Thirdly, local conditions or expertise may make research in niche areas attractive.

Japanese assemblers follow the general rule of centralization, with design centres established in California and Italy to learn from latest styling trends. Honda will employ 500 designers in California by 1991. Certain Japanese assemblers are also transferring some engineering capabilities to North America, notably Nissan and Mazda.

SECTION FIVE-RESPONSE OF CANADIAN INDUSTRY

Canada will clearly not be a leader in the changes in technological innovation shaping the global automotive industry, but must respond to changes in the environment. How well is Canada positioned to react to these changes? Positioning and opportunities vary by function: assembler, Tier 1 parts producer, lower tier producer and design house:

5.1 ASSEMBLERS

Opportunities for the Canadian assembly sector depend entirely on decisions made by American and Japanese assemblers as to the role of Canadian operations. The general trend is towards centralization. Canada has several advantages, however, which could cause assemblers to consider an enlarged role for Canadian R&D facilities: proximity to Detroit; favourable costs of performing R&D, due to favourable tax incentives and lower wage rates; and expertise in niche areas such as alternate fuels. With several large production complexes located in Canada, assemblers must also consider the need to perform simultaneous engineering, and the need to develop the technological capacity of Canadian parts companies. Weighing against these factors are a shortage of trained automotive engineers and technical personnel in Canada, and high costs of data transmission to the United States.

The greatest potential for Canadian assembly operations seems to be in process engineering, particularly linking product design to manufacture. Other specific opportunities exist for cold weather testing and product development, as well as niche product development in areas where Canadian universities and research community have proven expertise, such as alternate fuels.

5.2 TIER 1 PARTS SUPPLIERS

A tier structure among North American domestic suppliers is emerging slowly. Yet, in the long run, all observers agree that some form of fully capable suppliers with product design and sub assembly will be required, and the overall number of suppliers reduced. As the industry stratifies into suppliers of technology (Tier 1) and suppliers of manufacturing capability, with some process technology, the Canadian industry faces a profound watershed.

Of the 425 companies primarily engaged in the manufacture of automotive parts, the Ontario Centre for Automotive Parts Technology estimated in 1987 that approximately 34 were capable of becoming Tier 1 producers. Only 10 to 15 could be considered true Tier 1 producers now, with full design and engineering capability, and modular sub-assembly. Most potential for development of Tier 1 firms exists in the plastics, interior trim, and seating areas.

The most serious impediment to growth faced by these companies is the hesitation of assemblers to commit to Tier 1 suppliers. As described above, suppliers are being asked to commit new capital and increase fixed costs, with no guarantee of return. A second major barrier is simply that of scale. As very large international competitors emerge, through acquisitions and mergers, absolute R&D expenditures of Canadian firms will be dwarfed in comparison to those of competitors. Thirdly, extremely competitive market conditions restrict availability of capital for risky investments.

In surveys conducted by Industry, Science and Technology Canada in the spring and summer of 1989, leading Canadian parts companies, capable of reaching a Tier 1 level, were asked to list barriers to introduction of new technology. In addition to the above barriers, the most cited constraints were difficulties in training managers, and finding skilled product and process design personnel. Other barriers were legislative and regulatory, reflecting perceived over-regulation in Canada versus competing jurisdictions. Financial factors were also cited, such as lower labour costs in the United States, the high cost of the Canadian dollar, and the tightening of tax write-offs. Success factors in implementing new technologies were seen as management practices, strong middle management support, finding an internal champion, having skilled people, and relationships with suppliers. All these factors will be required if Tier 1 potential is to be developed.

Of options to address these problems, respondents showed little interest in using consortia, or hiring expertise outside the company. A frequently made comment was that knowledge has to stay within the company. Companies identified preference for support through the tax system and for the establishment of a training program for automotive engineers.

The need for trained personnel is consistent with comments made by the manufacturing sector as a whole, and by U.S. firms. The Conference Board reports that over half of firms conducting R&D in Canada project a shortage of trained personnel in the next five years, principally engineers, while one third experience a shortage now. The new President of the Society of Automotive Engineers, Edward Mably, recently cited an impending shortage of scientists and engineers in the American transportation industry. A conference held May 3, 1989 by the Natural Sciences and Engineering Research Council (NSERC) projected critical shortages in all fields of engineering and science, confirmed by industry representatives.

5.3 LOWER TIER PARTS SUPPLIERS

The Canadian parts sector is dominated by stampers and plastics producers, which are most likely to become lower tier suppliers, selling to a Tier 1 company, or occasionally, as assembler. These producers will supply parts, not design, and will be required to be expert in best practice manufacturing techniques and process technologies. It is only through manufacturing excellence that suppliers of essentially commodity parts will be able to compete against emerging producers such as Mexico and Korea. Lower tier producers must understand the assemblies in which their parts are used, and master process improvement techniques. While they need not have their own design and engineering department, they must at least have access to one, through an independent design house, or Tier 1 assembler.

This role is the easiest for the Canadian parts industry to assume, given the industry's high quality of production and adoption of process innovations such as SPC. What is required, however, is a dedication to continuous incremental improvement, which can lead to major process innovations. The major barrier to achieving this expertise is the need for increased process engineering capability, requiring increased investment in equipment and personnel. In addition, parts producers, accustomed to selling directly to assemblers, must develop new alliances with Tier 1 producers.

5.4 DESIGN HOUSES

The two large design houses operating in Canada agree that the major constraint to growth is shortage of trained personnel. Funding is not an issue, but locating people with the right skills. Shortages exist in all areas, from community college level draftspersons, to automotive engineers with CAD/CAM training, to creative designers. These firms are devoting considerable resources to training, and are also recruiting from the United States and abroad. All firms indicated that significant growth opportunities will be foregone if more trained personnel could not be located.

SECTION SIX - GOVERNMENT PROGRAMS

As noted at the outset, governments in Canada spend .59% of GDP on R&D, consistent with our competitors when defence expenditures are excluded. The following sections outline in more detail the nature of government support, in comparison to OECD countries.

6.1 FEDERAL

General

The federal government spent a total of $733 million on science and technology performed by industry in 1989-90. An additional $750 million is provided to industry through tax incentives.

Three departments dominate funding directed to industry: Industry, Science and Technology Canada (ISTC) ($254 million), the National Research Council ($111 million), and National Defence ($112 million). (1988-89 figures) Other departments contributing to science and technology performed by industry include Energy, Mines and Resources ($55 million); CIDA ($51 million); AECL ($20 million); Communications ($16.5 million); Agriculture ($14 million); and Environment ($10 million).

The federal government spent $476 million in 1988-89 on manufacturing technology, including both resources directed to the private sector and those spent internally. The primary funding sources are ISTC and NRC.

Of research and development conducted by the manufacturing sector in 1986, approximately 9 percent was financed by government, totalling $266 million. Federal expenditures are heavily skewed to the aerospace and electronics sectors, representing 47 percent and 27 percent of expenditures respectively. Federal contributions to the transportation sector totalled only 2 percent.

Industrial support

Funding for industrial research and development in Canada has shifted from company specific programs (PAIT, EDP, DIPP), to regionally weighted R&D programs (IRDP), and most recently, to non company specific support (Strategic Technologies, Technology Outreach program, Sector Campaigns). Company and product specific assistance is largely restricted to the aerospace and electronics industries, and to small companies.

The success of past programs in increasing research and development activities in Canada is open to question. The most recent program, IRDP Innovation, reached a small number of companies, and its effectiveness was questioned by program evaluators. More broadly, it is uncertain how successful government programs are in addressing structural problems such as low levels of R&D in an industry.

(Federal programs are described in more detail in Annex 6.)

Training assistance/assistance to hire personnel

Support for training for automotive technology activities is limited. Automotive engineering is not offered at any Canadian college or university, with the exception of a small program at St. Clair College. CAD/CAM training is widely offered by community colleges, but most community college graduates must be retrained on specific systems, and lack sufficient engineering understanding to actually design and test products. Most automotive engineers working in Canadian industry have received training elsewhere, either in Europe under the apprenticeship system, or in the United States, at universities such as the University of Michigan, and the General Motors' Institute. Companies report shortage of trained personnel as a critical constraint in expanding product and process design activities.

Support for on the job training and apprenticeships is also limited. Criteria of the Canadian Jobs Strategy favour the long term unemployed and target groups such as women and natives, not ongoing updating of employed and skilled workers. This is regarded as a corporate responsibility.

Tax incentives

Tax incentives, as outlined in Section 37 of the Income Tax Act, are a major source of government support for research and development activities in Canada. Approximately $750 million of benefits were directed to companies in 1988, compared to a total of $733 of direct assistance for all industrial science and technology activities.

The tax incentive program was revised substantially in 1986, following a major review prompted by misuse of the Scientific Research and Tax Credit program (SRTC). Canadian tax incentives are still considered among the most generous in the world. Section 37 of the Income Tax Act allows for the immediate deduction of the full cost of all current and capital expenditures for scientific research and experimental development conducted in Canada (Annex 7). Capital expenditures are not depreciated, but are immediately deductible, unlike the practice in most other countries.

In addition, a 20 per cent Investment Tax Credit is calculated on eligible expenses, increasing to 35 per cent in the Atlantic region, and to 35 per cent for Canadian owned small businesses (CCPC). A limit on the credit of 75 per cent of federal tax payable was applied to large corporations in 1988. Small privately owned businesses (maximum of $200,000 taxable income) are eligible for a 100 per cent refund on current expenses, to a maximum of $2 million, and a 40 per cent refund on capital expenses. Carry forward provisions for both deductions and credits apply for ten years, and carry back provisions for three years.

The key to the usefulness of these provisions to companies is the interpretation of "experimental development". In general, an activity must result in an advancement of knowledge of a product and process, involve an element of risk, and use the scientific method of experimentation, if it is to be eligible. Routine engineering with known results is not eligible; neither is routine testing.

While attractive in theory, several factors limit the usefulness of tax benefits. The Science Council has noted that the tax structure had a marginal impact on levels of R&D, as it is difficult for companies to determine eligible expenses, and to compute and forecast them with any certainty.

Discussions with companies indicated difficulty in documenting expenditures by cost centre, in isolating expenses incurred on the shop floor. Lack of clarity also exists regarding definition of experimental development, particularly regarding process optimization and use of prototype. Moreover, except for CCPCs, tax provisions only benefit those companies with tax liabilities. The Industrial Research and Development Incentive Act provided a cash grant of 25 per cent of capital expenditures in R&D, plus current expenditures in excess of the base period, but was abolished in 1977. It has also been noted that the attractiveness of tax incentives to foreign firms may be minimal, as reduction of subsidiaries' Canadian tax liability may result in an offsetting increase in the parent's U.S. tax liability.

However, even given this reservation, the full deductibility of capital expenditures and 20 per cent tax credit remain powerful incentives to conduct R&D in Canada.

6.2 PROVINCIAL PROGRAMS

In addition to federal programs to encourage R&D, provincial governments also offer R&D incentives. Total expenditures are small compared to the federal share, with expenditures of $480 million in 1988, compared to federal expenditures of $2.407 million. Quebec, Ontario and Alberta are the most active, with expenditures of $175 million, $136 million and $100 million respectively in 1988.

Programs in Ontario and Quebec are of most interest to the automotive sector, Approaches taken in the two provinces differ considerably. Ontario has chosen a highly directed approach, targeted at export oriented, Canadian owned companies. Programs are directed at strategic alliances, centres of excellence, support for university research, technology personnel support and strategic procurement. Assistance is not offered for high risk product development by single companies.

Quebec relies much more heavily on the tax system, and such is more broadly based. Quebec is the only province to offer tax incentives; combined with the federal tax incentives, tax benefits in Quebec for R&D are without equal in the world. In addition to tax incentives, Quebec also offers a technological development fund for large projects, risk sharing loan programs for small and medium sized projects, and out-sourcing of Hydro Quebec projects. Total assistance from these measures, as well as R&D programs of government departments and agencies, is estimated at $3 billion from 1989 to 1994. These programs are described in more detail in Annex 6.

SECTION SEVEN-INTERNATIONAL COMPARISON

7.1 GENERAL

While government funded expenditures on R&D are lower than our major competitors when defence R&D is excluded, government support for R&D in Canada as a percent of GDP in fact exceeds the United States, and is consistent with that of Great Britain, Japan and Italy. Only Germany and France spend proportionately more:

1987

	INDUSTRY FUNDED R&D AS % OF GDP	(% of total)	GOVERNMENT AS % OF GDP Civil	(Defence as % of total)	Total	TOTAL
Japan	1.97	(68.5)	.60	(3.5)	.62	2.87
Germany(*)	1.82	(64.9)	.96	(12.7)	1.10	2.81
U.S.	1.27	(47.1)	.40	(68.6)	1.28	2.69
UK(2)	1.17	(49.7)	.58	(50.4)	1.17	2.36
France	0.93	(41.0)	.91	(34.2)	1.38	2.27
Italy	0.93	(41.7)	.70	(7.0)	.76	1.27
Canada	0.71	(42.1)	.55	(7.4)	.59	1.40

(*) 1985 (2) 1986

OECD: Main Science and Technology Indicators, 1989 No. 1

The federal government's contributions to business expenditures on R&D are consistent with those of Germany and Sweden, and far greater than those of Japan, exceeded only by countries with large defence expenditures:

CONTRIBUTION OF GOVERNMENT, AS A PERCENT OF TOTAL BUSINESS EXPENDITURES ON R&D (1987):

Japan	1.7
Germany	12.1
Sweden	11.6 (1985)
U.S.	34.4
UK	19.4
France	22.8
Netherlands	14.5 (1986)
Canada	11.2

OECD: Main Science and Technology Indicators, 1989 No. 1 Table 21

7.2 GOVERNMENT SUPPORT

Various estimates have been made of the total impact of tax and non-tax support by government to industry among major industrial countries. Rankings are highly sensitive to whether expenditures on military R&D performed by industry is included at full value, or discounted:

GOVERNMENT SUPPORT FOR INDUSTRIAL R&D AS % OF R&D PERFORMED IN INDUSTRY

	Non-tax support		Tax support	Total	
	CMA (1986)	McFetridge (1983)		CMA	McFetridge
U.S. (1)	33	17.6	7	40	24.6
U.K.	29	15.5	8	37	23.5
France	22	4.1	7	29	11.1
Germany	18	12.6	6	24	18.6
Canada	12	10.5	8	20	18.5

1 Only part of defense expenditures considered as industrial subsidies.

CMA calculations place Canada significantly behind other countries. However, assuming that only a portion of defense grants of industry can be considered as subsidization, Canada does not lag significantly behind countries cited.

7.3 SPECIFIC PROGRAMS

A wide variety of approaches exists to support of R&D activities. Of ten countries examined, seven have programs directly targeted at stimulating product and process development (France, Italy, Finland, Norway, Netherlands, Sweden, and to a limited extent, Germany) (Annex 8). All are repayable conditional on project success, often with interest. Germany and Britain offer less assistance directly to companies; Britain, in particular, follows a non-interventionist strategy, but does offer assistance to hire personnel. The U.S. government funds large amounts of private sector research, primarily oriented to national goals such as defense and space. Japan combines structural support provided by low cost of capital, the government-industry relationship, resources of university educated engineers, with decentralized government diffusion activities.

The European Prometheus program is notable in that it brings together assemblers, suppliers and research institutes to conduct pre-competitive research in vehicle systems and electronics.

SECTION EIGHT - CONCLUSION

Structural changes in the automotive industry offer a significant opportunity for the Canadian automotive industry to add value to operations and develop technological expertise, rather than competing only on the basis of cost - a strategy which is becoming less and less tenable. Simultaneous engineering, faster cycle time, and increased expectations of suppliers present opportunities for both assemblers and parts companies operating in Canada.

Barriers to increasing levels of activity facing both assemblers and parts producers are rooted in the low levels of activity in the past, resulting in lack of a pool of trained personnel, lack of facilities and, within multinationals, a preference to centralize activities in the parent country.

As noted at the outset, at least three scenarios exist:

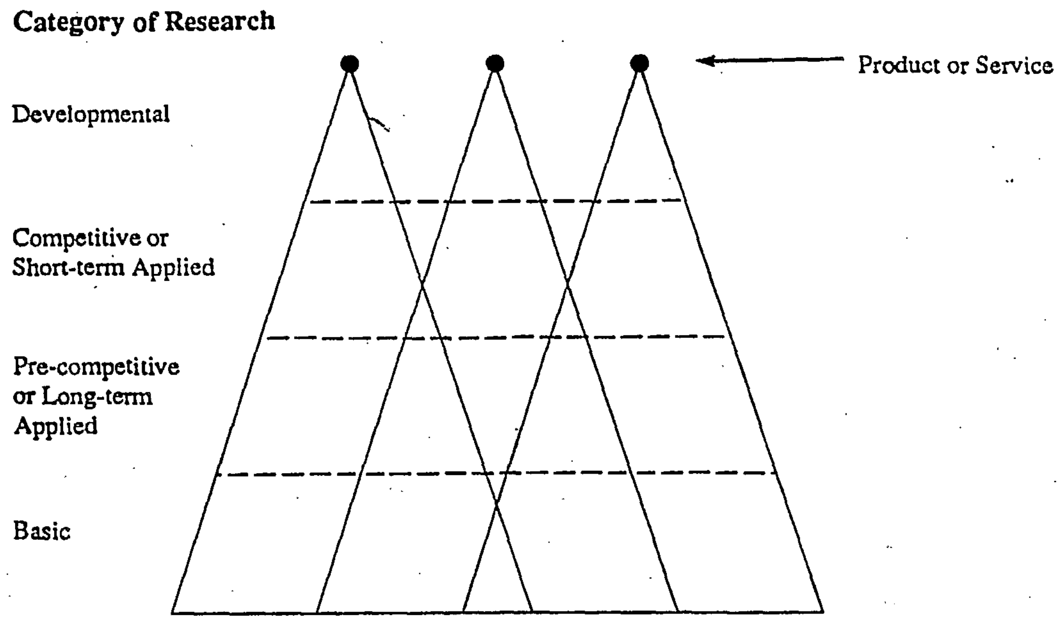
One is that Canada's position as a lower level manufacturer will be re-enforced, with assemblers continuing to centralize product and process activities in Detroit, and suppliers becoming sub-contractors to Tier 1 producers in the United States. Given existing levels of technology, Canada would simply be another commodity producer, losing ground to low cost countries such as Mexico and Korea.

A second scenario is that, in order to succeed against emerging competitors of commodity products, Canadian operations build on existing strengths to achieve a world class process development capability. An opportunity exists to define a niche of expertise in incremental process development, an area in which the Americans and Europeans are weak. To do this however, Canadian firms must develop engineering capability, and change organizational structures to make continuous incremental improvement possible.

A third scenario is that Canada will gain greater control over product development and greater value added, as some parts producers develop into Tier 1 operations. A handful of firms already operate on a Tier 1 level, albeit on a smaller scale than major competitors. A possibility also exists that assemblers could expand product and process responsibilities as a result of the need for simultaneous engineering and advantages from exploiting Canadian expertise in areas such as alternate fuels. If these possibilities are to be realized, considerable initiative is required by Canadian operations to convince assemblers of their potential, as well as making high risk investment in equipment and personnel.

This paper does not attempt to reach any definitive conclusion as to the nature of problems facing specific companies, or recommend how there barriers may be overcome. It is hoped that industry, labour and government, in examining this problem together, can devise creative approaches to tackling underlying structural factors which have limited activity in Canada in the past.

Figure 1: The Science-Based Pyramid of Research



Source: CIAR Innovation and Canada's Prosperity, 1988

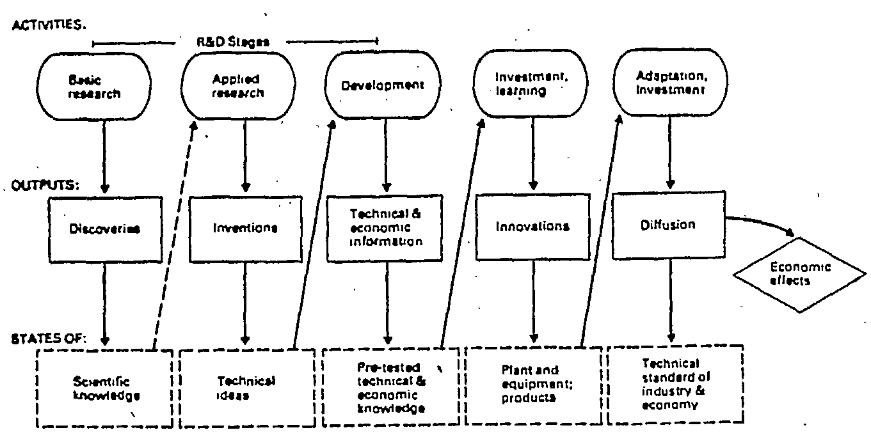
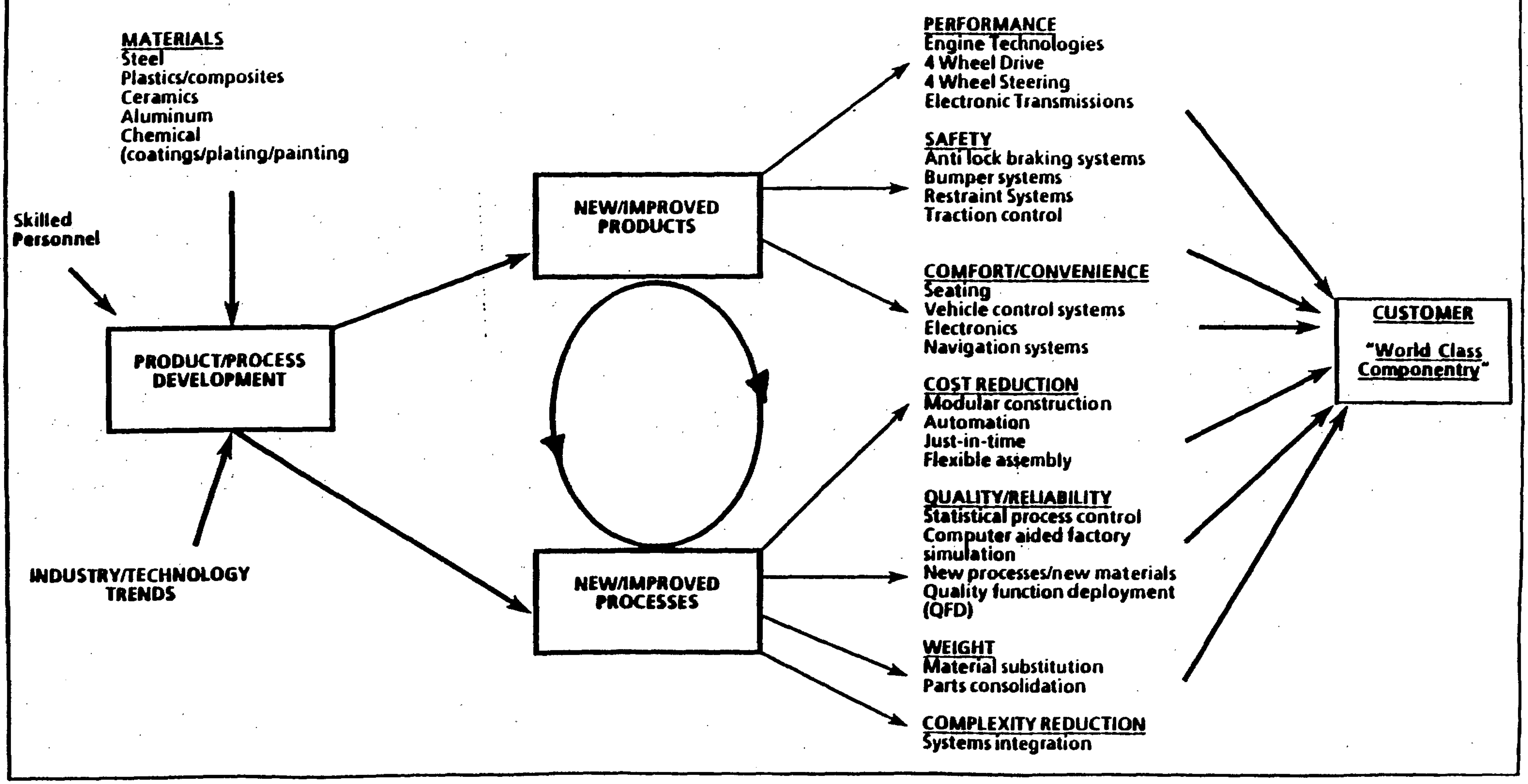


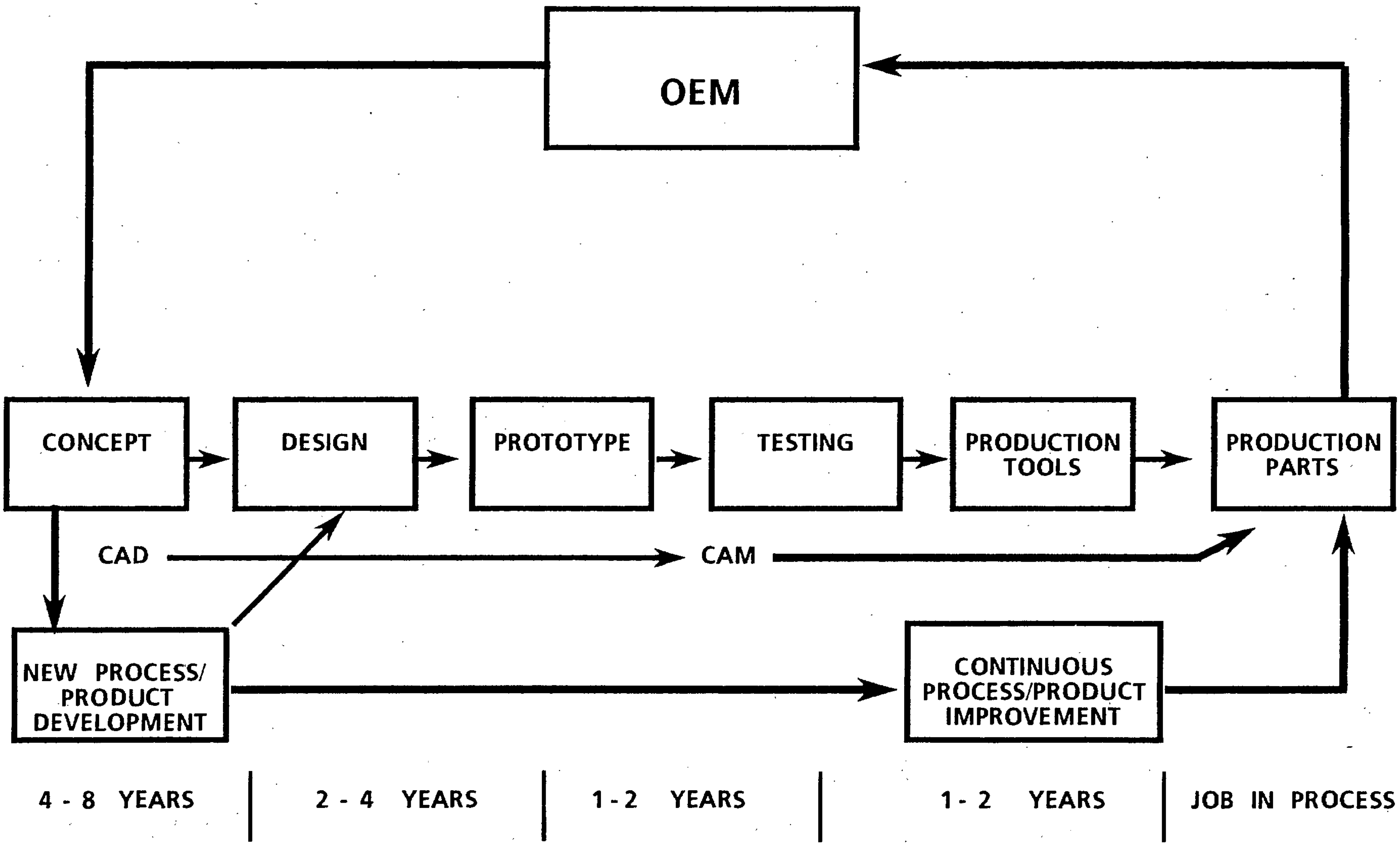
FIG. 1.1 Stage model of technological change.

Source: Gerhard Rosegger, The Economics of Production and Innovation, 1986.

PRODUCT/PROCESS DEVELOPMENT IN THE AUTOMOTIVE PARTS INDUSTRY



PRODUCT AND PROCESS DEVELOPMENT
(ENGINEERING OVERVIEW)



Annex 3

ANNEX 4

GENERAL MOTORS' DESIGN PROCESS

4 phase process:

0	Technology and concept development - include supplier	Development
1	Product/process development Prototype validation	
2	Process validation Product confirmation	Execution
3	Production and continuous improvement	Continuous Production

New technology frozen by end of phase 0.

Suppliers determined by end of phase 0.

SOURCE: **Auto in Michigan Conference March 1989.**

ANNEX 5

R&D PERFORMERS AND EMPLOYMENT IN CANADIAN AUTOMOTIVE INDUSTRY

TABLE 1. Number of Persons Engaged in R&D, 1986.

	PROFESSIONAL	TECHNICIANS	OTHER	TOTAL
SIC 3231	180	135	215	530
SIC 3251 to 3259	345	210	90	645

TABLE 2. Number of R&D Performers, by Size of R&D Program, 1986.

	(R&D SIZE $000)					
	$100	$100-199	$200-399	$400-999	$999	TOTAL
SIC 3231	CONFIDENTIAL					
SIC 3251 to 3259	6	7	5	4	12	34

TABLE 3. Number of R&D Performers, by Employment Size, 1986.

	EMPLOYMENT (PERSON-YEARS)								
	1-49	50-99	100-199	200-499	500-999	1000-1999	2000-4999	4999	TOTAL
SIC 3231	3	-	-	1	1	1	-	2	8
SIC 3251 to 3259	4	2	4	11	8	3	1	1	34

SOURCE: Special Tabulation, Statistics Canada, Science Statistics.

ANNEX 6

TECHNOLOGY PROGRAMS OFFERED BY THE FEDERAL GOVERNMENT AND PROVINCES OF ONTARIO AND QUEBEC

Federal and provincial governments offer a variety of programs to encourage R&D. These can be classified as direct assistance to single companies; support for strategic alliances of two or more companies, support for technology diffusion, technology transfer from abroad technology centres, and technology transfers from universities. The general trend is away from company specific support. A directory of technology programs relevant to the automotive industry will be available through ISTC by March 1990.

A - FEDERAL

1. FEDERAL - COMPANY SPECIFIC ASSISTANCE

Industrial Regional Development Program (IRDP) Innovation

Administered by the Department of Regional Industrial Expansion, IRDP Innovation offered support for product and process development, including prototype development, testing and marketing. The program was discontinued in June of 1988. In total, $300 million was disbursed, with sharing ratios ranging from 33.3 per cent in Tier I areas to 50 per cent in Tier IV. 90 per cent of expenditures occurred in Tier I and II areas, with only 1 per cent in Tier IV. Most expenditures were for high risk, new product innovations. Less use was made of process design, consulting elements, and funding for projects with limited risk.

Funding was most heavily concentrated in the electrical and machinery sectors, each receiving approximately 25 per cent of the total budget. The automotive parts sector received approximately 13 per cent of total funds, or $39 million. Under the predecessor to IRDP, the Enterprise Development Program (EDP), a total of $32 million was disbursed.

Defense Industry Productivity Program (DIPP)

DIPP is administered by Industry, Science and Technology Canada. Approximately three quarters of the annual budget of $250 million is directed to the aerospace industry, and 19 per cent to the electronics sector. Approximately three per cent is directed to the automotive industry, primarily to military vehicle programs of major assemblers. Over half of DIPP funds are directed to product development, the remainder for capital assistance and "source establishment".

Microelectronics System Development Program (MSDP)

The MSDP is a new ISTC program designed to cost share microelectronics system development, to assist companies in developing innovative products and processes. Funds total $60 million over five years. While funding is open to single companies, preference is given to companies collaborating with other companies or universities, who will diffuse technology among Canadian companies. The project must be more advanced than anything commercially available to the applicant, and must involve elements of reasonable risk.

Industrial Research Assistance Program (IRAP)

IRAP is the federal government's only program supporting high risk product development offered to companies outside the electronics and aerospace sector. The program, administered by the National Research Council, is primarily directed to companies with less than 200 employees. IRAP provides a variety of services, ranging from support to hire summer students (IRAP-H); support for use of independent or government laboratories, IRAP-L); cost sharing of salaries for product and process design (IRAP-M); all for companies with less than 200 employees, and cost sharing of salaries for major projects. IRAP operates through a national network of advisors, often working in cooperation with provincial research organizations, and various technology centers, and relies heavily on government departments for assessment of project proposals.

IRAP is highly regarded by users as being responsive and effective. Budgets have risen steadily, totalling $110 million in 1986-87. 85 percent of budgets directed to firms with less that 200 employees. These companies require, primarily, access to outside resources (laboratories, students), and assistance in establishing small research capability. IRAP's role has never been, however, to provide risk capital on a larger scale to large commercial enterprises. While selected larger companies have received major project funding, this element remains a minor portion of IRAP activities.

2. STRATEGIC ALLIANCES

Strategic Technologies Program

This new ISTC offering will fund pre-competitive applied research and development in advanced materials, biotechnology and information technologies. The program fits in the "applied" sector of the research triangle. While development costs to the point of commercialization are eligible, companies must participate in a consortium, and proposals must apply technology for the first time in Canada.

3. TECHNOLOGY DIFFUSION

Patent Information Exploitation

Consumer and Corporate Affairs will conduct world wide patent searches to identify new technologies for users, and to prevent duplication by prospective inventors.

Technology Outflow Program (ISTC)

The TOP program supports technology centres designed to increase outflow of new technologies to industry. TOP funded centres of most relevance to the auto parts sector are the Plastics Institute, run by the Society of Plastics Industries; the Management of Technology Institute (MTI) in Hamilton; CAN-MATE and the microelectronics centre at Sherbrooke. The Plastics Institute disseminates information on new technologies to members, and houses several IRAP representatives. MTI provides seminars and research on the management of technology. CAN-MATE coordinates inquiries from industry with CAD/CAM resources, whether government, community college or university based.

4. TECHNOLOGY INFLOW FROM ABROAD

Investment Counsellor Program/Scientific Adviser (DEA/NRC)

Investment and Scientific counsellors are located at major Canadian consulates aborad. They can identify opportunities for technology transfer, investment, and market opportunities.

Technology Inflow Program (Department of External Affairs)

TIP funds travel and salary costs incurred by companies to acquire technology from abroad. The emphasis is on acquisition of foreign technology; domestic expenditures are not covered. TIP is administered by IRAP, aided by Science Counsellors posted in embassies.

Investment Canada

Investment Canada provides technology prospecting and brokering services.

5. TECHNOLOGY CENTRES

Most federal centres actually performing research, as opposed to technology diffusion services (see above), are operated under the National Research Council, or through universities.

The NRC supports nine laboratories and 21 facilities offering research capabilities of interest to the automotive industry. Joint development projects with industry are encouraged.

Several universities offer research capabilities to industry on a contract basis. Waterloo and McMaster have strong manufacturing engineering capability.

The Department of Transport operates a comprehensive vehicle test centre in Blainville, Quebec.

6. PROCUREMENT

The Department of National Defence may sole source projects, covering prototype development costs.

7. CO-OPERATION WITH UNIVERSITY

Research Partnerships Program

The National Sciences and Engineering Research Council (NSERC) has placed increasing emphasis on the transfer of technology from the university to the private sector. Research Partnerships Program cost shares research conducted by universities for the private sector; all equipment remains university property at project completion.

University Chairs

Recently introduced university chairs share costs of hiring experts in fields of interest to industry. GM has established a chair in quality and process engineering at Waterloo.

Strategic Grants

NSERC awards to operating grants to universities for research in selected strategic areas. Industrial priorities are considered when awarding grants.

Post Doctoral Fellows

Post-doctoral Industrial Fellowships subsidize the cost of post-doctoral fellows working in industry.

Centers of Excellence (NSERC, SSHRC, MRC)

The centers of Excellence program, funded by the federal granting councils, supports research networks of world quality and includes industrial partners. None are directly relevant to the automotive industry.

B - ONTARIO

Both Ontario and Quebec have launched ambitious and well funded technology programs. Ontario's is highly directed, aimed at developing "threshold" size companies based in Ontario.

1. COMPANY SPECIFIC SUPPORT

Technology Personnel Program

This recently announced program offers assistance to small manufacturing firms to hire engineering, scientific and technical staff. Companies must be at least two years old, operating in the manufacturing or service sectors employing between 10 and 200 employees in Ontario, exporting and have head office functions in Ontario. These criteria exclude most automotive companies.

2. STRATEGIC ALLIANCES

The Technology Fund is directed at "threshold" firms, and is extremely selective and targetted. Companies must participate in a consortium, and must present a proposal involving technical risk. To date, approximately 20 firms have received funding ranging from $1 million to $20 million, including one automotive company, Linamar.

3.TECHNOLOGY DIFFUSION

See G - cooperation with universities

4.TECHNOLOGY INFLOW

The Ontario government maintains offices abroad; MITT staff also conduct technology transfer activities.

5.TECHNOLOGY CENTRES

Ontario has replaced technology centres with Centres of Excellence (see below). Ortech a large research facility covering a variety of technologies, ONCE supported entirely by the province, is almost self financed. Ortech is certified as a testing facility by GM.

6.PROCUREMENT

Strategic Procurement Program

This program provides funding to sole source new technology products.

7. CO-OPERATION WITH UNIVERSITY

University Research Fund

Matching funds are provided for short term contract research between universities and the private sector.

Centers of Excellence

Centres of excellence consist of research networks primarily based in universities, in targetted areas. The center of most relevance to the auto parts sector, the Manufacturing Research Corporation of Ontario (MRC) offers access to a network of experts in manufacturing technologies, on a user pay basis. These centers replaced the technology centers, which offered subsidized outreach services for automotive parts manufacturers (OCAPT- Ontario Center for Automotive Parts Technology); CAD/CAM (OCAM), and the machinery and farm implements sectors. OCAPT concentrated on manufacturing technologies, and played a significant role in the modernization of auto parts firms. OCAPT and OCAM have been privatized.

C - QUEBEC

Quebec has introduced a comprehensive R&D strategy aimed at stimulating industrial research, promoting collaboration between the private sector and universities, and facilitating the raising of venture capital to finance these activities.

Quebec's strategy is based on the tax system. Provincial Tax incentives, combined with federal, are considered the most generous in the world. However, other important elements include a Technological Development Fund; activities of Hydro-Quebec; loan programs of the Agence québécouse de valorisation industrielle de la recherche (AQVIR) and the Société de développement industriel du Québec (SDI); and provincial technology centres.

In total, these programs provide what has been described as the most fabourable environment for R&D in North America.

1. TAX SYSTEM

Special incentives available only in Quebec:

- refundable tax credit of 20% on wages for R&D projects carried out by large businesses; 40% for small and medium-sized.

- tax holiday of up to 2 years for foreign researchers (if similarly qualified persons not available in Quebec).

- refundable tax credit of 40% for all R&D spending by business in universities.

- refundable tax credit of 40% for all R&D spending for pre-competitive and catalyst projects.

- increase working capital by allowing firms to reduce monthly instalment payments for income tax and tax on capital by a sum equal to the R&D tax credit, and by financing a large portion of the value of Quebec and federal tax credits with a loan guarantee offered by SDI.

2. TECHNOLOGICAL DEVELOPMENT FUND

A total of $300 million is available, from 1989 to 1990 to 1994-95, to fund catalyst projects bringing firms and researchers together. These projects are eligible for a 40% refundable tax credit. The TDF supports upstream and downstream expenditures of these projects as well as expenditures that do not qualify for the 40% tax credit.

3. HYDRO QUEBEC

Hydro Quebec will allocate 60% of all R&D expenditures, or approximately $500 million, from 1989 to 1993, to the private sector.

4. RISK SHARING LOANS

R&D activities of small and medium sized business are supported through loans granted by AQVIR and SDI. A QVIR is oriented to start up firms, while SDI to firms past the start up phase.

5. OTHER R&D PROGRAMS OF GOVERNMENT DEPARTMENTS AGENCIES

- Value of R&D carried out by departments.

- Government research agencies, such as the Centre de recherche industrielle du Québec (CRIQ). The Centre de recherche industrielle du Quebec (CRIQ) encourages innovation in Quebec manufacturing enterprises, offering technical services, aid in technology transfer, and the development of manufacturing products and processes. The centre québécois pour l'informatisation de la production (CQIP) is an applied research centre designed to encourage research in automation, through coordination of companies and university.

- Contributions to financing R&D activities by universities, in particular, the Fonds pour la formation de chercheurs et l'aide à la recherche, and the Fonds de la recherche en santé du Quebec.

ANNEX 7

DEFINITIONS OF R&D-INCOME TAX ACT

Exploratory development is defined as:

- use of the results of basic or applied research for the purpose of creating new, or improving existing materials, devices, products or processes;
- advance in scientific/technical knowledge resulting in creation of new or improvements to existing materials, devices, products, or processes;
- must seek to result in something that takes a meaningful step beyond customary product evolution - element of technological uncertainty;
- "this may occur when technologies established in one field are introduced into products or processes in another field of technology";
- "projects involving only routine engineering or routine development" are excluded;
- can be resolved only on case by case basis.

Excluded activities:

- market research;
- quality control;
- commercial production of a new or improved material, device or product;
- style changes;
- routine data collection.

Definition of current and capital expenditures:

Current Expenditures:

Includes:

- subcontracting to approved entities (all Canadian universities, NSERC); non-profit research corporations; other corporations resident in Canada;
- materials, salaries, wages;
- not general administrative or factory overhead;
- interest expense - as long as to make SR & ED expenditures.

Capital Expenditures:

- acquisition of tangible assets;
- excludes property for which CCA is allowed;
- used 90 per cent of the time for SR & ED over life;
- if part of a new building is used - reasonable portion;
- if part of existing building - cost of conversion - not original cost - assistance is deducted from eligible expenses (eg. DIPP, IRAP);
- Capital expenses made outside Canada are not eligible.

For further information see Section 37 and regulation 2900 of the Income Tax Act, further detailed in Bulletin 86-4R2.

ANNEX 8

INTERNATION COMPARISON - GOVERNMENT PROGRAMS

Summary of Assistance offered by Major Industrialized countries

	LOAN PROGRAM *	PERSONNEL ASSISTANCE	SECTOR INSTITUTES - APPLIED R&D
France	YES*	NO	NO
Italy	YES*	NO	YES
Finland	YES*	NO	YES
Norway	YES	NO	YES
Netherlands	YES*	YES	NO
Sweden	YES*	NO	YES
Germany	LIMITED 1	YES	YES
Britain	NO	YES	YES
U.S.A.	NO	NO	NO
Japan	NO 2	NO	YES
Canada	LIMITED 3	LIMITED 4	NO

* repayable
1 small start-ups only
2 could be argued that low interest rates constitute loan assistance
3 firms with less than 200 employees
4 post-doctorate and summer students

1. FRANCE

With a GERD/GDP ratio of 2.27% (2987) industry funds 41 per cent of R&D in France. Government priorities are the "grandes programmes" such as Ariane, Air bus, and the High Speed Train. Assistance is available through Aide à l'innovation, administered under the Agence Nationale de Valorisation de la Recherche. The program provides loans to companies of all sizes, which are repayable proportional to volume of sales. Costs covered include patents, market research, design, experimentation, technical development, development of new products or processes, prototypes, pilot plants and production start ups. Companies may act alone or in association with others. In 1982, 1300 firms benefitted from the program, at a total cost of 630 million francs.

2. ITALY

Italy spends 1.27% of GDP on R&D, with 42% funded by industry. Research in Italy is controlled by the Italian National Commission for Nuclear and Alternative

Energy Sources (ENEA). ENEA offers a program to assist firms to develop and produce products, prototypes and processes with a high technological content. Assistance is availble for the formation of consortia; collaborative industry projects for common innovative products; training of company staff; and dissemination of information. Financing is also available, which must be repaid from the returns on the innovative product.

3. GERMANY

Germany spends 2.8% of GNP on research (1987) with 65% funded by industry. Strong basic research is a source of national pride. Germany does not have loans for ongoing product development, but does provide R&D personnel grants, which cover 40% of staff salaries on the first $150,000, for firms with less than 3,000 employees. In 1986, 3,000 companies used this program, at a cost of $200 million. The Fraunhofer Society conducts R&D on behalf of industry, and has a strong engineering orientation. The German Chamber of Industry and Commerce provides a consultancy service for problem solving, covering up to 30% of costs.

Other programs include exchanges allowing industrial scientists to work in one of Germany's many laboratories (societies); support for pre-competitive research consortia; subsidization of small firms for contract research; and venture capital for new technology based companies.

The European Prometheus project is a good example of the use of industry-government consortia to develop and apply advanced electronics information technology, to minimize the effects of fragmentation, to develop the European share of the global automotive electronics market. The Prometheus program consists of precisely targetted basic research in artificial intelligence, custom hardware, methods of communication and traffic scenarios. Industry research is concentrated in driver assistance by electronic systems, vehicle to vehicle communication, and vehicle to environment communications. $800 million will be spent over seven years, with contributions from EEC governments and industry. German assemblers and suppliers are leading the project.

The project recognizes that while collaboration is needed in the pre-competitive phase of new, risky, and expensive technologies, the priorities of the industry are to achieve quick returns on commercial spinoffs. To achieve this balance, demonstration designs are proprietary to companies.

4. FINLAND

Forty one per cent of research in Finland is conducted by industry. Total spending equals 1.6% of GNP (1987). With a relatively weak private sector, the government is trying to encourage innovation. The Ministry of Trade and Industry, through the Technology Development Center, offers loans for product development, on a matching basis, which must be repaid from revenues. Grants are available for particularly risky projects; once the project is focussed, support is restricted to loans. Direct company support is also available through the Special Jubilee Fund for Research and Development, established in 1967. This fund is administered by the Bank of Finland, and provides grants and loans to business to advance innovative activities; 25% of the funding is used for basic research.

Technology development is also available from universities and institutes: the Technology Development Center funds applied technical research in institutes and universities, while the Technical Research Center employs 2300 professionals to solve specific industrial problems. The Federation of Finnish Metal and Engineering Industries, cost shared by industry and government, employs 500 professionals to research production technology.

5. NORWAY

Industry funds approximately half of R&D in Norway; R&D expenditures total 1.8% of GNP (1987). Research is organized on a sectoral basis.

The Ministry of Industry oversees the Norwegian Council for Scientific and Industrial Research, which provides loans of up to 50% of the cost of development for industrial research projects. In addition, a Research Fund subsidizes the work of sector research institutes. Firms are encouraged to use universities and research institutes.

6. NETHERLANDS

Industry funds 53% of R&D in the Netherlands; R&D expenditures total 2.2% of GNP (1986). Two programs are of interest: the Innovation Simulation Program, which funds 25 to 40% of the personnel costs of corporate R&D, for both in house and contract research. Technical Development Credits provide up to 60% of product development costs, which must be paid back with an interest rate of 5% if the project is successful.

7. SWEDEN

Sweden spends 2.8% of its GDP on R&D (1987), with 63% from industry, indicating the strength of indigenous multinationals. All policies in Sweden are sectorally targetted. Given strength of large industry, most programmes are targetted to the SMES. Research and development programs with significant technical risk are eligible for grant and/or loan support of up to 50% through the National Swedish Board of Technical Development (STD), an agency of the Ministry of Industry. Most of these funds are non firm specific, spent by universities (25%), government (10%), trade associations (5%), and consortia (25%). The National Industrial Board finances innovation in its later stages, from prototype to pilot to test. Loans of up to 60% are available which must be repaid with interest plus a fee if the product is successful.

8. BRITAIN

Britain spends 2.3% of GNP on R&D (1986), with 50% funded by industry. Consistent with the general policy environment of Thatcher's Britain, a new R&D policy stipulates that government should limit its financial support to pre-competitive collaborative R&D, and that near market activities should be the sole responsibility of the private sector. As a result, government programs, other than those for consortia, are largely directed to consultancy services. The Enterprise Initiative offers consulting services under ten categories, ranging from marketing to design, quality, and research and technology.

One company specific program has been retained, however, the Teaching Company Scheme. This highly successful and popular program is designed to improve the competitiveness of British industry through subsidizing the cost of hiring a new engineer or science graduate, for three years, renewable. The government funds 75 per cent of costs for the first three year term, and 50 per cent for the second. Up to 50 per cent of related equipment costs are also covered. It is funded jointly by the Department of Trade and Industry and Science and Engineering Research Council and is administered through project teams representing the university, business and government. The number of projects sponsored is expected to increase from 200 in 1986 to 600 by 1990.

The Science Council of Canada evaluated the Teaching Company Scheme in 1986 and recommended that it be introduced in Canada. Benefits include technology transfer between universities and polytechnics and companies, providing an intellectual stimulus to companies. Types of activities supported include designing, testing, introducing new products and servces, and planning, developing and implementing new manufacturing processes. The Science Council recommends this approach as a "project specific (university-business) partnership at the development end of the R&D spectrum".

In addition, research associations exist which carry out R&D, testing and training for industry, each serving a particular industrial sector or horizontal technology.

9. THE UNITED STATES

The United States spends 2.7% of GNP (1987) on R&D, of which 47% comes from industry. Government exenditures are limited to areas of national importance, primarily defense, space, health and education. Most government funded activities are performed by industry. Debates exist as to the subsidy and spinoff effect of government contracts, with estimates ranging from 0 to 100%. In addition to direct benefits from contracts, agencies such as NASA and the Department of Commerce have technology transfer programs to ensure that technologies developed for national objectives are widely applied. NASA's

Technology Utilization Program is judged to be one of the most effective technology diffusion bodies in the world.

Assistance is more widely available at the state level. In the automotive sector, the Michigan government and State University have placed a priority on the modernization of the auto parts sector, through the Michigan Modernization Office, Institute of Technology (University of Michigan) and Auto in Michigan Project. Firms may use services of consultants through the Michigan Modernization Office, while the U. of Michigan and Ann Arbour area offers access to world class automotive engineering expertise.

A special tax credit was introduced in 1980, which is being extended until 1989.

Recent literature suggests that the U.S. emphasizes basic and applied research, at the expense of incremental product and process development, at both the government and industry levels. Government funded R&D, directed primarily at defense expenditures, is thought to have little effect on productivity. It has been estimated that American firms spend two thirds of their resources on new product and process development, and one third on incremental product and process activities. In Japan, the ratios are reversed.

10. JAPAN

Japan spends 2.9% of GNP on R&D (1987), 69% by the private sector. In the area of technology development, the government's role has been to provide excellent structural support (low cost capital, training); to commission development work with industry consortia (eg. ceramics); and to diffuse technology widely to smaller companies. Business associations throughout the country offer assistance in technology adoption, training, and skill improvement, while government consultancy services take technology directly to firms. Support is available through venture capital for high risk startups (Japan key technology firms).

SOURCE: Industry, Science and Technology Canada. Technology Diffusion Policies and Programs

(draft) April 1989.

BIBLIOGRAPHY

Anderson Consulting. Putting the Pieces Together. Sixth Automotive Delphi Report. 1989.

Arnsdorf, David. (Senior Engineer, Industrial Technology Institute.) "Breaking down the Barriers to CAD/CAM Implementation." Presentation, Ninth International Automotive Conference, University of Michigan, April 5, 1989.

Automotive Engineering. Volume 97, No. 1. "Automotive Engineering Systems".

Automotive News. OEM Edition. "Interviews - Harry Cook; John McTague; Robert Frosch". September 4, 1989.

Barnes, James G. and G. Ross Peters. The Teaching Company Scheme - A Study of its Application in Canada. Science Council, May 1987.

Beatty, Carol. Promoting Productivity with CAD. National Center for Management Research and Development, University of Western Ontario, School of Business Administration. Working Paper Series No. NC 86-05. September 1986.

Berger, Suzanne, M.L. Dertouzas, R.K. Lister, R.M. Solow and L. Thurow. "Towards a New Industrial America. Scientific America. June 1989 Volume 260 Number 6.

Business Week. "The Top Companies in 1987 R&D Spending". June 20, 1988.

Canada, Department of Industry, Science & Technology, Automotive Directorate. Industry Questionnaire - R&D in the Auto Parts Industry. April 1989.

______. Statistical Review of the Canadian Automotive Industry 1988. Sept. 1989.

______. Economic and Statistical Analysis Branch. Report on Industry and Technology. January 1989.

______. Evaluation Directorate. Innovation Program Framework. May 1987.

______. Evaluation Directorate. IRDP - Innovation - Program Usage Analysis. 1987

______. Multilateral Trade Division. Inventory of Foreign Subsidies and Canadian Industries Affected. March 20, 1989. (internal document)

______. Policy Branch. Research and Development Spending Targets (internal document). 1989.

______. Policy Branch. Science and Technology Resource Allocation Statistics Sept. 1989. (internal document)

______. Policy Branch. Technology Diffusion Policies and Programs (draft). April 1989. (internal document)

______. Policy Branch. Technology Diffusion Study-Pilot on Auto Parts Sector. Sept. 1989. (internal document)

______. Policy Branch. Tax Policy and R&D. April 1989. (internal document)

______. Program Branch. Program usage analysis. April 1989. (internal document)

Canada, National Research Council. The IRAP Network. Internal document, December 1987.

Canada, Ministry of State for Science and Technology/Department of Regional Industrial Expansion. Working Group, Strategic Technologies. Business Plan for Strategic Technologies in the Department of Industry, Science and Technology. May 1988.

Canada, Ministry of State for Science and Technology. Science and Technology in Sweden and West Germany. November 1987. (internal document)

______. Technology Diffusion in Canada: Myths and Realities. (A.D. Millington and Y. Van Ruskenveld). September 15, 1986.

Canada, Department of Revenue. Interpretation Bulletin. 33, 124-4 IT-151R3.

______. Interpretation Bulletin. 33, 124-4 IT-151R3.

______. Interpretation Bulletin 86-4R2.

______. Information Circular. IC 86-4R2 32,785-25.

Canada, Saskatchewan Research Council. Management in Crisis: Implementing Computer Integrated Manufacturing in Canada. A report by the Canadian CAD/CAM Council for the Advancement of Computer Integrated Manufacturing. In cooperation with the School of Business Administration, University of Western Ontario. July 1986.

Canada, Statistics Canada. Industrial Research and Development Statistics, 1986. 88-202.

______. Science Statistics. Catalogue 88-001. Monthly bulletins.

______. Science Statistics. Special Analysis of R&D personnel in automotive sector. April 1989. (internal document)

______. Science Statistics. Special run: R&D expenditures in automotive vehicle and parts sectors. April 1989. (internal document)

______. Survey of Manufacturing Technology. June 1987.

The Canadian Institute for Advanced Research. Innovation and Canada's Prosperity. October 1988.

The Canadian Manufacturers' Association. Canadian Manufacturing at the Crossroads. Feburary, 1986.

Clark, Kim. (Professor of Business Administration, Harvard University) "Product Development in the World Auto Industry". Ninth International Automotive Industry Conference, University of Michigan. April 4, 1989

Clark, Kim and Takahiro Fujimoto. "The European Model of Product Development: Challenges and Opportunity." International Motor Vehicle Program Policy Forum. MIT. May 1988

Clark, Kim B., R.H. Hayes and C. Lorez. The Uneasy Alliance. Managing the Productivity-Technology Dilemma. Harvard Business School Press. 1985.

Cole, David. "Future Product Development Process: Faster, Better." Discussion panel. David Cole, Donald Smith (University of Michigan), Suzanne Gatchell (Director, Quality Networks, General Motors), Dan Rivard (Director, Concept to Customer, Ford), Makato Tachekawa (Director, Product Strategy, Nissan Research and Development), John Vergg (Vice President, Quality and Technology, Budd). Ninth International Automotive Conference. University of Michigan. April 5, 1989.

Dertouzas M.L., R. Lester, and R.M. Solow, MIT Commission on Industrial Productivity. The MIT Press. 1989.

DesRosiers, Dennis. "The Size, Structure and Performance of the Canadian Automotive Parts Industry: Identifying Critical Success Factors." International Motor Vehicle Program Policy Forum. May 1987.

Ealey, Lance. "Kanban Car Design". Automotive Industries. February 1989, p. 61-62.

The Economist "who are the copy cats now?" May 20, 1989.

Ettlie, John and Stacy Reifeis. "Integrating Design and Manufacturing to Deploy Advanced Manufacturing Technology." Interface 17:6, Nov-Dec 1987, p. 63-74.

Financial Post. "Special Report: Research and Development". (Ranking). 1988 10 03.

Fujimoto, Takahiro and Antony Sheriff. "Consistent Patterns in Automotive Product Strategy, Product Development and Manufacturing Performance - Road Map for the 1990s." International Motor Vehicle Program Policy Forum. MIT. May 1989.

Gomory, Ralph, and Schmitt, Roland. "Science and Product". Science. May 1988.

Graves, Andrew. "Comparative Trends in Automotive Research and Development." International Motor Program Policy Forum.. MIT. May 1987

_____. "European Design and Engineering Capabilities - a Continuing Strength?" IMVP. May 1988.

_____. "Prometheus - A New Departure in Automotive R&D?" IMVP. May 1989.

Grilliches, Zvi. "Productivity Puzzles and R&D; Another Non-explanation". The Journal of Economic Perspectives. Vol. 2, No. 4. Fall, 1988.

Grilliches, Zvi. "Productivity, R&D and Basic Research at the Firm Level in the 1970's. American Economic Review. March 1986

Grilliches, Zvi and Frank Lichtenberg., "R&D and Productivity at the Industry Level; is there still a relationship"? NBER #850. February 1982. Also in Grilliches: R&D patents and Productivity. University of Chicago Press. Chicago 1984.

Grilliches, Zvi. ed. R&D, Patents and Productivity. NBER Conference Report. University of Chicago Press 1984.

Grilliches, Zvi. R&D and the Productivity Slowdown. NBER 1980.

Hayes, Robert, S.C. Wheelwright, and K.B. Clark, Dynamic Manufacturing: Creating the Learning Organization. The Free Press, New York. 1988.

Helper, Susan. "Changing Supplier REIationships in the United States: Results of Survey Research." IMVP. May 1989

Hoglund, William E. (Executive Vice President, Automotive Components Group and Power Products and Defense Operations Group, General Motors Corporation.) Presentation, Ninth International Automotive Conference, University of Michigan, April 4, 1989.

Hurter, Donald A. and Jeffrey L Staley. Opportunities for Canadian Research and Development Directed Toward the Needs of the North American Auto Market. Prepared for the Ministry of State for Science and Technology. Arthur D. Little. December 1979.

Ikeda, Masayoshi. "International Comparison of Subcontracting systems in the Automotive Components Manufacturing Industry." IMVP. May 1989.

Jones, Daniel. "Measuring Technological Advantage in the Motor Vehicle Industry." IMVP. May 1988.

Karlsson, Christer and Matts Carlsson. "Next Practice in Product Development." IMVP. May 1988.

Keller, Maryann. Automotive Parts Sector. Draft report for the Science Council of Canada. November 1989.

Keller, Maryann. "Auto Industry Observation #11". February 24, 1989.

Kobe, Gerry. "A Car is Born". Automotive Industries, March 1989, p. 33-38.

Lamming, Richard. "The International Automotive Components Industry: the Next Best Practice for Suppliers." IMVP. May 1989.

______. "Customer - Supplier Relationships." IMVP. May 1987.

Link, Albert. Research and Development Activity in U.S. Manufacturing. London: Praeger Scientific, 1981.

MacDonald, Gayle. "High-tech cars need more spent on R&D". Financial Post, 1989.

Mansfield, Edwin. "Industrial R&D in Japan and the United States". AEA Papers and Proceedings. Vol. 78, No. 2, pp. 223-228. May 1988.

Mansfield, Edwin. E. Technology Transfer, Productivity, and Economic Policy. Norton, New York 1982.

Marler, Dennis L. "The Post Japanese Model of Automotive Component Supply: Selected North American Case Studies." IMVP. May 1989.

McElroy, John. "Jack Telnack, 1989 Man of the Year". Automotive Industries, February 1989. p. 51-56.

McFetridge, Donald G. and Jacek Warda. Canadian R&D Incentives: Their Adequacy and Impact. Canadian Tax Paper No. 70. Canada Tax Foundation, 1983.

Miller, Roger. "New Locational Dynamics in the Automotive Industry: Assembly Facilities, Parts Plants and R&D Centres." IMVP. May 1989.

Munro, Hugh and Hamid Noori. Performance of Canadian Companies due to Technology Adoption. National Center for Management Research and Development, University of Western Ontario, School of Business Administration. Working Paper Series No. NC-88-19, July 1988.

May 1987 Canada and New Technology - Part 1 - Canada's International Performance. Working Paper Series No. NC 87-10.

Ontario Center for Automotive Parts Technology. An Evaluation of the Potential for Canadian Automotive Parts Manufacturers to Operate at a Higher Tier Level. May 27, 1987. (internal document)

Ontario Premier's Council. Competing in the New Global Economy. Queen's Printer, 1988.

OECD. Main Science and Technology Indicators. Advance Copy April 1989. 1989 No. 1. Paris: OECD

Plumb, Stephen. "New SAE President beats drum for tech education". Wards Auto World. 3-89.

Research Center for Management of New Technology. Annual Technology Survey 1987-88. Wilfred Laurier University, 1988.

Rosegger, Gerhard. The Economics of Production and Innovation: An Industrial Perspective, 2nd edition. Pergamon Press, 1986.

Rosenberg, Nathan and Edward Steinmuller. "Why are Americans Such Poor Imitators"? AEA Papers and Proceedings. Vol. 78, No. 2, pp 229-234. May 1988.

Sabel, Charles, Horst Kern, and Gary Herrigel. "Collaborative Manufacturing: New Supplier Relations in the Automobile Industry and the REdefinition of the Industrial Corporation." IMVP May 1989.

Scherer, Frederic M. "Interindustry Technology Flows and Productivity Growth". Review of Economics and Statistics. 1982.

Smith, David C. "Whatever happened to teamwork? Detriot's dissident suppliers speak out". Ward's Auto World July 1989.

Steed, Gerry. Threshold Firms - Backing Canada's Winners. Science Council of Canada, Study 48, 1982.

Stoneman, P. The Economic Analysis of Technology Policy. Oxford: Oxford University Press. 1987.

Warda, Jacek. R and D Outlook 1987. Research and Development in the Canadian Corporate Sector. Conference Board 34-88, December 1988.

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