Automotive Research and Development in Canada

A Report Prepared for
The Science Council of Canada
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16. Abstract

This report details the results of a project designed to identify the current role of and likely prospects for Canadian R&D activity in the automotive sector. The project draws on data from public sources and develops data from interviews with automotive company and engineering service industry executives to evaluate likely changes in the levels and types of automotive R&D activity and the national distribution of such efforts.

While estimates of North American automotive R&D expenditures vary widely, Canada's automotive R&D activity level is substantially below the U.S. level. Moreover, the gap may be somewhat narrower in applications R&D, the more applied and dominant type of R&D, than in developmental and basic R&D. These patterns have been stable over the past decade, and are expected to remain so over the next decade.

Canada has a mixture of strengths and weakness for automotive R&D compared to the United States. Its strengths are especially in its government policies, cost structure, and material endowment. However, these advantages may not be sufficient to overcome U.S. advantages, especially its developed infrastructure for and tradition of automotive R&D.

There are a number of possible strategies for increasing Canada's automotive R&D, but Canada might be better served by strategies that protect its relatively high rate of assembly activity, rather than increase its relatively low rate of automotive R&D, compared to the United States.

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Executive Summary

This report details the results of a project undertaken by The Office for the Study of Automotive Transportation (OSAT) for the Science Council of Canada. The report draws on a series of interviews, available public data, and OSAT analysis to evaluate the current role of and likely prospects for Canadian R&D activity in the automotive sector.

Estimates of North American automotive R&D expenditures vary widely, reflecting differing definitions of what activities constitute R&D, differing definitions of the automotive industry, and different sources. Estimates from industry sources are generally higher than public estimates, often by a factor of two to three. Interviewees estimate a range of $15 to $20 billion in 1989, while public estimates are on the order of some $7.5 billion. Roughly half of these total expenditures are funded by the Big Three, although both the NAMs (North American subsidiaries of offshore automotive manufacturers) and part suppliers will increase their levels in the future.

The bulk of automotive R&D expenditures (72%) are incurred in applications R&D, the type that is "closest to market" and farthest from "pure" science. Perhaps two-thirds of this application R&D is targeted to product efforts, especially vehicles, although our respondents anticipate a shift to process efforts in the future. Basic R&D receives as little as 7% of expenditures. The majority of R&D at the Big Three is performed in-house, but part suppliers are a major, growing outside source of R&D performance.

Canada's automotive R&D activity, on a per vehicle basis, is probably about 5% to 6% of the U.S. level, although our respondents estimate it at nearer parity. However, they assign a lower share of basic and developmental R&D to Canada than in applications R&D. Mexico's R&D share is small. The United States is the generally preferred site for automotive R&D, reflected in its 84% share of the total, although Canada is a strong contender in certain materials for which it is a source. These patterns have been stable over the past decade, and are expected to stay relatively stable over the next decade.

Decisions to site R&D in one or another nation reflect both technical factors, like capability, and political considerations, such as corporate relationships and image. Generally, the more political implications in the decision, the higher in the corporation it will be made.

Canada certainly represents an attractive location for automotive R&D siting. It has three areas of relatively clear strength compared to the United States: government policies that are viewed as more supportive and less burdensome, generally lower costs, and certain advantages inhering in its material endowment. However, these advantages may not be not especially significant when stacked up against the many areas where Canada and the United States are comparable, or the United States holds an advantage, including its developed infrastructure and tradition of automotive R&D.

In a sense, Canada suffers from being insufficiently distinct from the United States, both in terms of its endowments and in the views of decision-makers. This results in Canada receiving consideration only at the second stage of R&D siting decisions, and may limit its opportunities to secure R&D work. However, Mexico is

considered quite distinctly, and that has not led to increases in R&D, nor does it currently represent much of a threat to existing R&D activity in Canada and the United States.

There are a number of possible strategies for increasing Canada's automotive R&D, some focused on enhancing Canada's current strengths and others on ameliorating its weaknesses. Of course, effective strategies must reflect a realistic appraisal of the developing trends in automotive R&D as well as Canada's situation and potential. In all probability, such strategies will target efforts to sustainable, small increments in automotive R&D. Canada should seek to distinguish itself from other R&D locations, and this is probably most easily accomplished in selected, focused areas. It probably makes sense to develop an area of R&D expertise that addresses a material, a process, a product (family), or an intersection of all three. One clear way to bolster such efforts would be to create a center of expertise in a selected material(s) in the Canadian university system, or to focus on emerging areas, such as the Intelligent Vehicle Highway System (IVHS).

Government incentives can play a role in attracting R&D, although perhaps more through broad efforts in education and improving the business environment, rather than through targeted activities like tax credits. Canada might well benefit from an easy immigration policy for technical and engineering personnel, and perhaps even a targeted recruitment of such immigrants, to provide an experienced automotive R&D cadre. Government might support an automotive R&D service function, providing services to user companies, or even establish a broad-based automotive research laboratory at a Canadian university. Canadian universities could strengthen programs that provide training at the interface of engineering disciplines, or even provide training in systems approaches to engineering.

However, canada must ask itself a fundamental question: should it seek to increase its "low" rate of automotive R&D relative to the United States, or should it concentrate its efforts on protecting and increasing its relatively "high" rate of assembly activity?

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I. Introduction

Background. Industrial research and development (R&D) is increasingly viewed as an important component of manufacturing competitiveness for both firms and countries. For many firms, such R&D is a critical capability for producing new products for rapidly changing markets that are increasingly served by international competitors. For countries, industrial R&D capability is often viewed as an important attribute for independently attracting and holding other industrial activity, such as manufacturing jobs.

The Canadian automotive industry today primarily consists of facilities owned by Canadian subsidiaries of the U.S. Big Three.[1] Most of these facilities are final assembly operations for passenger cars, vans, and light duty trucks, and much of their production is targeted to the U.S. market. While Canadian share of U.S. and Canadian vehicle assembly has risen sharply since the creation of the 1965 Auto Pact, and even risen somewhat through the decade of the 1980s, this has not resulted in matching levels of expansion in Canadian automotive R&D, nor in accompanying supplier activity. In a sense, then, Canada's role in automotive production continues to depend heavily on its integration with Big Three activity elsewhere, especially in the United States.

Over the past 15 years, the Big Three have faced a serious competitive challenge from the Japanese automotive manufacturers in both U.S. and Canadian markets, and this challenge has grown as these manufacturers have established production facilities throughout the United States, Canada, and Mexico. The Big Three response to this challenge has involved a number of strategic decisions that potentially affect Canada's role in their operations. First, initially forced by local content laws, but now driven more by the pull of less expensive labor, the Big Three have all significantly expanded their operations in Mexico, and that presents a possible threat to their activity levels in both the United States and Canada. Second, both Ford and GM have increased their investment levels in their European

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[1]Chrysler, Ford, and General Motors (GM), the traditional North American automotive manufacturers.

operations. Thus Canada may eventually be part of a smaller U.S. and Canadian portion of Big Three global activities.

A more directed outcome of the Japanese challenge has been a strategic reconsideration of R&D at the Big Three, focused especially on the issue of what units or companies should perform such activity, and where it should be sited. In particular, the second half of the 1980s has witnessed varying efforts to "outsource" engineering work, to have it performed at suppliers of parts and components, and specialized engineering service (ES) suppliers as well. This same time period has seen part and component purchases re-sourced from traditional U.S. and Canadian suppliers not only to Mexico, but to a variety of producers outside North America as well. This is primarily driven by cost considerations. Some re-sourcing of R&D work has also developed, and more might develop in the future.

Canada clearly has two interests in automotive R&D work. First, such work might provide a more independent anchor for Canada's current automotive economy, and an attraction for the further expansion of that activity. This may become increasingly important as other producing areas improve, and Canada's relative advantages narrow.[2] Second, R&D activity provides well-paying, skilled work in its own right, and increasing R&D activity therefore offers direct economic benefits.

Overview. The Office for the Study of Automotive Transportation (OSAT) has performed a study and analysis of the automotive R&D process and the decisions controlling where that work will be performed. The primary focus of this effort was the geographical siting of automotive R&D, and the factors that promote or inhibit the selection of certain locations for such activity. Recent developments and changes in the focus and patterns of automotive R&D sourcing, particularly in regard to the roles of different functions, firms, and agencies in this process, constitute an important secondary emphasis.

The purpose of this report is to provide the client, the Science Council of Canada, the results of the study and our observations on possible strategies for increasing automotive R&D work in Canada. In addition to this introduction, the report encompasses four sections that parallel the major tasks of the project. Section II describes and analyzes major recent trends and likely future developments in automotive industry R&D work, highlighting the decisional context for locating such work organizationally. Section III examines the geographical distribution of North American automotive R&D, again focusing especially on the process and criteria governing this process. Section IV identifies Canada's current strengths and weaknesses as a location for automotive R&D. Finally, Section V reviews some of Canada's options for increasing its attractiveness as an R&D location, including enhancing its current strengths and ameliorating its weaknesses.

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[2] A recent survey of supplier attitudes about potential production sites found that Canada had declined an average of 0.4 scale points (on a five point scale) on five performance dimensions, compared to a survey conducted about 20 months earlier. This included a 0.4 point decline on "technical capability." Canada also declined an average of 0.2 points on five dimensions of attractiveness as a site for production. The earlier results are from Flynn, Michael S. and David J. Andrea "Capacity, Competition, and Change: The 1988/1989 Supplier Survey," OSAT, June 1989, 32 pp. (Permission to report these 1990 results was granted by the contracting agency, an economic development unit of an EEC country.)

The report includes a major separate essay, Appendix I. This essay, drawing on other sources of data, also addresses some of the issues covered in the interviews. It provides estimates of R&D expenditure patterns and reviews the effectiveness of investment tax credits as an incentive for R&D. It also analyzes Canada's relevant labor endowment, and describes Canada's contract engineering sector, an increasingly important source of engineering for the traditional North American Big Three.

Method. We collected information from a structured set of interviews covering a wide range of topics. This instrument is attached as Appendix II. Interview topics include: the current distribution of R&D, significant developments or changes since 1980, and likely developments by 2000, perceptions of Canada's strengths and weaknesses for both types of R&D, and any external barriers to or facilitators of Canadian location for such work.

Information from these interviews is supplemented by the essay in Appendix I. Drawing on publicly available data, this essay addresses an important subset of the issues covered in our interviews, including levels of automotive R&D expenditures in Canada and the United States, and factors that may render a location relatively more or less attractive as an R&D site. This essay, then, permits some comparison of the interview respondents' perceptions and attitudes with the reality revealed by official reports and statistics.

Respondents. We interviewed nine respondents for this project. Our strategy for securing respondents relied on nominations by OSAT staff, well placed executives in the industry, and initially nominated personnel from the companies themselves. This process identified engineering/technical personnel with broad experience and overview of R&D efforts, often at the industry level as well as within their own companies. They include seven executives with the Big Three and two executives of large engineering service (ES) firms. Both ES executives have extensive prior experience at major part and component suppliers, and one of them has been Director of R&D at such a parts supplier. We are persuaded that the experience and knowledge of these respondents make them appropriate and useful sources of the information required for this project.

Our efforts to obtain interviews at transplant manufacturers, or NAMs[3], have been unsuccessful. Why we have experienced this difficulty is unclear. In some cases, we simply have not been able to establish contact with identified personnel in spite of repeated efforts. In one case, the appropriate company representative, after numerous contacts, eventually refused to arrange an interview, stating that all their R&D would continue to be performed in Japan.[4] This project is not alone in failing to gain research access to the NAMs. The source of this reluctance of the NAMs is unclear. It might reflect a general company preference for restricting information, or an unwillingness, or perhaps simply an inability, of their North American-sited employees to make these decisions. Our own suspicion is that it is at least in part due to the NAMs' own uncertainties in regard to future R&D siting. We suspect that these policies are now under development and not yet finalized, and that these companies, as others, are reluctant to discuss policy decisions and issues that are not yet resolved.

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[3]For New American Manufacturer, an acronym these companies seem to prefer to the more temporary flavor of "transplant."

[4]This is difficult to accept, since this company has established an R&D center and design facilities in the United States, and, according to a recent Economist Intelligence Unit Report, plans to perform a third of its R&D in North America.

This failure to access the NAMs is somewhat ameliorated by information shared by two of our Big Three interviewees. One of these respondents has completed an extensive, high level assignment in Japan with an affiliated manufacturer, including exposure to its R&D efforts. Another has performed extensive analysis of Japanese automotive industry R&D practices. Both these executives shared their views on Japanese R&D and likely North American activity with the Project.[5]

Data. These interview responses do not support statistical analysis because the respondents do not constitute an appropriate sample for such techniques. Nor, in most instances, do they lend themselves to tabular presentation because their low number does not require such a summary approach. However, they still are a useful and potentially rich source of information because of the experience and expertise of the respondents. We will draw on these responses to develop an overall snapshot of current and likely developments in R&D, and to highlight the insights these respondents provide.

Section II: Developments and Trends in Automotive R&D

This section describes and analyzes major recent trends and likely future developments in automotive industry R&D work, highlighting the decisional context for locating such work organizationally.

Types of automotive R&D. The project attempted to address three forms or variants of industrial R&D, and these definitions were presented at the initiation of the interview. The first type is basic or "breakthrough" research, where the effort is targeted on new discoveries in the basic sciences and the applications to product, process, or materials technology is speculative rather than established. This type of R&D fulfills even the most restrictive definitions, and is the most heavily tilted to the research component of R&D. The second type is developmental engineering or "innovation," where the effort builds on established basic science and focuses on developing new product, process, or materials technology for automotive application. This type of R&D focuses on the commercial development of the kind of discoveries that might be yielded by basic research of the first type. The third type, applications engineering or "adaptation," where both the basic science and technology are established, focuses on adapting or enhancing its implementation in product, process, or materials. This type of R&D is incremental in approach, and is frequently tied to a specific developmental program, such as a new vehicle. It also includes many expenditures that are typically excluded from research and monitoring definitions of R&D.

The North American automotive industry engages in all three types of R&D, in varying mixes over time. Most importantly, for purposes of this report, the industry does not attempt to distinguish carefully among them, and often includes other expenditures under the rubric of R&D. Thus expenditures that might be better categorized elsewhere are often included as R&D. For example, this happens with capital expenditure for new tooling and new products, with respondents on occasion including entire costs of new vehicle programs and plant modernizations under one or another of these three types of R&D. Routine expenditures for product

[5]Appendix III contains two general industry press articles that review what is commonly known, suspected, and speculated about NAM R&D intentions in regard to North American siting.

testing and routine technical services are often included as well. Consequently, the levels and distributions reported by our interview respondents differ from the estimates provided in Appendix I, and, to a certain extent, reflect a different, more industry-oriented view of R&D.

Our respondents provided numerous examples of each of these three types of R&D that their companies and others have pursued over the past decade. Examples of basic research include research in ceramics, base metal catalysts to replace platinum in exhaust systems, friction materials, powdered metallurgy, fiberoptics, dense magnetic material for use in small motors, and electro-rheological fluids that change viscosity with a change in voltage applied across the fluid. Of course, all of these efforts are at least theoretically tied to possible improvements in the vehicle or its component systems. For example, base metal catalysts reduce costs, electro-rheological fluids can provide enhanced performance, and denser magnetic materials permit motor weight reductions. Even basic research in industry is typically tied to a product, rather than constituting science for science's sake.

Industry efforts in innovation or developmental engineering span an equally wide range, although more such efforts were common across the companies. The industry has invested heavily in material development efforts over the past decade, especially driven by the emphasis on weight reduction to meet the U.S. Corporate Average Fuel Economy (CAFE) standards and competitive cost pressures. Numerous new polymer-based materials have gone from the labs to installation on-board vehicles during that time, including various plastic and composite panels. Electronic and electro-mechanical controls, for emission control, fuel economy, and driveability have been major areas of developmental engineering effort. Perhaps the most publicized development has been the variety of antilock braking systems that have become available over the past decade, and have already become standard equipment on some light trucks and passenger cars.

These respondents reported numerous examples of application engineering, including enhanced computerization of processes and communication, expansion of Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) systems, refinement of plastic and metal processing and product technology, and improvements in a range of electronic controls and sensors.

<u>Levels and distribution of R&D expenditures</u>. As the discussion in Appendix I indicates, estimates of automotive R&D spending are variable, reflecting differences in both definitions of R&D and definitions of what companies are included in the automotive industry. The interviews indicated that our respondents were not always clear, nor in agreement with each other, on exactly where to classify various efforts. Unfortunately, exact classification probably requires far more detailed information on projects than either these respondents or OSAT could hope to develop. Nevertheless, we asked our respondents to estimate the total 1989 expenditures of the North American industry, including both manufacturers and suppliers, for all three types of R&D. Not surprisingly, the estimates varied widely: from \$12 billion to \$22 billion. Even the low estimate exceeds the definitionally more restrictive NSF results (\$7.5 billion) and the more industry restrictive *BusinessWeek* estimates (\$10.3 billion) reported in Appendix I.

Our respondents estimate that 1989 levels are up a bit over the past, perhaps on the order of 5% to 10% in real dollars. Competition has driven R&D expenditures up, as model proliferation, plant investments, regulations, and necessary quality improvements have all required R&D investment. As one respondent put it, the North American companies have recognized that technical advances are part of winning.

Looking to the future, most of our respondents see little threat to levels of North American R&D from other potential sources, although particular areas or projects may be shift between North America and other locations. In particular, Japan is not seen as a direct threat to R&D activity, although increased sales of Japanese vehicles in North America would perhaps lead to some decrease in Big Three levels. This may be somewhat compensated by a shift of some Japanese manufacturer R&D to North America. Both Ireland and Eastern Europe were identified as potential R&D sites because of availability of technical and engineering personnel.

These executives estimate that automotive R&D expenditures are allocated about 7% to basic research, 21% to developmental engineering, and 72% to applications engineering. There was little disagreement on basic research, with all respondents estimating between 5% and 10%.[6] There was some disagreement in regard to the other two types of R&D, with a few respondents seeing little more allocated to developmental engineering than to basic research, and the vast bulk of expenditures in the application area. However, this probably reflected the respondents' differing views on how to categorize certain efforts, such as antilock brakes, than to substantial differences of opinions. One (non-GM) respondent suggested that in the future virtually no truly basic research will be performed in the automotive industry, with the possible exception of efforts at GM's Technical Center. In his view, the competing needs for engineering dollars in the development and application stages will strip the funding for basic research at most automakers.

Within adaptation or application R&D, roughly two-thirds of expenditures go to product efforts and about one-third to process or manufacturing engineering. This has shifted over the past five years, with manufacturing engineering receiving a larger share than in the past. Two respondents expect the manufacturing share to increase even more as the traditional separation between the two disciplines and their functional separation within the companies lessens. In any case, the integration of product and process development engineering, through efforts like simultaneous engineering and design for manufacture, should render this distinction not only less clear, but perhaps less important.

Most product adaptation engineering expenditures are focused on the vehicle, simply because the packaging of the parts and components is a major category of expense. While it is difficult to separate the expenditures because many components are adapted and redesigned as part of new vehicle programs, it does appear that the majority of expenditures are tied to developing vehicles.

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[6] Appendix I reports NSF results that suggest that 3.9% of all U.S. industrial research is basic research. These results suggest that the automotive industry is probably not substantially different from this overall industry average.

It is clear that applications engineering for both products and manufacturing processes dominates the R&D budget of the automotive industry, and most of this is in some way tied to new vehicle programs. Only a small part of these expenditures, certainly less than 10%, is applied to basic R&D. One respondent suggests that at most 10% of traditional automotive R&D in North America goes into efforts that are not tied to an existing product, while 90% is focused in areas of "off the shelf" technology. In contrast, he estimates that as much of 30% of R&D at Toyota is to develop technology to put "on the shelf" for possible use in the future.

Sources of automotive R&D. The Big Three patterns of allocating their R&D budgets across different R&D sources appear to differ somewhat. Ford and GM perform the majority of all three types of R&D within their own facilities, while Chrysler relies more heavily on outside sources for basic and developmental engineering R&D. All three source some basic research from universities and participate in industry consortia. This may account for roughly 10% of Ford and GM basic research, but perhaps as much of 80 to 90% of Chrysler's. Ford concentrates its developmental engineering in-house and at its suppliers of materials, parts, and components, and relies even more strongly on its own capabilities for application engineering, although also drawing on other manufacturers and its suppliers in this area. GM draws more broadly from the available sources for all three types of R&D, perhaps performing more developmental engineering, and a bit less applications R&D in-house than does Ford. Chrysler is less vertically integrated than either Ford or GM, buying as much as 70% of vehicle value from outside suppliers. This undoubtedly accounts for its somewhat lower R&D per vehicle expenditures than either Ford or GM, and its greater reliance on outside sources of R&D. GM appears to rely more heavily than either Ford or Chrysler on ES firms for applications R&D, reflecting perhaps its recent moves to outsource more of its engineering functions.

All these respondents expect to see increased reliance on outside sources of R&D over the coming five to ten years. Some of this shift will be to industry consortia, as the legal climate permits more joint efforts, and some will be to automotive suppliers. This shifting, or outsourcing, of engineering to part suppliers and ES firms is confirmed by other research work, although the pace of this change does appear to have slowed somewhat from earlier expectations.[7] Moreover, Ford has already relied on Mazda, one of its alliance partners, to do the bulk of the engineering development for the new Escort model.

One respondent presented an interesting argument in regard to the role of universities. While respondents generally discussed universities in relation to basic research, this executive suggested that universities may show a significant activity increase in the developmental type of R&D. He argued that their basic cost structure is attractive because of effective public subsidies and the presence of a large pool of talented, inexpensive labor (graduate students). Furthermore, universities can focus their R&D efforts better than companies that must wrestle with day-to-day business concerns. Of course, universities have historically resisted R&D work that moves away from the pure science, knowledge-for-the-sake-of-knowledge model. However, pressures on university to expand their funding sources may alter this attitude in the future.

[7] Flynn, Michael S. "Engineering Outsourcing" AIM Newsletter November, 1986 2, 1, pp. 5-6.

Funding of automotive R&D. These respondents estimate that the Big Three fund about 50% of the total North American automotive R&D effort, allocated roughly equal to their sale shares, with perhaps GM a bit higher and Chrysler a bit lower on a per vehicle basis. That suggests that GM accounts for somewhat over 50% of Big Three expenditures, Ford in the low 30%'s, and Chrysler at about 10 to 15%. Probably a bit less than 50% of total North American automotive R&D is funded by their suppliers of raw materials, parts, and components. The engineering service firms do very little independent funding of R&D, since most of their contract expenditures in this area are funded by the Big Three. The North American governments are not seen as significant sources of automotive R&D funding.

Both *BusinessWeek* and NSF estimates suggest that the major performers of R&D, the manufacturers, account for the vast bulk of automotive R&D, perhaps over 90%.[8] Our respondents estimate that it is much lower, perhaps only on the order of 50%. While some of this difference may be due to different definitions of the "automotive industry," more is probably due to differences in definitions of R&D work. We suspect that these respondents include far more routine testing and applications engineering R&D in their definitions, and much of this work is performed at suppliers. Ultimately, the Big Three may pay for much of this R&D performed at suppliers through purchase prices, although it appears that less than 25% of supplier basic R&D is recoverable from the Big Three. On the other hand, R&D work at ES firms is typically negotiated for and billed out as separate items, so the Big Three recognize this as R&D they pay for, although it is performed at the ES firms.

At this time, these respondents feel the NAMs are funding very little automotive R&D *in* North America, probably no more than $100 million in 1989, although much of their R&D expenditure in Japan is targeted on North America. Total Japanese automotive manufacturers' R&D expenditures may be as high as $4 billion, and perhaps a third of that is in some sense targeted on North America. These respondents do expect to see some increased R&D expenditure in North America by the NAMs, although how much of an increase is unclear. Toyota, Honda, and Nissan are all installing more R&D capacity in North America, but whether this will go beyond design studios and manufacturing engineering support for their North American plants is simply not clear.

Our respondents expect these funding patterns to shift significantly over the next five to ten years in a number of other ways as well. First and foremost, they expect the Big Three to rely more on their suppliers of raw materials, parts, and components to pick up the R&D and engineering loads. This is driven by cost considerations, but also by the difficulty of developing and maintaining the human resources and expertise required across so many different areas. Second, they do expect that the ES suppliers will fund and perform more R&D work, for much the same reasons. Third, there may be some shift away from North America as the manufacturers around the world develop alliances and the Big Three begin to rely on these European and Japanese "partners" to perform engineering work.

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[8]See Appendix I, pp. 3-4.

R&D sourcing decisions. Decisions about where to source a particular R&D effort are literally made everywhere throughout the levels and functional divisions of the Big Three hierarchies. Exactly where such a decision is made depends on the specific R&D effort under consideration and its budgetary requirements. The actual decision maker can range all the way from a project engineer to the head of advanced engineering, the program manager, or vice president of engineering. Often these top managers will make a policy decision to outsource the work, but lower ranking managers in engineering and/or purchasing will select the actual source to perform the work.

The grounds for such decisions also vary widely from instance to instance. Expertise, cost, and confidentiality are probably the main factors that determine whether the R&D work will be performed in-house. If the Big Three believe they can perform the work, they will likely do so. If in-house expertise is lacking, or the cost of in-house performance is high, or would require adding capacity, and confidentiality is less important, then the Big Three are likely to seek outside sources. The selection among possible outside sources is typically driven again by cost and expertise, although resources to carry a project through to completion, and general reputation of the source weigh heavily as well. This decision process suggests that the Big Three essentially reserve a right of "first refusal" for in-house performance, and seek outside sources if that is appropriate. That first refusal is typically exercised at a fairly high level of management, but the consideration and selection among outside sources occurs at varying levels, often fairly low in the organizational hierarchy.

Summary. These respondents estimate that the North American automotive R&D budget for 1989 was in the range of $15 to $20 billion, up some 5% to 10% in real dollars over the past five years. Roughly half of these total expenditures are funded by the Big Three, although both the NAMs and part suppliers will increase their levels in the future. The clear majority of these expenditures (72%) are incurred in applications R&D, the type that is "closest to market" and farthest from "pure" science. Perhaps two-thirds of this application R&D is targeted to product efforts, although our respondents anticipate a shift to process efforts. Most of product R&D is allocated to vehicles programs. On the other hand, basic R&D receives only about 7% of these expenditures. The majority of R&D at the Big Three is performed in-house, but part suppliers are a major, growing outside source of R&D performance.

Section III: Geographical Distribution of Automotive R&D

This Section examines the national distribution of North American automotive R&D. North America offers three national sites for R&D, as it does for production: Canada, Mexico, and the United States. Our research effort again focused especially on the process and criteria governing geographical site selection.

National distribution of R&D. Our respondents believe that the overwhelming majority, at least 87%, of basic and developmental automotive R&D in North America is sited in the United States. They report virtually no basic or developmental research activities in Mexico, 2%, and no more than 11% in Canada. Applications R&D reveals a different pattern, with U.S. share falling to about 79%, Mexico doubling to 4%, and Canada's share rising to just over 17%. Summing these estimates, weighted by our respondents' estimates of the distribution of R&D by type, yields a total U.S. R&D share of 81%, a total Canadian share of just over 15%, and a total Mexican share of just over 3%.

Here our estimates differ substantially from the patterns revealed in official statistics. Those sources suggest that the R&D intensity of the Canadian automotive industry, on a production corrected basis, is on the order of 5% to 6% that of the U.S. industry.[9] Our interview estimates portray a level that approximates the U.S. level, with about 15% of R&D expenditures and assembly activity located in Canada. Again, we stress that differing definitions of "R&D" and "automotive industry" probably apply to all these sources. In particular, our definition of "applications R&D" reflects industry views, but includes many expenditures normally excluded from R&D.

Additionally, our respondents estimated in 5% intervals, and estimated Canada, then Mexico, and the balance to the United States. A reverse order of estimation might have yielded different results, as might the use of finer intervals. If we adjust these figures for our respondents' reports of how closely their own company's expenditures match their estimates of industry expenditures, Canada's shares fall to just under 9% in basic and developmental and 15% in applications R&D, for a total share of just over 13%, or about 16% of U.S. levels. These adjusted estimates of Canadian share of basic and developmental R&D suggest equivalent research intensity between the two industries, and are still quite different from the estimates presented in Appendix I.

In our judgement, these estimates err by overestimating Canadian and Mexican shares and underestimating U.S. shares. The lower estimates of Canadian R&D levels compared to U.S. levels provided in the Appendix are undoubtedly better approximations to reality than are these interview estimates.

However, these interview estimates do have some value. In particular, they suggest that Canadian R&D share is larger at the applications R&D stage than at either the basic or developmental stage. This is consistent with other information. On the one hand, the major technical and engineering centers of the Big Three are all located in the United States, and these centers are important for both basic and developmental R&D. On the other hand, the distribution of final vehicle assembly

[9]See Appendix I, pp. 6-8. Note that total automotive R&D spending in Canada may be more on the order of 1% to 2% of U.S. levels.

activity follows a different pattern, since Canada accounted for just under 15% of 1980 U.S. and Canadian vehicle assemblies, and just over 15% of 1989 assemblies. Canada has also seen significant comparative plant investments over the past five years. The focus of application R&D on vehicle programs and the shift in application R&D expenditure to process efforts both suggest the importance of final assembly activity in these expenditures.

We asked our respondents to identify which of these three countries represents the preferred site for R&D activity, and whether that preference varies depending on a range of specific factors. Most respondents indicated that the United States represents the generally preferred site, largely reflecting its current level of engineering and R&D activity. Most respondents mentioned at some point in these interviews that proximity in R&D is important, and that proximity means nearness to other R&D activity more than to manufacturing or assembly plants. They appear to view the synergies provided to R&D as important advantages fostered by close location of R&D facilities to each other. The preference for keeping basic research confidential also favors its performance in existing U.S. facilities.

Beyond this general preference for the United States, respondents indicated a number of specific preferences for Canada and none for Mexico. At the most general level, these preferences for Canada are all tied to its importance as a raw material supplier, and its current and potential expertise tied to those materials. Somewhat surprisingly, this general preference for the United States seems to vary little by type of R&D, product, process, in-house execution, or size of expenditure. In a sense, that reinforces the point that it is indeed a strong general preference.

Our respondents feel that these distributions of R&D activity across Canada, Mexico, and the United States have been stable over the past decade. One respondent thought that there might have been some marginal increase in R&D activity in Canada, but that this would have been at other companies. These executives generally expect that there will be no real shifts in these patterns over the coming decade, although one thinks that Canada might see an increase of 5% to 10% in its share because of its capabilities and a shift of ES activity to Canada to be close to assembly plants. Three other respondents noted that any shifts that might develop would likely occur as a result of Big Three outsourcing of R&D to part suppliers and ES firms. As the Big Three outsource some R&D activities, the national siting of these activities will depend on where these companies have or choose to open facilities. To the extent that other countries pose some threat to North American R&D levels, the level of the threats to Canada, Mexico, and the United States does not differ.

<u>R&D siting decisions</u>. Our respondents paint quite different pictures of where most decisions on siting R&D are made, and these views to some extent reflect what they feel are the grounds for such decisions. In general, all see these decisions being made at fairly high levels, but the exact level varies from engineering directors at the relevant unit all the way to the CEO and even the Board of Directors. The more general the political and image implications of the decision are, the higher the level of effective decision-making.

The grounds for siting R&D in different nations reflect a mixture of technical and political factors. More technical factors and considerations include the availability of expertise and facilities, and sometimes more specific considerations, like climate for hot and cold weather testing. More political considerations include company image, policies of the potential host governments, and possible union (UAW and CAW) reaction.

However, these general considerations can lead to quite different specific outcomes. One company may keep work at a current site to maintain its relations with local unions and/or current host governments, while another may seek new sites to avoid too much dependency on a union of government. Image, too, is a consideration that can have quite different specific applications. One company may locate its facilities close to its customer plants to foster the image of a "good supplier," while another may locate close to its customers' R&D facilities to provide the opportunity of communicating an image of technical sophistication and concern for cooperation.[10]

Summary. Canada's automotive R&D activity is probably at about 5% to 6% of the U.S. level, although our respondents estimate it at nearer parity. These respondents are probably correct in assigning a lower share of basic and developmental R&D to Canada than in applications R&D. Mexico's R&D share is small for all three types of automotive R&D. The United States is the generally preferred site for automotive R&D, reflected in its 84% share of the total, although Canada is a strong contender in certain materials R&D, reflecting its role as a source for these materials. These patterns have been stable over the past decade, and are expected to stay relatively stable over the next decade.

Decisions to site R&D in one or another nation reflect both technical factors, like capability, and political considerations, such as relationships and image. Generally, the more political implications in the decision, the higher in the corporation it will be made.

Section IV: Canada's Strengths and Weaknesses

This section focuses on respondents' views of Canada's current strengths and weaknesses as a location for automotive R&D, comparing and contrasting them with their views of the United States.

Canada's strengths. These respondents see many advantages to Canada as a location for automotive R&D. In the general area of government policy, some, but not all of these respondents see definite advantages to locating R&D in Canada. They mentioned the Canadian government's aggressive policy in support of R&D in general and in specific research areas, like dual fuel cars and crash studies, as well. They also mentioned tax and energy policies. Some other governmental policy advantages in Canada emerged as the respondents identified U.S. weaknesses: environmental, workplace health and safety regulations, and anti-trust policies are all seen as less burdensome in Canada.

Canada receives high marks for its general human resources and technical manpower, and its strong universities. Respondents also note that frequently lower costs, language and cultural similarity, and proximity all make Canada attractive to U.S. decision-makers and employees who might have to be relocated.

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[10]Note that this proximity can also lead to quite different outcomes, depending on how a company answers the question "proximity to what?"

Canada has some major attractions in specific areas of automotive R&D. It is a major source for automotive aluminum, a material that has seen increased usage in the face of pressures for vehicle weight reduction. Ford, for example, has an aluminum foundry and casting plant in Essex, and such facilities might draw R&D activity, especially if Canada develops broader expertise in aluminum. Canada is also a major source for natural gas, and this fuel, in both compressed (CNG) and liquid (LNG) form, is an important alternative fuel candidate and the target of some R&D activity. Canada also has some R&D strength in the powdered metals.

Canada's weaknesses. If Canada offers a location that is, in some senses, close to the North American automotive engineering and R&D facilities centered in the Detroit area, it is still farther away than many possible locations in southeast Michigan. One respondent suggested that this very proximity would make it difficult to justify investments in Canada that would often duplicate existing investments in the United States. Moreover, the trip crosses an international boundary, presenting its own types of custom delays and problems, via a tunnel or bridge that present simple but aggravating traffic delays. A number of respondents mentioned problems with moving R&D material, from computer programs, drawings, and designs to experimental and prototype products, across the border. Such goods are dutiable, often at the value of the project, and require time-consuming evaluation at the border.

Respondents noted the lack of a developed infrastructure for automotive R&D in Canada, including some feeling that the ES sector is weak. Nor were all respondents enthusiastic about Canada's human resources in the technical area, expressing a feeling that while they were acceptable in terms of skill, there is not an abundant supply of them. Some respondents specifically raised the issue of language unrest in Canada as a concern, and one suggested that Canadian unions are more radical than those in the United States.

While Canada possesses natural advantages in certain materials areas, our respondents raised some concerns about Canada's ability to exploit these areas. This is particularly problematic if automotive R&D activity moves to the supplier level of the industry. Canada is somewhat hurt by its lack of major, independent suppliers with the resources and experience to pursue aggressively the potential opportunities in R&D.

In terms of potential NAM R&D investments, Canada suffers a major handicap. Whatever advantages Canada might provide the NAMs, it appears that trade friction with the United States is one of their major concerns. They are not simply interested in locating work outside Japan to avoid bilateral friction, but wish to develop visible activity in the United States to mute that friction. In all likelihood, then, the substantial bulk of NAM R&D activity that comes to North America will be sited in the United States.

Canada compared to the United States. Canada seems to face three major handicaps in comparison to the United States as a location for automotive R&D. First, its areas of strength are largely areas of U.S. strength, and only in areas of cost and government policy is Canada seen as more attractive, and one respondent described these as minor differences in any case. Its universities are seen as strong, but no stronger, and perhaps not quite as strong as U.S. universities; at any rate, they are certainly less well known to U.S. decision-makers. Its workforce is as good as, but not better than, the U.S. workforce. Its culture and language may be similar to the U.S.'s, but they are not the same.

Second, whatever advantages Canada might confer, those advantages accrue to the companies only after they make the substantial investments required to overcome the developed tradition, infrastructure, and momentum of automotive R&D in the United States. These are not trivial advantages to overcome, and they even apply to decisions about new investments, if one feels, as do these respondents, that there is an advantage to closely concentrating R&D work to capture synergies. In a sense, then, the industry finds no compelling reasons to significantly shift its R&D activities to Canada, and many reasons to continue its current patterns.

Third, perhaps Canada's biggest handicap is that it is insufficiently distinguished from the United States in the view of automotive decision-makers. The long history of integration of the U.S. and Canadian activities of the Big Three and many of their suppliers has resulted in the United States and Canada becoming a blurred distinction to many industry participants on both sides of the border. While this has clear advantages to Canada, it sometimes imposes handicaps. These decision-makers are likely to accord Canada the same decisional status as a U.S. state like Michigan or Ohio. That means that the first stage decision--whether or not to site activity outside Canada/United States--is often made without specific and separate consideration of Canada, just as it may be made without specific consideration of Ohio. Canada is more likely to receive separate consideration at the second stage, after the decision is made to site the activity "here," and then it competes with various U.S. states. To be sure, it often has advantages over these U.S. states that are conferred by the Auto Pact. However, its failure to be considered at the first stage decision may seriously injure its chances at selection for R&D activity.

As one respondent put it, industry people think of Mexico when they consider "going abroad," but not Canada. In their view, Canada/United States is "here," and other countries are "there."

<u>Mexico</u>. The past decade has seen the shift of much automotive work from the United States to Mexico, especially in labor intensive processes. The major drivers for this shift have been Mexico's policies on domestic content and the attraction of less expensive labor. This shift probably captured some work that would otherwise have been sited in Canada. In view of the increasing investments of the Big Three in Mexico, might not Mexico represent an alternative site for R&D as well as for production, and might not this adversely affect Canada's chances for securing such activity? We raised this question with our respondents.

The Big Three experience in Mexico has generally been positive. Moreover, Mexico appears to have a supply of good technical workers and engineers, and its universities are strong in some engineering disciplines. However, at this time it presents no clear threat to Canadian automotive R&D activities or Canada's opportunities to secure more such activity. Mexico's major attraction to the Big Three is low wages, and that is simply not seen as a major attraction for R&D efforts. Beyond that, there are language and cultural differences that would be barriers to the smooth integration of large Mexican R&D investments into Big Three activities elsewhere in North America. While Mexico is clearly a competitor to Canada for some manufacturing investment, it is not likely to be a significant competitor for R&D investment over the next decade.

Summary. Canada certainly represents an attractive location for automotive R&D siting. It has three areas of relatively clear strength compared to the United States: government policies that are viewed as more supportive and less burdensome, generally lower costs, and certain advantages inhering in its material endowment. However, these advantages may not be not especially significant when stacked up against the many areas where Canada and the United States are comparable, or the United States holds an advantage, including its developed infrastructure and tradition of automotive R&D.

In a sense, Canada suffers from being insufficiently distinct from the United States, both in terms of its endowments and in the views of decision-makers. This results in Canada receiving consideration only at the second stage of R&D siting decisions, and may limit its opportunities to secure R&D work. However, Mexico is considered quite distinctly, and that has not led to increases in R&D, nor does it currently represent much of a threat to Canada/U.S. existing R&D.

Section V: Whither Canada?

This section reviews some of Canada's options for increasing its attractiveness as an R&D location, including enhancing its current strengths and ameliorating its weaknesses. There are three preliminary points that are important to this discussion. First, Canada's current capacities for automotive R&D may differ substantially from its capacities in other industries.[11] Second, Canada's strategies for increasing automotive R&D must target three quite distinct types of companies, parts suppliers and ES firms as well as the traditional manufacturers, and thus present a more complex challenge.

Third, the United States is the preferred North American location for Big Three automotive R&D, reflecting a long tradition that has established a strong infrastructure for that activity. The United States currently holds in excess of 80% of that R&D activity, and even higher proportions of basic and developmental R&D. The NAMs' R&D siting decisions are likely to tilt heavily to the political importance of establishing U.S. R&D facilities and to the attraction of siting in the Detroit area, where so much R&D work already exists. Therefore, there is no readily available opportunity for Canada to secure large-scale, general R&D activity, and hence no easy strategy that seems likely to yield substantial increases in automotive R&D. Rather, Canada should probably target its efforts to sustainable, small increments in automotive R&D. Such efforts must be well targeted to be successful, and should build on Canadian advantages to be sustainable.

Our respondents clearly identify expertise as the primary grounds for selecting R&D sources and sites. The Big Three are seeking "world class" performance from their supply bases, including R&D sources as well as parts makers. If it already exists, such expertise must be nurtured; if it needs to be created, it must offer a realistic chance of success and sustainability. Our respondents were better able to identify areas that Canada might develop than areas of expertise that already exist, although Canada should review its current activities to identify any such existing areas.

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[11] Data presented in Appendix I suggest that Canadian levels of R&D in the automotive industry compared to U.S. levels falls short of Canadian comparative levels in other industries.

Targeted expertise. One clear recommendation that comes through in these interviews is that Canada needs to distinguish itself not only from the United States, but from other possible R&D sites as well. Realistically, the general base for North American automotive R&D is, and will continue to be located in the United States. Canada should seek to establish itself as a world class R&D performer in selected, targeted areas, rather than seeking to establish itself as another automotive R&D generalist. An attempt to become an R&D generalist is unlikely to displace the established role of U.S. automotive R&D. Moreover, it runs the risk that Canada will consistently be a strong competitor for particular projects, but most often lose out to any number of different locations that are especially strong in the particular area under consideration. As one respondent expressed it, Canada needs to develop a "hotbed" of activity and expertise within an R&D area, attracting attention, consideration, and, ultimately, selection. Our respondents suggested a number of R&D areas for Canada to concentrate its efforts. Some of these suggestions reflect Canada's situation, while others are simply new areas that have not yet been developed by other locations.

One useful way to conceptualize the automotive industry is to think of it as a series of material, process, and product flows. Part suppliers increasingly are thinking of themselves as specialists along these dimensions, and they seem useful dimensions for considering an R&D strategy. The notion is quite simple: develop expertise within a restricted, defined area, based on a material, a process, or a product (family). In creating an R&D strategy, it probably makes sense to develop an expertise that addresses an intersection of all three dimensions.

Suggestions for developing targeted expertise that reflect some current Canadian advantage include four materials: aluminum, magnesium, plastic composites, and natural gas. The strategy would be to build Canadian experience and expertise in the automotive use and application of these materials, including processing and manufacturing products from them. Broad experience and expertise should draw associated R&D work to Canada.

One clear way to bolster such efforts would be to create a center of expertise in a selected material(s) at a Canadian university or a consortium of universities. This would not only provide an initial R&D effort, but would also contribute to the supply of technical workers and engineers with expertise in that material. Another path to build upon Canada's material strengths could involve the encouragement of strong Canadian materials firms to enter or increase their activity in supplying automotive demand, pursuing the expansion of automotive business upstream into product markets for parts and components. Some of these companies, such as Alcan and Stelco, are sufficiently large to support the R&D levels that will be required of major or "first tier" suppliers, while few of Canada's traditional automotive part and component suppliers are.

Identified areas of needed R&D expertise that bear no particular relationship to Canada's current advantages include the development of an Intelligent Vehicle Highway System (IVHS) center of expertise. The development of sophisticated communication between the vehicle and highway, spanning a range of information and control functions, seems an eventual certainty. IVHS offers significant savings in time and fuel consumption, permits denser usage of highways, and promises sharp reductions in accidents. The only question appears to be when it will develop. While extensive research and development efforts are currently being invested in IVHS, no clear centers of expertise have emerged, and efforts in Asia, North America, and Western Europe are still somewhat fragmented. A concerted effort to develop such a center might well pay handsome dividends. It is important that while Canada perhaps has no special advantage in this area, neither do other countries, and Canada does not appear to have any particular disadvantage. Indeed, Canada's strengths in telecommunications might even be construed as a comparative advantage.

IVHS is an example of an emerging area of R&D activity, and as such should be attractive to Canada. New and emerging areas of expertise provide Canada the opportunity to pursue R&D without challenging the established tradition and expertise of U.S. R&D centers, removing one of the major comparative weaknesses that Canada faces. The same logic applies to expanding R&D activities, such as testing. The demand for product testing has increased significantly, and the Big Three seem open to sourcing many kinds of testing from outside their traditional R&D functions, rather than expanding their own activities. It is possible that developing specialized testing capabilities can eventually lead to developmental expertise, as the tester incorporates upstream activities.

Government policy and efforts. While some of our respondents mentioned direct government incentives as factors in R&D siting decisions, most viewed these incentives as of marginal importance at best. For example, tax credits for R&D are fine, but they are simply not very important in the broader scheme of R&D costs and purposes. Nevertheless, tax credits that disappear upon closer examination might well become a disincentive for locating R&D facilities. The narrow definition of R&D applied by Revenue Canada and the rather broad and loose definition commonly employed in the automotive industry sets up potentially serious misunderstandings.

Unfortunately, government action that is most likely to be effective in securing sustainable R&D is more likely to be found in longer-term efforts, such as educational policies that yield the appropriate human resources and general policies that influence the business environment. To be sure, tax credits may be an important element of such strategies, but they will have little direct effect. One reason for this is that they in fact typically have relatively small effect on the total costs of R&D.[12]

If government policies are more effectively targeted to long-term strategies, or to more automotive targeted support activities, our respondents did raise one particular concern that calls for targeted government action. Nearly every respondent had an anecdote about terrible problems encountered in moving R&D material between Canada and the United States. These problems at the border have largely been resolved by the Auto Pact in regard to products, but remain in physical and intellectual R&D property. This seriously reduces any proximity advantage that southern Ontario might have, because it effectively makes it farther away, in a time sense, than it is in a physical sense. This issue may be important in the coming years. As R&D moves to suppliers, many suppliers will be seeking to establish R&D facilities close to Detroit. These new and/or added facilities are targets of opportunity for Canada, but they are unlikely to locate in the Windsor area if the border represents a time and cost penalty.

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[12] Appendix I provides estimates of the actual dollar values of such credits: they are indeed remarkably small as a percent of R&D expenditures.

Many automotive companies are currently under business pressure to expand their R&D activities, particularly those independent supplier companies that wish to remain or become major, key suppliers in the emerging industry, and ES firms that hope to offer full service capability to the manufacturers. Some of these companies will want to locate close to Detroit, and Ontario might compete for their new facilities. One government activity that might enhance Ontario's competitiveness would be an easy immigration policy for technical and engineering personnel, and perhaps even a targeted recruitment of such immigrants. Securing R&D personnel experienced in automotive work would provide a ready labor supply and overcome a major weakness in Canada: the lack of an experienced automotive R&D cadre.

Human resource strategies. Our respondents were in some disagreement as to whether Canada had the requisite technical personnel to support a major effort to attract automotive R&D, and whether expanded training at the university level was required to supply such personnel. Several respondents suggested that Canada has sufficient trained personnel, but that they lack the critical experience of working in the automotive industry. In a sense, this presents Canada with a dilemma: it lacks appropriately skilled personnel to attract automotive R&D because it does not perform enough automotive R&D, but it cannot develop the people to attract such work until it does more. At the same time, Canada faces some risk as automotive R&D shifts from the manufacturers to part suppliers and ES firms, as our respondents expect, because Canada's automotive endowment is weaker in these areas than in vehicle assembly.

One respondent suggested a strategy that might address both of these concerns. He recommends that Canada support the development of an automotive R&D service function, providing laboratory space and technical/engineering personnel at reasonable fees to user companies. The companies would provide some personnel, the R&D agenda, and support the cost of specific project equipment, material, and so on. This should not be the typical incubator approach popular in economic development circles, where the object is to subsidize the initial efforts of companies, some of which will establish successful presences in the local economy. This is more in the nature of a "rent-a-skunk-works," and would provide a training ground for Canadian R&D personnel, as well as attractive housing for the presumably expanding R&D efforts of many supplier companies. An alternative possibility would be to establish an automotive R&D laboratory that would provide "full-service" automotive R&D, simply taking on entire projects on a contract basis. However, this variant might have more difficulty attracting clients for the simple reason that there is no clear reason why a company should use its service. A "full-service" laboratory might be an appropriate spin-off after a period of successful years as a "rent-a-lab."

Another respondent suggested something that combines both the previous strategies, and that is to establish a broad-based automotive research laboratory at a Canadian university, providing a ready source for contract R&D, and gradually over the years developing needed areas of expertise. He estimates that a serious effort of this type would require the commitment of up to $100 million, and the efforts of numerous people. He notes that the university would benefit as well, since, in his view, none of the Canadian universities are particularly strong in mechanical engineering, and an automotive R&D lab might foster such a strength.

A longer-term strategy that involves drawing on the Canadian university base reflects the concerns of many in the automotive industry about the extreme separation of engineering disciplines. In particular, the automotive industry increasingly requires engineers that are conversant in both mechanical and electrical/electronics engineering. A Canadian university that developed an integrated program in these two specialties would not only supply personnel that would attract automotive activity to Canada, but would be a ready location for R&D work that spans these two historically separate disciplines. A similar program that integrated the disciplines of mechanical and industrial/operations engineering might play a similar role in the face of the increasing integration of product and process engineering in the automotive industry.

Beyond the integration of two or more engineering disciplines, it is clear that the traditional North American industry needs to adopt more of a systems approach to the design and execution of the myriad tasks required to produce a vehicle. Again, Canada might try to establish a clear center of expertise in the area of systems engineering, systems management, or even the integration of these engineering and business disciplines.

All of these human resource strategies require establishing some source of cross-disciplinary or multi-disciplinary expertise. The disciplines that would properly be involved would include, at a minimum, all engineering disciplines, perhaps especially mechanical, electrical, and materials. A strong systems orientation might require the addition of industrial/operations engineering, as well as the various management disciplines. Since there clearly are limits to the individual's capability of developing true expertise across a number of fields, this training and development would build a broad awareness and appreciation of other disciplines, anchored upon a specific disciplinary expertise.

<u>An alternative strategy focus</u>. Automotive R&D provides well-paying careers to technical, scientific, and engineering personnel, and that is sufficient reason for Canada to wish to enhance its R&D activity. Another source of attractive employment in the automotive industry is in design activity, particularly vehicle design, although this field offers far fewer jobs than does the full detailing and engineering of the automobile. There is a continuing demand for designers as the manufacturers seek to offer fresh and updated vehicles in the marketplace. Like automotive R&D, detailing, and engineering, this activity has historically been centered in the Detroit area. However, unlike those other activities, design activity has, to a very limited extent, broken free of that traditional base, and some design activity for the Big Three and the NAMs now takes place in California.

Two reasons are offered to explain this shift. First, designers reportedly prefer the California life style, and, since the activity is separable, the manufacturers are willing put it where the workforce wants to live. Second, California is a leading edge market in North America, and the manufacturers wish to design where the environment provides the signals and trends that will characterize the market the cars will eventually enter. It may be possible for Canada to offer itself as a type of leading edge market, or even a desirable living environment. Some Canadian cities, like Toronto and Vancouver, may offer attractive living, and there may be market niches, such as light trucks and sports/utility vehicles, where Canada might constitute a leading edge market. How one might develop a leading edge market position is beyond the parameters of this report, and such a strategy would, in all probability, be immensely difficult.

Compared to the U.S. automotive industry, the Canadian industry is relatively heavily concentrated in final vehicle assembly activities, and relatively light in supplier and R&D activity. That leads to the natural question that drives this study: what can Canada do to bring its R&D activity level up to its assembly level?[13] That question assumes that the assembly comparison portrays, if not the natural comparative level of the two industries, then at least an attainable comparative level. It suggests that Canada has been "less successful" in the R&D arena than in assembly. Perhaps Canada should consider a reformulated question: what can Canada do to ensure its continued relatively high level of assembly activity? This question raises the possibility that the R&D comparison reflects the natural or typically attainable comparison level, and that Canada has been "more successful" in securing assembly activity, rather than less successful in obtaining R&D. It may be that the better question for Canada is how to build on its assembly advantages to protect and expand that work, rather than to use it as an anchor to pursue activity in other automotive areas such as R&D.

From a strictly industry perspective, the blurring of Canada and the United States in the views of industry executives may render the appropriate national concern for achieving a balanced, full-range industry somewhat moot. The integration of Canadian and U.S. operations of the Big Three make it industrially unimportant whether Canada--or the United States, for that matter--has a full range industry within its national borders. Certainly it is no easy task to develop a completely independent industry, and R&D capability may be one of the most difficult industry elements to establish. South Korea has pursued this route, and it clearly is lagging in its efforts to become R&D independent.

If Canada focuses on buttressing its assembly endowment, it still may secure increased R&D work. As automotive R&D shifts more into the process area, and as more of it is sourced from part and ES suppliers, there is a chance that Canadian assembly plants will draw R&D work into Canada. Moreover, if Canada can become the sole national source for a particular vehicle or platform, the R&D work associated with the vehicle may well shift to Canada. A few of our respondents see these as possible outcomes over the next decade.

Finally, Canada should not underrate the susceptibility of corporate management to good, targeted marketing efforts. An aggressive, realistic campaign to bring automotive R&D to Canada might well pay handsome dividends. However, there is an important caveat in regard to this strategy raised by one of our respondents. R&D location decisions are made throughout the corporate hierarchy at the Big Three, and marketing efforts must be appropriately targeted. There is real danger in a strategy of top-down selling, where the agreement of a higher level manager inappropriately constrains the decision of a lower manager. In such situations, the lower manager almost always can and will subvert the constraint. So marketing efforts should address policy issues and source selection issues at the appropriate levels of the corporation, and not attempt to circumvent the traditional decision-making structure.

<u>Summary</u>. There are a number of possible strategies for Canada to increase its automotive R&D, some focused on enhancing Canada's current strengths and others on ameliorating its weaknesses. Of course, effective strategies must reflect a realistic appraisal of the developing trends in automotive R&D as well as Canada's

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[13]Presumably Canada is also asking what it can do to bring supplier activity up to that level as well.

situation and potential. In all probability, such strategies will target efforts to sustainable, small increments in automotive R&D.

Canada should seek to distinguish itself from other R&D locations, and this is probably most easily accomplished in selected, targeted areas. It probably makes sense to develop an area of R&D expertise that addresses a material, a process, a product (family), or an intersection of all three. One clear way to bolster such efforts would be to create a center of expertise in a selected material(s) in the Canadian university system, or to focus on emerging areas, such as the Intelligent Vehicle Highway System (IVHS).

Government incentives can play a role in attracting R&D, although perhaps more through broad efforts in education and improving the business environment, rather than through targeted activities like tax credits. Canada might well benefit from an easy immigration policy for technical and engineering personnel, and perhaps even a targeted recruitment of such immigrants, to provide an experienced automotive R&D cadre. Government might support an automotive R&D service function, providing services to user companies, or even establish a broad-based automotive research laboratory at a Canadian university. Canadian universities could strengthen programs that provide training at the interface of engineering disciplines, or even provide training in systems approaches to engineering.

Canada must ask itself a fundamental question: should it seek to increase its "low" rate of automotive R&D relative to the United States, or should it protect and increase its relatively "high" rate of assembly activity?

Appendix I

Trends in U.S. and Canadian Automotive R&D Expenditures

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This section of the report reviews recent trends in automotive research and development (R&D) expenditures in the United States and Canada. This information is analyzed in combination with other comparative trends in overall industrial R&D spending and capacity in the two countries. Several popular theories on the location of R&D are also discussed. The guiding purpose of this section is not to reach any final or original conclusions about the future of Canadian automotive R&D, or policies designed to alter these trends. Instead, the objective of this empirical essay is to provide a useful scale and background to the central interview analysis portion of this study.

Levels of Automotive R & D

New motor vehicles are the second largest category of consumer durable goods expenditures. They are also the single largest traded manufactured good worldwide. Only the privately owned energy industry may compete with motor vehicle manufacturing in terms of levels of annual corporate profits and revenues on a global basis. It is also probable that no other industry generates the same level of well-paid, private employment, or supports a wider variety of basic manufacturing industries than motor vehicle manufacturing.

It is not surprising, then, that global competition for vehicle markets and sales has dramatically intensified in recent years. Much is at stake, both to win or to lose. At least twenty-five major automotive producers now compete on a multi-regional basis in terms of sales. There is no question that their competition is fiercest in the potentially lucrative and largest regional market, North America (U.S. and Canada), which accounts for 37% of worldwide vehicle sales. To an increasing extent, this competition has recently focused on differences in product offerings to consumers. Product competition, of course, relies to a significant degree on both the effectiveness and commitment to research and development activities that promote innovation and manufacturing efficiency. The pace of research and innovation should accelerate because of remaining differences in the major regional markets for motor vehicles, and remaining differences between firms in manufacturing methods.

Research and development activities are also expected to increase in response to a new round of regulatory requirements for vehicle safety, emissions performance, alternative fuels, and fuel economy. Firms are once again confronted with the twin challenges of satisfying automotive consumers in the traditional product areas of performance, quality, styling and price, while also meeting or exceeding the demands of the public for safety and environmental performance as expressed in government regulations. World motor vehicle firms find this dilemma exacerbated by differences in patterns of regional requirements for emissions, safety, and fuel economy standards.

Definitions

It is typical to start any discussion of patterns in industrial research and development by defining these activities. The U.S. National Science Foundation (NSF) provides standard definitions in this area which are used in their ongoing, 30 year, annual survey measurement of U.S. industrial R&D:

Research and Development - - Basic and applied research in the sciences and engineering and the design and development of prototypes and processes. This definition excludes quality control, routine product testing, market research, sales promotion, sales service, research in the social sciences or psychology, and other nontechnological activities or routine technical services.

The survey section of NSF segregates overall industrial R&D into three familiar areas:

> **Basic research** - - Original investigations for the advancement of scientific knowledge not having specific immediate commercial objectives, although such investigations may be in fields of present or potential interest to the reporting company.
>
> **Applied research** - - Investigations directed to the discovery of new scientific knowledge having specific commercial objectives with respect to products or processes. This definition differs from that of basic research chiefly in terms of the objectives of the reporting company.
>
> **Development** - - Technical activities of a nonroutine nature concerned with translating research findings or other scientific knowledge into products or processes. Not included are routine technical services to customers or activities excluded from the foregoing definition of R&D.[1]

The underlined passages in the above NSF definitions make clear the certain qualification of almost any product or process development expenditure as R&D, either as applied research or as development. It is important to note here that expenditures on styling changes or other somewhat minor refinements to current products would also qualify generally as industrial R&D. The NSF survey, for example, reported $58.85 billion of company funded industrial R&D spending in the United States in 1986. Development expenditures amounted to $38.88 billion (74%), and basic research funding constituted $2.09 billion (3.6%) of total R&D spending.[2]

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[1]National Science Foundation, Research and Development in Industry: 1987, (NSF 89-323) (Washington D.C., 1989) pp.2-3. These definitions are, of course, quite similar in content and meaning to those used by the OECD, or the "Frascati Manual" definition.

[2]National Science Foundation, Science and Technology Resources in U.S. Industry, NSF 88-321 (Washington D.C., 1989), p.98.

The NSF industrial survey primarily concentrates on the measurement of U.S. based, "company performed" research and development by U.S. located industrial establishments. R&D expenditures or funding contracted out to other firms, or expended outside of the United States are measured separately and not well reported. This usually leads to differences between the NSF survey-based estimates of industry group R&D levels and those estimated by other organizations from other sources.

There are occasionally serious differences between NSF estimations of industrial R&D expenditures and those available from alternative sources. This is certainly the case for motor vehicle and equipment manufacturing. A recent business publication, *BusinessWeek,* provides an industry composite of R&D spending by 25 U.S. automotive firms that totals $10.3 billion in 1989, up 9% from $9.4 billion in 1988. About $9.5 billion (92%) of the 1989 total was reported by the 7 traditional U.S. original equipment (OE) producers, with the remaining $.8 billion reported by 17 large automotive suppliers.[3] In contrast, the NSF has recently estimated that the the U.S. motor vehicle industry expended $7.5 billion of company funds on R&D in 1989, a decrease from the previous year of 3.8% . In 1987, the NSF reported that the four largest performers of R&D in the motor vehicle accounted for 94% of the $7.3 billion in R&D spending that year.

BusinessWeek data are taken from the Compustat financial services program which contains corporate responses required by the U.S. Securities and Exchange Commission (SEC) on the form 10-K. The SEC does not limit the reporting of corporate R&D funding to expenses in the United States or to company performed (internal) activities. *BusinessWeek* overestimates, then, U.S. located automotive spending on R&D since it includes expenditures made overseas, and underestimates total U.S. global automotive R&D, since it reports for an industry composite made up of only 25 firms.

On the other hand, NSF's survey-based estimate of R&D funding understates U.S. company funded automotive R&D because projections are limited to companies located in the narrow standard industrial group classification of the motor vehicle industry in the United States (SIC 371). Thus, expenditures from other closely related industries such as automotive stamping (SIC 3465) are not included in the NSF total. The $1.8 billion difference between the survey based NSF estimate of $7.5 billion and the *Businessweek* estimate of $10.3 billion can largely be attributed to overseas expenditures by U.S. auto firms and R&D contracted out to engineering service firms and the like in the United States and elsewhere.[4]

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[3]"Innovation: The Global Race." BusinessWeek. June 15, 1990. pp.197-198.

[4]Drawn from an excellent discussion of information sources on R&D in: National Science Foundation, A Comparative Analysis of Information on National Industrial R&D Expenditures. (NSF-85-311)(Washington D.C., 1985).

Trends in 1980-1989

Table 1 shows estimated nominal levels for company funded and performed R&D for the U.S. and Canadian automotive industries. These figures are compared, for the 1980-90 period, with levels of total industrial spending (not federally funded) in the two countries. The Canadian statistics are drawn from a single source that did not separately list motor vehicle industry intramural R&D spending. Instead the numbers listed under the automotive heading are were drawn from a category titled "Other transportation equipment," listed apart from R&D spending in the Canadian aeronautics industry.[5]

As shown in Table 1, company funding of industrial R&D doubled during 1980-1989, and actually tripled in nominal terms in Canada. During the same period, automotive R&D in the United States increased only by about 25%, with the bulk of this rise occurring in 1983-86, a period of recovering U.S. auto profits and heavy spending on automation and some product development. Canadian nominal, automotive R&D actually doubled during 1980-1989, but remained fractionally far smaller than U.S. levels of spending throughout the period.

[5]Statistics Canada, Industrial R&D Statistics, 1987. (Cat.-88-202). p.52.

Table 1

Industrial and Automotive R&D (companies own funds, $bil.) and Vehicle Assemblies (millions of units) U.S. and Canada 1980-1989

	U.S. (U.S. $)			Canada (Can. $)		
	Ind. R&D	Auto R&D	Vehicle Assembly	Ind. R&D	Auto* R&D	Vehicle Assembly
1980	$30.48	4.30	8.01	1.36	.045	1.38
1981	35.42	4.22	7.94	1.85	.062	1.28
1982	40.48	4.32	6.99	2.15	.066	1.24
1983	45.04	4.75	9.23	2.25	.079	1.50
1984	52.73	5.38	10.94	2.52	.077	1.84
1985	58.48	6.16	11.65	3.04	.086	1.93
1986	61.73	7.19	11.32	3.38	.097	1.86
1987	62.80	7.30	10.93	3.50	.093	1.64
1988	66.50	7.80	11.22	3.83	.091	1.98
1989	68.5	7.50	10.85	4.03	.093	1.94

Sources:National Science Foundation, Science and Technology in U.S. Industry, (NSF 88-321), and Science Resources Studies Highlights, (NSF 90-307) (Washington D.C.). Statistics Canada, Industrial R&D Statistics, 1987, (Cat. 88-202). Ward's Automotive Yearbook, 52nd Ed.. Wards Communications, Detroit, MI, ISBN 0-910589, 1990, p.17.

To a certain extent, the low levels of relative Canadian automotive R&D follow a pattern of relatively low industrial R&D spending in Canada overall. In 1989, U.S. industrial R&D spending exceeded Canadian levels (in U.S. dollars) by a factor of almost twenty to one. In fact, the U.S. motor vehicle industry by itself, or even just one company in that industry, General Motors, expended more on industrial R&D in 1989 than the entire Canadian economy.

The difference in spending on automotive R&D between the two countries can be better understood by examining corrected figures contained in Table 2. Automotive R&D funding levels for 1980-89 shown in Table 1 are expressed in inflated June, 1990 dollars through an application of the motor vehicle producer price index. Canadian figures on spending were similarly inflated and then converted to U.S. dollars using appropriate average exchange rates for each year. In 1990 dollar terms, U.S. automotive R&D can still be said to have increased by 25% over the period, with little change since 1986. Canadian automotive R&D, however, now shows only a 50% increase in spending per year by 1989, as opposed to the 100% nominal increase displayed in Table 1.

Table 2 provides stark evidence on the continuing disparities in U.S./Canadian automotive R&D spending. Columns 2 and 4 of Table 2 list R&D expenditures per vehicle assembled in the two countries during 1980-1989. The level of claimed R&D spending per vehicle assembled in the United States ranged between $758 for a high and $583 for a low, with no appreciable increase apparent by the end of the period. In Canada, the corresponding range was from $36 to $51. The final column in Table 2 shows a simple ratio of levels in column 1 and column 3, or real U.S. automotive R&D to real Canadian automotive R&D. This ratio varied from a low of 68.5 in 1983 to a high of 107.5 in 1986.

Research Intensity

The apparent disparity in automotive R&D between the United States and Canada has been noted before. The Automotive Directorate has noted the low "research intensity" of the Canadian automotive industry in terms of R&D expenditures as a percentage of sales (0.3% in 1986).[6] When this ratio is itself divided by the comparative U.S. research intensity figure, the Canadian auto industry appears to perform at about 10% of the level experienced in the United States, the worst relative performance of any industry in Canada. Yet this comparison, like the per/vehicle and R&D ratio figures contained in Table 2, may or may not suffer from a basic misrepresentation of the actual structure of the Canadian automotive industry.

[6]"Product and Process Development in the Canadian Automotive Sector," by the Automotive Directorate, IS/IC, January, 1990, pp.17-23.

Table 2

Real Automotive R&D and per/assembly R&D (June 1990, billions U.S. $)

	U.S.		Canada		
	(1) Real R&D	(2) R&D/ Veh.	(3) Real R&D	(4) R&D/ Veh.	(5) R&D Ratio U.S./Can.
1980	$6.07	758	.054	39	111.8
1981	5.24	660	.064	50	81.9
1982	5.07	726	.063	51	80.5
1983	5.46	591	.074	49	68.5
1984	6.94	635	.067	36	103.6
1985	6.79	583	.069	36	98.4
1986	7.74	684	.072	38	107.5
1987	7.67	702	.074	45	103.6
1988	8.10	722	.077	39	105.2
1989	7.58	698	.079	41	95.9

Sources: See Table 1, and U.S. Department of Commerce, Bureau of Economic Analysis, Business Statistics, 1961-88. Washington D.C.: U.S. Government Printing Office, (December 1989), p.28, and Survey of Current Business, Vol. 70, No. 7, (July 1990), p.S-6.

The Canadian auto industry can still be fairly described as a "head without a body." In other words, an industry overwhelmingly dominated by a large number of final assembly plants, a few captive component plants, and a relatively small, independent parts industry. The 1965 Auto Pact may have brought about this curious, trade-determined structure. A pattern still exists that calls for large imports of U.S. (and now Japanese and Korean) parts and components which are used in the final assembly of up to two million vehicles, the majority of which are destined for export to the United States. This pattern has produced significant Canadian automotive trade surpluses with the United States in recent years. The reliance on billions of dollars of imported parts and components, however, makes the sales or dollar shipments figure for the industry highly suspect in comparisons with other national automotive industries. A value-added basis for the U.S.-Canada R&D comparison is more reliable, we suspect, than one based on sales levels. In 1986, the

Canadian motor vehicle and auto parts industries shipped about $37.3 billion worth of product. Value added in the auto industry, however, amounted to only about $6.8 billion, or 18% of shipments. Automotive R&D in 1986, according to the Automotive Directorate, amounted to about $92 million, or 1.35% of value added.[7]

In 1986, the U.S. motor vehicle industry group (SIC 371) shipped about $191.5 billion in product, much of this total representing double counted sales between suppliers and OE shipments. The sum total of industry value added, however, was $59.2 billion, or about 31% of gross shipments. U.S. automotive R&D in 1986 according to the NSF was $7.2 billion, or about 12.2% of value added.[8] The ratio of "value added R&D intensities" in Canada and the United States was roughly 1.35/12.2 or about 11%. This figure is very close to the Automotive Directorate's 10% ratio, and should carry more meaning than a sales based comparison.

Another International Comparison

The largest national motor vehicle industry in the world is the Japanese motor vehicle industry. In 1985, the NSF reports, the Japanese motor vehicle industry expended $3.2 billion 1982$ on R&D, or 3.0% of sales.[9] Surprisingly this total was below the 1982$ figure of $5.5 billion for the U.S. motor vehicle industry, or 3.2% of sales. Yet these figures can be misleading. Within a year and a half of this comparison period, the U.S. dollar had fallen by about 45% against the yen, and it could be argued that Japanese automotive R&D spending now exceeds or matches that of U.S. industry in terms of the current devalued dollar. In any event, aggregate R&D funding levels that are this close have little to say concerning the competitive effectiveness of such activities. Several studies have been performed that indicate the presence of a considerable advantage in Japanese design productivity over levels that can be performed by U.S. OEs.[10]

The growth trend in Japanese industrial R&D spending has been a well-discussed concern for its international competitors for a number of years. Japan surpassed the United States in terms of total R&D spending as a portion of GNP in 1985 and 1986. More importantly, Japan has surpassed the United States in terms of nondefense R&D expenditures as a portion of GNP for the last two decades, with a 2.8% ratio to the U.S. ratio of 1.9% in 1985. The NSF has also reported that Japanese government R&D expenditures amounted to $7.6 billion 1982$ in 1985, compared to U.S. government expenditures of $46.0 billion the same year. Yet, no less than 72% of the U.S. expenditures were committed to defense and civil space objectives, compared to 11% for Japanese government R&D. U.S. federal expenditures on nondefense R&D, then, amounted to only $12.9 billion versus $6.8 billion for the Japanese, in 1985.[11] The subsequent dollar devaluation may have

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[7]Canadian statistics on industry supplied by Science Council of Canada, Ottawa Canada.

[8]U.S. Department of Commerce, 1986 Annual Survey of Manufactures: Statistics for Industry Groups and Industries, (M86(AS)-1) (Washington D.C., May 1988), p.1-22.

[9]National Science Foundation, The Science and Technology Resources of Japan: A Comparison with the United States, (NSF 88-318)(Washington D.C., 1988), p.58.

[10]See for example, Kim B. Clark, Takahiro Fujimoto, and W. Bruce Chew, "Product Development in the World Auto Industry," Brookings Papers on Economic Activity, No.3, 1987.

[11]Reported in NSF 88-318, p.55.

equated these two amounts - a striking development considering that Japan has roughly half the population of the United States, and that the Japanese government funded nondefense R&D at twice the level of total industrial R&D funding in Canada in 1985.

R&D: Causes and Effects

There is a rich tradition of literature and research on the economic effects of R&D, and to a lesser extent, its causality. The appealing subject of the determinants of R&D location has, unfortunately, received less attention from formal researchers and is being left to the focussed efforts of consultants in local economic development. The central issue for this study is an especially rare topic: the national location of R&D activities performed by multinational manufacturing firms.

Factors that determine the level and the geographic location of R&D can be usefully separated into two types. Facilitators of R&D naturally include all of the elements that determine the productivity of or demand for such activities. In the case of motor vehicle manufacturing, this would usually involve differences in markets and regulatory requirements. This is part of the "proximity" argument of R&D location, and, unfortunately, unlike the case of W. Europe, the Canadian market for motor vehicles differs only slightly from the enormous U.S. market. Scale economies would tend to tilt such investment to the larger, essentially similar market to the south, as might legal issues concerning patent protection.

The other half of the proximity argument seems to argue that automotive R&D is performed best in close proximity to major customers, in the case of automotive suppliers, or to other automotive research activities, in the case of OE expenditures. Canada is not yet home to the headquarters of a single large or medium motor vehicle producer. However, Detroit is certainly not so distant, one would think, for the proximity argument to prohibit R&D work in Canada. Indeed, proximity to Detroit might even confer a clear advantage in the case of Ontario. The influence of these facilitators is discussed and analyzed, for the most part, in the context of information gained from the study interviews.

The other set of factors commonly held to influence the location of R&D have to do with certain barriers to or costs of R&D performance. This would include the fixed cost of facilities and equipment (R&D capital), the critical cost of highly skilled labor, and perhaps, certain communications costs. Common policy instruments for inducing R&D activity, of course, have been public measures to reduce these costs, either through direct subsidies such as investment tax credits, or through labor supply measures that increase the number of suitable employees through education or immigration. Although the interview analysis covers these issues rather thoroughly from a field perspective, it is felt that a brief discussion in this section is also warranted. In particular, three barriers will be discussed below: the influence of investment tax credit policy, the ready supply of critical skilled labor, and the capacity of the contract engineering service sector.

R&D Investment Tax Credits

A recent article in *The Globe and Mail* reviews a new Conference Board of Canada report that found that Canada continues to offer the most generous research and development tax breaks of any major industrialized country, yet Canadian "industrial companies have fallen further behind international competitors in their financial commitment to research and development." Canada's level of total research and development spending, from all sources, the study reported, proved to be less than half the portion of GNP typically expended in other industrialized nations. The tone of this article, as well apparently as that of the Conference report, is one of bemusement: Why haven't Canada's generous R&D tax breaks proven to be successful?[12]

In fact, there is little evidence to support the position that R&D tax breaks have any significant influence on R&D spending or location. Paul Stoneman, a British economist, reviews several comprehensive, empirical studies on this subject in his impressive work on the economics of technology policy. Stoneman concludes from his review that typical tax break schemes for R&D "have not been very successful."[13] He cites results from one thorough, multinational, survey study performed by the well-regarded R&D economist, Edwin Mansfield, that showed an increase of only $1 of R&D expenditure for each $3 of tax breaks granted by the taxing authority.[14] Furthermore, a U.S. study performed by Eisner, et.al., determined that the effective credit rate was actually "on the order of 3-4% rather than the (usual) statutory rate of 25%," and that they have "as yet been unable to detect reliable evidence that the credit is having a positive impact on total R&D expenditure."[15]

Stoneman notes that the formulas used in the R&D tax credit schemes may have much to do with their ineffectiveness in promoting R&D activity. Typically the formulas reward incremental R&D spending over a base average calculated from prior years. They also tend to limit eligible R&D activity to certain rather arcane definitions of basic research, which of course, may or may not lead to company, industry, or national competitiveness. Common failings of the credit schemes include the difficulty of using them in any strategic planning of long-term industrial R&D by a firm, or their tendency to elicit outright confusion and resulting irritation. In addition to this general problem, there is the fact that a considerable percentage of operating firms (close to 40%) may not possess eligibility for tax credits because of low levels of qualifying net income.

[12]Drew Fagan, "Canada's R&D lagging despite tax credits," The Globe and Mail, June 20, 1990, p.B5.

[13]Paul Stoneman, The Economic Analysis of Technology Policy, Clarendon Press, Oxford, 1987, pp.201-203.

[14]Edwin Mansfield, "The R&D Tax Credit and Other Technology Policy Issues," American Economics Review, 76:2, pp.190-194.

[15]R. Eisner, A. Albert, and M. Sullivan, "Tax Incentives and R&D Expenditure," paper presented at a Conference on Qualitative Studies of R&D in Industry, CNRS, Paris, September, 1983.

Cases in point, of course, are the various U.S. R&D tax credit schemes employed during 1981-1990. Originally included as part of the 1981 Economic Recovery Tax Act, the R&D tax credit originally allowed firms to apply for a 25% credit on incremental R&D expenditures using a base of the average of the prior three years of such funding. The Tax Reform Act of 1986 lowered this incentive to 20% of incremental R&D expenditures using the same base period, and extending the 20% credit to 65% of outside contracted research. This program lapsed on December 31, 1989, and has been replaced by an entirely new, "temporary," scheme employed that grants the 20% credit to an amount calculated on a new base involving the last four years of expenditures and the use of a "fixed base percentage." In actual fact, the latest scheme is scheduled to lapse on December 31, 1990, when the prior, through 1989, "scheme may or may not be reemployed." A phone call to the Internal Revenue Service (IRS) contact revealed the unsurprising situation that no explanatory forms or schedules were available for the current scheme as of September, 1990.[16]

The IRS definition of allowable R&D for tax credit application excludes research for styling purposes, or the modification or improvement of existing business "components." During the 1986-1988 period, for example, General Motors reported an average R&D expenditure of $4.4 billion.[17] GM reported an R&D expenditure of $5.3 billion in 1989, or an gross increment of $823.3 million over the average of the three-year base period. GM actually took a $28.6 million research and experimentation credit in 1989, or about 17.4% of the apparent, gross increment.[18] While this calculation is not exact, it suggests that about 83% of GM's incremental R&D expenditures did not qualify for the investment tax credit in 1989. The final claimed tax credit represented a little over one-half of one percent of total GM research and development expenditures. Since other national R&D tax credit programs are quite similar to that employed in the United States, one can fully understand the general inability of such policy to affect trends in R&D expenditure.

Demand and Supply of Skilled R&D Labor

No other area of automotive manufacturing requires a higher average level of skilled labor input than research and development activity. An adequate supply of trained and trainable R&D labor is essential to maintaining and improving the product and process programs of any vehicle producer. Recent upward trends in required cost of R&D plant and equipment actually intensify the importance of the labor assigned to work with R&D physical capital. The cost of employing such labor, and cost of acquiring such capital, are critical factors in determining the location of R&D expenditures.

[16] See U.S. Internal Revenue Code 1986 - -Subtitle A, Ch.1A, Part IV D, Section 41., Commerce Clearing House, Inc.,pp.4346-4359.

[17] Reported in, General Motors Corporation Form 10-K, Annual Report for the Year ended December 31, 1988, p.1-3.

[18] Reported in, General Motors, 1989 Annual Report, p.35.

The U.S. economy still contains the largest number of employed engineers, natural scientists and related technicians in the world. No less than 2.45 million degreed engineers and natural scientists, were employed in 1988. An additional 1.27 million related engineering and science technicians and technologists can be added to this figure, for a total of 3.73 million scientific and engineering personnel.[19] A comparable, and perhaps rather favorable figure, for the Canadian economy was 433 thousand in 1988.[20] To the U.S. figure must be added almost 101,500, Ph.D.-level natural scientists and engineers, that teach as faculty in universities and colleges, as well as perhaps 173,000 active graduate students in these fields in 1988.[21]

The U.S. Department of Labor (USDOL) reports that in 1988, engineers made up about 4.3% of total employment in the U.S. motor vehicle industry (SIC 371). A rough count, then, for that year would be 37,000 engineers. About half of these professionals were mechanical engineers, with the rest distributed across the fields of electrical, material science, and industrial engineering. To this figure can be added 27,000 natural scientists, computer programmers, and engineering and science technicians. Altogether, the count for these occupations constitutes about 7.4% of total employment in the industry, a not especially high proportion for the science and engineering fields, particularly when compared to percentages in the aerospace and electrical equipment industries.[22]

The NSF surveys the number of full-time-equivalent scientists and engineers, and related technicians solely engaged in industrial research and development. In 1987, for example, NSF estimates that the U.S. motor vehicle industry employed 50.6 thousand R&D natural scientists and engineers full-time.[23] This level represents an all-time record for such employment, at almost twice the level estimated for 1978. Yet the NSF's measurement differs significantly from that of the USDOL. NSF results indicate that an almost unbelievable 79% (50.6/64.0)of total engineering and science personnel in the industry are fully committed to R&D activities. In truth, the 1987 NSF R&D employment figure is a serious overestimate. NSF permits one of the large responding firms (GM) to include employment of scientists and engineers at two new nonautomotive acquisitions (Hughes Aircraft and EDS). R&D activities at these two subsidiary firms are of such a general scale that even the NSF's overall post-1985, estimates of U.S. automotive R&D spending must be placed in serious doubt.[24]

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19 U.S. Department of Labor, Bureau of Labor Statistics, Occupational Projections and Training Data, Bulletin 2351, (Washington D.C. April 1990), p.20-22.

20 Statistics Canada,"Labour Force and Employment by Detailed Occupation and Sex, Canada, Annual Averages 1988," Labour Force Annual Averages, 1981-88, Cat. 71-529.

21 National Science Board, Science & Engineering Indicators - 1989, (Washington D.C.: U.S. Government Printing Office, 1989) (NSB 89-1), pp.223, 234.

22 U.S. Department of Labor, Bureau of Labor Statistics, Occupational Employment Statistics Survey: 1988, (Washington D.C., 1989).Results for SIC 371.

23 NSF 88-321, p.99.

24 See the discussion of R&D employment figures for the U.S. motor vehicle industry in NSF 88-321, p.51.

The 1985 NSF total of 28,700 may be the most recent, reliable estimate of R&D employment in the U.S. motor vehicle industry. This level represents a serious decline from the 1980 peak figure of 38,200, a reduction that matches well the considerable anecdotal information regarding reductions in Big 3 engineering staffs, and the increase in contracted R&D activity to engineering service firms. The NSF also reports that in 1985, the U.S. motor vehicle industry employed 28 engineering and science R&D personnel per one-thousand in employment. The ratio makes sense, for in conjunction with the 28,700 figure above, it produces a total employment figure of about 804 thousand, which matches reasonably well the USDOL estimate for that year of 883 thousand.

The NSF reports that 33 R&D scientists and engineers were employed per one-thousand total employment in the Japanese motor vehicle industry in 1985. This level of research employment intensity appears to be 18% higher than that in the U.S. industry. However, Japanese motor vehicle producers, as well as other industrial respondents, are not required to report the employment of R&D scientists and engineers in full-time-equivalents, so there is little reason to expect significant differences in industrial research employment intensity between the two countries.[25] Similar information for the Canadian motor vehicle industry was unavailable to this study.

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[25] NSF 88-318, p.58.

Table 3

U.S. Automotive Employment Total and R&D (thousands) 1978-1987

	(1) USDOL Employ.	(2) R&D Employ.	NSF (3) Per 1000	(4) R&D per R&D Employee
1978	1,004.9	31.9	26	$115,600
1979	990.4	35.2	26	122,900
1980	788.8	38.2	30	135,200
1981	788.7	35.1	30	147,400
1982	699.3	30.0	31	162,900
1983	753.7	29.0	30	185,300
1984	861.7	28.6	27	211,600
1985	883.5	28.7	28	224,700
1986	872.4	33.9	38	D
1987	866.6	50.6	D	D

D = Not disclosed by NSF to protect operations of individual companies.

Source: U.S. Department of Labor, Bureau of Labor Statistics, Employment and Earnings.

National Science Foundation, Science and Technology Resources in U.S. Industry, (NSF 88-321) (Washington D.C. 1989)

The most outstanding characteristic of R&D employment in the U.S. motor vehicle industry is the NSF reported total expenditures per engineer and scientist employed. This statistic is simply computed by dividing total industry R&D expenditures by total industry R&D employment. In 1985, this ratio was $224,700 per R&D worker in the motor vehicle industry, or 64% higher than the $137,000 U.S. industry average.[26] R&D cost per worker in the motor vehicle industry has always been the highest of any industry studied by NSF, and this difference has increased in recent years. Since the NSF estimate of R&D expenditures excludes the funding of non-U.S. R&D and outside contracted R&D, the higher per-employee cost of motor vehicle R&D can result from either higher salaries or the use of more expensive R&D plant and equipment, or both. There is evidence to believe that both reasons have applied in recent years, with some considerable extra weight for the cost of

[26]NSF 88-321, p. 100.

CAD/CAM and CAD/CAE equipment. If so, the high relative cost of R&D for the motor vehicle industry makes decisions on location especially sensitive to differences in the costs of capital, income taxes, and the ready ease of acquiring equipment from outside of the location.

The NSF information discussed above can be used with recent numbers on Canadian automotive employment to project a comparable estimate of potential Canadian automotive R&D. In 1986, 118,200 Canadians were employed in the motor vehicle and automotive parts manufacturing industries.[27] A U.S. ratio of 28 engineering and science R&D personnel per one thousand of industry employment projects a potential Canadian automotive R&D employment total of 4,221. This number can be used in turn with the $224,700 per employee R&D cost figure to project a potential of $948.6 million (U.S. $) in Canadian automotive R&D spending, or roughly ten times the amount actually reported in Canada for 1986. This level of R&D spending would have constituted 2.5% of the dollar value of Canadian total automotive shipments in 1986, still less than the corresponding U.S. ratio of 3.8%.

In early 1990, General Motors (GM) announced a six month, $1 billion cost cutting program that included reductions in expenditures for advertising, outside consulting, new tooling, program engineering materials, travel, and product development, as well as delays in salaried employee merit increases. Many types of hiring were suspended as well, except for one special category-500 new college graduates, especially newly graduated engineers. Of the almost uncountable number of expenses and programs the corporation could have cut, only the hiring of new, technical labor was protected. This action gives evidence that the continued supply of adequate, technical labor continues to be a necessary priority in the U.S. motor vehicle industry.

There have been some recent concerns in the United States about the adequacy of the science and particularly the engineering labor supply. In 1986, U.S. colleges and universities granted a total of 213,971 "first" degrees in natural science and engineering, larger than the sum total of 175,395 for France, W. Germany, Japan, and the United Kingdom combined. Yet, only 77,061 of the U.S. degrees (36%) were awarded in engineering fields, a level almost matched alone by the Japanese graduation of 73,316 engineers (74% of the 99,668 1985 science and engineering graduates). A striking related statistic is that the Japanese "first degree" engineering figure represents no less than 4.4% of their of 22-year-old population, compared to 1.9% for the United States.[28]

At first glance, it would appear that the U.S. supply of Ph.D. graduates in engineering and natural science is considerably stronger than that for "first-degree" recipients. A total of 12,974 such doctoral degrees were granted in 1986, compared to 2,961 in Japan. The lead in new engineering doctorates was smaller, 3,376 for the U.S. to 1,404 for Japan, but still the United States apparently maintained a comfortable two-to-one advantage in supply. Yet, over half of the new U.S. engineering doctorates were granted to foreign students, a startling turnaround in the potential competitive meaning of these figures.[29] This possibly serious problem

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[27]Employment data provided by Science Council of Canada.

[28]National Science Foundation, International Science and Technology Data Update 1988, (NSF 89-307)(Washington D.C., 1988), pp. 44-45.

[29]Ibid, p.48-49.

is offset by the fact that less than 5% of the graduating foreign students were citizens of competitor nations such as Japan, France, Germany, or the United Kingdom. Of even greater importance, perhaps, is the continuing trend in immigration of natural scientists and engineers to the United States, which amounted to 10,746 in 1986. Of this total, 8,389 (78%) were graduate engineers, a large portion being recent graduates from U.S. colleges and universities.[30]

It can be argued that a proposed change in U.S. immigration policy regarding "shortage" technical occupations is one of the few effective industrial policies now pursued at the federal level by the United States. Such a liberalization would match the general acceptance of foreign graduate students in U.S. engineering education. R&D managers in the United States could enjoy, then, a truly competitive world price for engineering and scientific talent. If domestic supply proves inadequate, needed personnel can be imported with relative ease. Canada has, of course, followed such a policy of selective immigration in recent years. Similar policy in the United States would require Canada to continue, if not expand, selective immigration policy concerning technical occupations in short supply. The true effect of targeted immigration policy, however, on relative R&D activity is unclear, given Canada's position in this area.

A final observation should be made regarding the demand for, and the supply of, engineering and science technicians. Even at this late date in 1990, the USDOL has yet to define or track a new variety of engineering technician occupations closely related to the use of computer equipment in the design and testing phases of product innovation, or to the higher content of programmable electronics in durable goods such as motor vehicles. The number of employed "drafters," or those in drafting occupations, still forms an archaic definitional basis for labor projections in this area. As a result, little is known in an aggregate sense, about the present or future employment of such new technical occupations, or their training and supply characteristics. Anecdotal evidence clearly indicates the essential importance of such staff in R&D activity in the motor vehicle industry, and recent difficulties in finding such employees.

Capacity for Contract Engineering

The U.S. contract engineering and research service industries are enormous by any scale or definition. In 1987, the industry group, engineering and architectural services (SIC 871) employed 747,000, and generated $53.6 billion in revenues from 62,300 establishments. A separate industry group, commercial and noncommercial research, development and testing services, employed 330,000, and generated $22.5 billion in revenues from 64,000 establishments. To these figures should be added parts of the $54.0 billion computer programming (SIC 737) industry, which employed 637,000 in almost 40,000 establishments in 1987.[31]

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[30] Ibid, pp.40.

[31] U.S. Bureau of the Census, 1987 Census of Service Industries, Geographic Area Series, SC87-A-52.

The NSF has produced a recent separate estimate for the number of engineering and science personnel employed in the U.S. business and related services sector in 1988. A total of 417,000 scientists and engineers were employed in these industries in 1988. This total contained 310,000 engineers, which included 47,000 mechanical engineers and 108,000 electrical engineers.[32] Additional survey results from the NSF indicate that in 1986, 157,400 U.S. engineers reported themselves primarily engaged in consulting in the service-producing sector, a 200% increase over the level reporting this activity in 1976.[33]

Information concerning the portion of automotive R&D contracted to the independent engineering services is quite sketchy. The NSF reports that $2.58 billion in R&D were contracted to outside organizations by U.S. industrial firms in 1987. This represents only 4.1% of the $62.80 billion in company, industrial R&D funding that year. A separate amount for the motor vehicle industry was not disclosed. The NSF also reports that U.S. companies, or their foreign subsidiaries, performed $5.02 billion in R&D in other countries in 1987, at a ratio of about 8.0% to U.S. activity. Once again, a separate estimate for the motor vehicle industry was not disclosed. In fact the last time the automotive, foreign R&D figure was revealed by the NSF was 1977. That year, U.S. motor vehicle firms reported spending $514 million on foreign-source R&D, at a ratio of 17.8% to total R&D domestic funding of $2.89 billion. There is reason (primarily 10-K form data) to believe that the NSF has clearly underestimated both outside, contracted, and foreign sourced industrial R&D in recent years.

The Canadian contract engineering industry generated revenues of $3.43 billion ($ Can.) in 1986, and employed 52,000 in 35,000 separate establishments. While revenues per employee were not too distant from U.S. (SIC 871) levels, in terms of total average revenue, the average U.S. engineering firm was almost nine times the size of the average Canadian services firm. The Canadian computer programming industry achieved revenues on the order of $1.11 billion in 1986, and employed almost 35,000 in 5,600 establishments. The difference with the scale of U.S. firms (SIC 737) in this area is even more severe than that in contract engineering.[34]

Canadian contract engineering firms exported $450 million in services in 1986, a considerable surplus over the $25 million in imports of engineering services for that year. The low import level for contract engineering is quite surprising. If this surplus is the actual result of severe trade restrictions on the activities of foreign engineering service firms in the Canadian economy, the long-term cost of this policy may indeed outweigh the short-run trade benefits. Large, multi-national engineering service firms value highly the mobility and accessibility of their performing staff, regardless of nationality. The same can be said for the major customers of these firms. Residency and nationality restrictions on the movement and placement of technical staff may be too high a price to pay for many of even the largest of these firms, and certainly makes little sense in terms of policies designed to promote the long-term development of such an industry.

[32]National Science Board, Science & Engineering Indicators - 1989, pp.237-238.

[33]National Science Foundation, op. cit., p. 83

[34]Data for Canadian contract engineering industry provided by Science Council of Canada.

Conclusions

The ability to derive and state conclusions on the subject of relative Canadian automotive R&D is directly limited by the scarcity of information available to this study. This is true despite the considerable effort made to obtain every available source of aggregate information on the subject. Nevertheless, general findings or observations are as follows:

- The recent trends in U.S. and Canadian funding of automotive R&D still appear to be cyclical in nature. After initial increases in the mid-1980s, growth in funding, as reported by the OEs, appears to have leveled off, and perhaps slightly decreased. This is an ominous development, given any reasonable forecast of competitive and regulatory future challenges to the North American motor vehicle industry.

- The relative disparity between U.S. and Canadian automotive R&D activity is real and still exists. On any comparative basis, automotive R&D is performed in the United States, as much as ten times the Canadian rate.

- Investment tax credit policy has little relevance to reported levels of automotive R&D. Less than 20% of incremental spending may qualify for such credits. There is little reason to believe that basic research, as defined, is fundamental to the competitive performance of the industry, or even specifically automotive R&D activity. The range of qualified tax credit activity must be broadened for this type of policy to generate any effectiveness.

- The supply of skilled labor is critical to the performance of automotive R&D. The United States enjoys enormous advantages in this area due to the scale of its higher education system, and relatively open immigration policies related to shortage occupations. Canada has aggressively matched and exceeded U.S. policy on immigration, but may lag the U.S. educational base in technical education. Little is known about the development of new critical occupations in automotive R&D, and a possible leverage point can be achieved by training and supply programs in these skill areas.

- Little is known, also, regarding contract engineering activity in the motor vehicle industry. Once again, the U.S. possesses considerable relative advantage in the scale and flexibility of its hi-tech service sector. Some leverage could be gained by Canadian policies that exclude this sector from trade restrictions, or certain value-added business taxes.

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Appendix II
AUTOMOTIVE RESEARCH AND DEVELOPMENT PROJECT

I. INTRODUCTION

As we indicated in our phone call, these interviews are being conducted for two reasons. First, we are generally interested in recent developments and changes in the focus and patterns of automotive R&D sourcing, particularly in regard to the roles of different functions, firms, and agencies in this process. Second, we are interested in the geographical siting of automotive R&D, and the factors that promote or inhibit the selection of certain location for such activity. Both of these interests reflect our broader interest in changes in the North American industry as a result of global competition.

As you know, automotive R&D effort can take many forms. We are particularly interested in three types. First, basic research or "breakthrough", where the effort is targeted on new discoveries in the basic sciences and where the applications to product, process, or materials technology is speculative rather than established. Second, developmental engineering or "innovation", where the effort builds on established basic science and focuses on develping new product, process, or materials technology for automotive application. Third, applications engineering or "adaptation", where both the basic science and technology are established and the research effort focuses on adapting or enhancing its implementation in product, process, or materials, frequently tied to a specific developmental program. We are interested in all three of these forms or types of automotive R&D.

While our interest focuses on the vehicle manufacturers, we are interested in the R&D efforts of the entire industry. This includes both the Big Three and the NAM's (for New American Manufacturer, the North American facilities of offshore companies). It also includes suppliers of raw materials, parts, and components (RMPC suppliers) for new vehicles, and contract engineering, or engineering service firms, as well. Any of these types of companies can be important sources of R&D effort.

Your responses will be completely confidential: nothing you tell us will be reported in a fashion that would indicate that you or your company were the source. It is important for our efforts that you give us your frank opinions and views on these issues. We realize that your schedule is quite full, and we appreciate the time you're giving us. We are confident that the results of this assessment will benefit the North American industry as it continues to change and develop.

Interviewee:

Date and time:

Interviewer(s):

osat

II. LEVELS AND TYPES OF AUTOMOTIVE R&D ACTIVITY

We are interested in both the level of automotive R&D activity and the types of activities it encompasses, spanning breakthrough, innovation, and adaptation efforts.

1. a. First, what are some examples of breakthrough or basic research that your company has pursued over the past ten years?

b. Second, what are some examples of innovation efforts that you have pursued over the past ten years?

c. Third, what are some examples of adaptation that you have pursued over the past ten years?

2. a. Considering all three kinds of R&D effort, what would you estimate the entire North American industry, including manufacturers and both types of suppliers, spent in total on automotive R&D during 1989? ____

b. How about the annual average for the past five years, 1985-1989? _____

3. Considering the past five years of North American automotive R&D,

a. What percent of this would you estimate was funded by the Big Three? ___

b. By the NAM's? ___

c. By the automotive RMPC suppliers? ___

d. By the engineering service firms? ___

e. By the National governments? ___

f. Do you expect that this distribution of R&D effort will change over the next five to ten years? ___Yes ___No. (If yes) How do you expect it to change, and why do you think it will?

g. You estimate (from 3a) that ___% of this total R&D effort is funded by the Big Three. How do you think this is spread over GM ___, Ford ___, and Chrysler ___?

4. We'd like to develop a better understanding of how the industry's total R&D effort breaks out:

a. First, what percent of the total would you estimate goes to adaptation engineering efforts, such as those tied to particular product programs ___ versus more innovative efforts ___ or to breakthrough research ___?

b. Second, what percent of this total adaptation engineering effort goes to product engineering ___ versus manufacturing or process engineering ___?

c. Third, what percentage of product engineering goes to vehicle programs ___ versus part/component programs ___?

d. Do you think there has been any shift in these expenditure patterns over the past five years or so?

III. SOURCING OF AUTOMOTIVE R&D

5. We are also interested in how your company's R&D budget is allocated across different potential sources of R&D. Thinking first of adaptive engineering, what percentage of your R&D expenditure is actually incurred in each of the following potential sources? (READ LIST) Next, developmental? (READ LIST)

	BREAKTHROUGH	INNOVATION	ADAPTATION
In-house?	___	___	___
Other vehicle makers?	___	___	___
RMPC suppliers?	___	___	___
ES firms?	___	___	___
Universities?	___	___	___
Industry Consortia?	___	___	___
Any other sources?	___	___	___

6. What shifts, if any, do you expect to see in this allocation over the next five to ten years? (PROBE FOR AMOUNT, NOT JUST DIRECTION.) What factors will drive this process?

7. What are the major factors that influence the decision to use a particular source of R&D, say, in-house versus an engineering service firm? (PROBE: COST, TIME, TECHNICAL EXPERTISE, EQUIPMENT, EVENTUAL MANUFACTURE.)

8. In your company, where are most of the decisions about where to source automotive R&D made? Does this depend on the type of R&D, size of project, budget responsibility, and so forth?

IV. GEOGRAPHICAL SITING OF AUTOMOTIVE R&D

North America offers three national sites for automotive R&D, just as it does for production. We are interested in the distribution of automotive R&D across Canada, Mexico, and the United States, and how that may change and develop in the future.

9. Thinking first of adaptive engineering, what percentage of total North American 1989 R&D expenditures would you estimate were incurred in each of these nations? (READ LIST) Next, innovation? (READ LIST) Finally, breakthrough? (READ LIST)

	BREAKTHROUGH	INNOVATION	ADAPTATION
CANADA?	___	___	___
MEXICO?	___	___	___
UNITED STATES?	___	___	___

10. Does your company's distribution of automotive R&D across the three countries follow this pattern? (PROBE FOR DIFFERENCES, IF ANY.)

11. There have been shifts in production activity across Canada, Mexico, and the United States over the past decade. Do you think there have been any such shifts in automotive R&D activity over that period, or would these 1989 estimates hold for 1980 as well? Does this differ across the three types of R&D: breakthrough, innovation, and adaptation?

12. What shifts, if any, do you expect to see in this distribution over the next five to ten years, out to 1995 or 2000? (PROBE FOR AMOUNT, NOT JUST DIRECTION, AND WHETHER MORE OR LESS APPLICABLE TO BIG THREE, NAM, AND ES FIRMS.) IF SHIFTS: Do these changes relate in any way to the changed sourcing patterns we discussed earlier?

13. What are the major factors that influence the decision to site R&D in one country or another? (PROBE: COST, TIME, TECHNICAL EXPERTISE, EQUIPMENT, EVENTUAL MANUFACTURE, GOVERNMENT AND TAX POLICIES.)

14. In your company, where are most of the decisions about where to site automotive R&D made? Does this depend on the type of R&D, size of project, and so forth?

15. Does sourcing of automotive R&D or engineering from outside North America, say in Europe or Japan, pose a significant threat to current levels of North American activity in general, or to any of these three countries in particular? Why is that?

16. Considering each of these countries, which one represents the preferred site for North American automotive R&D, and why is that?

17. Does that preference vary significantly

a. over type of R&D (breakthrough, innovation, or adaptation)?

b. by product type?

c. by material?

d. by process?

e. by whether the work is performed in-house or outsourced?

f. by size of expenditure?

Now we'd like to explore your views of the suitability of these three countries as sites for automotive R&D in a bit more detail. First, considering Canada....

18. What are Canada's current major advantages or strengths as a site for automotive R&D? (PROBES: Technical resources/infrastructure? Educational infrastructure? Human resources? Government policies? Cost structure?)

19. What are its current major disadvantages or weaknesses as a site for automotive R&D? (PROBES: Technical resources/infrastructure? Educational infrastructure? Human resources? Government policies? Cost structure?)

20. What are the one or two changes or developments that would have the most effect in making Canada more attractive as an automotive R&D site?

21. Your response to question 12 indicates that you expect automotive R&D in Canada to (grow, decrease, stay about the same). What factors will drive this process, and do they differ for different types of companies, for example, the Big Three versus the NAMs? (PROBE FOR TECHNICAL, POLICY, ETC.)

Next, considering the United States....

22. What are the U. S.'s current major advantages or strengths as a site for automotive R&D? (PROBES: Technical resources/infrastructure? Educational infrastructure? Human resources? Government policies? Cost structure?)

23. What are its current major disadvantages or weaknesses as a site for automotive R&D? (PROBES: Technical resources/infrastructure? Educational infrastructure? Human resources? Government policies? Cost structure?)

24. What are the one or two changes in the United States that would have the most effect in making it more attractive as an automotive R&D site?

25. Your response to question 12 indicates that you expect automotive R&D in the United States to (grow, decrease, stay about the same). What factors will drive this process? (PROBE FOR TECHNICAL, POLICY, ETC.)

26. And what about Mexico? How is it positioned in regard to securing R&D work?

V. SUMMARY

27. Finally, are there any general comments or observations you'd care to make on general developments in automotive R&D sourcing and siting that we haven't covered?

THANK YOU VERY MUCH.

Appendix III

Relevant News Articles

Automotive News.

November 26, 1990 — 65th year—$65.00 per year, $2.00 per copy

The Japanese-American car

U.S. design centers, American engineers make Japan poised for even greater sales

First of two parts

By Lindsay Chappell
AUTOMOTIVE NEWS STAFF REPORTER

Nissan's Gerald Hirshberg in California: "What was it about the Gobi that made people in America smile? You really have to be here to feel it."

First came the Japanese imports. Then came the transplant car factories. Now come the technical centers.

The Big 3 are under siege once again.

And consistent with their long-term view, the Japanese automakers may not see the full results until the next century.

All seven Japanese carmakers with American factories are operating U.S. companies that will vastly improve their ability to design and engineer vehicles for American consumers. And most of these technical centers are undergoing aggressive expansion:

- At least $270 million is being sunk into new U.S. research and design facilities — some of them in the Big 3's home turf in Michigan.
- More than 2,400 designers and engineers will be on the American staffs of the Japanese automakers by the end of 1992.

The numbers are still modest by Detroit standards. Chrysler Corp., for instance, will consolidate several thousand engineers, designers and research and development personnel at its new Auburn Hill Tech Center by 1992.

But Japan's new U.S. technical networks make one thing clear: To pay for their investments in new staffs, new studios and testing operations, the Japanese automakers expect to sell hundreds of thousands or millions of additional vehicles in North America during the 1990s and beyond.

Some of America's hottest vehicles are Japanese imports born in U.S. design studios, including:

- Nissan's 240SX, Maxima and Pathfinder
- Toyota's Celica, Previa minivan and, from a Japanese designer on sabbatical, the Lexus LS400
- Mazda's Miata and MPV minivan

But the full integration of design, engineering and manufacturing in America is more difficult. Because most of the transplant factories here are already straining to fill demand for basic products, the launch of new vehicles by self-sufficient U.S. subsidiaries remains years away for many.

One exception is Honda's Accord station wagon, which will

see R&D, page 42

California and styling: Be there or be square

By Lindsay Chappell
AUTOMOTIVE NEWS STAFF REPORTER

In September, the king of luxury carmakers broke down and joined a commoners' club.

Mercedes-Benz AG sent designer Gerhard Steinle to California to open an American styling studio in Irvine. His mission: to find inspiration in the crowded streets of Southern California and translate it into design ideas for future Mercedes-Benz models.

"Mercedes is and always will be a German car," Steinle cautions. "But we must stay in touch with the market around us."

Not to be left behind, Germany's Volkswagen AG will open a studio in Simi Valley, Calif., this month, for largely the same reasons.

Such design centers are nothing new. Since Toyota Motor Co.'s Calty Design Research Inc. set up shop near the beach back in 1973, importers from Volvo to Mazda to Subaru have gotten into the act.

Detroit acknowledges California, too. Ford has an exclusive contract with a private studio there, and Chrysler and GM operate design centers.

As global competition heats up, those centers will play an increasingly vital role. In addition to generating vehicle concepts with an American flavor, the studios serve as monitoring posts, keeping overseas manufacturers up to date on consumer trends and changing tastes on issues from windshield slope to seat fabrics.

Gerhard Steinle: California helps Mercedes stay in touch.

"You can see any car in the world on the streets here," explains Dave Hackett, studio director at Toyota's Calty facility. "That kind of environment is great for a designer."

Toyota is spending $17 million to triple the size of the operation and expand its design staff from about 45 to 65.

The urgency for U.S.-influenced design may be greater for the Japanese: the United States is their largest export market. Honda Motor Co. Ltd. sells two cars in the United States for each one sold in Japan.

More than that, the Japanese are now attempting to develop integrated U.S. subsidiaries capable of designing, engineering and producing cars and trucks in America for America. Most of the West Coast salons are still too young for any of their concepts to be in production at the Japanese transplants. But plans call for greater U.S. design influence:

- Honda of America Manufacturing Inc. will soon launch an Accord station wagon that was designed as a joint U.S.-Japanese endeavor.
- Nissan Motor Co.'s next-generation Pathfinder sport-utility — a concept originally drafted at Nissan Design International in San Diego — will probably be built at Nissan's Smyrna, Tenn., plant in the mid-1990s.
- Nissan Design International also participated in the design of a new Stanza replacement that Smyrna will produce in late 1992.
- And Subaru-Isuzu Automotive Inc. in Lafayette, Ind., will eventually add a new Subaru car to its production mix that might be based on a design from Subaru Design Center in Garden Grove, Calif. That four-year-old studio has submitted at least 15 concepts to headquarters in Japan for the project, all of which have been rejected, according to studio head Yuji Uemura.

So far, Japan's U.S. production — largely focused on basic, high-volume products — and its California showmanship are years apart. The concept labs focus on products that are three to five years ahead of the market. Few transplant factories even have capacity to build for new products.

Meanwhile, studio heads in California claim the mixture of laid-back West Coast culture and youthful energy is a flourishing creative environment for designers.

Calty will add a color lab to concentrate on trends in color. A fabric research office at Mazda Reseach and Development of North America Inc. in Irvine, Calif., bears almost no trace of belonging to the automotive industry. Nissan's design unit once adjourned for the afternoon so that its design staff could go see the movie "Batman," believing it to be rich in new trends.

Not everyone is convinced that California is the best place to experience America. James Womack, research director of the International Motor Vehicle Program at the Massachusetts Institute of Technology, calls the California salons "trendy" and says the West Coast is not typical of the country.

"If Honda really wants to seize the heartland, they'll take their designers out of California and put them in Ohio, which is a lot closer to real America," Womack says.

Such a move isn't likely. Studio heads also point out that young automotive designers seem to like living on the West Coast. "To attract young designers, we must be here," Mercedes' Steinle says. "The California lifestyle is very attractive."

R&D

FROM PAGE 1

begin production in the next few weeks in Marysville, Ohio, and which was largely engineered and designed by Honda Motor Co.'s U.S. employees. Though based on the Japanese-designed Accord sedan, the new wagon uses U.S.-designed machinery, U.S.-designed and -engineered body parts and a host of U.S.-engineered components.

Slowly but surely, the Japanese are getting closer to integrating design, engineering and manufacturing in America.

Gobi shelved

Consider the Nissan Gobi, the concept vehicle that crossed a sophisticated pickup with something off the streets of Roger Rabbit's 'Toon Town.

The cheerful little Gobi was the brainchild of Nissan Motor Co.'s San Diego creative team, Nissan Design International. It stole the North American International Auto Show in Detroit last January when it was unveiled.

Nissan officials said the U.S. manufacturing company would build the low-volume vehicle. Its U.S. engineers were already looking into if, when and how. To all appearances, it was a U.S. project using U.S. technical resources to produce a U.S.-designed and -engineered vehicle under a Japanese nameplate.

But by summer, the whole idea had been canned — deemed financially unfeasible.

The Gobi probably would have required Nissan to build a second U.S. assembly plant and strained U.S. engineering resources. Chassis assembly would have consumed capacity at Nissan's plant in Smyrna, Tenn., which is currently juggling a new Sentra, a pickup, and plans for a second sedan and, possibly, the Pathfinder.

The Gobi now sits in an r&d center in Japan. Although it won't be built, Japanese designers are curiously scrutinizing it to learn how their California colleagues tapped the American fancy.

"It's a difficult thing to explain to them," says Gerald Hirshberg, Nissan Design International executive vice president. "What was it about the Gobi that made people in America smile? You really have to be here to feel it."

Apparently, plenty of importers agree with Hirshberg.

Toyota Motor Co. is spending $44 million to expand its Calty Design Research Inc. in Newport Beach, Calif., adding another 20 design engineers.

Isuzu Motors Ltd. occupies a new studio in Cerritos, Calif. Fuji Heavy Industries Ltd. maintains a design center in Garden Grove, Calif., to produce concepts for its Subaru vehicles. Even Mercedes-Benz AG, the king of the European imports, opened shop in September in Irvine, Calif., to send designs back to Germany.

Volvo AB of Sweden operates a California studio in Camarillo, and Volkswagen AG opened one this month in Simi Valley.

Nissan's Hirshberg, a former rising star in design at General Motors, came to Nissan and to California 11 years ago to find new, creative opportunities. His story is not unusual among the studios up and down the coast.

"It's a wonderful feeling to design a car the way you think it should look, and to have the company take the drawing and build it like you said," Hirshberg explains. "If they wiggle our surface more than three millimeters, I get letters of apology from Japan."

Adds Dave Hackett, a former Ford Motor Co. designer who is now studio director at Toyota's Calty: "In Detroit, you're too close to some vice president's office. It's too easy for the business guys to drop around to see what you're doing. After a while, you know what they think, so you sort of censor yourself."

Ties that bind

Japan's burgeoning U.S. technical centers are proving adept at translating drawings from Japan into machinery and components that meet U.S. specifications.

AUTOMOTIVE NEWS/JOE WILSSENS

Takeshi Tanuma, CEO of Nissan Research and Development, at his rising new facility in Michigan: "We need good engineers . . . and 80 percent of all U.S. automotive engineers live in this area."

But marshalling cohesive U.S. car-producing machines could be a slow process. So far, the path from the California studios to the transplant factories still winds its way through the Japanese tech centers.

Nissan Design International's 240SX design, for example, went to Japan for production, while Nissan's Smyrna plant concentrates on producing the Japanese-spawned Sentra.

"It will take at least a decade to bring these operations up to speed," says James Womack, research director for the International Motor Vehicle Program at the Massachusetts Institute of Technology.

"It will take young people who can learn the company's way of doing things from the ground up," Womack said. "And it will take a lot of domestic suppliers who will have to learn new methods of operating. I predict we will only begin to see the real results of these moves in the next century."

Yet the moves continue. Nissan has nearly completed a $50-million r&d center in Farmington Hills, Mich., in the heart of Big 3 country, where it will employ a technical staff of almost 500. A second Nissan office in Ann Arbor, Mich., now conducts engine and powertrain research: an indication of the carmaker's plans to open a U.S. engine plant.

Little by little, Nissan's U.S. operation is gaining experience in vehicle development.

The two-door Sentra that went into production this fall was largely U.S.-engineered from Japanese clay models. A new Stanza slated for model-year 1992 production in Smyrna will have considerably more U.S. involvement.

More expansion

At the same time, Toyota Motor Co. is midway through a technical expansion across the United States that will boost product and component-engineering personnel from 190 now to about 600 in four years.

Toyota just kicked off a $45 million expansion of its Toyota Technical Center in Ann Arbor, Mich. That project follows last year's opening of a Southfield, Mich., center to handle design engineering on body panels and trim.

Toyota also announced this year that it would develop a 12,000-acre vehicle proving ground in Arizona — one of the country's largest.

Honda Motor Co. Ltd. has committed at least $27 million to expanding Honda Research and De-

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R&D

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velopment North America in Marysville, Ohio. The project — referred to as the "first phase" — will nearly double the Ohio staff to 300 in the early 1990s. The closely tied Honda Engineering North America in Marysville will be expanded from about 180 technicians to about 300, with more r&d expansions likely to follow.

Expansion of the two Honda engineering subsidiaries will boost its total U.S. r&d staffing over the next two or three years from the current 300 to more than 600.

Isuzu, which owns 49 percent of the Subaru-Isuzu Automotive Inc. transplant in Lafayette, Ind., broke ground in Novi, Mich., this summer on a new branch of its California r&d office, where it eventually plans to employ 150 in component engineering, engine testing and technical support.

Mitsubishi Motors Corp. and Mazda Motor Corp. each maintain two technical offices in Michigan.

Takeshi Tanuma, president of Nissan's r&d operation in Michigan, is bullish on growing technical roots in America.

"We need good engineers in America in order to produce American cars, and 80 percent of all U.S. automotive engineers live in this area," he says.

"Most U.S. suppliers have operations here. How can we establish relationships with these people if we live in Tokyo? How can you imagine the American customer's way of living if you live in Tokyo, in a Japanese house, and drive on Japanese highways?"

Grand strategies

Why bother recreating expensive design and development centers here when existing Japanese organizations already claim nearly 28 percent of the U.S. car market?

An obvious reason is Japan's desire to keep up with an evolving American customer. Subtle market shifts — like the demand for curvier, more "European" styling — keep importers hopping. By establishing North American facilities to watch for such shifts and to speed up product alterations and factory tooling, the Japanese feel they will respond faster to consumer trends.

Self-sufficiency spells competitive advantage. The Big 3 are already working to reduce the time to bring new concepts to market. GM wants to cut its lead time from an average 48 months to 24 months. Honda shaved several months of development time off its current Accord model by calling on r&d and engineering staffs at the Marysville Accord plant.

Another reason is the complex world of U.S.-Japanese trade politics. Congress and U.S. trade officials continue to pressure Japanese automakers to use more American-made components. As the transplants commit themselves to purchasing greater volumes of U.S. parts, they are virtually bound by logistics to open technical centers to make it possible.

In addition, the expense of the technical centers and staff counts as domestic content. Higher domestic content opens import-export doors and can be of advantage in calculating corporate average fuel economy.

All of the centers are taking on a growing list of duties: qualifying suppliers, helping suppliers develop new components, and testing the final products. Travel time is reduced for U.S.-based manufacturing engineers and suppliers, and the level of U.S. componentry in the cars is slowly increasing.

Almost All-American

Honda's upcoming Accord station wagon offer a glimpse into what the expanded North American operations can do. Although based on the Japanese-developed Accord sedan, the new wagon is the closest that any of the transplants has come to creating an American car from design through manufacture.

In December, Honda's Marysville Accord plant will launch the wagon, based on prototypes that were built by Honda Engineering in Marysville. Honda will use machinery and dies that were built on-site. It will rely on specifications from Honda r&d in Marysville, and incorporate designs produced both in Japan and in its studios in Torrance, Calif.

Some of the machinery was developed in Japan. From the front seat forward, the car is largely the work of Honda of Japan. But the rest — including hundreds of unique components developed and supplied by North American firms — is decidedly Honda of America.

The door handles for the new product show why expanded U.S. support is necessary. In Japan, Honda knows little about tooling for handles, which are outsourced. To create handles for the wagon, American engineers had to develop the tooling from scratch, working in the Marysville facility with the prototype.

"We had to be here to do that," says John Adams, a Honda engineering vice president who came to Honda from a computer automation company in Columbus, Ohio. "If we're going to develop one section of our company in North America, we believe it's necessary to develop totally. For our manufacturing to continue to develop and be successful here, you need engineering and r&d support."

The lingering gap

Honda's decision to build the wagon prototype in-house rather than though a U.S. prototype shop, as the Big 3 commonly do, illustrates lingering differences between the transplants and the Big 3.

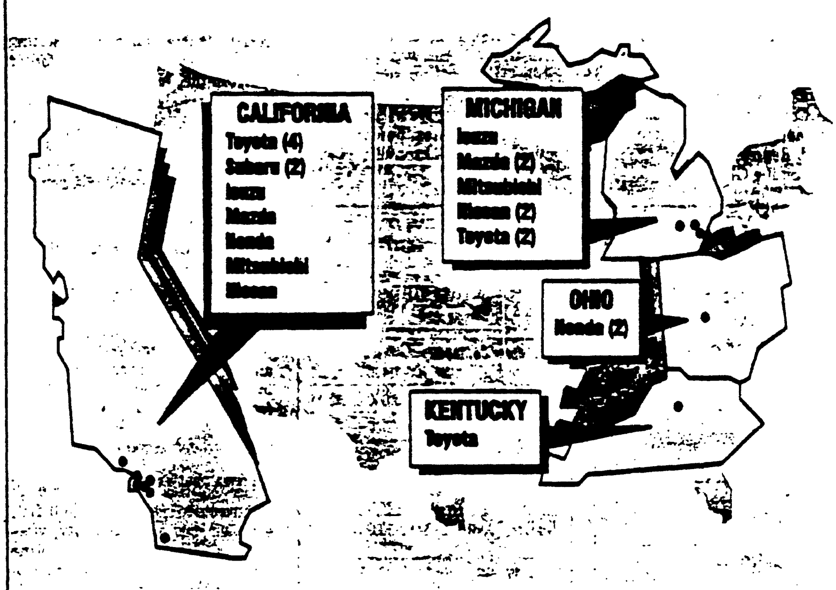
Initially, Honda officials were concerned that security might be breached by involving an outside shop in the Detroit area. Further, no one outside Honda appeared to understand the company's meticulous method of producing vehicles on short schedules. Honda officials demand to be firmly in command of the project's cost and quality decisions — a posture that Adams and other Honda executives refer to as "the Honda way."

"We have no timetable for when we will be self-sufficient, but we are moving toward that goal," Adams says. "It's not a skills issue, it's capacity. We're working on a manpower problem. We're trying to find people who are willing to come learn the Honda way."

For now, the greatest benefit of the expanding American r&d and design operations may be simple convenience. Considerable development work still takes place in Japan, requiring suppliers and U.S. staffs to shuttle back and forth for prototyping, meetings and production runs.

Suppliers for Nissan's two-door Sentra project still had to take numerous trips to Japan for prototyping, even though the model was largely engineered in Tennessee. Work on Nissan's next U.S. car in 1992 will mean numerous trips only as far as the Detroit suburbs.

Where Japanese automakers have research & design facilities



IMPORT R&D DESIGN CENTERS

Company	Year opened	Current employees	Senior official	Principal function/Major models
Honda R&D North America Inc.				
Torrance, Calif.	1975	125	Kumitaka Sakai, president	Design and develop autos, motorcycles and power equipment.
Marysville, Ohio	1985	175	Noboru Hashimoto, senior vice president	Produce and test prototype vehicles; qualify suppliers; develop vehicle components. '91 Accord wagon.
Honda Engineering North America				
Marysville, Ohio	1988	180	Ryo Mikawa, president	Design and develop body and drivetrain-production equipment, dies and welding machinery.
Isuzu Technical Center of America Inc.				
Cerritos, Calif.	1985	62	Iidra Watanabe, president	Vehicle design studio; vehicle testing; emissions testing.
Plymouth, Mich.	1990	18	Susumu Goto, vice president/general manager	Component engineering; engine-testing; emissions testing.
Mazda Research and Development of North America Inc.				
Irvine, Calif.	1972	85	Hiroshi Moriyoshi, president	Product planning, design, engineering and testing. Miata, MPV, MX-6.
Ann Arbor, Mich.	1988	20	Hiroshi Ozaki, executive vice president	Emissions testing; engineering research.
Flat Rock, Mich.	1988	39	Hiroshi Ozaki, executive vice president	Air conditioning system engineering; local parts sourcing.
Mitsubishi Design Studio				
Cypress, Calif.	1973	88	T. Ohnouwe	Design engineering of vehicles.
Mitsubishi Motors of America				
Southfield, Mich.	1984	NA	H. Yoshizawa	Emissions testing; coordination of business affairs between Mitsubishi Motor Corp. and Chrysler Corp.
Nissan Design International				
San Diego	1979	45	Hidehiro Iizuka	Design studio for vehicles and components. 240SX, Gobi concept truck, Maxima, Pathfinder, Pulsar NX.
Nissan Research & Development				
Plymouth, Mich.	1983	400	Takashi Tanuma, president	Engineering of parts for U.S.-made vehicles.
Ann Arbor, Mich.	1978	NA	Kazumasa Katoh, general manager	Vehicle emissions testing; engine and powertrain research; technical planning.
Subaru Technical Center				
Garden Grove, Calif.	1973	65	Walter Biggers	Test vehicles; develop and test components.
Subaru Research and Design				
Garden Grove, Calif.	1986	13	Yuji Uemura	Concept design studio, production drawings. SRD1 concept sports wagon.
Calty Design Research Inc. (Toyota)				
Newport Beach, Calif.	1973	45	Hiroaki Ohba, executive vice president	Produce vehicle concepts. Previa, 1990 Celica, Lexus LS400.
Toyota Technical Center U.S.A. Inc.				
Gardena, Calif.	1977	NA	Kanji Ito	Coordinate vehicle development and testing in North America.
Torrance, Calif.	1977	82	NA	Test prototype vehicles for U.S. market.
Southfield, Mich.	1989	50	NA	Design engineering for body-panel, trim components; develop new production technology; provide technical support to North American manufacturing plants.
Ann Arbor, Mich.	1984	48	NA	Evaluate prototype parts; EPA emissions certification.
San Francisco	1989	4	NA	Technical support for NUMMI plant.
Lexington, Ky.	1989	6	NA	Technical support for Toyota plant.

Three European car manufacturers also have design centers in the United States. They are: Mercedes-Benz Advanced Design of North America Inc. of Irvine, Calif., established 1990, 4 employees, Gerhardt Steinle, president; Volkswagen of America Inc. Design Center of Simi Valley, Calif., established 1990, 10 employees, Michael Tezer, director; and Volvo Monitoring and Concept Center of Camarillo, Calif., established 1986, 10 employees, Sylvia Vogel, general manager.

AUTOMOTIVE NEWS / DAVID L. [illegible]

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Japanese, Big 3 will compete next for design talent

Second of two parts

By Lindsay Chappell
AUTOMOTIVE NEWS STAFF REPORTER

Al Palma, 26, went to work last year for Toyota Motor Co. as a vehicle designer.

A recent graduate of the Art Center College of Design in Pasadena, Calif., Palma mulled over the career question that more and more young automotive professionals will face in coming decades: whether to go to work for a Big 3 American automaker in Detroit, or whether to work for the Japanese.

"I talked to General Motors," says Palma who ended up doing a four-month GM internship before going to Toyota's California vehicle design studio. "I didn't think about whether I would end up with a domestic company or a Japanese company. To me it was all design."

Half of the graduates of the nation's two leading automotive design schools — the Art Center and the Center for Creative Studies in Detroit — now opt for jobs with the Japanese, according to program directors at the schools. A decade ago, the Big 3 had their pick of design and engineering graduates across the country.

> ❛ I didn't think whether I would end up with a domestic company or a Japanese company. To me it was all design. ❜
>
> **Al Palma**
> Toyota vehicle designer

Not only are the Japanese battering away at the Big 3's market positions — now, faced with the construction of large new Japanese technical centers in Michigan, Ohio and California, the Big 3 have to compete for the engineers, designers and computer science technicians who represent their future.

In the short run, the big American companies continue to attract and keep their share of good engineers and designers from the top

see TECHNICIANS, page 51

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California studio gives American flair to Mazda designs

By Peter Brown
EDITOR

IRVINE, Calif. — Hovering over the airy atrium of the Mazda technical center here are shapes as recognizable as a Coke bottle: the front and rear fenders of the MX-5 Miata.

Tom Matano drove the people at Mazda crazy when he constructed those white shapes high into the white wall 2½ years ago — nearly a year before the petite roadster was to be unveiled publicly.

Back then, when he was asked about the mysterious quarter panels, "I said, 'Oh, that's the rejects that we sent to Japan. Mazda didn't like it, but we like it, so we put it up there,' " Matano recalls with a laugh.

The now-classic lines came from Mazda designers in California, almost unaltered by Mazda designers in Hiroshima.

"We used to say our design (in California) is wine and butter," says Matano, the 43-year-old vice president for product design and development at Mazda Research and Development of North America Inc. Back in Japan, "they put vinegar and soy sauce in it to tone it down."

The Mazda design studios in Irvine are like a mini version of a Big 3 design operation. Clay models of concept vehicles and prototypes of imminent vehicles sit, veiled or unveiled, awaiting more tweaks.

In one studio, Matano's staff just finished a pink concept car. It rides long and low for highway driving, but it shortens and raises itself over a telescoping steel beam to create a tall, short "city car" for congested areas and easy parking.

Like California studios of other Japanese automakers, Matano's Mazda studio brings the American perspective to an international company. And it has offered creative work to young designers who might otherwise have ended up in Detroit.

Among his design staff of 22 are seven designers. One is Mark Jordan, son of Charles Jordan, vice president in charge of the design staff at General Motors.

Matano, his long black hair flowing over his black Benetton sweatshirt, is Japanese, international and as American as the appeal of the Miata.

At 21, and speaking no English, he left his native Japan to study at Art Center College of Design in Pasadena, Calif. He wanted to study environmental design, but found that he couldn't draw interiors of buildings. So in his application, he drew cars and was admitted to study automotive design.

After college, he worked in the Oldsmobile studio at the General Motors Technical Center in Warren, Mich., for 18 months, then moved to General Motors Holden's Automotive Ltd. in Australia for 6½ years. A 14-month stint at BMW AG in Munich, West Germany, ended seven years ago with his return to California when Mazda called.

In virtually unaccented and perfectly idiomatic English, he is a funny and enchanting storyteller.

He says, for example, that he first figured he could make it in America when he discovered he preferred the lukewarm coffee served here to the scalding hot coffee of Japan. These days, he eats lunch at an Italian restaurant four days a week — so that if he works in Italy he will have absorbed the language.

But the design work is no joke. The Mazda studio produced the basic designs of the Miata, the popular MPV minivan and the MX-6 coupe.

Mazda design aims at a clear brand identity. Matano says the next generation of the 626 intermediate sedan, due in the 1992 model year, will share some of the flavor of the Miata.

The Irvine studio is expected to influence all Mazda cars, Matano says — "not just one car straight from our design, and another not at all."

TECHNICIANS

FROM PAGE 1

engineering and design schools.

A stream of top Big 3 people have gone to the Japanese automakers during the past decade. But so large and deep are the engineering and product planning staffs at General Motors, Ford Motor Co. and Chrysler Corp. that recruiting young technicians isn't a problem, Big 3 executives say.

A few of the Japanese newcomers to southeast Michigan are learning just how different the U.S. labor market is from Japan, where an employee typically spends his career with the same company.

But in the long run, the new competition for professionals presents one more challenge for the Big 3.

The arrival of the Japanese in the Midwest guarantees a tightening of industry personnel problems. Those problems include a dearth of qualified engineers, ever-escalating wage competition and the constant loss of trained and trusted personnel to competitors.

Existing plans call for Japanese carmakers to have some 2,400 U.S. engineers and designers on staff by 1992, up from about 1,350 last year and virtually no one 15 years ago. The growth of these staffs is spurred by the Japanese makers' desire to create more self-sufficient U.S. car companies.

Since most of the Japanese research and development and design companies are still growing, the number of designers and engineers will likely go even higher.

Automakers such as Toyota Motor Co., Nissan Motor Co., Isuzu Motors, Mitsubishi Motors and Mazda Motor Corp. are all operating or expanding technical centers in the Detroit area, in addition to the vehicle design studios they maintain in California.

Honda Motor Co. is expanding its product-developing Honda R&D North America Inc. staff in Marysville, Ohio, to 300 employees by next year, up from about 175 now.

Combined Honda technical staffs in Ohio, California and Michigan will grow from about 480 people today to more than 900 during the next two or three years.

The Marysville expansion is referred to as "Phase One." In keeping with Honda's aggressive U.S. posture, a Phase Two — requiring more recruits — can't be far behind.

To find the people they need, the Japanese have largely gone to the U.S. automotive home turf. Honda has run newspaper ads in Detroit and elsewhere featuring a 24-hour, toll-free number to help reel in engineers.

> The Japanese have little choice but to raid the Big 3 for U.S. personnel. They can't risk the political damnation of importing large staffs of experienced designers and engineers from Japan, although most of the burgeoning operations have small numbers of transplanted technicians.

At Nissan's emerging vehicle and parts development center in Plymouth, Mich., recruiters have hosted job fairs that allow engineers to sit and discuss career opportunities in a casual after-hours environment.

Nissan Research and Development hopes to have about 500 technical personnel by next year, up from a couple of hundred two years ago. The group will be housed in a nearly completed, $50 million center in Farmington Hills, Mich., where it will direct engineering for Nissan's expanding North American manufacturing base.

The company's car and truck plant in Smyrna, Tenn., maintains its own 200-engineer staff.

About three-fourths of Nissan R&D's current engineering staff came from other automotive companies, both Big 3 and suppliers. About half of Honda's staff did.

The Japanese have little choice but to raid the Big 3 for U.S. personnel. They can't risk the political damnation of importing large staffs of experienced designers and engineers from Japan, although most of the burgeoning operations have small numbers of transplanted technicians.

The other alternative, training non-automotive people from the ground up, is time-consuming, although Honda often does it.

The benefits of raiding are apparent at Toyota's Calty Design Research Inc. in Newport Beach, Calif. Studio director Dave Hackett came to the company from Ford, as did chief designer Allan Buyze and project manager David Doyle. Senior chief designer Dennis Campbell joined from Chrysler. Others on the mostly young, 40-member staff also came from the domestics.

Whatever the source of personnel, the mixture is working. Calty has turned out such Detroit-stompers as the Previa minivan and the recent Celica. Other U.S. studios came up with concepts for the Mazda Miata and MPV minivan and the Nissan 240SX and Pathfinder sport-utility.

Big 3 managers play down the growing people competition, but the Detroit industry establishment is showing signs of strain.

Salaries for computer-aided design system engineers are running at around $60,000 a year in Detroit these days, up from $40,000 in the mid-1980s. Starting salaries for designers are also inching up, from a typical $28,000-a-year level in the mid-1980s to about $35,000 today, personnel recruiters report.

Psychologically, at least, the Japanese also have California going for them when it comes to attracting talent.

The high cost of living in California, home of many of the Japanese design and technical centers, pushes starting design salaries to $46,000 to $48,000 a year. The same job with GM or Ford back in Michigan promises about $35,000, according to Carl Olsen, chairman of transportation design at Detroit's Center for Creative Studies. Even though the salaries are roughly the same if the cost of living is factored in, the higher numbers dazzle many young people, he believes.

The competition goes far beyond the Big 3. Independent studios, prototype shops and engineering businesses often feel the pinch of the tighter job market.

"It was already difficult to find the right person for the job," explains Jim Williams, chief engineer for C&C Inc., the Brighton, Mich., design, engineering and conversion company. "But things are getting a little tougher now."

For a year, C&C has tried and failed to fill a position for a structural engineer, Williams says. After months of advertising for nine other engineering openings, Williams finally stopped looking in the United States and brought in recruits from Great Britain.

Nissan's Michigan recruitment effort has also been slow. For the past two years, officials there have advertised for hundreds of engineers, conducted a series of well-attended job fairs and interviewed candidates. But about 100 of the planned 500 slots remain open.

Had the company pursued an initial plan of building the engineering center in Tennessee rather than in Michigan, the number of empty slots might be larger.

C&C's Williams, who served as director of engineering for Nissan in Smyrna, says luring automotive professionals to Tennessee was a chore. Despite the lower cost of living there, few engineers were willing to trade a high-paying Michigan job for one in Tennessee with a smaller company at roughly the same salary level.

John Collandro, Nissan R&D's manager of human resources, suggests that switching from a Detroit company to Nissan is more than a career hop. It's a change to a new philosophy, he says. Engineers at Nissan — as at all of the Japanese companies — participate in parts procurement. They assist suppliers in designing parts. They also participate in early design and prototyping stages.

The allure of a young, growing company doesn't always win out, reports H.H. Kluver, owner of The Henry Group, a Detroit-area executive search, recruiting and consulting firm.

The new Japanese companies are still relatively small, and the opportunity for upward advancement is not great, he says. Mid-level engineers at the transplant companies can succeed to a point, but the best jobs are often retained by Japanese, he says. Most of the 22 Japanese vehicle design studios and technical centers in the United States have key designers and engineers who are alumni of the Big 3. Yet all studios and most of the tech centers have a Japanese senior official.

Michael Flynn, associate director of the University of Michigan's Office for the Study of Automotive Transportation, believes that the whole push to build U.S. technical staffs by the Japanese could be hampered by the difficulties of hiring and keeping Americans. He contends the Japanese carmakers are at a disadvantage in competing for employees here.

"The Japanese automotive trade doesn't face the competition for young engineers that it does in America," Flynn notes. "Interviews with U.S. engineering graduates consistently reveal that 'automotive' ranks near the bottom of job preferences, behind aerospace, the defense industries and other trades. It isn't like that in Japan."

Finding enough people has been hard enough. Finding the right people, enthusiastic about Japanese management attitudes and practices, could be even harder. While the new firms hire freely among their U.S. competitors, they avoid bringing in large staffs of former Big 3 employees, a move that could upset their own corporate identities.

With growing technical centers from Michigan to Tennessee to California, Japanese automakers are making a new challenge for the future.

Wanted: young auto engineers

Even without the new challenge from Japanese companies, the Big 3 are facing a huge potential problem in maintaining a technical edge: The pool of automotive engineering talent is dwindling.

U.S. colleges are enrolling far fewer engineering students than even in the early 1980s. While the big Midwestern schools like the University of Michigan, Purdue University and the University of Illinois remain a crucial source of young blood for Detroit's technical centers, the picking is getting slimmer.

According to the National Science Foundation in Washington, engineering majors have dropped from 15 percent of all U.S. college enrollments in 1982 to about 6 percent today. The number of students in computer programming analysis, a cornerstone for modern research and development, fell from 10 percent of enrollment in 1982 to 3 percent by decade's end.

"Industry demand for these disciplines is increasing while the supply of people is falling," reports Carlos Kruytbosch, group director for the foundation's science and engineering indicators office. "The gap is getting wider. My own analysis is that we're headed for trouble."

The repercussions of a technical labor shortage for such a strategically vital business as the automotive industry are great, officials among both the domestic and the Japanese auto companies agree. Most are funding university programs to encourage math, engineering and science study.

— Lindsay Chappell