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MULTINATIONAL ACTIVITIES OF MAJOR U.S. AUTOMOTIVE PRODUCERS

Volume III -- Research, Development, and Engineering Abroad

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16. Abstract

The multinational activities of General Motors, Ford, Chrysler, and American Motors are documented and analyzed. The study consists of this and four other volumes. Volume I is a summary of the four main volumes. Volume II contains a compilation of data related to multinational operations; specifically it addresses research, development, engineering, production, marketing, and sales activities performed abroad. Volume IV provides a preliminary assessment of the technology transfers within each U.S. multinational producer. Volume V examines the diffusion of production and sales operations abroad; the timing and location of these investments are shown consistent with the Product Life Cycle Theory of International Trade and Investment.

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FOREWORD

This is Volume III of the report on the multinational activities of the four major U.S. automotive producers: General Motors Corporation, Ford Motor Company, Chrysler Corporation, and American Motors Corporation.

Much of the data in the volume comes from Volume II: Foreign Facilities and Operations.

Volume IV presents A Preliminary Evaluation of the Multinational Aspects of Technology Innovation and Transfer by the Four Major U.S. Automotive Producers.

Volume V evaluates the Diffusion, Abroad of Production and Sales Operations. This volume excludes American Motors.

The primary objective of Volume III is to evaluate the RD&E activities performed abroad by the U.S. automotive multinationals in order to determine:

a) which foreign subsidiaries participate in RD&E efforts;

b) the magnitude of RD&E efforts made by these foreign subsidiaries;

c) the particular location and capabilities of RD&E efforts performed abroad; and,

d) the particular type of RD&E performed at different locations abroad.

In addition, the report assesses:

e) the factors which cause the establishment and evolution of RD&E activities abroad by the U.S. automotive multinationals; and,

f) the significance and probable future of RD&E performed abroad by the U.S. automotive multinationals.

Also, unless otherwise indicated, the aggregate data in this report include individual data from the General Motors Corporation, Ford Motor Company, and Chrysler Corporation.

The term "foreign" or "abroad" refers to countries other than the United States and Canada.

Finally, we have attempted to distinguish between research and development (R&D) activities that are narrowly defined to exclude engineering and design activities versus research, development, and engineering (RD&E) activities that are broadly defined to include engineering and design activities. These latter RD&E figures correspond to the research and development figures published by the three leading U.S. automotive producers in their Annual Reports and Form 10K statements.

Although the data come from published sources and interviews with managers of General Motors, Chrysler, Ford,

and American Motors Corporation, the reader should not infer that the above companies officially endorse the data or findings of this report.

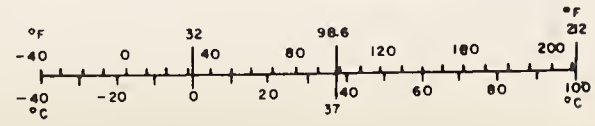
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	squsre centimeters	cm^2
ft^2	square feat	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablaspoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic ysrds	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. SUMMARY OF KEY FINDINGS

Both R&D and RD&E activities* are growing abroad. Various factors and trends indicate that R&D and RD&E performed abroad by the major U.S. automotive producers will continue to increase in absolute amount and relative share of total RD&E expenditures in the future.

Presently, we estimate that R&D and RD&E performed abroad by the major U.S. automotive producers constitute respectively 7% and 23% of total R&D and RD&E performed worldwide by the General Motors Corporation, Ford Motor Company, Chrysler Corporation, and the American Motors Company.

The latter organization performs essentially no R&D or RD&E abroad. Also, the vast majority of R&D and RD&E abroad is performed by General Motors and Ford, while Chrysler performs smaller shares of both total R&D and RD&E abroad.

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*Note: In this report, the term "R&D" refers strictly to fundamental research, applied research, advance development and product and process development. It excludes engineering and design activities. The term "RD&E" includes all activities mentioned above plus engineering and design and is comparable to figures published by the U.S. automotive producers on their research and development expenditures in their annual reports and Form 10K's.

Very little fundamental or applied research is performed abroad by the foreign subsidiaries of the three U.S. multinationals. Most R&D/RD&E work abroad is related to product development, engineering, and design activities that are short-term projects consisting of work on existing car models or the next generation of car models.

Significant R&D and RD&E resources have been acquired abroad (rather than created) by General Motors and Chrysler. These acquisitions occurred when both U.S. multinationals acquired foreign companies with on-going RD&E activities. Evidence exists that the acquisition of these RD&E resources was unintentional or incidental to other factors. No evidence exists that the foreign companies were acquired specifically for their RD&E resources.

The lion's share of this foreign R&D and RD&E activity is located in Europe, principally in two nations: Germany and the United Kingdom.

RD&E performed outside Europe and the United States is mainly process adaption work that has been expanded to product adaption work in some subsidiaries with manufacturing capability. Also, a few subsidiaries in third world nations work on new product development and/or development and engineering activities associated with alternative engines or power sources. This work is concentrated in a few large or potentially large national markets

such as Brazil and Australia.

The critical factors causing R&D and RD&E abroad are associated directly with the process of foreign direct investment in production operations. Specifically, RD&E operations are created or acquired in subsidiaries abroad that possess a manufacturing capability (as opposed to solely an assembly capability). A need develops to create at least a strong engineering function with manufacturing activities that provide even a minimal amount of local content. The subsequent expansion of engineering activities into more sophisticated RD&E work seems to be caused by the growth and sophistication of manufacturing operations and actions taken by host governments regarding not only regulations affecting local content but, more recently, regulations regarding emission control and safety.

The primary purpose of R&D and RD&E activities abroad is to modify and develop new and improved products or processes expressly for indigenous national and regional markets (e.g. Europe). Furthermore, no evidence exists of planned RD&E to develop new or improved products for simultaneous (or near simultaneous) manufacture in several major world markets (including the United States). From an international RD&E/manufacturing perspective, the term "world car" is a misnomer because these products (Chevette, Fiesta) are neither planned nor produced for simultaneous manufacture in world markets. Instead, they have been developed as "national or regional cars" that, if successful, have been introduced subsequently in other markets.

Overall, new and improved products and processes that result from RD&E abroad are used first and primarily by the national subsidiaries that produce them. Some new and improved products and process technology are used in other national markets and regions if the recipient foreign subsidiaries or the U.S. parent feel they can use the technology. (The exception, of course, is RD&E performed in the United States expressly for foreign subsidiaries.)

In the future, an evolution of RD&E may occur into "multinational technology work" to produce new and improved products or processes for near simultaneous manufacture in major world markets. Currently, Ford is most likely to move first into multinational technology work since its experience with the Fiesta most closely approaches a multinational RD&E/manufacturing strategy.

2. CURRENT LEVEL, COMPOSITION, AND GROWTH OF RD&E ABROAD

The data in Exhibit 1* show an estimate of total R&D and RD&E performed abroad by the major U.S. automotive multinationals in 1976. R&D abroad represents 7% of total R&D expenditures, while RD&E constitutes 23% of total RD&E outlays.

This R&D versus RD&E distribution provides two basic observations about the general composition and location of innovative activity by the U.S. automotive producers. First, most research and development (narrowly defined) continues to be performed in the United States. Second, most innovative activity (97%)** performed abroad is related to engineering and design activities. Also, Exhibit 2 shows the relative share of R&D abroad (3%) is one-fourth the size the U.S. share (12%).

Exhibits 3 and 4 show respectively the absolute dollar and percentage distributions of R&D expenditures for each major U.S. automotive producer. Exhibits 5 and 6 present similar data for RD&E expenditures. Together, these exhibits show that General Motors and Ford are responsible for the vast majority of R&D abroad (89%) or RD&E abroad (84%). Also, the exhibits show that American Motors Corporation is not a performer of R&D nor RD&E abroad. Consequently, the remainder of this evaluation will focus solely on the three other producers.

*All exhibits are located at the end of the text.
See Page 19.

**(562-17/562)100=97%, from Exhibit 1.

Several interviewees at the different companies felt R&D and, particularly, RD&E activities had been growing abroad. Data from several sources supported this conclusion.

First, the expansion of "Research and Engineering" facilities abroad for General Motors and Chrysler shows an absolute increase in facilities' space over the recent past (1973-1976) (See Exhibit 7), although no significant growth in relative share (Exhibit 8) is shown.

Second, data over a longer time period (1920-1965) show a pronounced increase in the number of subsidiaries abroad that performed some RD&E abroad (See Exhibit 9). By 1965, RD&E had been performed in 60 different subsidiaries abroad and had experienced a six-fold increase from 1950. However, these data included temporary RD&E missions and possibly production engineering at assembly operations which were not included in the data we collected from the companies.

Overall, our data show the existence of 29 permanent R&D and RD&E operations abroad in 1976 (See Exhibit 10). Of these, 11 were R&D operations that existed outside the United States and Canada, while RD&E operations abroad numbered 19. Detailed information on 18 of the total 29 R&D/RD&E operations is summarized in Appendix A of this report.

The inhouse RD&E performed abroad was almost entirely development, engineering, and design activities according to company managers. A small amount of

research was contracted out in Germany by General Motors. The possibility also existed that Chrysler was performing (inhouse) a small amount of research. Overall, the data support this view insofar as no subsidiary was created abroad to perform primarily R&D activities (Exhibit 11). Other research on R&D performed by U.S. multinationals shows that these organizations tend to create separate subsidiaries when they decide to perform fundamental research abroad in order to keep these "research activities" administratively separate from operating subsidiaries.*

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*Robert Ronstadt, Research and Development Abroad by U.S. Multinationals, Praeger, 1977, pp. 73-75.

3. LOCATION OF RD&E ABROAD

The location of R&D and RD&E abroad is discussed in two ways:

a) the general location in terms of geography; and,

b) the specific location within the nation vis-a-vis other organizational units (manufacturing, sales, headquarters, etc.).

All R&D/RD&E activities are located in 10 countries and 45% of all sites are in Europe.

Exhibit 12 lists the nations where foreign subsidiaries possess an ongoing RD&E capability. All of these nations (with the possible exception of Venezuela) represent important markets and important sites of production efforts within major geographic regions.

However, the number of sites understates the relative importance of three European nations: the United Kingdom, West Germany, and France. According to company officials, these three countries account for nearly all R&D performed abroad and a very high percentage of RD&E (See Exhibit 13).

Interviewees were asked to note the location of RD&E sites with respect to other organizational units. The data in Exhibit 14 show:

a) a positive relationship between manufacturing and the location of RD&E abroad; and,

b) no relationship between national subsidiaries with only assembly and/or sales operations and RD&E abroad.

The relationship between manufacturing and RD&E is probably stronger than Exhibit 14 suggests. First, the data include multiple manufacturing sites within single nations. Second, the possibility exists that centralized RD&E resources service several manufacturing plants within a given nation or that, in fact, these RD&E resources are decentralized at the plant level though administratively centralized at one location within a nation. Whichever the case, 29 of the 34 nations with manufacturing capability also have RD&E capability (85%). The exceptions are countries like Belgium where component manufacturing is highly standardized and does not require an RD&E capability (or the RD&E is provided by German RD&E units when needed) and nations like Turkey where major production operations are relatively new and the existence of RD&E was possibly unknown to interviewees.

4. PRIMARY PURPOSE, EVOLUTION, AND USE OF RD&E ABROAD

The primary purpose of RD&E activities performed abroad in 1976 by the U.S. automotive producers was to produce new and improved products or processes expressly for specific national or regional markets. (Indigenous Technology work). No evidence was found indicating that either General Motors, Ford, or Chrysler was performing RD&E abroad primarily:

a) to develop new and improved products or processes expressly planned for simultaneous (or near simultaneous) production in major world markets; or,

b) to develop new long-range technology <u>expressly</u> for the corporate parent (See Exhibit 15).

In fact, the evidence suggests that the 29 RD&E units perform indigenous technology work exclusively.

According to interviewees, all RD&E professionals located abroad are working on projects to develop new and improved products or processes expressly for specific national or regional markets. Certain products have been developed, notably Ford's Fiesta and General Motors' Chevette, that have had wide application in major world markets. However, managers noted that these cars were <u>not</u> initially developed as "world cars", nor were multinational RD&E activities

performed simultaneously in several nations to develop these models before they were introduced in any one nation. For instance, existing technology for General Motors' Opel (Germany) was used to develop the prototype for the Chevette. This technology (some of which had been transferred earlier from the United States to Germany) was transferred to Brazil where, after additional engineering work, the Chevette was introduced in 1973, expressly for the Brazilian market. Later, the decision was made to bring the Chevette to the United States.

As one executive mentioned, "Basically, the development and engineering work is done for a specific market. Later, if some other subsidiary can use the work, then fine. We'll move it. But we do not perform work in Germany that is planned for use in Germany and other regional markets (North America, Latin America) at the same time." According to interviewees, most of this indigenous technology work was in support of the existing business to produce traditional (conventional engine) motor vehicles. Little RD&E was performed abroad to develop new high-risk business based on alternate engines or power sources; however, we found some examples of some "high-risk" work being performed in Germany, Brazil and Taiwan. Furthermore, interviewees believed all of the RD&E performed abroad was expected to have commercial application within six years (in the case of product development work) and considerably shorter periods for most product/process adaption work.

5. CRITICAL FACTORS CAUSING ESTABLISHMENT AND EVOLUTION OF RD&E ABROAD

RD&E activities have been established abroad by the U.S. automotive producers either by

a) acquiring companies with ongoing RD&E functions; or,

b) creating the RD&E function themselves.

We can make several observations about the establishment of these RD&E activities given our information about RD&E performed abroad by General Motors, Ford and Chrysler. We believe these observations will help explain why RD&E has been created or maintained abroad by the U.S. automotive multinationals.

First, we found no instance of a disbandment of an RD&E function possessed by a foreign company that was acquired by General Motors, Ford or Chrysler.

Second, all RD&E activities are associated only with subsidiaries that have a production activity.

Third, only production engineering is associated with subsidiaries that have solely an assembly activity.

Fourth, all other RD&E activities (excluding process adaption of assembly operations performed by production engineering) are associated only with subsidiaries that have some manufacturing capability.

Fifth, principal sites for RD&E abroad are associated with older subsidiaries.

Sixth, principal sites for RD&E abroad are associated with subsidiaries serving larger markets relative to other foreign subsidiaries of the U.S. parents.

These observations (supported by information provided by interviewees) suggest the following scenario for RD&E activities created abroad:

At some point in time, an assembly operations is created abroad. Different local conditions regarding materials, energy, and government regulations may force an adaption of assembly technology. A sharp difference in production output may also cause adaption of process technology. As one interviewee noted, "We can't afford to make the same investment in assembly equipment for a smaller market nation that we'd use in a larger nation. So we end up substituting less expensive equipment which forces us to change the assembly process. But as the domestic market grows and we assemble more vehicles, the need arises to continue adapting the process."

Once assembly operations exist, market growth and/or government regulation over local content forces the automotive parent to decide to establish local component manufacturing or license and transfer this technology to foreign suppliers in the country for manufacture. However, as one executive noted, "the facts of the matter are we don't often like to license some technology to foreign suppliers because strategically it doesn't make sense. Essentially, we would be providing component suppliers with a capability to compete against us in other national markets five or six years down the line. So we often decide to do the manufacturing ourselves."

Once the U.S. multinational starts manufacturing operations, engineering activities expand. As another manager mentioned, "It doesn't matter much whether local content is 10% or 90%. Once we start manufacturing, we need a strong engineering function."

Yet, as local content increases, engineering resources also increase in magnitude. Eventually, the need arises for more sophisticated kinds of engineering which phase into product development activity. The dividing line is not always distinct between engineering and development according to interviewees, nor do they clearly explain the rationale for this evolution. One factor appears to be the build-up of competitive pressures produced by an expanding local market. Larger markets and increased competition for these markets force the development of vehicle models designed expressly for foreign local needs. While market growth is probably an important factor, in-depth examination

of similar situations in other industries showed that the existence of experienced engineers seeking more challenging work was also a key factor influencing the decision to permit more sophisticated RD&E activities.

The consequence of these factors -- market growth sufficient to justify distinctive models and RD&E managers and engineers seeking more sophisticated work -- encourage the expansion of RD&E abroad at strategic foreign locations.

6. CURRENT IMPORTANCE AND PROBABLE FUTURE OF RD&E ABROAD

The current allocation of R&D resources abroad (excluding engineering and design activities) is relatively small compared to total R&D expenditures in the United States. However, we estimate that over one-fifth of total RD&E resources used by General Motors, Ford and Chrysler Corporation are located abroad. The main purpose of these RD&E resources is to develop new and improved products expressly for indigenous markets abroad.

Also, some evidence exists that shows these foreign-based RD&E resources are expanding in absolute terms. However, the growth of RD&E abroad appears to be occurring slowly.

Under certain conditions, RD&E growth abroad can expand rapidly. Other research suggests that the rapid growth of RD&E abroad will result also in the performance of more sophisticated forms of R&D (narrowly defined) abroad.* Such growth in R&D and RD&E can occur with a change in the primary purpose of RD&E abroad as performed currently by the U.S. automotive multinationals. The change is from indigenous technology work to develop new products and/or processes expressly for national or regional markets to multinational technology work. The latter purpose involves developing new or improved products for simultaneous manufacture in major world markets. When a change to multinational technology work occurs, a "step function" increase in RD&E resources also occurs. Exhibit 16 portrays this quantum increase as

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*Ronstadt, Research and Development Abroad in U.S. Multinationals, Praeger, 1977, See Chapter 9 on the "Evolution of R&D Abroad."

it has occurred in other U.S. multinationals.*

What are the conditions that will foster a change in primary purpose to multinational technology work and rapid growth of R&D and RD&E abroad for the U.S. automotive multinationals?

Possibly, different (not necessarily stricter) government regulations may force some expansion of RD&E abroad where principal manufacturing and RD&E capabilities already exist. Also, the decision to perform some development and engineering work in selected countries for new high-risk projects (related to alternative engines and fuels) will probably cause some small expansion of RD&E resources abroad.

However, the experience and potential capabilities of existing RD&E resources abroad are oriented overwhelmingly toward work in support of the existing motor vehicle business as built around conventional engine and fuel technology. Consequently, the transition which seems most pausible is the use of RD&E abroad in specific regional locations to develop world car models based on conventional technology for simultaneous production in major national markets.

Four factors or trends encourage the evolution of RD&E abroad into primarily multinational technology work.

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*Ronstadt, op. cit., pp. 86-90.

The first factor is the growing experience and capability of RD&E operations abroad. Alone, this capability is not a sufficient condition to force a change of RD&E purpose, but it is a necessary condition. The implementation of large scale multinational RD&E projects cannot occur overnight. A core of professional RD&E personnel must exist who are familiar with their organizations. These resources now exist abroad and are quite sophisticated in Europe and developing rapidly in other selected nations.

A second trend which favors the move into multinational technology work is the growing worldwide standardization of the automobile. The critical element forcing a greater uniformity is imposed vehicle efficiency for fuel economy, emission control, and safety by governments in major markets. In short, vehicles will become more similar as they become smaller and more efficient. The uncertainty of market acceptance in different national markets will be reduced. The reduction of uncertainty will encourage the delegation of worldwide responsibility for specific models to particular foreign subsidiaries with advanced RD&E and manufacturing capability.

A third factor favoring the shift to multinational technology work will be the reduction of RD&E duplication across national boundaries. Worldwide responsibility for RD&E for particular models will be given to specific RD&E groups in the United States and abroad. Their activities will be focused and susceptible to control and planning. Knowledge and experience for particular product lines will be accumulated

at particular locations and economies of RD&E will be realizable when needed. This trend of RD&E specialization is being stimulated by the international manufacturing strategy of complementation implemented by Ford, General Motors, and Chrysler over the last decade. As national subsidiaries assume particular manufacturing specialities, they will acquire corresponding RD&E capabilities because of the need to link geographically these manufacturing and RD&E activities for the purpose of insuring effective communications between them.

Finally, a fourth factor which may favor the move into multinational technology work is the emerging political need of the automotive multinationals to move toward an equalizing of the "technology balance of payments" for deficit nations. In this case, deficits are caused by national subsidiaries exporting disembodied* technology without payment to other subsidiaries within the multinational system instead of exporting the physical product. Exhibit 17 diagrams the current directions of disembodied technology transfer which are mainly one-way. The same exhibit shows a more balanced scenario, assuming major RD&E centers emerge in Latin America, the Far East, and eventually Africa.

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*blueprints, technical personnel and information related to a product or process as opposed to the product itself which "embodies" the technology.

7. EXHIBITS

Exhibit 1
Estimated R&D and RD&E Performed Abroad By U.S. Automotive Multinationals in 1976

(excludes engineering and design)

	Total R&D	U.S. R&D	R&D Abroad
Millions of $	249	231	18
%	100	93	7

(includes engineering and design)

	Total R&D&E	U.S. R&D&E	R&D&E Abroad
Millions of $	2481	1919	562
%	100	77	23

Source: Consultants' calculations from
Exhibit 3 for R&D figures and
Exhibit 5 for RD&E figures.

Exhibit 2

Ratio of R&D to RD&E Expenditures

for Major U.S. Automotive Producers

	Total	U.S.	Abroad
$ R&D	249	231	18
$ RD&E	2481	1919	562
R&D as % of RD&E	10%	12%	3%

Source: Consultants' calculations from Exhibit 1.

Exhibit 3

1976 R&D Expenditures in United States and Abroad by Each U.S. Automotive Producer*

(in millions of $)

	Total	U.S.	Abroad
General Motors	126	117	9
Ford	91	84	7
Chrysler	28	26	2
American Motors	4	4	0
Total	249	231	18

*Excludes engineering and design work.

Source: Consultants calculations.
See Volume II.

Assumes relationships between R&D and total RD&E for Ford are same for other producers, (i.e. R&D is about 10% of total RD&E, and R&D for U.S. and abroad is approximately 92% and 8% respectively of total R&D, except for American Motors Corporation which performs no R&D abroad.

Exhibit 4

Percentage Analysis of R&D Performed in United States and Abroad by Major U.S. Automotive Producers*

	% Total**	% U.S.	% Abroad
General Motors	51	51	50
Ford	37	36	39
Chrysler	11	11	11
American Motors	2	2	0
Total	100	100	100

*Excludes engineering and design work.

**Does not sum to 100% due to rounding.

Source: Consultants' calculations. See Volume II.

Exhibit 5

RD&E Expenditures in United States and Abroad by each U.S. Automotive Producer* - 1976

	Total	U.S.	Abroad
General Motors	1257	981	276
Ford	906	707	199
Chrysler	280	193	87
American Motors	38	38	0
Total	2481	1919	562

*Includes engineering and design work.

Source: Total figures from 1976 Form 10K of each producer. Other figures based on estimates made by interviewees and consultants. See Volume II.

Exhibit 6

Percentage Analysis of RD&E Performed in United States and Abroad by Major U.S. Automotive Producers

	% Total	% U.S.	% Abroad
General Motors	51	51	49
Ford	36	37	35
Chrysler	11	10	16
American Motors	2	2	0
Total	100	100	100

*Includes engineering and design work.

Source: Consultants' calculations from Exhibit 5.

Exhibit 7

Estimated Growth of RD&E Facilities in United States and Abroad for General Motors and Chrysler-(in thousands of square feet)

	Total	U.S.	Abroad
1976	22,164	16,939	5,225
1975	21,803	16,884	4,919
1974	21,288	16,484	4,801
1973	20,853	16,152	4,701

Source: 1976 Form 10Ks of General Motors and Chrysler. See Volume II.

Exhibit 8

Estimate Percentage Growth of RD&E Facilities in United States and Abroad for General Motors and Chrysler

	% Total	% U.S.	% Abroad
1976	100	76	24
1975	100	77	23
1974	100	77	23
1973	100	77	23

Source: Consultants' calculations from Exhibit 7.

Exhibit 9

Data for U.S. Automotive Multinationals Year of Entry of Manufacturing Subsidiaries*

That Also Performed R&D Activities by Country of Incorporation

	Year of Entry / Country	Pre-1920	1920-40	1941-50	1951-55	1956-60	1961-65	Unknown	Total
1)	Australia	0	0	0	1	3	1	0	5
2)	South Africa	0	0	0	2	1	1	0	4
3)	Mexico	0	0	0	1	2	1	0	4
4)	Chile	0	0	0	0	0	1	0	1
5)	Argentina	0	0	0	0	0	1	0	1
6)	Belgium	0	0	0	0	2	0	0	2
7)	France	1	0	0	0	0	4	0	5
8)	Germany (West)	0	0	0	1	5	3	0	9
9)	Italy	0	0	1	0	1	2	1	5
10)	Netherlands	0	0	0	1	1	0	0	2
11)	Denmark	0	0	0	0	0	1	0	1
12)	United Kingdom	2	3	1	1	3	3	0	13
13)	Switzerland	0	0	0	0	1	1	0	2
14)	Somali Republic	0	0	0	1	0	0	0	1
15)	Turkey	0	0	0	0	0	1	0	1
16)	Zambia	0	1	0	1	0	0	0	2
17)	Japan	0	1	0	0	0	2	0	3
	Total	3	5	2	9	19	22	1	61
	Cumulative Total	3	8	10	19	38	60		

*Subsidiaries which have done any R&D work. This includes temporary missions as well as permanent ones.

Source: Multinational Project Databank, Harvard University and consultants' calculations of cumulative totals.

Exhibit 10

Estimated Number of R&D and RD&E Operations Existing Abroad in 1976

The Estimated Number of:

	R&D Units	RD&E* Units	Total
General Motors	4	7	11
Ford	3	7[1]	10
Chrysler	3	5[2]	8
Total	11	19	29

* Does not include R&D unit (narrowly defined) that also performs engineering and/or design work.

Notes: [1]Some RD&E assumed in Argentina, Brazil, Mexico, Australia, South Africa, France, Spain, which have major manufacturing operations.

[2]Some RD&E assumed in Argentina, Brazil, Mexico, Australia, South Africa.

Source: Derived from Exhibits A-1 through A-10 in Appendix A and interviews.

Exhibit 11

Data for U.S. Automotive Multinationals

Total Subsidiaries by Principal Activity

Presently Alive in 1976

Activity	Manufacturing	R&D	Sales	Other	Unknown	Total
Total at Entry	168	0	149	26	29	372
Total at Latest	124	0	106	43	99	372
Exited	12	0	10	2	55	79

Source: Harvard Multinational Enterprise Databank.

Exhibit 12

Location of R&D and RD&E

Abroad by Country in 1976

Country	R&D RD&E Units	Percent*	Cumulative Percent
1) United Kingdom	6	21	21
2) France	4	14	35
3) Germany	2	7	42
4) Spain	1	3	45
5) Argentina	3	10	55
6) Brazil	3	10	65
7) Mexico	3	10	75
8) Venezuela	1	3	78
9) Australia	3	10	88
10) South Africa	3	10	98
Total	29	98*	98*

*Does not sum to 100% due to rounding.

Source: Company interviews.

Exhibit 13

Estimated Distribution of R&D and RD&E Abroad by Geographic Region in 1976 by Major U.S. Automotive Multinationals

	RD&E Millions $[1]	R&D %	R&D Millions $[2]	R&D %
Total Abroad	562	100	17	100
Europe	366	65	15.3	90
Latin America	84	15	.85	5
Australia New Zealand and Far East	84	15	.85	5
Middle East and Africa	28	5	0	0

Source: Consultants' calculation.
See Volume II.

[1]Assumes GM distribution of RD&E is roughly the same for all three U.S. producers.

[2]a) assumes all Chrysler's R&D in Europe;
b) assumes roughly $1 million of GM's $9 million of R&D abroad being performed in Australia and Brazil based on information from interviewees.
c) assumes Ford is spending 10% of R&D abroad ($7 million) outside Europe.

Exhibit 14

Location of RD&E Abroad for 1976 in Relation to Other Organizational Units of Three Major U.S. Automotive Multinationals

	Total	Number of Subsidiaries with RD&E Function	Percent of Total
Total Manufacturing and Assembly Sites	127	29	23
Have Manufacturing and Assembly	80	29	36
Assembly Only	57	0	0
Sales Only	74	0	0

Source: See Volume II.

Exhibit 15

Primary Purpose of RD&E Abroad in 1976
For Three Major U.S. Automotive Multinationals

	Total RD&E Units	(1) Indigenous Technology Units	(2) Multinational Technology Units	(3) Corporate Technology Units
General Motors	11	11	0	0
Ford	10	10	0	0
Chrysler	8	8	0	0
Total	29	29	0	0

(1) Indigenous Technology units are defined as RD&E units working on new products or processes expressly for a specific national or regional market.

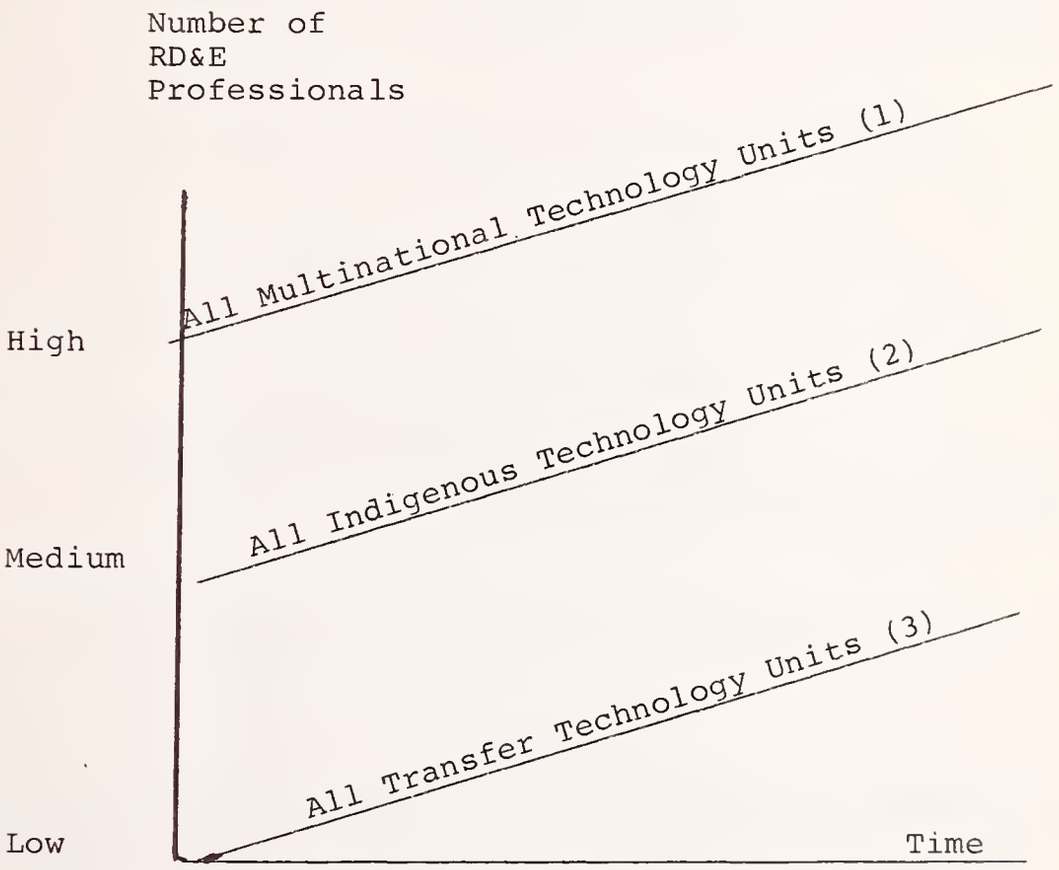
(2) Multinational Technology units are defined as RD&E units working on new products or processes expressly planned for simultaneous (or near simultaneous) production in major world markets.

(3) Corporate Technology units are defined as RD&E units working on exploratory research of a long-term nature expressly for the corporate parent.

Source: Exhibit 10 and company interviews.

Exhibit 16

Change of RD&E Purpose
and Size of RD&E Investments Abroad



(1) Defined as RD&E operations to produce new and improved products or processes expressly for near simultaneous manufacture in major world markets.

(2) Defined as RD&E operations to produce new and improved products or processes expressly for a particular national or regional market.

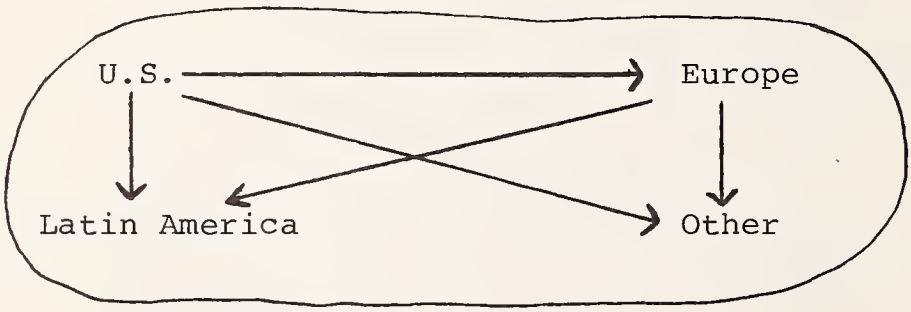
(3) Defined as RD&E operations of a technical service nature but based on technology supplied by the multinational parent.

Source: Robert Ronstadt, Research and Development Abroad by U.S. Multinationals, Praeger, 1977, See Chapter 8, "R&D Creation Abroad."

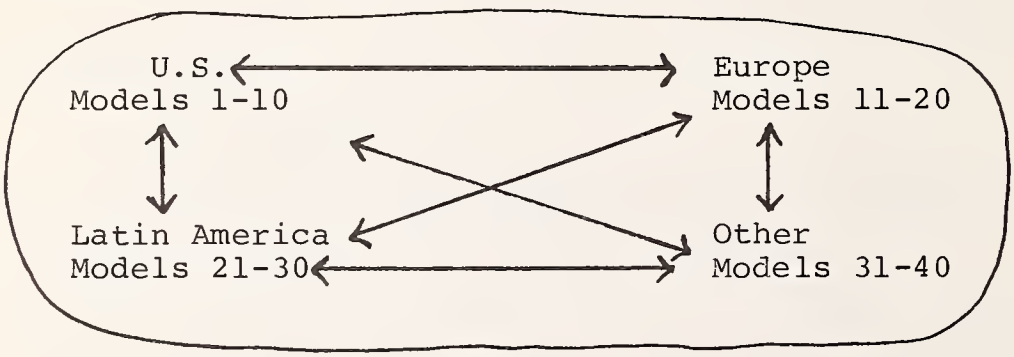
Exhibit 17

Current and Future Possible International Patterns of Technology Transfer

Current Dominant Patterns of Technology Transfers by the U.S. Automotive Producers



Future Possible Patterns of Technology Transfers by the U.S. Automotive Producers



⟷ Arrows represent disembodies (blue prints, people, etc.) technology flows to be used for near simultaneous production in major markets.

Source: The current patterns are supported by preliminary evidence. See Volume IV.

APPENDIX

Selected Data on Specific Sites of RD&E Activity Performed Abroad by General Motors, Ford, and Chrysler Corporation.

Exhibit A-1

General Motors Corporation

Location and Selected Characteristics of RD&E Performed Abroad in 1977

Name & Location of R D&E Activity	Primary Purpose	Primary User(s)	Time Horizon and Nature of R D&E Work
#1 GM Argentina	Mainly Process Adaption	National Market	Nearly all work is short-term (one year or less). All work is in support of existing business.
#2 GM Brazil	Same, but under-going transition -some new product work -alternative engine work	National Market	Same as above except for product work which is on four-year cycle.
#3 GM Mexico	Mainly Process Adaption	National Market	Nearly all work is short-term (one year or less). All work is in support of existing business.
#4 GM Venezuela	Mainly Process Adaption	National Market	Same as GM Mexico

Source: Company interviews.

Exhibit A-1 (continued)

General Motors Corporation

Location and Selected Characteristics of RD&E Performed Abroad in 1977

Name and Location of R D&E Activity	Primary Purpose	Primary User(s)	Time Horizon and Nature of R D&E Work
#5 GM Australia General Motors - Holden Ltd. Elizabeth, S. Australia	Product Development; Process Development and Adaptation.	National Market	Product work is within 4-6 year model cycle. Process work is tactical or short term given size of project, usually under one year.
#6 GM South Africa GM South African (PTY) Ltd. Port Elizabeth	Mainly process adaptation.	National Market	Most work is short term (one year or less).

Exhibit A-1 (continued)

General Motors Corporation

Location and Selected Characteristics of RD&E Performed Abroad in 1977

Name and Location of RD&E Activity	Primary Purpose	Primary User	Time Horizon and Nature of RD&E Work
#7 GM France	Mainly Process Adaption	National market	Most work is short term (one year or less).
#8 GM Germany Adam Opel A.G. Russelsheim West Germany	Product Development Process Development and Adaption	National market	Majority of product work within four year model cycle and totally in support of existing business.
#9 GM United Kingdom Vauxhall Motors, Ltd. Luton, Bedfordshire England	Product Development Process Development and Adaption	National market	Same as above (GM Germany)

Source: Company interivews.

Exhibit A-1 (continued)

General Motors Corporation

Location and Selected Characteristics of RD&E Performed Abroad in 1977

Name and Location of R D&E Activity	R D&E Activity Created or Acquired	R D&E Activity Associated with Manufacturing	Why R D&E Activity Started and/or Maintained
#10 GM United Kingdom GM Limited	Created	Yes	Process adaptation required with start of components manufacturing.
#11 GM United Kingdom A.C. Delco	Acquired	Yes	- same as above -

Sources: Company interviews.

Exhibit A-2

General Motors Corporation

Location and Selected Characteristics of RD&E Performed Abroad in 1977

Name and Location of R D&E Activity	R D&E Activity Created or Acquired	R D&E Activity Associated with Manufacturing	Why R D&E Activity Started and/or Maintained
#1 GM Argentina	Created	Yes	Process adaption required with assembly work. Expanded with start of manufacturing Product adaption started with component mfg.
#2 GM Brazil	Created	Yes	- same as above -
#3 GM Mexico	Created	Yes	- same as above -
#4 GM Venezuela	Created	Yes	- same as above -

Source: Company interviews.

Exhibit A-2 (continued)

General Motors Corporation

Location and Selected Characteristics of RD&E Performed Abroad in 1977

Name and Location of R D&E Activity	R D&E Activity Created or Acquired	R D&E Activity Associated with Manufacturing	Why R D&E Activity Started and/or Maintained
#5 GM Australia	Acquired	Yes	Activities maintained and expanded to develop new products for Australian and Far East markets.
#6 GM South Africa	Created	Yes	Process adaptation required with assembly work. Expanded with start of manufacturing. Product adaptation started with component manufacturing.

Source: Company interviews.

Exhibit A-2 (continued)

General Motors Corporation

Location and Selected Characteristics of RD&E Performed Abroad in 1977

Name and Location of R D&E Activity	R D&E Activity Created or Acquired	R D&E Activity Associated with Manufacturing	Why R D&E Activity Started and/or Maintained
#7 GM France	Created	Yes	Process adaptation required with start-up of assembly and manufacturing work.
#8 GM Germany Adam Opel	Acquired	Yes	Activities maintained and expanded to develop new and improved products for German market.
#9 GM United Kingdom Vauxhall	Acquired	Yes	Activities maintained and expanded to develop new and improved products for U.K. market.

Source: Company interviews.

Exhibit A-2 (continued)

General Motors Corporation

Location and Selected Characteristics of RD&E Performed Abroad in 1977

Name and Location of R D&E Activity	Primary Purpose	Primary User(s)	Time Horizon and Nature of R D&E work
#10 GM United Kingdom General Motors Limited	Mainly product (components) and process adaptation	National Market	Nearly all tactical, short-term work under one year in support of existing business.
#11 GM United Kingdom A.C. Delco Ltm.	Same as above.	National Market	Same as above.

Source: Company interviews.

Exhibit A-3

Ford Motor Company

Location and Selected Variables of R&D Performed Abroad in 1977

	Name and Location of R&D Unit	Purpose of Unit	Type of Unit	User of Unit	Nature of R&D
1)	European R&D facility in support of car production located in Dunton, England and in Merkenich, Germany	created to support European car production	functions primarily as an indigenous technology unit	approximately 95% of R&D output is used by Ford of Europe; 5% by Ford of North America	all work is in support of existing business
2)	European R&D facility in support of truck production located in Dunton, England	created to support European truck production	same as above	same as above	same as above
3)	European R&D facility in support of manufacturing located in Dunton, England and in Merkenich, Germany	created to promote manufacturing efficiency in Europe	same as above	same as above	same as above

Source: Personal interviews, Ford Motor Company and Public Affairs Staff, Ford Motor Company, Brentwood, Essex, Great Britain, Ford Product Development in Europe, 1976.

Exhibit A-4

Ford Motor Company

Location and Selected Variables of R&D Performed Abroad in 1977

	Name and Location of R&D Unit	Period Created or Acquired	Role of Govt. Incentives in Creation of Unit	Organizational Location	Person to Whom R&D Director Reports
1)	European R&D facility in support of car production located at Dunton, Essex in England (near London) and at Merkench in Germany (near Cologne)	created in the mid-1960s*	none	Located near manufacturing, marketing and engineering sites	Director, located in Cologne, reports to engineering V.P.
2)	European R&D facility in support of truck production located in Dunton, England	same as above*	none	same as above	No director in truck facility.
3)	European R&D facility in support of manufacturing located in Dunton, England and in Merkenich, Germany	same as above*	none	same as above	Director is manufacturing coordinator at staff level, reports to V.P. in charge of manufacturing.

* All three units replaced and/or consolidated other RD&E units that had existed in Europe for many years.

Source: Personal interviews, Ford Motor Company and Public Affairs Staff, Ford Motor Company, Brentwood, Essex, Great Britain, Ford Product Development in Europe, 1976

Exhibit A-5

Chrysler Corporation

Foreign Passenger Car RD&E Facilities

Name and Location	Departments	Nature
(1) Chrysler U.K. Whitley Technical Center Abbey Road Whitley Coventry CR3 4GB	Body Engineering-Car and Truck Chassis Engineering - cars Product Proving & International Engineering Truck Engineering Advanced Engineering Materials	Numerous special experimental techniques for general vehicle developments; equipment includes dynometers, exhaust emission testing facilities, cold test room, electronic and rig test apparatus.[1]
(2) Chrysler France Engineering Center Poissy, France		
(3) Chrysler France Mortefontaine, France		Large test ground, high speed circuits, used extensively by Chrysler U.K.[2]

(1) Source: Industrial Research in Britain, 7th edition.
(2) Source: "Simca - Chrysler with French Dressing", Motor, June 19, 1971, pg. 24.

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