International Strategic Alliances and Technology Strategy: The Case of Rotary-Engine Development at Mazda

Daniel Arturo HELLER*

(ABSTRACT) *This case presents Mazda's over forty-year history developing the rotary engine for use in motor vehicles and explores the role played by international alliances in the implementation of technology strategy. Two key touchstones in the discussion are Mazda's initial technology-licensing agreement with NSU/Wankel and Mazda's long-standing alliance with Ford. The case suggests that strong efforts at internal capability-building may be needed for a firm to maximize the use of alliances in innovation management.*

（和文要約） マツダは，40年間以上にわたってロータリエンジンを設計・開発してきた。本稿では，その過程において，初期のマツダ＝NSU ワンケルの技術ライセンス，およびマツダ＝フォードの長期継続的な提携が果たした役割について検討し，企業間関係が技術戦略に与える影響について探った。その結果，イノベーション管理において，提携のポテンシャルを最大に活用するためには，企業内部での能力構築指向が不可欠であることが示唆された。

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* Lecturer, Faculty of Economics, Shinshu University (daniel@econ.shinshu-u.ac.jp)

1. Introduction[1]

There are many examples of cross border inter-firm linkages playing an important role in the development and exploitation of new technology. By covering the past forty years during which Mazda Motor Corporation has been researching and developing the rotary engine and commercializing it for use in its motor vehicles, the present case illustrates some of the ways in which interna-

tional strategic alliances may interact with a firm's technology strategy. The case pays particular attention to internal and external contextual factors confronted by Mazda during this time period to probe the conditions that may assist a firm in maximizing the benefits of strategic cooperation with other firms.

While reviewing the case, the reader should consider how the presence of a strategic partner can, often simultaneously, both facilitate and complicate the strategic positioning of innovative firms. It is commonly understood that, while an alliance can create opportunities for innovation that are unavailable to firms that strictly follow a go-it-alone strategy, the existence of an alliance may also place unwelcome constraints on a firm (cf., Lei and Slocum, 1992). However, this case shows that such opportunities and constraints should not be viewed from an over-simplified perspective. That is, the opening up of new opportunities is not necessarily positive for a firm, nor is the emergence of new constraints necessarily negative for a firm. In both instances, the key issue is the firm's managerial response to changes in environmental and internal conditions.

In its coverage of a relatively long period of time, the case demonstrates the delicate and often non-linear interplay among the evolution of market needs, technological developments, and product differentiation. Finally, the case suggests that a firm's internal capability-building efforts may be the single most important contributing factor for a company to both exploit the potential benefits of a technology-acquisition alliance and bring out the positive aspects of the limitations that may be imposed by a broad-based tie-up.

2. Rotary-Engine Related Development at Mazda

(2-1) Historical background—A diversifying industrial company in Hiroshima

Present-day Mazda Motor Corporation began as Toyo Cork Kogyo Co., Ltd. in 1920.[2]

1 The author would like to express his sincere thanks to Mazda Motor Corporation for the firm's assistance in the preparation of this case. Between November 2003 and May 2004, interviews lasting from one to four hours were conducted in Japan with Nobuhiro Hayama (General Manager, Powertrain Development Division), Noboru Katabuchi (Program Manager, Program Management Office), Keiichi Wakabayashi (General Manager, Global Communications Planning Department) and in the U.S. with Kelvin Hiraishi (Director, Research and Development Engineering, Mazda North American Operations) and Weldon Munsey (Vehicle Line Manager, Product Development and Strategy, Mazda North American Operations). The author also was present at a September 26, 2003 presentation by Ikuo Maeda (RX-8 Chief Designer, Design Division) at the Mazda R&D Center in Irvine California during Sevenstock 6 (an annual gathering of rotary-engine enthusiasts). In addition, two 1999 interviews conducted by the author with marketing managers at Ford were referenced, as well as notes from the author's numerous visits to Ford, Mazda, and Ford-Mazda joint facilities between July 1999 and May 2004. A special mention of appreciation is extended to Mazda's Domestic Corporate Communications Department (Kazuyuki Mitate, Yuji Kato, and Mayumi Handa), Brian Long (2004), an automotive historian who provided key comments on an earlier draft of this manuscript, and Takaharu "Koby" Kobayakawa, who was the project leader of of the 3rd Generation Mazda RX-7, without whose assistance the case could not have been written. Horoki Ohri and Hidetada Higashi participated in various phases of the gathering and processing of the data upon which this case is based. Funding for this research was provided by the International Motor Vehicle Program and the teaching materials development program of the Japanese Ministry of Economics, Trade and Industry through its allocation to Shinshu University in Fiscal Year 2003.

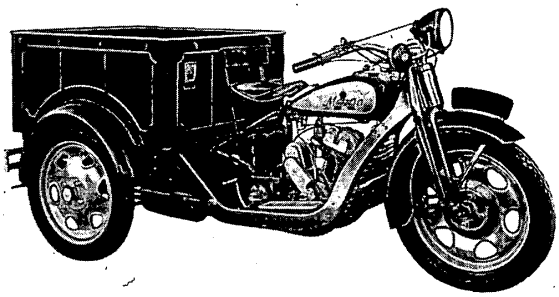

Figure 1 : Mazda's first three-wheeled truck
(Source : Mazda Motor Corporation)

The company was founded in the city of Hiroshima, located in the western part of the main island (Honshu) of Japan, by a group of local businessmen that included Jujiro Matsuda, who became the company's president in 1921. Following business difficulties and a fire that destroyed 70% of the company's production facility, the cork producer sought to diversify into the machine tools business, which was accomplished in 1929. Subsequent diversification led the company to develop its own three-wheeled truck, which the company began to sell in 1931 under the brand name, Mazda (**Figure 1**). The propulsion system for this vehicle was the gasoline-powered reciprocating engine. Further expansion of the scope of the company's business interests occurred in 1935 when the company began producing rock drills and gauge blocks.

The devastation of World War II was acutely felt in Hiroshima, over which an atomic bomb was detonated in early August 1945. Together with the rest of the city, Mazda embarked on the laborious recovery process that included re-industrialization. For Mazda this involved an increased commitment to its motor vehicle business. Three-wheeled truck development continued and

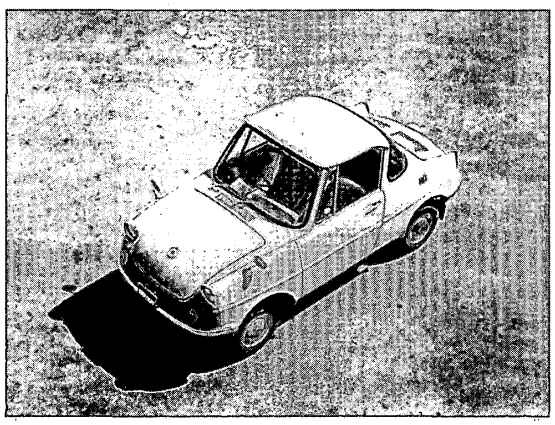

Figure 2 : R360 Coupe, Mazda's first four-wheeled passenger car
(Source : Mazda Motor Corporation)

Mazda became the largest producer of such vehicles in Japan in 1956. The company's renewed drive into the motor vehicle business culminated in the introduction of its first four-wheeled passenger car, the R360 Coupe, in 1960 (**Figure 2**).

Shortly thereafter, in 1961, Mazda entered into a technical licensing agreement with NSU/Wankel of West Germany to develop the rotary engine. The company also continued to work on traditional-engine powered vehicles, and various three- and four-wheeled passenger cars and trucks with reciprocating engines were introduced throughout the 1960s. In addition, Mazda began to research diesel engines in 1965 through a technical cooperation agreement with a firm in the United Kingdom. In that same year, Mazda also opened a vehicle proving ground in Miyoshi about 70 km away from Hiroshima. With a vision for the future, the proving ground was built with a high-speed track (over 200kmh) even though very few highways existed in Japan at the time.

As outlined above, Mazda strongly in-

2 For ease of reading, throughout the remainder of the case the firm's present name, Mazda Motor Corporation (abbreviated as Mazda) is used. The firm's official name was Toyo Cork Kogyo Co., Ltd. until 1927 and Toyo Kogyo Co., Ltd. until 1984.

creased its presence in the growing motor vehicle industry in the 1960s. At the same time, Mazda maintained its active presence in various other industries—most notably materials and precision machine-tools—and achieved various product successes. For example, Mazda is known in Japan for its contribution to machines that were used in the drilling of the tunnels of the Japanese Shinkansen (bullet train) line which began operation in 1964 to coincide with the Tokyo Olympics.

(2-2) Rotary-engine licensing agreement

A rotary engine contrasts with a reciprocating engine in its basic mechanism. In a reciprocating engine, the up and down movement of a piston within a cylinder is converted through a complicated process into the rotational movement that ultimately drives a vehicle's wheels. On the other hand, the movement of a rotary engine is already rotational. As such, there is no need for the complicated conversion process. The result is a smoother running engine with fewer parts (**Figure 3**).

The basic concept of a rotary engine can be traced back to 16th Century Europe, and

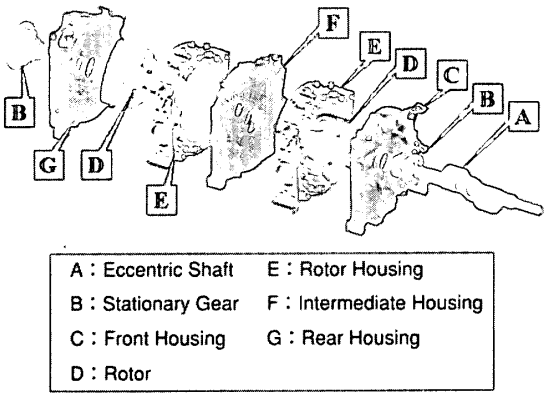

Figure 3 : Basic Structure of Rotary Engine
(Source : Kanbara et al., 2003, p. 5)

the first prototype rotary-engine is generally dated to 18th Century England. It was not until the second half of the 20th Century, however, that the engine was developed to the extent that it could realistically be viewed as a possible alternative to the reciprocating engine that has been dominant in the automobile industry since the turn of the 20th Century. Dr. Felix Wankel contributed greatly to the advancement of rotary engine technology. In 1954, NSU, a major motorcycle manufacturer in West Germany began working with Wankel on the development of this revolutionary engine type.

After various prototypes were developed and refined, NSU announced in 1959 the completion of a functioning 400 cubic centimeter (cc) displacement, single-rotor engine, the Type KKM250 Wankel Rotary Engine. In the wake of this announcement over 100 companies, including 34 of Japanese origin, sought license agreements with NSU/Wankel for the use of the technology embodied in the company's KKM engine.

Mazda managed to secure a license with NSU in 1961. Even as it rapidly grew its auto business, Mazda remained a latecomer and minor regional player in the Japanese automobile industry. As such, the company was facing the possibility of the forced discontinuation of its automotive activities due to government efforts at the time to promote rationalization of the sector. In this context, Mazda viewed the rotary engine as a means to attract widespread attention, markedly differentiate its vehicles, and secure its future in the industry. Maintaining its automobile buisiness would allow Mazda to participate in what was seen as a high-growth sector, as motorization in Japan and other parts of the world progressed rapidly.

(2-3) Three technological challenges

① Commercialization of the rotary engine for use in the automobile

Mazda's licensing agreement allowed it to receive technical assistance from NSU, and Mazda engineers made multiple visits to West Germany for this purpose. However, Mazda soon learned that NSU did not possess the solutions to various fundamental developmental hurdles that remained before the rotary engine could be successfully commercialized for use in automobiles. These hurdles included the development of engine parts that required many times the precision needed for typical reciprocating engines of the time.

While NSU had indeed developed a working rotary engine, it was quite limited in its functionality. Most notably, while the engine that NSU demonstrated to Mazda could indeed run for many hours at high engine revolutions per minute (rpm) without any problems, Mazda discovered that changing the engine's rpm, that is, repeatedly accelerating and decelerating the engine eventually caused it to fail. The problem lay in the inadequacy of the rotor's three cast-iron apex seals. The role of these seals is to close up an engine chamber, just as a piston ring does in a reciprocating engine. Adequate sealing is needed for the intake/compression/power/exhaust cycle of the internal combustion engine to function. In the engine developed by NSU, changes in engine speed caused the seals to scratch the inner surface of the rotor-housing unit, rendering the engine inoperable. These scratches were called "chatter marks" or "nail marks of the devil" (**Figure 4**). The chatter marks and other problems were responsible for severe reliability issues that plagued the first rotary-engine car sold

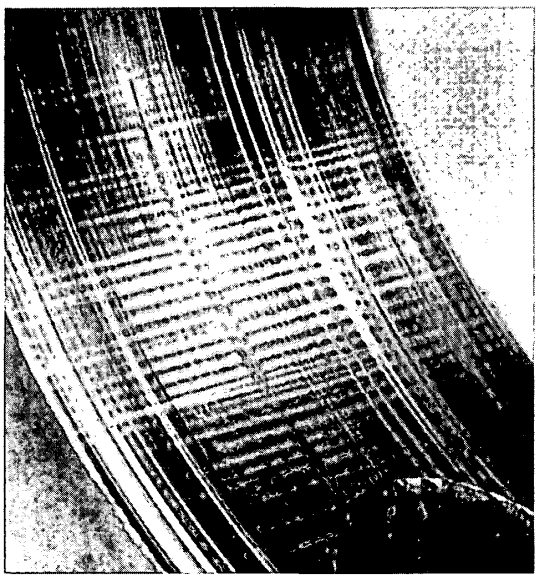

Figure 4 : Chatter Marks
(Source : Rotary Engine Press Information 2003)

to the general public, which featured an engine with a single rotor that NSU began to sell in the 1964 season.

Leading the rotary-engine development charge at Mazda was Kenichi Yamamoto, who had a passionate devotion to rotary-engine development. From 1963, he headed a dedicated team of Mazda developers, which came to be known as the "47 Samurai." Many of the engineers hired by Mazda during this period of very high demand in Japan for people with technical skills were individuals who sought to work at Mazda specifically because it offered the potential opportunity to work on the challenging rotary engine.

As for the specific chatter-mark problem, an intensive and broad-based iterative search and simulation effort was undertaken to find a suitable replacement to the cast iron used by NSU for the engine's apex seals. A strong materials department at Mazda and expertise at the company in sealing technology facilitated this initiative. Ultimately, a material consisting of aluminum and carbon was developed, which made use of carbon's

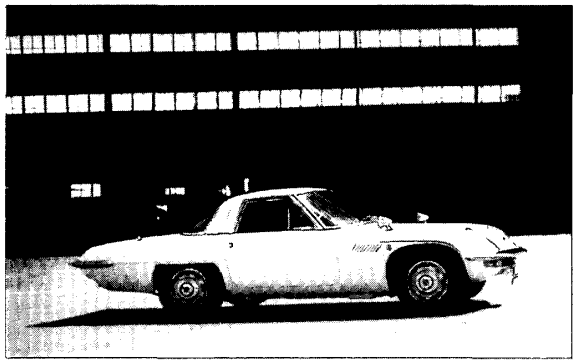

Figure 5 : Cosmo Sport
(Source : Mazda Motor Corporation)

self-lubricating properties to overcome the scratching problem.[3]

As a result of the effort noted above and other initiatives, Mazda developed the world's first commercialized two-rotor engine. It was mounted in Mazda's first rotary vehicle sold to the public, the Cosmo Sports (**Figure 5**), which went on sale in 1967. Nearly all of the approximately 1,200 vehicles produced were sold domestically in Japan. Following the Cosmo Sports, Mazda rapidly expanded its line-up of rotary-engine powered vehicles.

② Overcoming emissions regulations

Though the passenger car market in Japan was growing rapidly in the late 1960s, it was much smaller than the U.S. market at the time. Mazda sought to exploit its novel engine in the U.S. as well. However, the company faced a difficult hurdle in exporting its vehicles to the U.S. At the time, pressure from a growing environmental protection movement had created strong momentum in the U.S. to limit automobile emissions for new cars. This was particularly the case in California, notably the Los Angeles basin, were smog conditions were reaching intolerable levels. Thus, shortly after Mazda had succeeded in developing a viable rotary engine, the company had to begin the arduous task of making the engine compliant with proposed strict emissions restrictions in the U.S.

Initially, when exhaust emissions first became an issue, the rotary engine was cited as a "dirty engine," primarily because of the high level of hydrocarbons present in its raw exhaust gas. After many trials and hard work, Mazda developers succeeded in adding a thermal reactor to the exhaust system that reduced the engine's emissions level. Only Mazda and Honda were able to offer engines that could comply with the strict emissions regulations for new products that had been proposed in Washington, D.C. by Senator Edmond Muskie in the so-called "Muskie Bill," and which were ultimately passed in the 1970 Amendments to the Clean Air Act. With the addition of the thermal reactor technology, some even began calling Mazda's rotary engine a "clean engine," together with Honda's CVCC engine.

One disadvantage of the thermal reactor technology, however, was that it reduced a vehicle's fuel efficiency, due to the rich fuel/air mixture that it required to burn the exhaust fumes effectively. This was not viewed as a major drawback because gasoline prices in the U.S. at the time were generally below 30 cents per gallon. The idea of using a thermal reactor to reduce emissions was also

3 The composite material used for the apex seals in Mazda's engine also had some reliability issues. Carbon's somewhat brittle nature made the seals liable to break if a foreign particle somehow entered the engine. Several years later, Mazda replaced the carbon-aluminum seals with newly developed metal ones which had undergone heat treatment giving their surfaces ceramic-like qualities.

tried in reciprocating engines, but was not widely adopted. Mazda choose thermal reactor technology over catalyst technology, which requires unleaded gasoline, a type of fuel that was not widely available at the time.

Mazda's exports of rotary engine vehicles to the U.S. started in 1970 and soon began to increase rapidly. At least three factors were responsible for this market success: the engine's smooth operation, the high performance characteristics of the vehicles, and their good cost-performance ratios. For example, two-rotor engines in these early Mazdas could deliver vehicle performance equivalent to that of cars with much larger V-8 engines, but at significantly lower prices.

③ Overcoming the oil crises

Mazda's rapid increases in sales in the U.S. and Japan abruptly came to an end in 1973 when the first of the oil shocks began. In the U.S., gasoline prices more than tripled, coupled with shortages. In addition, the rotary engine's relatively poorer fuel efficiency vis-à-vis reciprocating engines caused it to be singled out by the Environmental Protection Agency as a "gas guzzler." The subsequent fall in sales caused production of rotary engine power vehicles at Mazda to fall from a high in 1973 of 240,000 to only 42,000 in 1977.

During this period other automakers that had endeavored to develop their own rotary-engine powered vehicles abandoned these development efforts. Most notable among these was General Motors, the world's largest producer of automobiles, which under the leadership of President Ed Cole had reportedly been very close to beginning sales of a compact passenger car powered by a rotary engine in the mid-1970s.

Mazda's response was twofold. First, Mazda began to offer optional reciprocating engines in what had previously been rotary-engine-only vehicles. However, this action should not be interpreted as a weakening of Mazda's commitment to the rotary engine, which had enabled it to become among the fastest growing automobile manufacturers in the world. In addition to expanding its lineup of vehicles with reciprocating engines, Mazda sought to respond to the negative publicity surrounding the rotary engine by making an internal commitment to achieve a rapid 40% increase in the fuel economy of its rotary-engine vehicles within a few years, a goal the company was able to achieve. The project at Mazda was named "Operation Phoenix" after the mythical bird that is reborn from its ashes.

(2-4) RX-7

Falling sales at Mazda in the mid-1970s created a difficult financial situation at the company. Rumors circulated that Mazda would exit the U.S. market or even give up rotary-engine production entirely. Amid such an atmosphere, Mazda developed and then began selling in 1977 a new reciprocating-engine-only compact passenger car, called the Familia in Japan and the GLC ("Great Little Car") in the U.S., which met with broad success. In addition, rather than give up the rotary engine, Mazda management instead initiated the development of an attractive and affordable new sports car to be powered solely by the rotary engine. The car debuted in 1978 as the RX-7, laying to rest any questions about the company's commitment to the rotary engine (**Figure 6**). The vehicle featured high performance and decent gasoline mileage. It was designed around the rotary engine and was not offered with the option of a

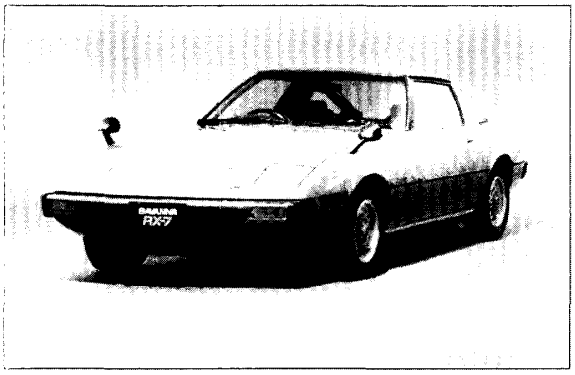

Figure 6 : First Generation RX-7
(Source : Mazda Motor Corporation)

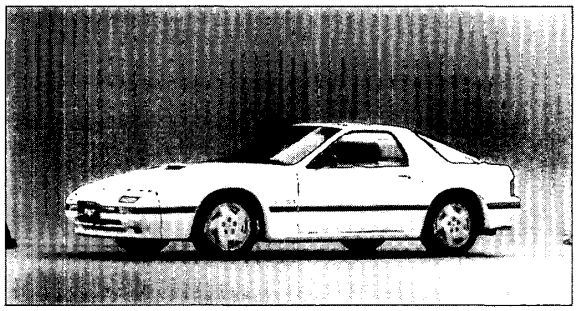

Figure 7 : Second Generation RX-7
(Source : Mazda Motor Corporation)

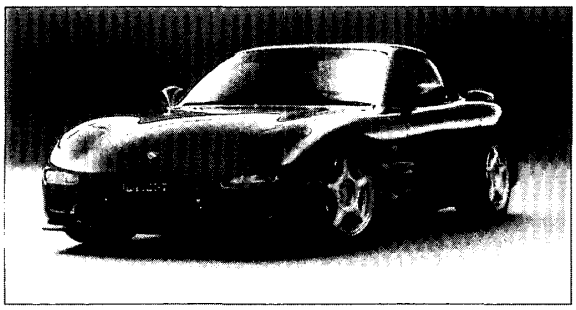

Figure 8 : Third Generation RX-7
(Source : Mazda Motor Corporation)

reciprocating engine. From this period, Mazda sought to develop vehicles that had been optimized for each engine type, rather than allow consumers to choose between a reciprocating engine or rotary engine in some of its vehicles.

By 1979, there were only three rotary-engine vehicle models offered by Mazda. This was a dramatic reduction from the high of 10 models in the mid-1970s, which even included a rotary engine microbus and pick-up truck. From the late-1970s, Mazda's view of the rotary engine began to change. Gradually Mazda began to see the engine in more complex terms than simply as a substitute for the reciprocating engine. While the engine's qualities of compact size and high performance made it ideal for sports cars, its relatively lower fuel economy and need for higher precision parts made it less well suited for other types of motor vehicles.

The first generation RX-7 was followed by a second in 1985, where the car moved upscale aiming for better sports-car performance (**Figure 7**). The third generation RX-7 was launched in 1991 and was moved further upscale (**Figure** 8), though under Mazda's highest-end three-rotor sports car, the Eunos Cosmo. Through these three iterations, the character of the RX-7 became increasingly closer to the ideal of a true sports-car. Each of the three generations have received accolades for their styling and performance. To this day, the vehicles command loyal followings and fan clubs around the world.

(2-5) Mazda and racing

Mazda used racing as a means to test its rotary-engine technology under extreme stress. Racing also provided a means of attracting attention and proving the technology to the public. Beginning with the company's first rotary engine car, the Cosmo Sports, Mazda entered its vehicles in various domestic and international races. In Japan, there is a long history of dueling between Mazda's rotary-engine vehicles and Nissan Skyline vehicles. In the U.S., the RX-7 has been very popular in racing especially in International Motor Sports Association

(IMSA) races. However, the race that is perhaps best know to rotary-engine enthusiasts is the victory of the Mazda 787B at the 1991 French Le Mans 24-Hour endurance race.

Mazda's rotary engine first began competing in the Le Mans race in 1973. After many years of trying, the three-rotor engine powered racing prototype 757 finished 7th overall in the 1987 and the four-rotor engine powered 767B finished 7th overall in 1989. However, the international motor sports regulating body sought to ban from Le Mans all engines other than the standard 3.5 liter naturally aspirating piston engine. Mazda decided to make company-wide efforts aiming to finish in the top rankings in 1990, which looked to be the last eligible year for the rotary engine.

In preparation for the 1990 race, the prototype's horsepower was increased from 600 to 700ps together with improved fuel economy. The results, however, were disastrous. Two of the three Mazda vehicles retired in the middle of the race, and the third vehicle finished out of the top positions. On the heels of this crushing defeat came a welcome surprise: the eligibility of non-standard engines was extended for one more year. Mazda and its racing team, Mazdaspeed, worked closely together in an all out effort and the prototype vehicle they developed, the 787B, captured the outright winning position in 1991 defeating Mercedes, Jaguars, Porsches, Peugeots, and others (**Figure 9**). The achievement demonstrated the potential of the rotary engine and greatly encouraged rotary engine enthusiasts both within and outside of Mazda.

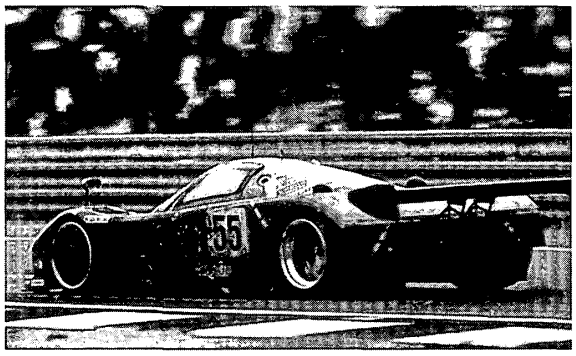

Figure 9 : 1991 Le Mans Winning Car, Mazda 787B (Source : Mazda Motor Corporation, Rotary Engine Press Information 2003)

(2-6) Declining sports-car market

Even as a push toward real motor sports was occurring at Mazda, demand for sports cars in the general market was waning, with sales beginning to decline from the late 1980s and early 1990s in Japan, the United States, and elsewhere. In line with this trend, production of the RX-7 began to decrease from 1987, and fell far below the peaks of nearly 73,000 RX-7 vehicles produced in 1978 and 1986. Rough estimates suggest that total sports car sales worldwide would ultimately fall to just a third of their previous peak.

In 1995, slow sales and stricter emissions regulations led Mazda to stop exporting the RX-7 to the U.S. market. The same year marked the final year of production of the Eunos Cosmo, making the RX-7 the sole remaining rotary-engine vehicle in production. This diminishing presence of the rotary engine at Mazda is epitomized by the MX-5 Roadster/Miata, which went on-sale in 1989. This car, which re-established the lightweight open-top sports car segment in markets around the world, was developed at Mazda from its inception as a reciprocating-engine-only vehicle. The MX-5 model shows that the general perception of the rotary engine within Mazda had been transformed

to the extent that not only was it viewed as an engine that was essentially limited to use in sports cars, but even that its use was limited to only certain types of sports cars.

(2-7) Changes and challenges in the 1990s

① Company crisis

Although Mazda's total yearly rotary engine vehicle sales began to fall markedly from the 1980s, its sales of reciprocating engine vehicles did not. Total sales at the company grew through the 1980s. By 1990, Mazda's domestic sales totaled nearly 600,000 vehicles and its exports from Japan were over 800,000 vehicles. However, domestic sales would fall to just over 400,000 by 1993, and to nearly 300,000 by 1996. Mazda's exports from Japan also declined dramatically, falling to 450,000 by 1996. These decreases in domestic sales and exports were generally more severe than those experienced by Mazda's Japanese automaker counterparts, during this difficult economic period in Japan.

Prior to these declining sales, Mazda spent heavily for expansion increasing its fixed cost burden and incurring large debts. The company opened in the U.S. its first major overseas plant in 1988. A major new domestic plant was also built in Hofu, Japan, which opened in 1992. Two new dealer channels were opened in Japan in 1989, bringing the number of dealer channels distributing Mazda vehicles in Japan to five. Furthermore, the company continued to expand the number of dealers and showrooms affiliated with these channels even as overall sales performance began to disappoint.

Decreasing sales and increasing costs combined to create a financial crisis at Mazda. Profits declined and then became negative. As the crisis deepened Mazda's lead bank, Sumitomo Bank, which first became active inside Mazda's management in the mid-to-late 1970s and then again from the mid-1980s, increased its influence in the company. In 1991, a second Sumitomo Bank-dispatched executive was promoted to serve as a vice-president in Mazda. Then, in 1992 Yoshihiro Wada became the president of Mazda. Wada had been dispatched from Sumitomo bank to serve as an advisor to Mazda in 1983, served as the company's sole vice-president from 1985 to 1990, and served as one of three vice-presidents in 1991. Through its increased presence in Mazda's management, Sumitomo Bank sought to restore Mazda to enduring business health, and thereby protect its large volume of loans to the company. The bank's efforts naturally turned to Ford Motor Company, Mazda's longstanding corporate partner.

② Strengthened alliance with Ford

Mazda's business alliance with Ford Motor Company began in 1969, when the two companies, together with Nissan Motor Company, formed a joint venture in Japan to manufacture automatic transmissions. Although Ford failed in its subsequent attempt to acquire an equity stake in Mazda in the early 1970s, other forms of cooperative relations between the two companies followed. For example, from 1972 Mazda began supplying Ford with a small pick-up truck, the Ford Courier, to be sold in the U.S., an arrangement that lasted for ten years. In 1979 with the support of Sumitomo Bank, Ford was able to acquire a 25% equity stake in Mazda. The companies went on to pursue various other cooperative projects throughout the 1980s. Most notably, Ford sought to

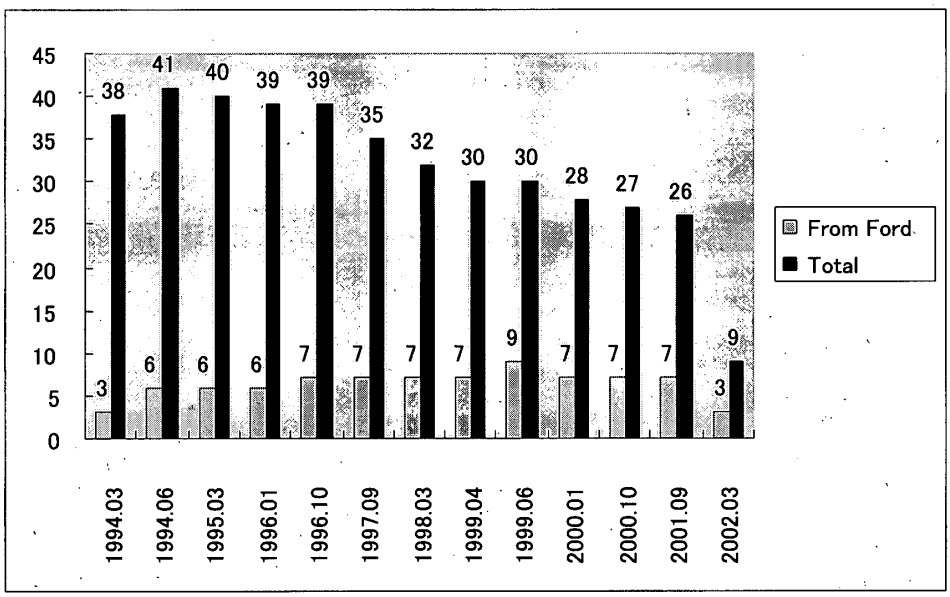

Figure 10 : Size of Mazda's BOD and number of Ford-dispatched directors
(Source : Heller, 2003)

use the relationship with Mazda as a means to engage in organizational learning to improve its manufacturing and product development capabilities as the company faced intense competition from Japanese automakers.

The character of the relationship between Mazda and Ford went on to evolve rapidly in the early 1990s, triggered by the company crisis at Mazda described earlier. Under the guidance of Sumitomo Bank, Mazda began turning to Ford for various forms of assistance. First, in 1992 Ford acquired a 50% ownership stake in Mazda's U.S. manufacturing facility, providing Mazda with a much needed cash infusion. Next, following a comprehensive review by Ford of Mazda's corporate capabilities and assets, Ford and Mazda agreed at the end of 1993 to make their relationship more strategic in nature. In mid-1994 Ford increased its presence on Mazda's board of directors from three (out of a total of 38) to six (out of a total of 41), and for the first time, some Ford dispatchees also assumed specific functional responsibilities within Mazda.

The watershed in the evolution of the Mazda-Ford relationship came in April 1996 when Ford increased its equity stake in Mazda to 33.4%, essentially giving Ford managerial control of its partner. Henry Wallace, who had been dispatched from Ford to Mazda since 1994, became the new president of Mazda, taking over from Yoshihiro Wada. Subsequently, the overall influence and functional range covered by Ford executives dispatched to work inside of Mazda increased throughout the 1990s (**Figures 10 & 11**).

③ Rotary-engine crisis

Ford's increased presence within Mazda management led to a number of changes. Cost cutting was more strongly pushed, as was achieving better asset utilization and cash-flow management. An increased emphasis was also placed on making the company's various decision-making processes more explicit. Financial and market data was sub-

Figure 11 : Responsibilities of Ford-dispatched Directors
(Source : Based on Heller, 2003)

	1994	1995	1996	1997	1998	1999	2000	2001
President			Wallace	Wallace	Miller	Miller	Fields	Fields
Vice President	Wallace	Wallace		Miller				
Finance					Hexter	Hexter	Shanks	Shanks
Corporate Planning/ Strategy	Hexter	Hexter	Hexter (Shanks)	Hexter	Shanks	Shanks	Kent	Wolthers
Information Systems			Hexter					
Affiliated Companies					Hexter	Hexter	Shanks	Shanks
Product Planning/Strategy	Witschonke	Witschonke	Witschonke	Shanks	Leach	Leach	Martens	Martens
Cost Planning			(Shanks)	Hexter (Shanks)	Shanks (Kent)	Shanks (Kent)	Kent	Wolthers
R&D/ Technology Development	Witschonke	Witschonke	Witschonke					
Development Promotion/ Product Development					Leach	Leach	Martens	Martens
Program Managers					Leach	Leach		
Design					Leach	Leach	Martens	Martens
Purchasing				(Stokes)	(Stokes)	Stokes	Stokes	Stokes
Marketing		Leicht	Leicht	Leicht	Leicht	Fields	Thomas	Thomas
Sales/Parts			Leicht	Leicht	Leicht	Fields	Thomas	Thomas
Customer Service						Fields	Thomas	Thomas
North America					Beattie	Beattie	Beattie	
Europe						Bretebraten	Bretebraten	Bretebraten

Note : Parenthesis indicate assistant to director in charge of this function.

jected to more rigorous analysis, and there was also an attempt to utilize more comprehensive financial and market data when decisions were made. For example, financial control was increased in product development with the introduction of stricter enforcement of gateways concerning profitability estimates that had to be passed for development to continue.[4] Under the leadership of Ford's dispatchees, a comprehensive review of Mazda's resources and assets, research activities, and product development initiatives was undertaken.

The rotary engine was naturally included as one of the subjects for review, as were the Eunos Cosmo and RX-7, which as a result of the early 1990s were the only rotary engine vehicles Mazda was making. Sales of the Eunos Cosmo were never robust, with less than 9,000 manufactured over the six years it was in production. Sales of the RX-7 remained relatively robust through 1992, helped by a well-received model change in 1991.

Between 1989 to 1992, yearly production volume of the RX-7 ranged from a low of 16,000 to a high of 37,000 units. While this level was only about a third of the yearly volumes recorded by the car a decade earlier, it was still acceptable for a high-performance

4 See Taniguchi and Nobeoka (2003) for additional details.

sports car of relatively high price. However, as the effects of the bursting of the Japanese economic bubble rippled through the economy and worldwide demand for sports cars continued to decline, sales of the RX-7 soon plummeted. Yearly production volume of the vehicle fell below 7,000 in 1993, below 5,000 in 1996, and below 2,000 in 1998. Volumes of this level correspond to only a few hundred of the vehicles being produced a month.

In the face of the fallen demand for sports cars, it became increasingly difficult to justify large investments in the rotary engine, which was essentially an engine that seemed limited to use only in sports cars. This reality was accentuated within the strict data-based decision-making environment that Ford had introduced into Mazda's management processes. While the rotary engine and its development were long viewed as key touchstones by many within Mazda, this was not necessarily true for those who had only been closely associated with the company for a short period of time.

In particular, the Ford-dispatched leadership at Mazda had not been part of the building of the long and deep rotary engine tradition at Mazda. Nor had they experienced first hand the high volume sales of the RX-7, which sold much of its nearly 700,000 units manufactured through the late 1980s in the U.S. with a favorable yen-dollar exchange rate, making it a very profitable product line for Mazda. As a result, for these Ford-dispatched managers rotary-engine related development was simply viewed as one of many initiatives at Mazda that had to be reviewed.

Given this environment, the relative level of corporate resources (e.g., people, money, facilities, and equipment) at Mazda committed to rotary-engine related development began to fall in the 1990s. It reached the point where, officially, new development of the rotary engine was essentially frozen for much of 1996 and 1997. Two factors further compounded this trend of reduced resource allocation to rotary-engine development at Mazda.

First, there were the general cost-cutting efforts at Mazda that were implemented to restore Mazda to financial health as quickly as possible. Mazda's severe resource constraints in the early and mid-1990s forced the company to concentrate its available resources on those projects that had short projected turnarounds. Rotary engine related development generally did not meet this criterion. Since Mazda is essentially the sole manufacturer working on the rotary engine for use in automobile, the resulting technological progress on the engine therefore tends to be slower than for the reciprocating engine, which is produced by many firms that continually benchmark each other's products and by doing so keep abreast of any new technological advances.

The second factor contributing to a diminishing emphasis on the rotary engine at Mazda was the overall strategy of the larger Ford group, of which Mazda had become an integral part, at least since the mid-1990s.

Ford's global strategy underwent a significant reorientation in 1994. It was in this year that Ford launched a corporate-level initiative called "Ford 2000" that was intended to remake the company for the next millennium. The initiative sought to create an integrated worldwide enterprise out of Ford, which at the time was an entity generally characterized by relatively high levels of operational autonomy across regions and

functions. Among the broad-based efforts to reach this goal included increased coordination among the various automobile product-development organizations within the Ford group, which at the time consisted of Ford North America, Ford Europe, Mazda, Aston Martin (a premium luxury car manufacturer acquired by Ford in 1987), and Jaguar (a luxury car manufacturer acquired by Ford in 1989).

The primary goal of this inter-organizational coordination was achieving synergies. One important synergy target was increased commonization of vehicle parts and components across product line-ups, which would allow the Ford group as a whole to save on product development costs and achieve greater economies of scale in manufacturing and purchasing. A key reference point in this commonization strategy is what is generally referred to as a vehicle platform or architecture. Although precise definitions tend to differ by automaker, generally an automobile platform is said to consist basically of a vehicle underbody (e.g., suspension system, engine, transmission/transaxel, braking system, steering system, etc.) A platform determines the general performance characteristics of a vehicle, although there is room for fine-tuning the feel of a vehicle's dynamics within a platform's structure. Making platforms common across vehicles is generally perceived to be an efficient way of pursuing a parts-commonization strategy.

From the 1980s, even before the Ford 2000 initiative, Mazda and Ford were already pursuing in the Asian region an extreme form of the parts commonization strategy outlined above. Most of the relatively small volume of vehicles Ford sold in the Asian region were actually simply Mazda vehicles (with slight cosmetic alterations) that had been re-badged with a Ford emblem (**Figure 12**). Thus, for this limited subset of Ford-branded vehicles, virtually all parts were shared with their counterpart Mazda vehicles. Under Ford 2000, Ford sought to expand the range of vehicles within the Ford group that contained common parts to further reduce costs.

Under this umbrella strategy of the larger Ford group, expensive rotary-engine related development at Mazda received a very low priority. Such programs were unlikely to produce vehicles that would share many common parts with other Mazda vehicles or the vehicles of other Ford group brands. As Mazda grew progressively closer to Ford through the 1990s, the strength of this negative influence on rotary-engine related development at Mazda increased.

(2-8) Rebuilding the Mazda brand

While there is great pressure on automakers to pursue lower costs for mass-market vehicles, especially in the increasingly intense competitive environment of the world auto

Figure 12 : An example of a re-badged vehicle, the Ford Ixion (top), and its twin, the Mazda Premacy

(Source : Mazda Motor Corporation)

industry, it is not the only issue with which automakers must struggle. Another critical issue is achieving sufficient differentiation of an automaker's individual vehicle models, its entire vehicle lineup, and the overarching brand under which the vehicles are marketed, sold, and serviced. In fact, some argue that an automobile, with its high price and multi-faceted impacts on many areas of a person's life and lifestyle, is actually a product for which the differentiation vector, or the level of product integrity, is actually the single most important aspect that must be considered as an automobile is developed.[5]

Thus, as the Ford 2000 initiative evolved, in addition to efforts to lower costs and achieve greater integration across the Ford group, an initiative was also begun in the mid to late-1990s whereby Ford headquarters sought to define more clearly and actively manage the brands that made up its automobile portfolio. In conjunction with this effort, a process was begun at Mazda whereby Mazda's brand was carefully and thoroughly reviewed, with the aim of improving the product integrity of individual Mazda vehicles and the overall vehicle line-up.

① Mazda's brand identity

Brand-building efforts at Mazda began with an attempt to define the Mazda brand's current market-position and determine how the company would like the brand to be positioned in the world's major auto markets vis-à-vis other brands. The Senior Managing Director of Marketing at Mazda at the time was an executive who had been dispatched from Ford. Under him, two Ford-dispatched managers at Mazda headquarters worked as part of a large team of Mazda proper managers charged with pursuing this brand-based project. Mazda personnel in all three of the company's major markets of Japan, the U.S. and Europe worked on this project, and it was done in close cooperation with Mazda's Japanese advertising and research agency.

The team undertook a rigorous analysis of Mazda's corporate and brand heritage and its past and current brand positioning in the various markets. Results of the investigation revealed that the company's brand positions in its three main regional markets were actually quite similar. As such, the decision was made to unify them into one global brand strategy, as is outlined in the Mazda communication below.

In order to globally communicate Mazda's unique value, Mazda established a "World Wide Brand Positioning" (WWBP) in April 1998, as part of the overall brand management strategy. The WWBP incorporates the Brand Personality of "Stylish," "Insightful" and "Spirited;" and the Product attributes of "Distinctive Design,""Exceptional Functionality," and "Responsive Handling and Performance" to create the Mazda Brand DNA. Mazda's DNA is summed up in the new brand message "Zoom-Zoom (love of motion experienced as a child)," which is promoted in the major markets around the world.[6]

Mazda sought to make this brand philosophy the central theme of the entire company. As such, Mazda sought to re-orientate

5 Clark and Fujimoto (1990, 1991) contain additional discussion of this point.

6 The source of this quote is Mazda in Brief (November 2002), a public relations document released by Mazda Motor Corporation. The current edition of this document is available on Mazda's website 〈〈http://www.mazda.co.jp〉〉.

itself so that ultimately it would build and sell only those products that would support its brand positioning. For this to happen, Mazda's sales, marketing, and product development activities had to be closely integrated with its brand-development activities.

Introducing, diffusing, and solidifying this new orientation throughout the Mazda corporate entity and its sales and service affiliates qualifies as an attempt at large-scale organizational change, which is generally a difficult undertaking in any organization.[7] It was particularly so at Mazda due the company's longstanding tradition of its engineering and sales organizations having a relatively heavy weight in corporate decision-making. Further complicating the transition was what can be considered a winnowing of corporate aspirations that the brand reorientation required. For example, while the brand message above emphasizes the sporty aspects of the Mazda's tradition, which are rooted in the company's position as one of the largest produces of sports cars in the world, the message at the same time may be interpreted as de-emphasizing the longstanding "family car" tradition at Mazda.

As time passed Mazda's expression of this new brand philosophy could be seen in the new and refreshed products the company released. However, the combination of the relatively long lead times of product development in the auto industry and the amount of time generally required for large scale organizational change to occur, it was not until 2002 that products which fully incorporated Mazda's new brand orientation began to be

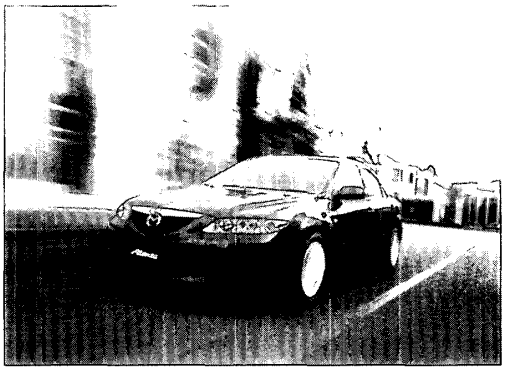

Figure 13 : Atenza/Mazda6
(Source : Mazda Motor Corporation)

released. The first of this new generation of vehicles was a C/D-segment passenger car, the Atenza/Mazda6 (**Figure 13**). This car and others that have followed have won numerous awards in markets around the world and have generally been well received by the public.[8]

② Strategy refinements at Ford headquarters

The initiative to rebuild the Mazda brand outlined above was initiated by the company's Ford-dispatched management. It was done in conjunction with efforts begun slightly earlier in the marketing section of Ford headquarters which sought to establish an overall brand strategy for the Ford group. The effort at Ford headquarters led to the development of the Ford Motor Company "trust mark," which displayed each of the Ford group brands along with each brand's "personality." In addition to the brands mentioned earlier, Ford acquired Volvo Cars in 1999 and Land Rover in 2000.The resulting make - up of marques under the Ford umbrella is such that among them they cover

7 See Beer and Nohria (2000) for discussion of the challenges of large-scale organizational change.

8 For example, the Atenza/Mazda6 placed second in voting for the 2003 European Car of the Year award and was selected as the 2003 RJC (the Automotive Researchers' & Journalists' Conference of Japan) Car of the Year.

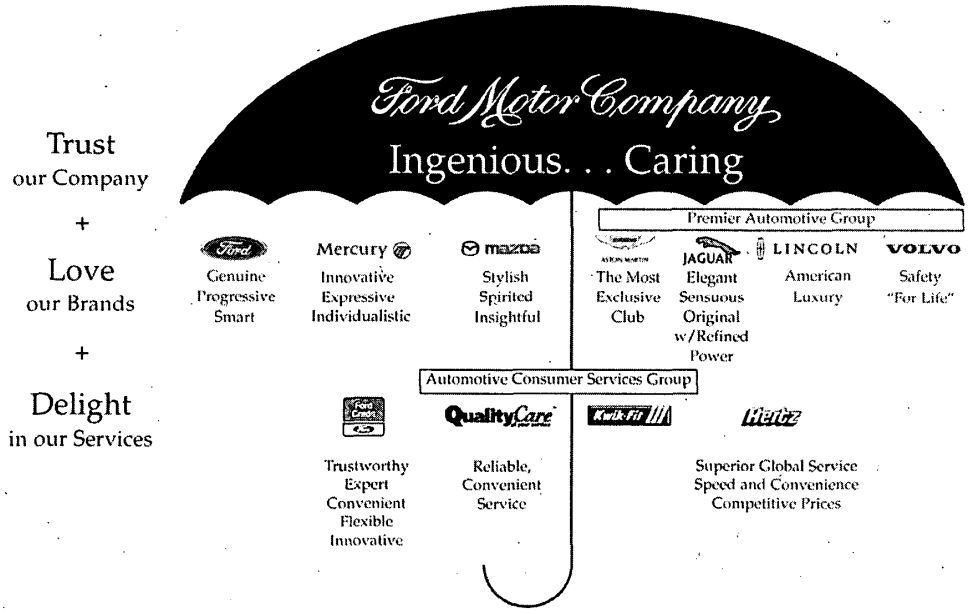

Figure 14 : Ford Motor Company "Trust Mark"
(Source : Ford Motor Company 1999 Annual Report, p. 7)

a wide of spectrum of many major auto markets, from import and domestic to mass-market and luxury brands (**Figure 14**).

The primary means for the Ford group to maintain a favorable broad market coverage by its brands, and at the same time minimize direct cannibalization among its vehicles, is to have products, product line-ups, and brands that are highly differentiated from each other. Achieving this level of differentiation in markets around the world thus became an increasingly important managerial goal at Ford headquarters during the late 1990s. In coordination with this push at Ford, the primary managerial focus at Mazda began to shift from the pursuit of product synergies with other brands in the Ford group to creating distinct styling and performance traits for specific Mazda vehicle models and for the entire line-up of vehicles as well as for the overall Mazda brand.

So, while platform and parts sharing was still to be pursued, the decision was made to seek as much as possible differentiation of whatever can be seen and felt by a consumer of Ford-group products. Likewise, the decision was made to reduce or eliminate the simple re-badging of extremely similar products. For example, from 2004 Ford dealers in Japan no longer sell any new re-badged Mazda vehicles. Recent vehicles that have common platforms among Ford group brands exhibit a much higher level of diversification both in their driving characteristics and appearance than previous re-baged vehicles. For example, in the C-segment Ford of Europe, Volvo, and Mazda used a common platform to develop three distinct vehicles that were released in late 2003 and 2004 (**Figure 15**).

As described previously, development of the rotary engine and its associated vehicles languished within the Mazda organization when one of the foremost managerial goals of the company's management was the pursuit of synergistic benefits between Mazda vehicles and other vehicles in the Ford group. In such an environment, very little of the com-

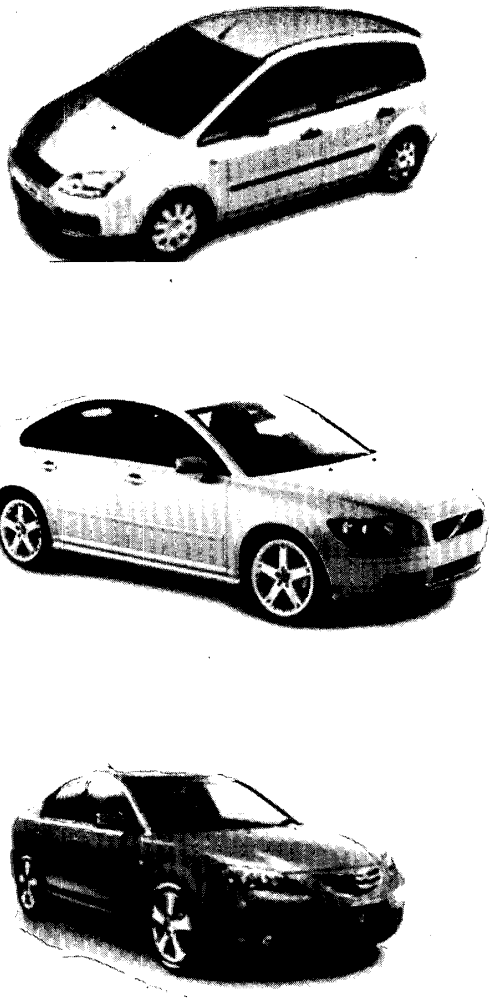

Figure 15 : Ford Focus C-Max, Volvo S40, Mazda 3/Axela (Source : Websites of Ford (UK), Volvo, and Mazda)

pany's scant available resources at the time could be channeled into Mazda-unique initiatives, such as the rotary engine. However, as the emphasis of Mazda's management began to shift from pursuing synergies to pursuing product and brand differentiation, the value of greater utilization of Mazda's position as the sole automaker producing the technically challenging and widely known rotary engine became increasingly difficult to dispute.

(2-9) Rotary redux

Mazda's severe resource constraints for much of the 1990s did not allow the company to pursue rotary engine development with the same vigor as it had in the past. Nevertheless, this period should not be viewed as "lost years." First, despite waning official support for rotary-engine development at Mazda, limited levels of "unofficial" support were allocated. In addition, fewer Mazda resources allocated for rotary development did not mean there was diminished interest in the engine at the company, including by at least two notable Ford-dispatched product-development specialists and bona fide "car guys" at Mazda, Martin Leach and Phil Martens. The passion of rotary engine enthusiasts both inside and outside of the company, in Japan and abroad, persisted throughout the 1990s.

As sports-car demand weakened in Japan and around the world, Mazda engineers and managers began to recognize, even in the early 1990s, some of the limits of their present vector for rotary-engine development. While doggedly pursuing incremental refinements to the engine technology, they also began to search for new ways of creating value for customers by making better use of the unique characteristics of the rotary engine in automobile development. This search for new directions had to be done without relying on increases in human and monetary investments. On the contrary, it faced a decreasing level of resource allocation as major investments in rotary engine development became increasingly difficult to justify. Yet the demands placed on rotary-engine developers were actually even greater than in the recent past.

The high-pressure corporate atmosphere that resulted, where at times even the fundamental reasons for continuing rotary engine development at all were questioned, tested

the creativity, determination, and hard work of Mazda's developers. Although upper management would commend them for achieving interim targets, the ultimate demand for a major break with current performance levels was not removed. Many times the engineers were told just to let rotary development die if they couldn't make additional progress. At the same time, they were reminded that their predecessors at Mazda had overcome the three major technological challenges in the 1960s and 1970s and had tasted the same crucible they were experiencing. The deeply rooted belief of these engineers in the high potential of the engine helped them carry on with their development work, as it had for previous generations of Mazda engineers.

① RENESIS engine

A major change in the structure of the rotary engine occurred in 1992. It was in this year that Mazda engineers succeeded in moving the exhaust port from the rotor housing to the side housing creating a "Side-Intake/Side-Exhaust System" (**Figure 16**). The change allowed for increases in port areas: 30% larger intake-port area providing better intake charging, and 100% larger exhaust-port area permitting later opening for better thermal efficiency and higher output. Moving the port to the side housing also allowed for the elimination of the overlapping of the exhaust and intake ports that had occurred in the traditional engine layout. As a result, with the new layout only minimal amounts of already burned residual gases go into the next engine cycle, improving combustion, especially during idling and light loads. These and other effects combine to enhance fuel efficiency, reduce emissions, and deliver higher output. As early as the 1960s, the change in exhaust-port location had been attempted but it could not be accomplished without unacceptably large performance sacrifices until 1992.

Throughout the 1990s, Mazda engineers continued to build on this new rotary-engine design. Efforts accelerated after Mazda's resource allocation to rotary engine related development began to increase from the late 1990s as preliminary work was begun on a new rotary-engine powered sports car at Mazda. The new generation of the rotary engine that began with the design change to the side-intake/side-exhaust system was later named the RENESIS—a combination of Rotary Engine and Genesis.

The current mass-produced version of the RENESIS has two rotors for a total displacement of 1308 cubic centimeters (654cc multiplied by 2). The engine contains numerous advances over the latest version of the previous generation of the mass-produced rotary engine that can be found in the third generation RX-7. The RENESIS is smaller, contains 40% fewer parts, and weighs 40kg less. The elimination of turbo charging contributes greatly to these reductions, as does

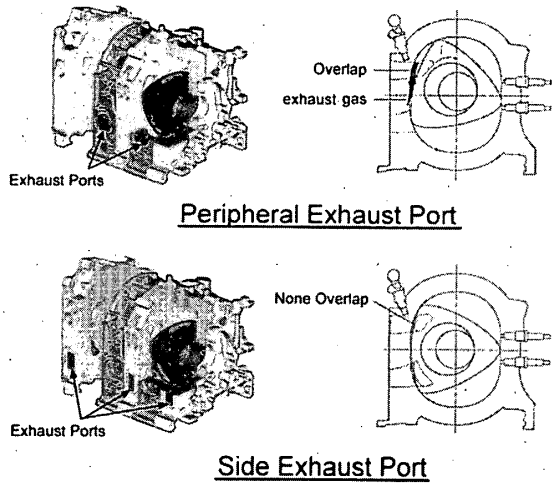

Figure 16 : Change in Exhaust-port Location
(Source : Tashima et al., 2003, p. 20)

increased use of plastics, more compact parts, and super-computer aided optimal placement of rib locations and determination of wall thicknesses. The weight of the RENESIS is comparable to that of a 4-cycliner reciprocating engine with an aluminum engine block, but its size is only 70% of the typical I4 engine.

Though the RENESIS is naturally aspirated, its maximum horsepower output of 250ps is greatly enhanced over the 160ps the RX-7 rotary engine could achieve before engaging its twin turbo charger. Numerous improvements in addition to those outlined above combine to give the RENESIS improved fuel economy of up to 20%, depending on driving conditions. Hydrocarbon emissions have also been reduced to as low as 10% of previous levels. In addition, the opening of the exhaust ports when the apex seals cross the ports has been made more gentle, making the engine's raw exhaust sound easier to tune. In 2003, a body of 50 motoring journalists from 22 countries voted the RENESIS as the coveted "International Engine of the Year" award winner.

Despite many modifications and improvements to the engine's design, Mazda was able to minimize new investment needed for its manufacture. The required new investment in manufacturing equipment was only one third of the amount that is typically required at Mazda to modify an engine production line to produce a new engine. This dramatic reduction was achieved by the creative melding of modern and traditional manufacturing techniques on the line. The line makes good use of the highly skilled craftsmanship of Mazda manufacturing personnel, most notably in the part of the line referred to as the "RE Workshop" where the main assembly of the engine is performed.

② RX-8

The vehicle that would ultimately be powered by the RENESIS emerged over a long process. Its technical roots can be found in the RX-01, a sports car that was displayed by Mazda at the 1995 Tokyo Motor Show (**Figure 17**). The two-door sports car illustrated the directions Mazda sought to pursue with its new rotary-engine-vehicle develop ment. The concept car pushed traditional RX-7 characteristics even further, such as with a lower-slung nose, a further pushed back engine placement (later termed "Advanced Front-Midship"), and a lower engine placement for a lower center of gravity. The vehicle also had the advanced safety feature of a crash zone between the hood and the engine made possible by the RENESIS engine's compactness. However, the combination of the continued depressed state of the sports car market and Mazda's financial difficulties prevented the RX-01 from being approved to go forward to a production version. The addition of still more new value was necessary to clear the remaining hurdles to commercialization.

A major breakthrough began to emerge when vehicle planning decided to look into the feasibility of Mazda's next rotary-engine sports car having four doors. While the auto market has seen many sporty four-door sedans, there has never been a true sports car

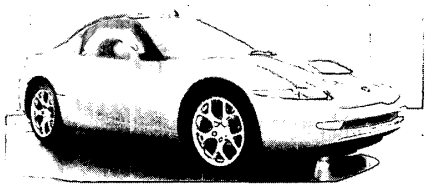

Figure 17 : RX-01
(Source : Tohda and Nakamura, 2003, p. 51)

that has four doors. Mazda's formal attempt at just such a four-door/four-person sports car was a concept car called the RX-EVOLV, which was shown at the 1999 Tokyo Motor Show. The vehicle's very favorable reception by the press and public contributed to its being given managerial approval to continue to be developed.

Many challenges had to be overcome to reconcile the conflicts between the developmental demands of a sports car and those of a four-door/four-person passenger car. A sports car needs to have a high-output engine, a low center of gravity, minimal yaw moment of inertia, a low overall vehicle weight, a rigid body, etc. A passenger car on the other hand needs generous interior space for good leg and headroom, a spacious trunk, easy access to the back seats, etc.

The final outcome of Mazda's efforts to marry a sports car and a passenger car is the RX-8 (**Figure 18**), which was released in 2003 and which is based closely on the RX-EVOLV. Although the RX-8 is 27.5 cm longer than the RX-7, its yaw inertia moment is 5% lower. This could be accomplished by reducing engine/driver distance due to the design of the RENESIS. The engine's design also allowed the car to have a lower center of gravity. The trunk of the RX-8 has a capacity of 290 liters, enough for two large suitcases. The rear doors open "freestyle," that is, on rear hinges, allowing easy access to the rear seats, while keeping the vehicle's body shorter. Numerous technological innovations allowed body rigidity to be increased even though there is no pillar between the front and rear doors. A new suspension system was developed to achieve simultaneously sports car dynamics and passenger comfort. Since the RX-8 began to be sold in 2003, sales have been brisk both in Japan and abroad, and it has been well received by the press. It received the 2004 RJC Car of the Year Award in Japan, among other distinctions.

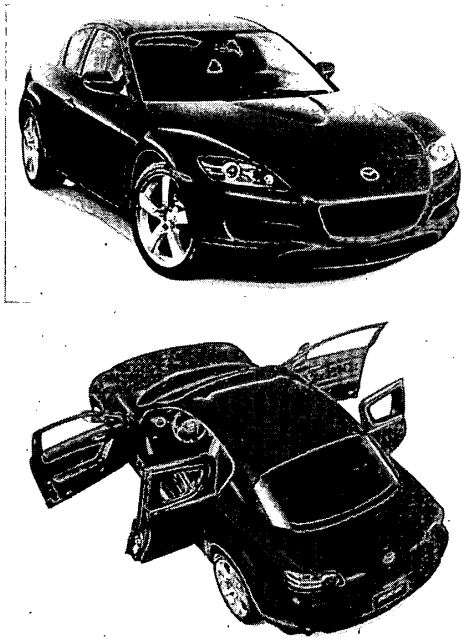

Figure 18: RX-8
(Source: Katabuchi Doi, 2003, p. 40 (front); Moriyama et al., 2003, p. 64 (open doors))

(2-10) Future prospects

The search for new directions in rotary-engine development led to the development by the early 1990s of a rotary engine that works equally well with hydrogen as with gasoline. In fact, the rotary engine is better suited for hydrogen than the reciprocating engine. In the rotary engine, the intake of the fuel/air mixture occurs in a different area from where ignition, compression, and exhaust occurs (**Figure 19**). This creates a cold zone and a hot zone within the engine. In contrast, in a reciprocating engine the same cylinder is used for intake/compression/ignition/exhaust, which keeps the whole area at a high temperature. While this difference is not an issue for engines powered by gasoline,

it becomes one when hydrogen is used, since hydrogen will ignite at a lower temperature than gasoline. In a hot reciprocating engine, the hydrogen may ignite prematurely at injection or compression, that is, before the spark plug fires. To prevent this, a reciprocating engine that is using hydrogen as fuel must be cooled down after each cycle, a technologically difficult and inherently wasteful process that is not needed in a rotary engine.

If the infrastructure issues of hydrogen fuel production, storage, and delivery begin to be resolved, the value of the rotary engine as an environmentally friendly alternative can be expected to increase.

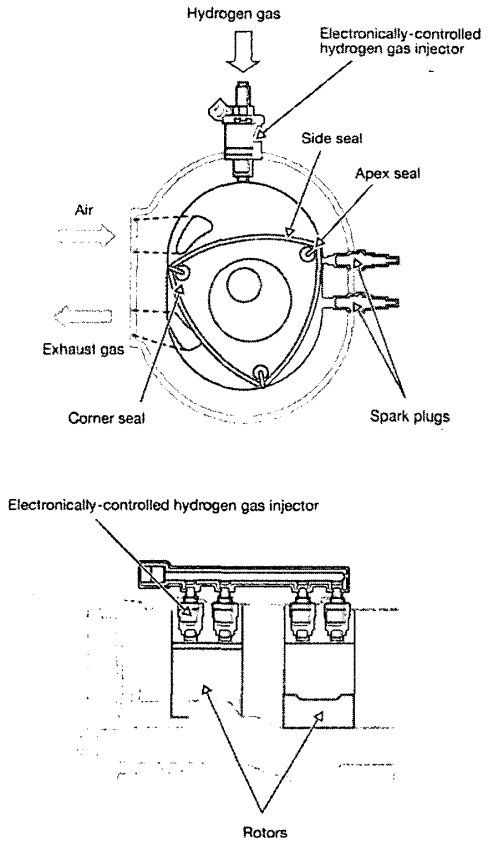

Figure 19 : RENESIS Hydrogen Rotary Engine (Source : Mazda Motor Corporation, The 37th Tokyo Motor Show Press Information)

3. Concluding Remarks

After licensing the basic technology of the rotary engine, Mazda was able to commercialize it successfully only after engaging in intense internal engineering efforts. Overcoming the subsequent environmental, market, and technological challenges faced by the engine in the 1970s also required Mazda to push its developmental capabilities. The vector of rotary engine related development reached a dead end in the 1990s, however; and it was not until additional value was somehow introduced that the RENESIS and RX-8 could be produced. The factors that synchronized to allow this new added-value to emerge are summarized below.

As the emphasis of Ford-group strategy began to shift toward increased brand differentiation, Mazda committed itself to delivering products that supported a sporty brand-message in the late 1990s. By this time, development of the next-generation rotary engine had reached an advanced enough state that it justified the additional resource commitment needed to pursue the potential worth that a car designed around the rotary engine might have in marrying the technical prerequisites of a sports car with the market-size merits of a passenger car. In this way at the close of the 20th century, by combining the advantages of the rotary engine with the new concept of a four-door/four-person true sports car, Mazda's rotary-engine development was brought into alignment with Mazda's managerial goals.

By creating a sports car that can also serve as a passenger car, Mazda's family-car heritage could be successfully melded into its sporty brand-message. Thus, Mazda is able to deliver its sporty message to consumers in a way that is different from other automa-

kers. As such, the company has created a means of product and brand differentiation that is only available to Mazda. Freelance automotive writer, Jack Yamaguchi, described the RX-8, as follows.

> The RX-8 does not have competitors. It is unique. Not only for its rotary package. There are many 2+2s with barely usable emergency rear seats, requiring acrobatic talents for ingress and egress. But the RX-8 seats four adults in comfort, with sufficient head and leg room and easier access to the rear compartment than in most middle-size four-door sedans, all within the length of a Porsche 911.[9]

While there was no direct involvement of Ford in the actual day-to-day development work of the RENESIS engine and generally only high-level managerial guidance in the development work of the RX-8, Ford did play an important role in their development at Mazda. First, Ford's financial support of Mazda seems to have been one factor that allowed Mazda to continue to exist in its present form. In addition, executives who had been dispatched from Ford to work at Mazda applied relentless pressure on rotary-engine developers at Mazda to meet very high technical and commercial targets, even in the face of exceedingly tight resource constraints. Mazda developers had to rely on their own determination, creativity, and hard work to overcome these challenges, very much in the spirit of the rotary-engine developers who had come before them.

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This case was prepared for the purpose of stimulating class discussion. It should not be interpreted as an evaluation of the managerial decisions depicted herein.

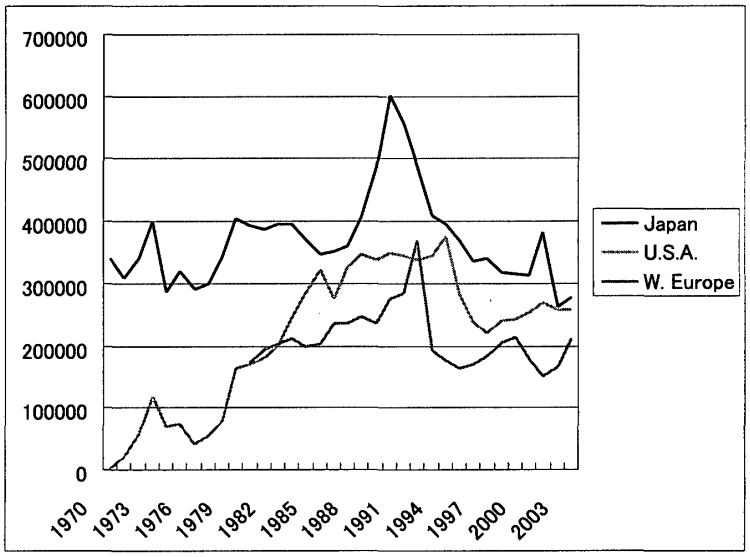
[Journal of Economics & Business Administration], 187(3):1-17 (in Japanese).

Tashima, S., Shimizu, R., Koto, H., Ebino, H., Okazaki, S., and S. Ueki (2003) "Side Exhaust Port Rotary Engine," *Mazda Technical Review*, 21:18-23 (in Japanese).

Tohda, I. and Y. Nakamura, (2003) "Package of RX-8," *Mazda Technical Review*, 21:49 - 55 (in Japanese).

5. Reference Exhibits

Exhibit 1 : Mazda's Vehicle Sales in Japan, U.S., and Western Europe
(Sources : Mazda Motor Corporation and yearly editions of Ward's Automotive Yearbooks, *Jidousha Toukei Nenpou*, and *Jidousha Nenkan*)



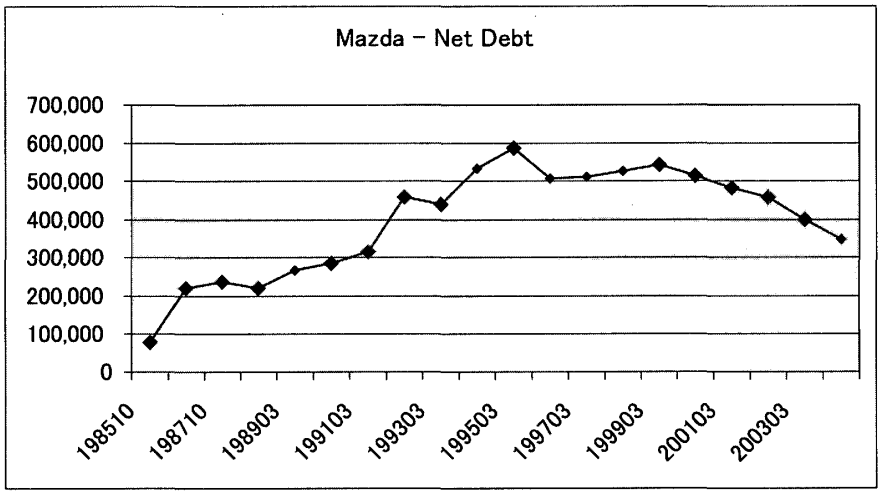
Note : Years are January to December; Data for Japan is new vehicle registrations and includes micro vehicles (*kei*) ; Data for Western Europe is for new vehicle registrations and was unavailable prior to 1983; Data for the U.S. is for light vehicle sales and Mazda's sales in the 1970s and 1980s do not include the Ford Courier pickup truck, which was build by Mazda but sold in the U.S. by Ford

Exhibit 2 : Production Units of Rotary-Engine Vehicles by Model

	110S (Cosmo Sport)	R110 (Familia)	R130 Coupe/RX-4 (Luce)	RX-2 (Capella)	RX-3 (Savanna)	Rotary Pickup	Parkway (Small Bus)	Roadpacer	RX-5 (Cosmo)	RX-7	Eunos Cosmo	RX-8	Total
1967	343												343
1968	172	6,925											7,097
1969	159	28,041	542										28,742
1970	258	31,238	431	34,242									66,169
1971	126	21,907	3	63,389	33,004								118,429
1972	118	5,720	10,903	58,433	79,719								154,893
1973		2,060	77,028	54,962	105,819	2							239,871
1974			66,998	7,656	29,678	14,364	18						118,714
1975			41,668	5,960	26,236	113	18	491	12,014				86,500
1976			13,284	553	9,825	632	8	183	43,792				68,277
1977			13,480	253	1,606	1,161		126	25,273				41,899
1978			6,484	240					1,561	72,692			80,977
1979			5,705						5,896	71,617			83,218
1980			4,213						1,108	56,317			61,638
1981			2,292						2,785	55,321			60,398
1982			2,046						4,170	59,686			65,902
1983			1,402						3,026	57,864			62,292
1984			1,349						3,477	63,959			68,785
1985			506						1,062	63,105			64,673
1986			2,533						265	72,760			75,558
1987			633						60	52,204			52,897
1988			1,048						22	34,592			35,662
1989			395						8	37,624			38,027
1990			318							29,411	4,325		34,054
1991										16,623	1,700		18,323
1992										26,899	1,373		28,272
1993										6,801	711		7,512
1994										5,962	435		6,397
1995										5,202	331		5,533
1996										4,762			4,762
1997										3,556			3,556
1998										1,423			1,423
1999										4,151			4,151
2000										2,611			2,611
2001										2,589			2,589
2002										3,903			3,903
2003												60,100	60,100
2004												50,813	50,813
Total	1,176	95,891	253,261	225,688	285,887	16,272	44	800	104,519	811,634	8,875	110,913	1,914,960

(Source : Mazda Motor Corporation and Rotary Engine Press Information 2003)

Exhibit 3



(Unit : million yen; Source : Datastream)