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The changing role of the automotive supplier

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The Changing Role of the Automotive Supplier

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Abstract

As automobiles become more complex, the Big Three auto makers are turning to suppliers for the engineering and manufacturing of components. But rather then just supplying parts, suppliers will soon be asked to design and manufacture whole modular assemblies, such as wired and painted doors, which are ready for final assembly.

In the past, modular assembly has failed. It has caused both suppliers and car companies to go out of business. Single source suppliers have in the past evolved into fat and inefficient manufacturers. At the same time, modular design pushes much of the value-added work (profit) out of the assembly plant and into the shop where the modular construction is taking place. Despite this, the relationships of the past are being entered into once again, with the hope that new agreements giving both suppliers and automakers more ownership of the risks and rewards will prevent history from repeating itself.

In the past few years suppliers have provided the automakers with some brilliant innovations, such as air bags, anti-lock brakes, and ready to assemble plastic body panels. However, at the same time they have been developing specialized areas

of expertise that the automakers depend on, yet would be hard pressed to duplicate.

Thus, the automakers are again at the mercy of their suppliers.

Complicating matters is the threat United States suppliers face from Japanese competition. As these suppliers suffer lost market share and smaller (or non-existent) profits, so too will the automakers suffer.

The only hope for a sustained healthy United States automotive industry is for this trend of modular outsourcing to be reversed. The automakers must bring back in-house design, manufacturing, and development of technologies. Otherwise, the United States automobile industry will slowly evolve into nothing more then a sales and marketing enterprise selling others' products.

Introduction

There is a new type of relationship developing between the automakers and their suppliers.

Vehicles are becoming much more complex. They have sophisticated electronic systems which effect the whole manner automobiles are designed and assembled. They are made of new materials, and are assembled using processes developed to take advantage of these materials.

These new complexities and technologies have lead to a new type of relationship between the automakers and their suppliers. Suppliers are becoming system integrators, bringing together different technologies to provide packaged solutions. Where in the past a supplier might manufacture just a door panel, today that same supplier may be expected to supply a completed door assembly with electrical and mechanical subassemblies already installed. The door would be painted and trimmed, and have an electrical plug that mates with the primary wiring harness. This trend has forced suppliers to move into technologies beyond their former areas of expertise, taking over many of the tasks previously performed by the automakers. It is becoming common for suppliers to be given a functional specification of a part, from which they will design the actual component [1].

The automakers have found that in order to win the trust of their suppliers, and to get the suppliers to develop expensive research and development capabilities, they have had to make a long term commitment to them. This has led to the frequent single sourcing of components from suppliers. As the assembly plants move towards JIT (Just In Time) deliveries, the number of suppliers are being reduced. In order to win new contracts, suppliers must provide a quality product at the right time. The suppliers that evolve to JIT must change radically the way they schedule, ship, and package their products.

Suppliers are starting to provide assemblies that are integrated packages ready for the assembly line. These modular build packages frequently require technologies or components outside the supplier's area of expertise. Suppliers are buying these components from outside sources and assembling them into their products. This has had the effect of off-loading some of the assembly work from the assembly plants to the component suppliers, and has given these first tier suppliers the choice of lower tier suppliers from which to source these sub-subassemblies [2].

General Motors Corporation's APV minivan, built in Tarrytown, New York, is examined as one of the examples of the new supplier-automaker relationship.

Because of General Motor's wish to get this new product to market very quickly, along with a lack of experience with the APV's many new technologies, GM choose to use outside suppliers for most of the research and engineering work.

The APV contains more polymers then any production vehicle ever before. Instead of developing this new plastics technology themselves in-house, General Motors relied on suppliers to do this development work for them.

Outside suppliers provided the project with very high levels of materials, tools, and services. Not since the earliest days of automobile production has an automaker relied so heavily on suppliers.

This supplier relationship puts the Tarrytown plant at great risk that one supplier's shortages could shut down the plant. The quality goals set for the APV have made the production startup very difficult [3].

Five suppliers to the GM Tarrytown plant are examined in detail, showing the large degree of early supplier involvement, supplier design and capitol investment, Just-In-Time parts sequencing, and emphasis on quality.

There are many changes that must take place in order to manage these changing business relationships. As automotive manufacturers become more dependent on their suppliers, the managing of these suppliers is becoming increasingly critical.

In the past engineers usually chose suppliers based on technical decisions. These engineers were more interested in the functionality of components rather then the their overall cost. Many times, purchasing responsibilities were left to buyers who did not have a sufficient technical understanding of what they were buying, and who counted on their suppliers to provide the most technically appropriate components [4].

The automakers have begun to have experts from various departments and functions work together as a group to choose suppliers. These people are chosen to select suppliers because they know what to look for.

Because suppliers are now investing heavily in research and development for products they may not get to actually manufacture, suppliers are beginning to sell their design services on a contract basis before work is begun. Many times, automakers will buy a design and then have a different supplier manufacture the part.

Outsourcing gives the tier-one suppliers more freedom in choosing sub-suppliers. This means that suppliers are now taking on the role that was formally performed by the automakers' purchasing departments. Suppliers must also assume responsibility for most of the engineering tasks that were once done by the automakers.

One major reason that the automakers are so willing to transfer the design and development responsibilities to suppliers is the current corporate focus on short term earnings. Many times, work is outsourced to minimize long term investments in research and development. The heavy reliance on suppliers seems very attractive to automakers when viewed in the short term. However, over a longer period of time it is shown that this relationship can make the automakers too reliant on their suppliers, and that they will therefore become vulnerable to their suppliers' problems.

American automakers are relying more heavily on their suppliers for new technology. As the automakers shrink their in-house research and development groups, and fail to develop in-house experts on new technologies, suppliers will be expected to provide more innovation and develop technologies themselves.

American suppliers, and therefore the entire American automobile industry, are being damaged by Japanese transplants and their suppliers. High value added suppliers for these transplants are mostly Japanese [5].

As the Big Three market share drops, the American supplier base is also losing market share. The automakers are running the risk of having access to only second generation technology by becoming fully dependent on its shrinking American supplier base [6].

This increased reliance on suppliers puts the automakers in a very dangerous position. By depending on suppliers, they lose control of their own products. They lose valuable value-added manufacturing, and are at the mercy of suppliers whose own technologies they depend on.

In order to assure their own survival, the automakers must bring back in-house the modular components that they have outsourced.

Chpt 1: The Changing Role of Automotive Suppliers

Component complexity increasing

New cars today are much more complex than they were just a few years ago. Cars today have very sophisticated electronic systems which control the vehicle and its many 'systems'. These electronics have greatly complicated the way automobiles are designed and assembled. They are made of new materials that have been especially engineered for automobiles, and are assembled using new processes developed to take full advantage of the special properties of these materials.

It is obvious that electronics are playing a rapidly expanding role in automotive design, manufacture, and operation. In addition to the sophisticated CAD/CAM equipment used to design and manufacture a vehicle, automotive suppliers and manufacturers must contend with the demand for computer-based service diagnostic centers, improved environmental controls, safety, and performance.

All of these factors have mandated a myriad of in-vehicle electronics. Some experts predict that electronics will account for 15 percent of the cost of the automobile by the mid-1990's and 20 percent by the year 2000. One of the high-cost items in building and servicing vehicles is the electrical wiring. Wiring of varying length and diameter form the interconnection link between each electrical/electronic component in the vehicle. Virtually the entire electrical wiring for a car is made up in the form of a complex, expensive cable assembly called a harness. Building and installing the harness requires manual assembly and is time consuming. The increased use of electrical and electronic devices has significantly increased the number of wires in the harness. Even today, the average American luxury car has over 5,000 feet of copper wire to connect existing electronic and electric devices [7].

Today's extremely complex wiring harnesses also typically contain several microprocessors and interlinked "systems". Examples of these systems are anti-lock brakes and traction control. These complex harnesses are custom built for the larger luxury cars. The makeup of a harness is determined by what electrical options are specified. This requires much early planning between suppliers and harness manufacturers to make sure that a car's wiring can accommodate all necessary electrical components. This custom wiring harness creates a real logistical problem at the assembly plants.

When coiled for assembly, all harnesses look the same. The solution has been for suppliers to sequence their harnesses so that they arrive at the assembly plant in the proper sequence according to the factory's build plan [8].

Components becoming systems

The nature of electronics is changing from independent subsystems to interrelated control systems. An important difference between future electronic systems and present electronic systems, even those performing a similar function, is the supplier integrated systems approach that will be used by vehicle manufacturers.

The car of the future will have a number of multifunctional microprocessors, all linked together to share information. To accommodate these microprocessors, General Motors has allocated the area under the deck, behind the back seat, as the location for all control modules [9].

Examples of Conventional Vehicle Systems:

- o Fan Control
- o Lamp Controls
- o Power Windows
- o Power Door Locks

Examples of Supplier Integrated Systems:

- o Fuel Injection
- o Anti-lock Brakes
- o Electronic Transmission Control

o Ride Control

Some of these systems, such as cruise control and wheel slip control, have evolved from being purely mechanical and independently functioning options to highly integrated, electronically controlled systems. Others, such as Anti-Lock Brakes, Self-Diagnostics, and Automotive Navigation systems, are made possible for the first time by new advances in automotive electronics, and are still not available on most cars.

Each of these "systems" integrates features and functions via electronic feedback and control. They require the designer, manufacturer, and supplier to understand and plan for the interactions of seemingly separate items, for example cruise control and the limited-slip drive axle. Both cruise control and the limited slip drive axle control function in part by controlling the engine speed. They do this by sharing common sensors and actuators. In the future, both of these tasks will be performed by a single, multifunction microprocessor. But today, slip control is a system typically designed and built using more than one independent supplier, each one requiring coordination to properly manage the development of the system as a whole.

Suppliers designing systems

The future of automotive electronic development is evolving towards a totally integrated vehicle electrical and electronic system. Suppliers will escape from the mechanical function replacement and "add-on" approaches of the past. They will seek to optimize the performance of the total vehicle through electronics. The total system will have great flexibility and adaptability, with extensive software control of multi-function features. This will offer customers new opportunities to customize their vehicle. Vehicle characteristics such as ride quality, handling, steering effort feedback, brake feel, information display format, and engine power versus economy tradeoffs will be controlled by the driver.

Operating as an information based system, the automobile's on-board electronics will use extensive computing capacity, multiplexed circuit technology, and extremely large amounts of program memory.

Examples of these features include multi-purpose touch screen displays and speed control integrated with engine control. These examples represent only the leading edge in integration of functions. This change will completely alter the future role of electronics suppliers.

The first generation of new supplier designed and manufactured electrical-electronic systems such as anti-lock braking systems and multiplex wiring are present mostly in luxury vehicles. Other systems, still in the concept or early development stage, will require electronic components beyond the level used in present vehicles. In order for these systems to be implemented in lower cost production vehicles, cost reductions will be required. New electronics technology which integrates both control and power promises to play a substantial role in cost reduction and is the key to making the transition from concept to volume production for future electronic systems. In addition, these power devices will provide space and weight savings, increased reliability, as well as offer diagnostic capability. Other areas of electronics will also require improvement, such as increased microprocessor speed, increased memory, advanced sensing, and improved packaging techniques. The combination of new power technologies and these other electronic advances will enable automotive electronics suppliers to design future electronic systems [10].

New engineered materials and adhesives are replacing stamped metal and welding. Suppliers are now able to manufacture whole body panels that are pre-painted and ready for assembly. These panels can then be glued onto the automobile frame, instead of being welded [10].

This new level of complexity and advanced technology has lead to a new type of relationship between the automakers and their suppliers. Suppliers are becoming system integrators, bringing together different technologies to provide packaged solutions. Where in the past a supplier might manufacture just a door panel, today that same supplier may be expected to supply a completed door assembly with electrical and mechanical subassemblies already installed. The door would be painted and trimmed, and have an electrical plug that mates with the primary wiring harness. This trend has forced suppliers to move into technologies beyond their former area of expertise. These suppliers are developing their own research and development groups, and are becoming true design partners with their customers. It is also becoming common for suppliers to be given nothing more than a functional specification of a part, from which they will design the actual component [1].

Parts outsourcing

The relationship between suppliers and automakers has come almost full circle since the first days of the mass produced car. The early automakers were essentially designers, assemblers, and marketers of cars. Having perfected their prototype, they would farm out the manufacture of its parts.

As volumes increased, and the automakers were better able to manage the 'buy or build' decision using the new techniques of cost accounting, automakers brought back in-house those manufacturing tasks that they could perform at a profit.
Automakers became more vertically integrated, manufacturing as many components as possible.

Perhaps the best example of this vertical integration was Ford's River Rouge plant. River Rouge, a two thousand acre facility, became one of the most highly vertically integrated automobile factories of all time with a manufacturing operation so complete it was virtually self-sufficient. It had a deepwater port, a thirty thousand-kilowatt power plant, the world's largest foundry, machines to machine all castings produced, and even purchased the Detroit, Toledo and Ironton Railroad, which meant that it could supply itself with adequate supplies of coal, iron ore, and wood by both water and rail. Ford had its own navy of ships to move raw materials from its own forests and mines to River Rouge [11]. Ford even had its own rubber plantations in the Amazon jungle [12]. Ford created what has been called an "industrial colossus".

However, despite this almost total vertical integration, Ford's engineering department (not purchasing) kept very close track of the cost of components available from outside suppliers. In the process, despite the increasing integration of the Rouge, Ford's engineers came to the unpleasant realization that in many instances "going outside" could be profitable [13].

An earlier example of this was the changing relationship between Henry Ford and the Dodge Brothers. Dodge provided Ford with engines, transmissions, and chassis for the first Model A cars. Around 1905, Ford brought the engine and chassis back in house to save money. Over time, however, much of the work was again farmed out. For many years the Briggs Body company supplied car bodies to Ford. What is significant about this relationship, as well as later outsourcing at the Rouge, is that while Ford alternated between outsourcing and in-house manufacturing, they always had total control of design [14].

Up until the early 1950's Briggs Manufacturing was a major supplier of bodies, doors, deck lids, and hoods to both Ford and Chrysler. Briggs not only made the stampings for these parts, they also did the design. Chrysler became very much locked into Briggs and for all practical purposes Briggs became a single source supplier. There was no competition, consequently there was no incentive to control costs and all increases were merely passed on to Chrysler.

The relationship between Briggs Manufacturing and Chrysler developed such that Chrysler found itself a prisoner to Briggs pricing decisions, and Chrysler was unable to control costs.

In 1954, Chrysler found it had no choice but to purchase Briggs in order to get its costs under control. The physical assets of the purchase included three plants, all of which were antiquated because Briggs had no incentive to keep them efficient. Today none of these facilities exist [13].

After Briggs was purchased by Chrysler, Ford shifted its major body panel work to the Budd Company of Philadelphia. Budd at one time built all the truck bodies for Ford. Ford would have liked to have bought Budd, but Budd was too big and diversified at the time. Budd was eventually purchased by a German company, but not before Ford had already been forced to pull all of its truck body operations in-house [17].

The same type of relationship existed between General Motors and Fisher Body. Fisher Body was purchased by General Motors in the 1920's, and operated as a wholely owned subsidiary. The motto for years was cars by GM, body by Fisher [14].

A more recent example of single source problems occurred with TRW's subsidiary that provides the firing mechanism to inflate airbags. This vendor is the sole American producer of propellent packs to inflate airbags, and is a second tier supplier to other companies such as Bendix. The manufacturing process to produce this propellent is very hazardous, and through poor safety practices this supplier suffered two fatal explosions that devastated the manufacturing plant. This caused a severe shortage of propellent packs, which forced Chrysler, which had been putting air bags in all its cars, to quickly retool for and purchase conventional seat belts [15].

Ford was also affected, and has postponed indefinitely the installation of passenger side air bags on its Lincolns [16].

Today, 5,000 or 6,000 of the approximately 13,000 parts that go into every car produced by Detroit's Big Three carmakers, Ford, Chrysler, and General Motors, are produced by independent outside manufacturers [14]. Shorter lead times, increasingly complex component systems, and the high costs of internal research and development, have made it no longer practical, or even possible, for automobile manufacturers to design and manufacture all the individual components and systems that make up an automobile.

Shrinking product development times and increasingly complex technology are forcing automakers to ask suppliers to do more design and engineering than ever before.

When deciding which manufacturing and design projects should be sent outside to vendors, the automakers are trying to keep high volume components in-house when ever possible. These are the components where the traditional economy of scale yields the most profit, and where they can most easily recover their research and development investments.

Low-volume components, or components that are made by suppliers that are recognized as experts in their field, are perfect candidates for outsourcing. Examples of successful outsourcing using supplier expertise are the Navistar and

Cummings diesel engines that Ford and Dodge are using in their 1990 pickup trucks [17]. Neither Ford nor Dodge currently makes a small diesel engine of their own, and the capital costs of getting into this business are so great that neither automaker has any interest in doing so.

Automakers will keep anything that determines the character of a vehicle in-house whenever possible. While the actual part may be engineered and manufactured outside, the automakers work hard to define the required "feel" for the supplier. A good example of this type of situation is the pedal feel on a brake system. The concept of how brakes work is straight forward. It is a simple force-versus-travel curve. But the right "feel" for one car may be totally different than that for another. A luxury car like a Cadillac, for example, is expected to have different handling characteristics than a sporty car like a Corvette. Defining such intangible requirements is becoming more difficult as the systems that create these characteristics become more complex. ABS brakes and active suspensions are two examples of where this has already been a problem [23].

Single source suppliers

The automakers have found that in order to win the trust of their suppliers, and to get the suppliers to develop expensive research and development capabilities, they have had to make a long term commitment to them. GM has implemented a comprehensive vendor certification program where once a vendor is evaluated and certified, they are frequently awarded a single-source supplier contract. While this has obvious benefits for the vendor, it also greatly reduces the administrative expenses of tracking multiple vendors, scheduling parts from different suppliers, etc.

Single sourcing is the trend today, but it must be a very carefully managed relationship in order to be successful. Pitting supplier against supplier in order to achieve the lowest possible price is now considered short sighted thinking. However, the previous examples illustrate that without competition, or some equally effective means of motivation, suppliers have no incentive to keep their facilities modern and their prices competitive.

Parts suppliers as system integrators

The complex electrical and mechanical systems in today's automobiles are the result of years of expensive research and development. Some of these systems were made possible through innovative materials and manufacturing processes which were developed by suppliers. Many of these developments are the result of joint ventures between the automakers and suppliers, or between suppliers and second tier vendors of their own choice.

The automakers have been increasing their percentage of outsourced materials, tools, and services for some time. Parts suppliers, both allied and non-allied, have been expected to take increasing responsibility for system integration, design, and research and development. This trend has yielded two results; that of shortening the time it takes new models to go into production (lead time), and the short term reduction of design costs. This has been accomplished primarily by utilizing the smaller and more efficient expertise among supplier research and development groups. There is a growing trend to give potential suppliers only functional specifications for parts or services to be bid on. Thus, vendors are being asked to engineer a solution, rather than simply supply a product or service [18].

Automobile manufacturers are relying more and more on suppliers to provide packaged systems that perform a specified function, instead of supplying "build to print" products. The "build to print" suppliers are becoming second or third tier suppliers. It is becoming more common for first tier suppliers to do most or all of the design work. This design work has historically been an enormously expensive task when done in-house by the automaker.

Suppliers are increasingly developing in-house research and development groups as weapons against competition from other suppliers, each attempting to become "the expert" in a chosen niche.

As Japanese transplants capture more and more of the American market share, parts suppliers are finding that research and development capabilities are essential for earning transplant business. Tetsuo Arakawa, executive VP of Nissan Motor Co., made the following comment in Automotive Industries magazine on American parts suppliers: "The biggest problem we find with US parts manufacturers is their lack of research and development capabilities. At Nissan, we tend to want to involve parts suppliers at the initial stages in the design of a new car. We find that hard to do in the United States. If we ask 'can you have this part by next year,' we find very few say 'yes' [19]."

Increased accountability for quality

All the automakers have become very serious about shipping quality products. An example of putting quality above all else is the way General Motors started up the Tarrytown plant for the production of the APV minivan. The start of production was delayed months, and the line speed halved, until assembly quality problems were fixed. The line still runs below its designed speed. The slowing of a new production line, by choice, is a very strong message from upper management. This same strong message about quality is being sent to General Motor's supplier network.

Suppliers are being forced to increase quality, and the single source supplier base has helped. Assembly plants in the past have used large supplier bases as leverage to negotiate short term contracts solely on cost. However, quality has been found to almost always increase as a result of a single-source vendor relationship, as the vendor is no longer forced to sacrifice quality to be just a little less expensive than the competition. It is not uncommon for contracts to be awarded to suppliers who are not the low cost bidders because they have proven to be the most competent supplier when measured by quality and schedule conformance.

Suppliers are expected to increase their product quality continually, while at the same time reducing costs.

Suppliers are finding themselves closely scrutinized by the automakers, who are demanding more input into how suppliers run their businesses. IBM is notorious for trying to manage their suppliers. This is the type of controlling relationship the automakers would like to have with their suppliers.

Just-In-Time

Automakers are well aware of the lower inventory carrying costs and improved quality that results from just-in-time delivery. JIT also benefits from single source suppliers, as the logistics of scheduling becomes simpler with fewer suppliers. There has been significant success in this area; General Motors of Canada currently sole sources 99 percent of its components [20]. Even though many of these components are simply sourced from General Motor's American allied supplier base, this is none the less an amazingly high number.

As the assembly plants move towards JIT deliveries, the number of suppliers are being reduced to those who can provide both quality and timely delivery. The suppliers that evolve to JIT must change radically the way they schedule, ship, and package their products.

Part sequencing

By requiring vendors to arrange arriving materials to match production schedules, as in the case of seats at Chrysler's Sterling Heights plant, inventory control and materials handling is greatly simplified. The seat manufacturer for GM Tarrytown has built a dedicated factory 15 miles north of the assembly plant, in Central Valley, New York, in order to supply sequenced seats on a JIT schedule.

As mentioned previously, General Motors sequences wiring harnesses on its production line, using barcodes for tracking. Because each harness is custom built for a particular option combination, sequencing is not a convenience, but rather a necessity.

Modular build packages

Suppliers are now expected to supply assemblies that are integrated packages ready for the assembly line. These packages, called modular build packages, frequently require technologies or components outside the supplier's area of expertise. Suppliers are buying these components from outside sources and assembling them into their products [21]. This has had the effect of off-loading some of the assembly work from the assembly plants to the component suppliers, and has given these first tier suppliers the choice of lower tier suppliers from which to source these sub-subassemblies. Frequently, lower tier suppliers are the first tier supplier's competitors in other areas [22].

This modular design concept greatly simplifies the assembly process as well. Doors, for example, will arrive from vendors already painted and wired and ready to be assembled. Once the door is hung on the car, the connection of one plug marries it to the wiring harness.

This trend towards supply of complete modular units for assembly is having a significant impact on the component manufacturing divisions of the major automakers, because what was once a captive market to parent companies is now open to global competition.

For example, right now Packard Electric has contracts to supply body wiring to all American built General Motors vehicles except the NUMMI Toyota joint venture. If doors were to be outsourced, the supplier building the door would have the option of sourcing the door's wiring harness from whichever supplier he chose. This would make it possible for an American built door to have a Japanese wiring harness. Likewise, other allied General Motors divisions and long time non-allied suppliers that make door trim, glass, handles, etc, would find themselves facing tough new competition. These present first tier suppliers would then become second or third tiers.

The 1991 Buick Park Avenue and Oldsmobile 98 will have a completely modular headliner manufactured by United Technologies. Everything from the sunshades, assist straps and overhead consoles with electronics, switches, lamps, complete wiring harness and other designed features are incorporated into a one-piece system.

The headliner can be snapped onto the car at the assembly plant by two people, compared with the 12 or more required to install a traditional headliner. This saves General Motors time, money, and manufacturing space. Right now, Packard Electric supplies the complete wiring harness to United Technologies. In the future, however, United Technologies is free to purchase wiring from wherever it can get the highest quality at the lowest cost.

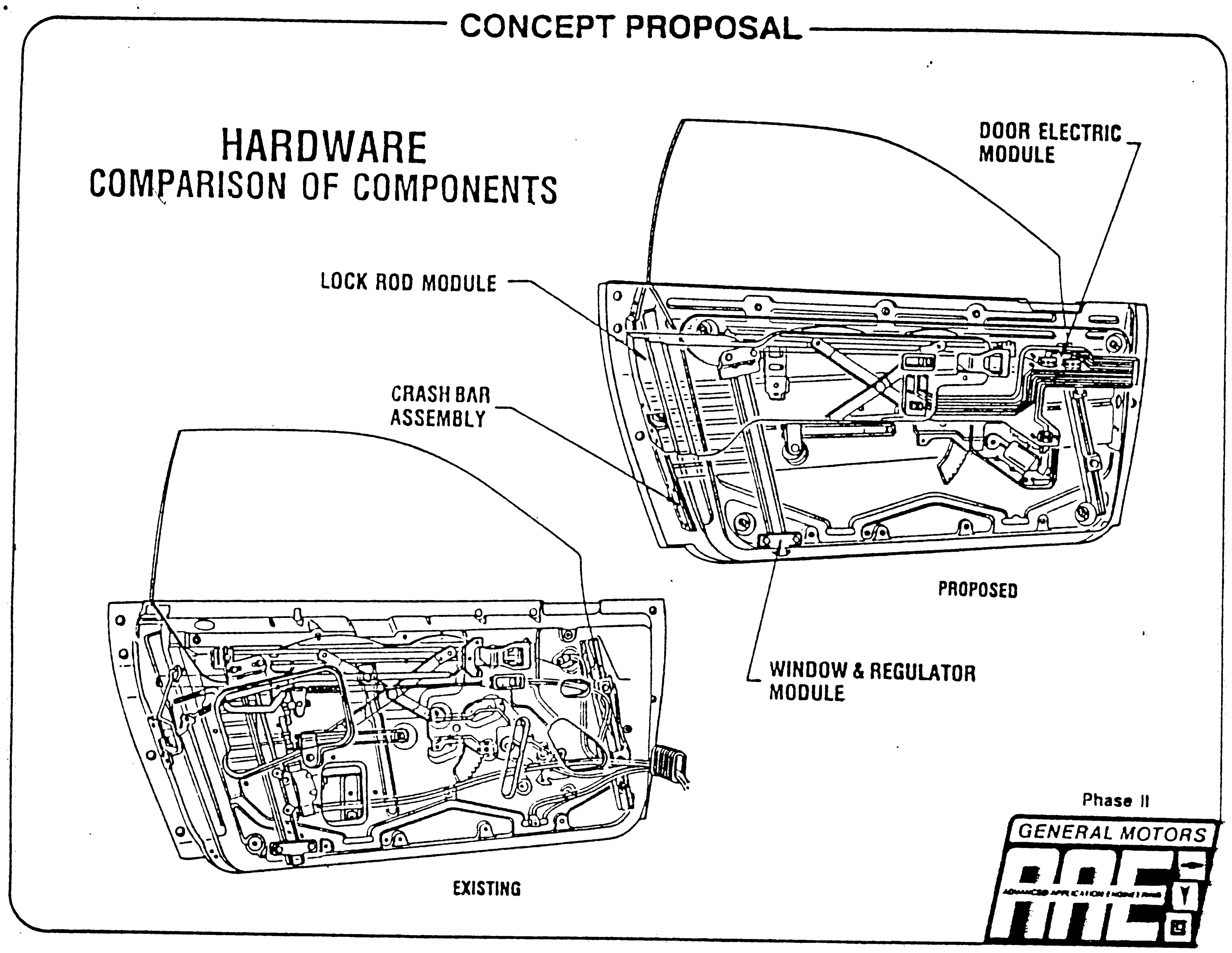


Figure 1 - Modular Door Hardware

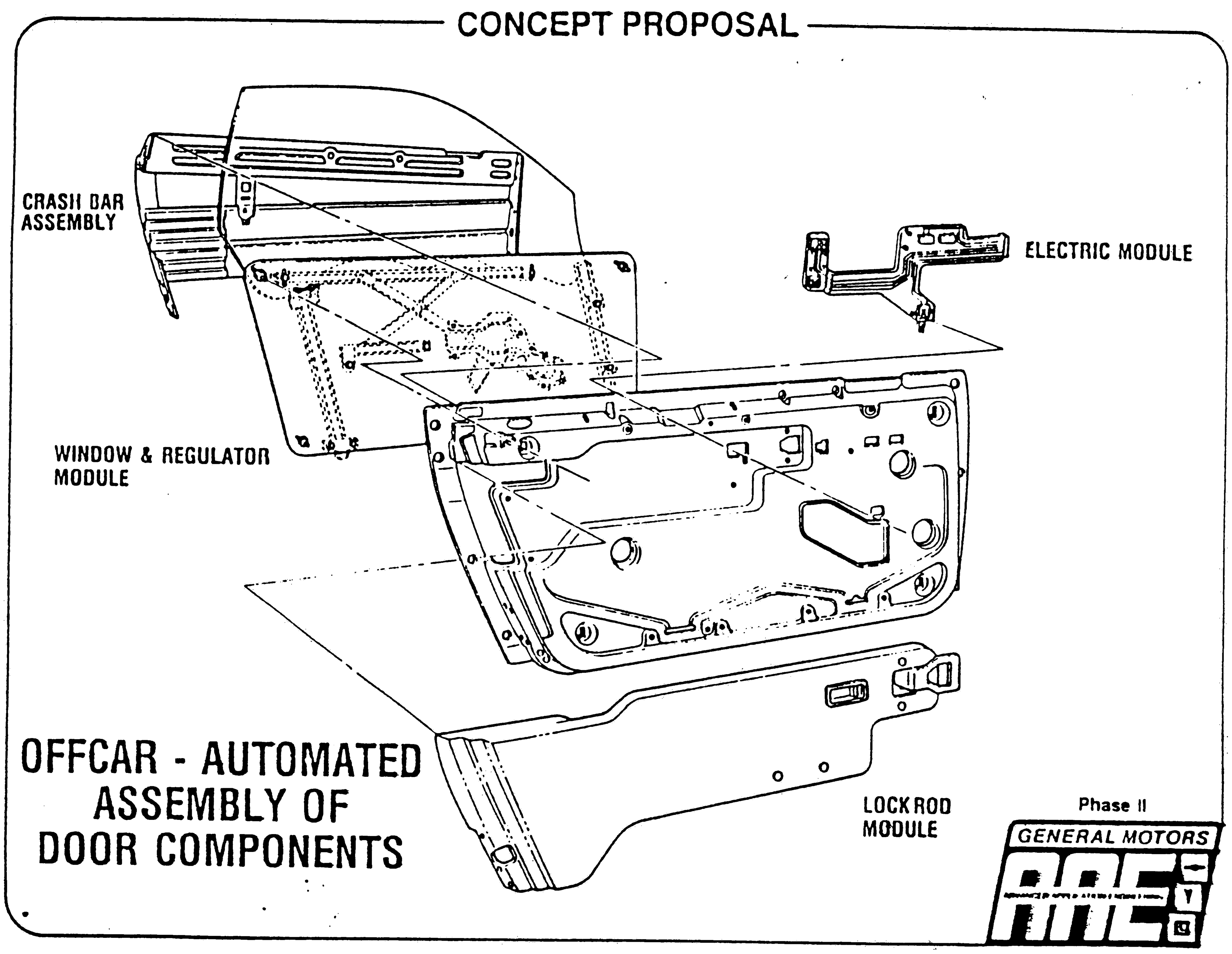


Figure 2 - Modular Door Assembly

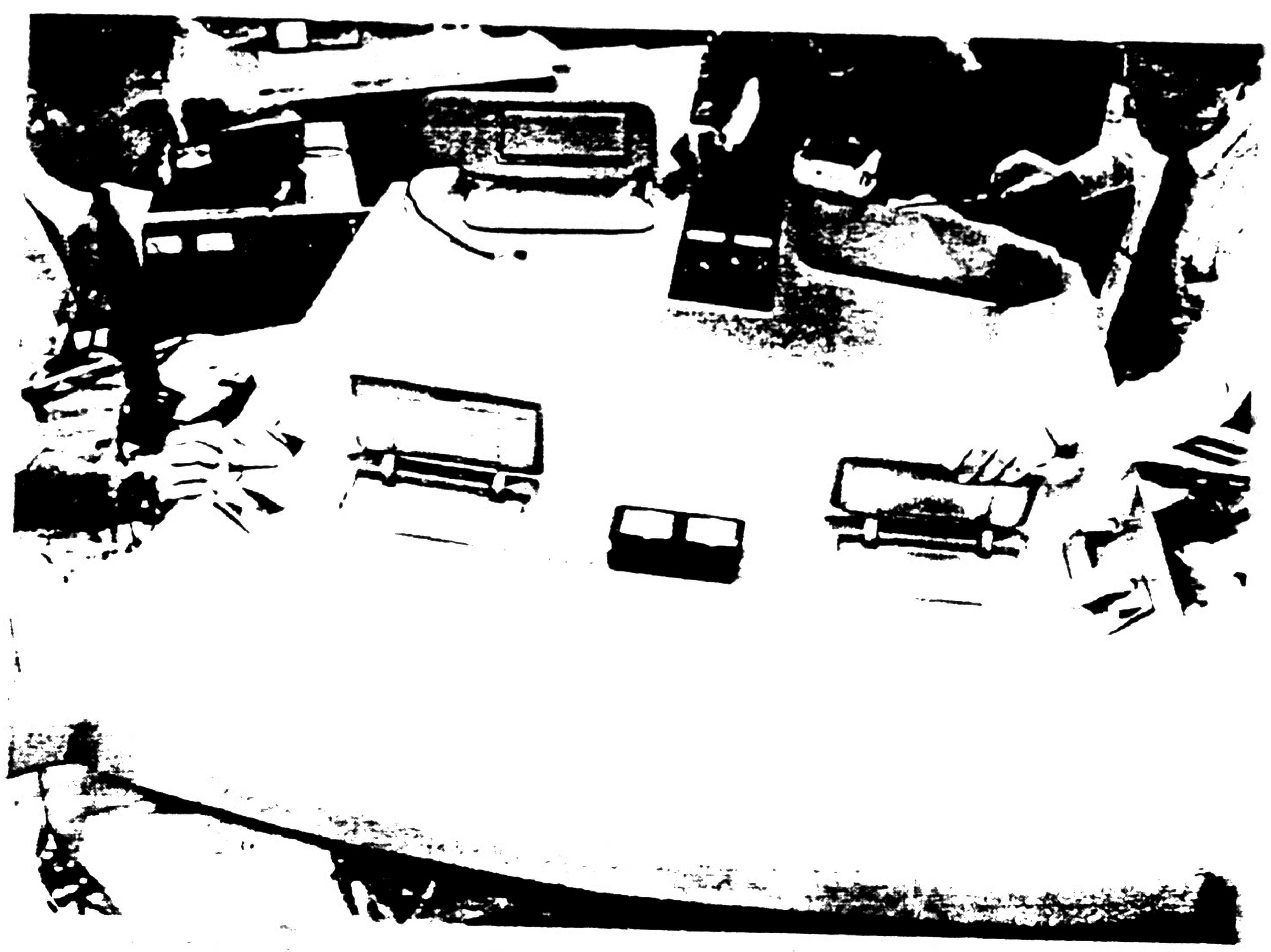


FIGURE 3 - MODULAR HEADLINER

Chpt 2: Suppliers As Designers and System Integrators

Bendix airbags

Many problems exist in the design and implementation of air bag systems. Some of them relate to sensor design, inflator design and air bag design and are independent of the particular car model on which they are used. Specific to the vehicle are the steering column performance, the knee bolster performance, car structural characteristics, and the placement and calibration of the sensor systems. The major problem facing most automotive manufacturers when implementing an air bag system is the performance of the steering column. The steering column angle for many vehicles is too high to properly position an air bag. Many steering columns are too weak to withstand the loads and torques during a crash.

The second most critical problem is the design and implementation of the knee bolster. Usually an equal amount of effort is spent on the knee bolster as on the air bag system itself. The task is complicated by the presence of structural members behind the knee bolster [23].

The structure of the vehicle also has a critical effect on the performance of the air bag system.

When the 1990 Chevrolet Geo Metro Convertible, built by the Suzuki Motor Company, needed a complete driver air bag system, Bendix Safety Restraints Group was chosen to design, develop, and integrate the entire program in July 1988 [24].

The Geo Metro Convertible, a unique vehicle, is one of the smallest passenger cars sold in the U.S. The smallness of the vehicle made the installation of the air bag a difficult task for Suzuki, who did not have any air bag expertise developed in-house. One of the biggest challenges for Suzuki was the lead time. Pilot production parts were due by the fall of 1989 - substantially less time than a project of this size had previously taken [24].

Because of their lack of in-house expertise, along with the difficult time constraint, Suzuki contracted the project to Bendix. Bendix is one of the largest first tier suppliers and designers to the automotive industry.

Building upon technology they had previously developed in their own research labs, Bendix defined an air bag system for the vehicle and specified system components that were already designed and available. A variety of tests and studies were conducted to calibrate the system to the vehicle: computer math modeling, static and dynamic sled tests, full-scale vehicle crash tests, and rough-road and abuse testing. In addition, extensive component tests were undertaken for computer input data and air bag component validation.

Crash sensor modeling and testing determined the optimal locations to position the sensors on the automobile. Sensor calibration levels were established to discriminate between crashes and non-crashes across the vehicle's entire operating temperature range and the sensor operating tolerance range.

Vehicle, air bag system, and occupant simulation studies provided design information for performance under various test conditions and also for different size and out-of-position occupants.

The driver air bag module and sensing system were electrically integrated with a diagnostics module and a steering wheel contact coil, then packaged into the vehicle with its own wiring harness. The wiring harness was designed to interface directly with the cars master wiring harness, and could be plugged together during assembly.

Bendix was responsible for verification of designs, validation of processes, and reliability studies, including failure mode and effects analyses (FMEA). Suzuki, along with Bendix, validated the performance of the complete production air bag system in the Geo Metro. In support of Suzuki's assembly and service program, Bendix coordinated the design and development of test equipment and procedures.

Bendix was able to complete the project in just 18 months. This was accomplished by drawing on their past restraints system experience, and state-of-the-art technology from second-tier suppliers. Continuous and candid communication among all the involved parties - from manufacturer to first and second tier suppliers - helped smooth out problems and allowed orderly transitions from one phase of the project to the next [25].

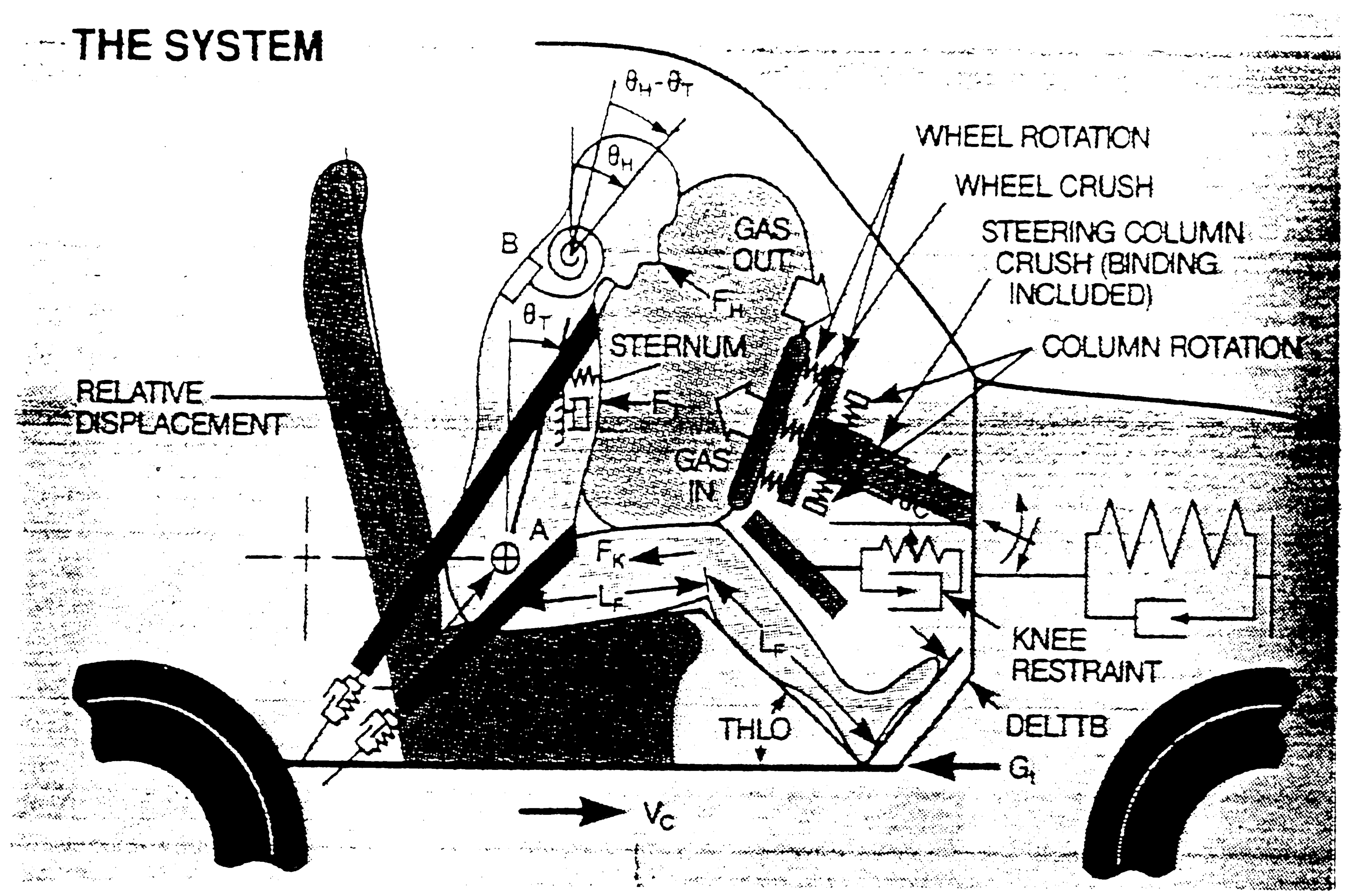


FIGURE 4 - ELEMENTS OF BENDIX AIRBAG

Bendix antilock brakes

Another good example of a systems application of supplier designed and manufactured electronics is the antilock braking system (ABS). This system functions to prevent wheels from locking when the brakes are applied in a relatively low wheel/road friction situation, such as on wet or icy roads.

If the brakes are applied with sufficient force (panic braking) one or more of the wheels may "lock" (cease rotating) and the tire skid over the road surface. In a severe skid, there is usually a loss of steering control over the vehicle. Severe loss of steering control in a panic braking situation can result in collision, and is clearly an undesirable condition.

An ideal ABS system would measure wheel skid by measuring the difference between wheel speed and vehicle speed. However, no cost effective sensor for vehicle speed has been developed that operates independently of wheel speed.

On the other hand, a number of ABS systems have been developed by suppliers that are based upon measurements of wheel deceleration. Wheel speeds at two closely spaced instants are measured and subtracted. Whenever the earlier wheel speed exceeds the later by a threshold value, a skid condition is detected.

In a skid condition, the ABS system generates an electrical signal that lowers the brake pressure by an amount which is sufficient to eliminate brake lock. Suppliers have designed many systems that have been produced and sold.

The first anti-lock braking systems functioned by controlling the braking forces on each wheel individually, known as Individual Control (IC). Early results showed that this provided maximum adhesion between the tire and road, and resulted in the shortest possible braking distance without wheel lockup.

Chrysler engineers had been working for years on designing an antilock braking system (ABS) for a light truck vehicle. They had a lot of difficulty perfecting a system that could operate in both 2 and 4 wheel drive.

Because their loading tends to vary more widely than passenger cars, light trucks are especially good candidates for 4-wheel ABS, where improved steerability and stability are needed on slick road surfaces regardless of loads.

In developing the antilock system for the 1989 Jeep Cherokee and Wagoneer models, Chrysler contracted with Bendix to supply a total integrated system. Bendix was chosen by Chrysler for two reasons:

(1) Bendix already had extensive experience in developing 4-wheel passenger car ABS.

(2) Bendix had extensive experience with complete hydraulic brake actuation systems for light trucks, from master cylinders to vacuum power boosters. This gave Bendix a technical depth and knowledge of the intricacies and difficulties of ABS that Chrysler did not have, and could not develop cost-effectively. Even if Chrysler did develop the expertise in-house, it would have taken years to do so.

A first step in designing the Bendix 4-wheel ABS was to develop a fast and powerful electronic logic to compute the individual speeds of all four wheels and command solenoid valves to react accordingly. This resulted in an electronic control unit (ECU) based on a 16-bit microprocessor used to monitor the brake system operation from data provided by wheel speed sensors and pressure switches. To assure proper operation, the ECU continuously checks the sensor presence, solenoid continuity, battery voltage, system and motor pump relay states, and hydraulic integrity. In addition, the unit monitors the microprocessor to determine if it is working properly.

Simultaneously Bendix needed to design a system that would permit 4-wheel drive antilock despite axle interaction. The answer was new software filtering plus sophisticated acceleration measurement. This combination gave a better indicator of overall vehicle speed and could be used effectively in all types of 4-wheel drive modes.

The final phase in perfecting the Cherokee and Wagoneer ABS system was thousands of hours of laboratory and vehicle testing. 1.5 million miles were logged testing durability and reliability [26].

APV minivan

The General Motors APV minivan vehicle was developed as a totally new design show vehicle in 1986. The vehicle was developed because General Motors was being criticized for its look-alike styling.

At the time, the Chrysler Corporation's minivan had created its own niche market, and was producing huge sales and profits. General Motors wanted to create a vehicle to capture some of Chrysler's minivan market share.

General Motors Chairman Roger Smith and GM's outside board of directors saw the APV as a very bold and important move to silence the growing criticism from inside and outside GM about look-alike styling, and announced the launching of the project with much publicity.

General Motors felt that it was important to get the APV to market as soon as possible. Because the APV was given such strong support from within the corporation, the project was given special importance and was launched with a timetable that would be impossible using traditional design and production development procedures.

Although the vehicles are based on GM's A-body, front drive car platform, the body is so radically different, with its plastics, glues, and wide expanses of glass, that the APV was treated as a from the ground up project [27].

Because of the time constraints and General Motor's lack of experience in these new technologies, GM was unable to develop and engineer the APV in the usual manner.

A similar situation occurred when Roger Smith had his vision to manufacture the Saturn. In this instance, General Motors chose to create a whole new organization that hopefully will be able to shorten successfully the time it takes to engineer a totally new product.

For the APV, General Motors chose to turn to outside suppliers for almost all of the research and engineering work. The APV minivan was the largest General Motors sub-contracted production engineering project ever done outside General Motors [3]. The development and production of the minivan depended on suppliers for almost all of its new advanced materials and assembly technologies. GM let their suppliers develop the most extensive use of plastics ever used on a production vehicle, instead of doing it themselves in house. This development work included the largest vehicle body panels ever made [3]. Adhesives suppliers developed space-age glues to hold the plastic exterior panels to a metal "space-frame" cage [29].

The APV is on the leading edge of many supplier developed manufacturing trends. Perhaps the most significant trend in materials is the use of plastic body panels instead of sheet metal. These panels will be increasingly used because of their light weight, resistance to corrosion, ability to be pre-painted by suppliers, and their much tighter manufacturing tolerances. However, these panels require a totally new assembly process which is incompatible with sheet metal [28].

Because of environmental restrictions on fluorocarbon coolants, air conditioners will become less powerful and effective. This trend, combined with the trend of cars becoming more aerodynamically shaped with larger glass areas, has led to the development of space age glass that can be used in automobiles. This glass reflects infrared and ultraviolet radiation, while appearing less tinted than today's auto glass [30].

New fastening techniques, some in conjunction with plastic panels, have been developed. These processes, both mechanical and chemical, are more reliable, but more complex, than welding. Outside suppliers supplied the project with more materials, tools, and services better than for any other new car ever.

Suppliers had to make a pledge of absolute commitment to complex JIT supply lines in order to be awarded contracts. This supplier relationship put the Tarrytown plant at great risk that one supplier's shortages could shut down the plant. The quality goals set for the APV have made the production startup painful and very slow by traditional Big Three standards [3].

Suppliers knew up front that the APV was a high risk project, yet agreed to invest millions in new facilities in order to be chosen as suppliers. Because of the compressed lead times, the suppliers suffered significantly from engineering changes, and these changes strained their relationship with General Motors [17].

The APV uses very high levels of new materials in a revolutionary assembly process. A large team worked together to come up with the processes required to produce the APV. Many of the materials and processes used for the minivan were used for the first time ever. No one had ever built a high-volume, plastic vehicle over a space frame with such huge plastic panels. For General Motors it was a new experience working with other GM component divisions and outside suppliers under such tight time constraints. These time constraints proved especially painful when working with so many unproven technologies [28].

All major suppliers had full-time representatives inside the Tarrytown plant. This level of supplier involvement is rare in the automotive industry.

Tarrytown's capacity at full speed was designed to be as high as 60 vans an hour on two shifts. However, General Motors management has said that the ability to meet stringent quality standards will dictate production rates, not customer demand. Because of this philosophy high volume orders were very slow to materialize, which hurt suppliers' cash flow, especially during the early stages of production.

General Motors has produced two other vehicles using plastic panels, the Fiero and the Corvette. The Fiero had a similar 'space-frame' construction, but the body panels were milled and bolted into place, instead of glued as in the APV. The APV's planned annual production is far more than the other plastic vehicles, about 225,000 annually. The Fiero's biggest year was 125,000, and the Corvette is only 25,000 per year [17].

If the APV technology proves successful over the next few years, many more cars being developed for the future will probably use the much more plastic and glass intensive 'space frame' design.

If this 'space frame' design becomes the trend, the APV's plastics and adhesives suppliers will benefit from a huge gain in credibility. If adhesives become widely used, these suppliers will have the advantage of a significant head start on this new technology, and have the potential to earn huge profits from the new business.

If the vehicle is a failure, either technically or by low sales, it will be a major setback for these suppliers. Many have invested so much money in this project that very low sales and no new adoption of this technology could cause them to go bankrupt.

Despite the risks, major automotive suppliers have been forced to commit themselves to the minivan if they want to be part of the automotive industry trend of sourcing more business with fewer suppliers. These suppliers have spent millions to build plants and products dedicated to just the APV. Five of the suppliers that have made the largest investments are listed below:

GenCorp Automotive has spent $65 million on a new high-tech plant in Shelbyville, Indiana, to produce the major sheet molding compound (SMC) panels for the APV's right side and the rear liftgate.

GenCorp's new plant is totally dedicated to APV panel production. The plant employs 450 workers and incorporates the latest in sheet molding manufacturing and processing technology.

Nineteen state of the art computerized compression molding presses are used to mold parts. The parts are then placed on overhead conveyors and run through autoplant style paint booths for a coat of primer before being shipped to Tarrytown. This eliminates a painting step at the final assembly plant. In the future it is planned to finish paint the panels at the supplier's plant. The parts would then arrive sequenced for the production line at Tarrytown, ready for assembly without painting [29].

Budd Corporation has built a $24 million plant in Kendallville, IN, to produce the big SMC panels for the APV's left side. This plant employs around 500 people, and uses special computerized, fast-acting SMC presses, including one specially built for the APV that is the world's largest.

Both GenCorp Automotive and Budd have gone to extraordinary lengths and expense to ensure top quality finishes and fits with their panels. General Motors insisted that both companies install computerized coordinate measuring machines for statistical quality control and dimensional analysis.

The reason is that SMC parts cannot be bent and hammered like steel to accommodate sloppy fits on the assembly line. Dimensions must be perfect the first time [42].

PPG Industries Inc. was responsible for developing and manufacturing the APV's huge sloping windshield. The glass contains a solar control coating that PPG developed to reduce interior heat buildup inside the minivans.

Standard tinted glass windshields tend to absorb infrared and ultraviolet light rays from the sun, significantly increasing interior temperatures. The APV's windshield is so huge that standard tinted glass would make the interior unbearably hot during the summertime.

PPG's solar control windshield - found only on the APV, and sourced only from PPG - has a special layer of material sandwiched inside the windshield that reflects heat producing infrared and ultraviolet radiation, while allowing visible light to pass through unimpeded.

This reflective quality makes the windshield relatively clear compared to tinted glass, allowing for better vision at night.

PPG has invested several million dollars in the equipment to produce the windshield.

The trend is for new vehicle designs to contain more glass surface area. This, combined with future environmental curbs on refrigerants that will make air conditioners slower and less efficient, will make temperature control more difficult. If the APV's solar-controlled windshield performs well, PPG will have a significant lead in any future heat absorbing auto glass market [30].

Dow Chemical Company, developed the polyurea used in the APV's fenders. While there are other polyureas on the market, Dow's material, chemistry, and knowledge led to technical developments that have made their product superior, and has led to Dow's being chosen as the only polyurea supplier for the APV. Dow's polyurea dimensional stability is better, and its overall physical properties make it easier to process than other polyureas on the market. Dow's improved polyurea allows for better surface quality on finished fenders than in the past, and it processes far better than polyureas used on Fiero. General Motors was finally convinced to use Dow as their only supplier of polyurea because of Dow's willingness to work with GM to develop a new material that was able to be processed on the old Fiero equipment. The other suppliers offered materials that required new, faster, and more expensive equipment.

If the APV is a success Dow will realize a significant new volume of business. Dow's plastics are used in 35 interior applications for a total of 100 pounds of plastic per vehicle [42].

Ashland Chemical Company developed the adhesive being used to fasten the major plastic panels to the APV's steel space frame. While this technology has been used for 20 years on the Corvette, and more recently on the Fiero, and on truck front ends, the APV will be the first high volume vehicle to make extensive use of structural adhesives. Unlike the Fiero, many major panels will be fastened only with adhesives, with no back-up bolts.

Ashland, the sole structural adhesive supplier for the APV, has been developing the APV adhesives with General Motors for four years. It designed and supervised the manufacturing of the adhesive dispensing equipment, and worked on prototypes with Pininfarina during early development stages of the APV.

The result is Ashland's Pliogrip, a family of polyurethane adhesives that have made possible a much faster, higher-production line than that of the Fiero or Corvette. The glue was engineered to have a high resistance to sag, which allows it to be applied by robots without dripping. In order to accommodate JIT delivery, the adhesives were engineered to flow by gravity, so that they could be pumped throughout the assembly plant easily before application, even though once applied they set up faster then the older polyurethane adhesives. This makes it possible for the adhesive to be delivered in 300 gallon bulk returnable shipping containers, simplifying materials handling [28]. This also solves the expensive problem of disposing of empty glue drums, which are considered hazardous waste because of residual glue still inside.

Chpt 3: Managing the Automotive Supplier Relationship

The new need to manage suppliers

As automotive manufacturers become more dependent on their suppliers, the managing of these suppliers is becoming increasingly critical. Strategic manufacturing is becoming a partnership between the big corporations that supervise the design, assembly, and marketing of finished products, and fewer, smaller, smarter suppliers - often single source suppliers. Getting this partnership going, and keeping it competitive, is no easy task. It may be the single most important task of the people who run the manufacturing organization.

One of the most significant differences between traditional supplier management and future-focused single source supplier management is the realization that the cheapest component is, in the long term, not necessarily the least expensive. Once the cost of poor quality is factored in - downtime, rework, scrap, warranty work, etc. the cheapest may in fact be the most expensive. Because poor quality is so expensive, purchasing agents and engineers have to be much more careful in selecting suppliers, and they must learn more about suppliers technical, research, and development capabilities than ever before. They need to research carefully suppliers, and work to develop mutually beneficial relationships once a supplier is chosen [31].

Historically, purchasing agents have recommended the award of two or more contracts for the supply of critical material. This assured that the automakers were not captive to any one supplier, and that the suppliers would keep their prices low based on the fear of losing contracts to the competition. The auto industry was notorious for driving hard bargains aimed at getting the lowest possible price from its suppliers. American car manufacturers tolerated a 1 % to 3 % defect rate in incoming purchased materials, or 10,000 to 30,000 defects per million [32].

Today, the automakers have shifted their focus from the lowest price to the lowest "total" cost. They have carefully researched the capabilities of potential suppliers. They have assisted suppliers with statistical quality control and CAD/CAM training. The automakers have motivated their suppliers by offering them long term single source contracts, and have seen reduced prices by helping suppliers to improve their efficiency.

Selection of suppliers

In the past, the selection of suppliers was usually the responsibility of engineers who were not very concerned with the financial implications of their decisions. They tended to look for products and technologies that advanced the state of the art of the product they were designing. They looked for improved performance features of the products, and for suppliers who had excellent engineering capabilities but may have been weak in manufacturing or quality, or lacking in financial resources. Even more often, purchasing responsibilities were left to buyers who lacked sufficient technical understanding and counted on the market forces of competition to produce suppliers with technological depth [33].

The selection of a critical supplier should be a team effort. Big companies need to have experts from various departments and functions recruiting suppliers. The people choosing these suppliers should be people who know what to look for.

When selecting a new supplier, progressive companies develop a team made up of people from purchasing, design engineering, quality, manufacturing, product planning, finance, and related functions. The team should review the potential supplier's capabilities carefully in research and development, production, and quality management [34].

At Ford, product development teams invite two or three qualified suppliers to compete on the design of new parts. Ford analyzes these suppliers' designs, quality plans, and price proposals. Then purchasing, with assistance from other team members, conducts a cost analysis, and proceeds with negotiations. The successful proposal must satisfy a balance of objectives: function, quality, aesthetics, price. The successful supplier normally becomes the only source of supply for the life of the product [35].

General Motor's evaluation procedure begins with a supplier filling out a self-assessment form that asks about operating philosophies, business systems, research and development, and overhead costs, among other things. Then a team of three or four GM people visit the supplier's facilities for three or four days, focusing on five critical areas:

(1) organizational effectiveness and commitment

(2) planning systems and documentation

(3) cost awareness, monitoring, and reduction

(4) scheduling and delivery compliance

(5) technology capabilities and research and

development [36].

Developing suppliers as designers

Automakers have been working to develop further the manufacturing and technological capabilities of outside suppliers. When they fail to do so, problems with quality, cost, and technical evolution can result. Suppliers must be active from the beginning in product design, when they can have a major impact on design and cost. The best managed suppliers will create product designs from functional descriptions, and provide their customers with new products and solutions by anticipating future needs.

To involve suppliers effectively, and early, manufacturing companies should invite suppliers' engineers into their own engineering departments. Packard Electric, a major supplier to the auto industry, places its engineers, called CIE's (cooperative involvement engineers) in each of its customers plants. These engineers review the design of the entire wiring subassembly before committing to it. This helps Packard to understand the true needs of the customer, and anticipate the customer's future needs.

The growing trend among the automakers is to develop an "envelope" of performance specifications for suppliers to bid on. This forces the designer to do at least some preliminary design work before bidding. This is attractive to the automakers because they can look to their potential suppliers for the most innovative designs, and do not have to invest their own resources to design many parts.

To improve their services constantly and attract new customers, many suppliers have built world-class Technical Centers in the Detroit area as well as in locations around the United States. In the April 1990 issue of Automotive Industries magazine, the annual automotive suppliers issue, there were no less than 35 automotive suppliers with either one full page or two full page advertisements describing their technical research and development facilities. These suppliers have applied "quality tools" such as Statistical Process Control, Taguchi Methods and knowledge based reasoning to their operations aggressively. They are spending time and money on data compatibility, training, and vendor certification programs [37].

Asking suppliers to invest so heavily in research and design has created a new type of business arrangement between suppliers and automakers. It is not uncommon for suppliers to sell their design services outright, or to have the automaker buy a design but choose a lower-tier supplier to manufacture the part, as illustrated in the following example.

Simpson Industries, Inc. is typical of this new relationship. It has a research and development budget of $1 million and a laboratory staff of 15. It has six engineers co-located in its largest customers' engineering departments, where they provide design help from the very start of a project.

Simpson has a variety of design contracts with its customers. It has recently entered into a nine year agreement with Consolidated Diesel that required Simpson to invest $ 9 million for a new plant in North Carolina. This is an open ended agreement. Under the terms of the contract, Consolidated reviews Simpson's costs annually. From this relationship Simpson has gained $145 million in new business, and an anticipated extension of the agreement. At the same time, Consolidated is free to choose another manufacturer if Simpson does not maintain a high level of quality, cost control, and schedule conformance [38].

Simpson also developed the balance shaft for the General Motors BOC (Buick, Olds, Cadillac) division's 3800 series engine. BOC called for bids and Simpson, along with other suppliers, developed and built a prototype to be tested by BOC. BOC structured its bids in a way that allowed it to reserve important benefits. In effect, it called for design ideas, leaving itself some flexibility in production negotiations. Under its contract with Simpson, if Simpson's design is chosen, BOC may still select another supplier for production. If this were to happen, Simpson would be paid for its research and development. Good suppliers may thus be thought of as two tiered operations, research and development, and manufacturing. Each tier must be approached separately and to mutual advantage [38]. Thus, as automakers are increasingly outsourcing the design and manufacture of components, they are sometimes further separating the design and manufacturing functions.

Second tier suppliers

As outsourcing gives the tier-one suppliers more responsibility in dealing with sub-suppliers, they must now take on the administrative work, as well as the engineering tasks, that were once done by the automakers. The automakers are choosing tier-one suppliers based on their abilities in these areas, and are strongly encouraging them to initiate the same type of quality and supplier recognition programs that the Big Three have in place.

In 1988 Bendix established a Preferred Supplier Program that set its supplier selection criteria based on quality, price, delivery and technology. It asks suppliers to use production based machines and processes, to develop prototype capabilities whenever possible. Bendix emphasizes the need for just-in-time delivery, and awards long term contracts to the sub-suppliers that best meet these objectives.

Bendix, as well as the big three automakers, have come across some suppliers that are unwilling or unable to make the changes necessary to compete in today's auto industry. Bendix has found that they, like the automakers, must carefully cultivate suppliers to assure the availability of lower tier parts and services [17].

Chpt 4: Reasons for the Changing Supplier Relationship

Corporate focus on short term earnings

The heavy involvement of suppliers seems very attractive to automakers when viewed in the short term. However, over a longer period of time this relationship becomes more destructive than beneficial.

Corporate performance in the United States today is judged on the most recent quarterly earnings report, without regard for long term capability and stability. Facility modernization, improving production processes, and product design seem counterproductive when measured in terms of quarterly profits. This problem is not unique to the automobile industry. The semiconductor, consumer electronic, and steel industries have suffered significantly under this type of thinking [39].

American managers are preoccupied with restructuring operations and selling businesses that do not contribute immediately or directly to profit. This can destroy the capability of a corporation to develop new products and to generate profits in the future [39]. It will, however, usually help quarterly profits.

When a company takes this approach to cutting operating costs, it is forced to look elsewhere to find new technologies and innovations.

Some supplier driven research and design projects are healthy, an example being General Motor's search for a supplier for the plastic body panels for the APV minivan. The polyurea developed by Dow Chemical was the result of Dow's competing for business with other chemical companies. It is also an example of a business that General Motors probably does not want to be in - it does not make sense for General Motors to try to duplicate the research capabilities of a company such as Dow.

Suppliers innovate for new business

Sometimes, suppliers develop products on their own in order to generate business. In 1960, when Ford was starting to bring Budd's stamping work back in-house, Budd was manufacturing the body panels for the Ford Falcon economy car. At the time, it was known that Ford was looking to manufacture a small, affordable sporty car.

Budd knew that if a sporty derivative could be spun off the

Falcon it would probably mean more business for them, as Ford was unlikely to bring back in-house a chassis Budd was already tooled up for. So Budd designed and built their own concept of a sporty car using the Falcon chassis.

Ford took Budd's design, worked with it in "concept car" form at auto shows, and eventually came out with the Ford Mustang.

The Mustang became an instant hit, generating 418,000 sales in 1965, a record for any new model introduced up to that time. Lee Iacocca took full credit for the Mustang, but the original concept was developed by Budd - a supplier hungry for new business. It is important to recognize that this innovation on the part of Budd was the result of its trying to compete with another manufacturer. It just so happens that in this case the other manufacturer was Ford itself, and not another outside supplier. Had Ford not been in the process of taking Budd's work back in-house, Budd would probably not have taken the risk of spending development money on something as high risk as a totally new car [39].

Even though the Mustang was developed in part by Budd, it was still very much a Ford. Ford refined the design, did much of the engineering, and controlled the 'feel' of the car; brakes, steering, etc.

Outsourcing whole platform designs

There is a difference between these types of supplier-automaker relationships of the past and the more basic design work being outsourced today. A good example is the Ford Escort. The Escort of the past was introduced by Ford a decade ago. The Escort became one of the world's best selling cars. At the time Ford was advertising the Escort as the "world car"; designed, engineered, and sourced all over the world. This was an excellent example of using the best suppliers, wherever they might be, and assembling the finished product near the regional market where local engineers were sensitive to those particular customers, and who were able to modify the product accordingly.

In 1991, Ford introduced a totally redesigned Escort to replace the aging original. However, in this case Ford took a very different approach to design and outsourcing. For the 1991 Escort, Ford hired Mazda for the design and production engineering. The 'world' car had become a car totally engineered in Japan.

Ford claims that it never made any money on the old style Escort, and for many years sold the car at a slight loss to keep prices in line with the competition. Ford also kept prices low because it needed to generate sales of Escorts in order to keep its CAFE (corporate average fuel economy) average low. Rather then address the issue of how to make money manufacturing an inexpensive car, Ford chose to simply buy someone else's car and put their name on it. This illustrates the quarterly profits mind set, as opposed to long range planning.

The Ford Probe is another example of an automaker giving up control of its own product design. The Probe was sculpted in clay in Detroit and sent to Hiroshima, where Mazda designed the body and drive train around its existing MX6 car. Mazda also did all the production engineering for the Probe, which is assembled at Mazda's Flat Rock, Michigan plant [40].

The story of the Probe has been repeated at Chrysler and General Motors. The Big Three automakers cannot remain world-class car manufacturers if they contract out the design and engineering of their own products. Just as General Motors must not let itself rely on Bendix for crucial technologies, neither can Ford rely on Mazda for innovative styling. If the automakers continue the trends of outsourcing parts and designs, they run the risk of evolving into little more then sales and marketing enterprises.

Joint ventures formed to access transplant markets

For good or bad, there is little doubt that American automakers are relying more and more heavily on their parts suppliers for new technology. As the automakers shrink their in-house research and development groups, and fail to develop in-house experts on new technologies, suppliers will become the driving force for innovation and new technologies. Therefore, it is quite clear that the health of America's automakers is directly related to the health of their suppliers.

However, the health of American suppliers is being threatened by Japanese transplants. By investing in American factories, the Japanese have woven themselves into the fabric of the American industry - so much so that the Big Three are partners with the Japanese in four of the nine transplant
operations [41].

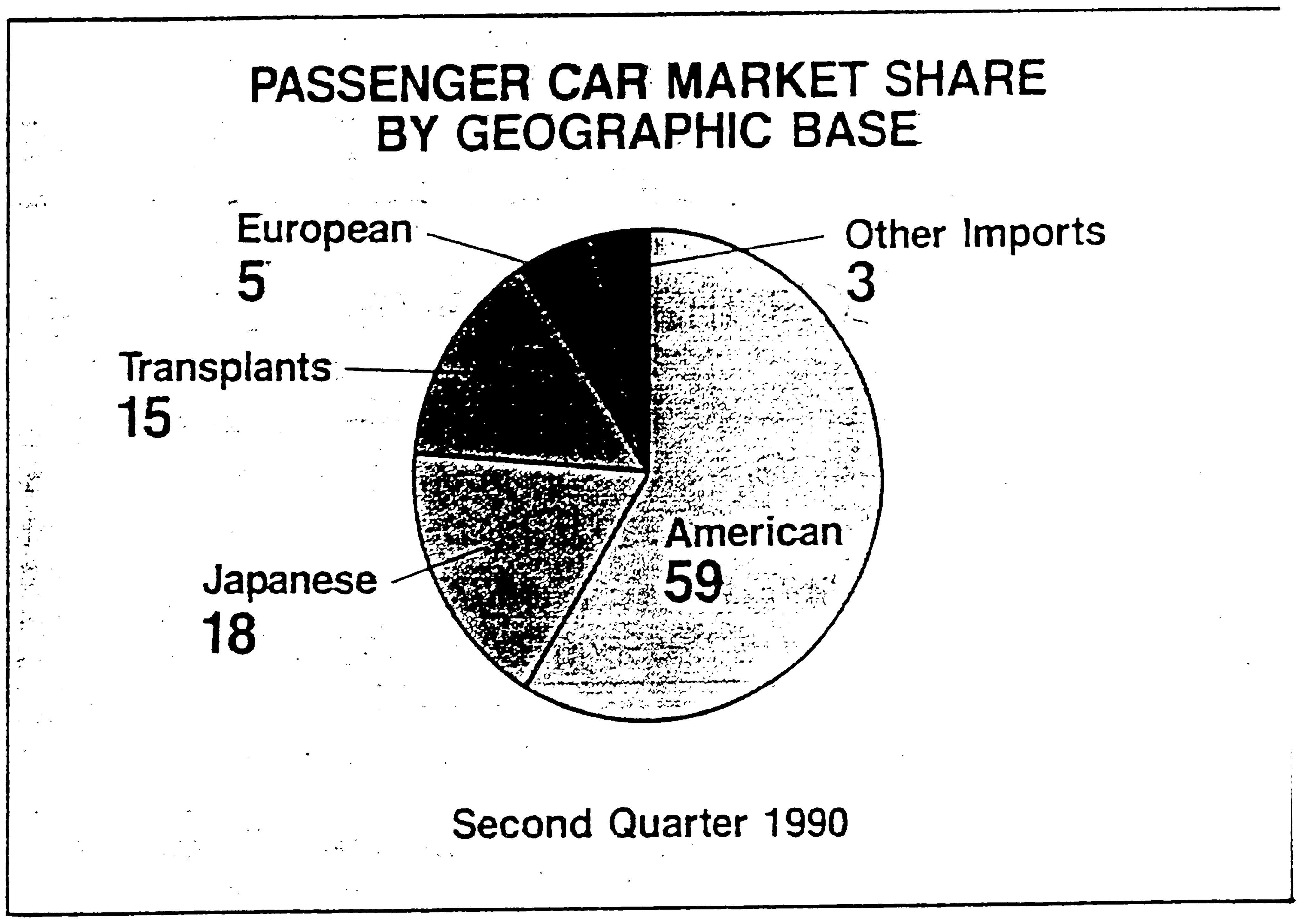
With transplants now producing cars in the United States even more cheaply than in Japan, given the strong yen, the Japanese are poised to grab an even bigger share of the United States market. The Toyota Motor Corporation, the biggest Japanese car maker, recently announced that its goal is to increase American sales of cars and trucks to 1.5 million by the mid-1990's, up from about 950,000 now. And about half those vehicles will be assembled here [42].

Thus the Japanese car companies have become important employers of American workers. State and local governments court the transplants as sources of additional jobs, offering generous incentives if new plants are located in their communities. At the same time, the Japanese have cultivated a very strong lobbying effort in Washington to counter anti-Japanese and protectionism sentiment.

Many people are concerned with the trend of more manufacturing jobs moving from American to Japanese owned companies. This trend of Americans working for foreign headquartered companies, instead of United States headquartered, is not necessarily bad for the country. Robert Reich has proposed that it is the American workforce, the American people, and not particularly the American corporation, that determines the competitive performance of the United States economy. He has proposed that the growth of transplants is a healthy trend, that the foreign owned businesses that fully commit their "engines of competitiveness" to the U.S. will most benefit our national competitiveness [43].

This Japanese transplant trend is definitely bad, however, for United States based component suppliers to the domestic automotive industry. During the last 10 years, the shift toward imports and Japanese transplant automobiles has had a devastating impact on United States parts suppliers. Few suppliers have been able to offset the business that has been lost at General Motors, Ford, and Chrysler with sales to the transplants.

The United States automotive parts industry faces a crisis in the coming years, unless Japanese transplant companies increase parts sourcing from American owned suppliers. In 1989 General Motors, Ford, and Chrysler produced 5.7 million automobiles in the United States, compared with 7.4 million cars in 1986 and 9.0 million cars in 1978. Auto output by the three American companies was the lowest in 1989 since the 1982 recession, when 4.9 million cars were assembled [44]. As the chart below shows, the American market share has stabilized at around 59% for the first two quarters of 1990.



Passenger Car Market Share By Geographic Base

First Quarter 1990

Manufacturers	Total Sales	Total Market Share
American	1.487,546	58.80%
Japanese	464,231	18.35%
European	123,612	4.89%
Transplants	384,991	15.22%
Other Imports	69,511	2.75%
Total	2,529,891	100.00%

Figure 5 - Passenger Car Market Share

Much has been written in the automotive journals about more business flowing from transplant automakers to domestic suppliers, but these claims must be examined closely. Much of this work is being done through joint ventures, and some of these deals are being made by the transplants in order to ease political tensions. United States automotive parts suppliers are increasingly seeking joint ventures for no other reason than to gain access to the growing transplant market.

The industry has seen many parts suppliers go out of business. Others have been acquired by stronger, healthier companies, and others have tried to find business outside of the auto industry. Most of the successful domestic operations selling to the transplants have been joint ventures between American and Japanese companies or transplant Japanese parts producers.

In 1984, 18.5% of all supplier companies in business with transplant carmakers in the U.S. were involved in joint ventures. In 1987, 31% of supplier companies starting an operation were joint ventures; in 1988 they accounted for 44% of new supplier business; and in 1989 46% of new transplant business was a result of joint venture [5].

Some business with transplants is political appeasement. The Japanese Ministry of International Trade and Industry (MITI) is very concerned with the public image of Japanese transplants, and has taken steps to improve it. They have gone as far as to publish brochures urging Japanese companies operating in the U.S. to give money to charity, and instructing them how to best publicize it, something culturally foreign to the Japanese. Japanese carmakers are being urged to be nice to Americans in order to prevent anti-Japanese sentiments from rising.

Components from off-shore

High-tech suppliers to transplant automakers - those providing high value added products from seat assemblies to engines and engine parts - tend to be Japanese. A study was done by Easton Consultants, Inc. to find out the product engineering content of outsourced parts at the Mazda Motors plant in Flat Rock, Michigan, and to see what types of components were made by wholly owned American suppliers. It was found that the majority of raw materials and low-technology (hence low value-added) products are purchased from suppliers based in the United States, Canada, and Europe. High tech (high value added) components are bought from Japanese companies or companies involved in joint ventures with Japanese firms. Typically, wholly owned American companies supplied things like steel, glass, and resins. Japanese transplant companies, or Japanese joint ventures, supplied things like transmissions, radiators, engines, seat assemblies, and instrument panels. This trend is similar at all of the Japanese transplants [45].

The Japanese argue that the American suppliers, in many cases, simply are not as good as the their Japanese competition. There are many examples of American suppliers that have not attained world class standards, and have lost market share or gone out of business. These are suppliers that suffered mostly from bad management, who failed to recognize the changing needs of their customer, and therefore lost the business. However, there are many United States parts manufacturers who have invested in new facilities. They have reduced costs and improved their quality. These are companies that are totally competitive, and yet they are finding that they cannot penetrate the Japanese transplants [46].

The reason for their failure to get transplant business often has nothing to do with quality, costs, technology or willingness to invest to accommodate the needs of the Japanese customer. After many years of sincere effort, some manufacturers are concluding that they are victims of a closed system that excludes American suppliers from ever having a fair chance to get business [47].

Observations

The growing use of suppliers is a move away from vertical integration. In theory, there would seem to be enormous benefits from vertical integration. It is logical to think that internal parts manufacturing capability would speed vehicle development. The allied component divisions would work in tandem with vehicle groups to reduce design lead time, with the assurance that the work will be kept secret and proprietary. Vertical integration ought to give the automotive enterprise access to state-of-the-art technology faster than less vertically integrated competitors that must rely on suppliers.

However, automotive managers today generally feel that vertical integration is bad. General Motors has used vertical integration as an excuse for not paying profit sharing. Ford, which relies heavily on suppliers, and is not vertically integrated, has been paying large bonuses. It is thought that vertical integration is always more costly than purchasing parts from outside suppliers.

Allied internal component divisions such as Packard Electric are at great risk of losing all their business if they do not recognize and reverse the trend towards more outsourcing and a less vertically integrated parts acquisition and manufacturing process.

As future automobile designs move towards component systems and modular construction, the value added in vehicle production can be expected to shift from assembly plants to components parts production. If, for example, GM buys high value-added modular headliners and doors from non-GM suppliers, much potential profit is lost. Modular construction is cost effective today only because it has the effect of shifting construction out of the final assembly plants, which are extremely difficult to schedule and control. The concept of moving this type of work to a smaller, easier to manage facility is a good one, but to send the work outside the corporation is a big mistake. Modular assembly is the trend of the future, for it greatly simplifies the final assembly process, de-coupling it from the build-up of components. But to send it outside will threaten the profits and eventually the very existence of the automakers.

The trend has been that as automobile technology gets more complex, the American automakers increasingly turn to outside suppliers to augment their research, development, and sourcing. As this trend continues, the management of suppliers will have a much greater impact on the automotive enterprise than ever before.

The trend of more outsourcing, combined with more single source suppliers, makes the automakers particularly vulnerable to their suppliers' problems. A problem with just one JIT supplier can shut down an entire final assembly plant. This situation creates a new challenge for the manufacturing enterprise. The enterprise must be extremely careful of whom it picks for its suppliers, and constantly work to help the suppliers continually improve. Dealing with suppliers, which was once primarily a purchasing function, is evolving to more of an industrial/manufacturing engineering task.

Companies such as Bendix, which developed the airbag system for the Geo Metro, have developed such sophisticated research and development capabilities that they have in fact created their own barrier to entry for competing suppliers.

The automakers have off-loaded much of the design responsibilities to large first-tier suppliers like Bendix, which puts the automakers at great risk. General Motors must be careful that it does not find Bendix in the same uncompetitive mind set situation that developed at Briggs. And, just as Ford was forced to bring in-house its body fabrication when inefficient Briggs was bought by Chrysler, General Motors runs the same risk when it has, for example, all of its airbag design work being done by a single supplier. Besides short term problems, such as that of propellent discussed previously, General Motor's management must worry about access to Bendix technology in the future. If Bendix were to become controlled by unfriendly owners, General Motors might very well lose access to leading edge airbag developments, among other things.

The measuring of corporate performance by the most recent quarterly earnings, without regard for long term capability and stability, has been extremely harmful to United States manufacturers. Facility modernization, improving production processes, and product design have been severely neglected. This problem is not unique to the automobile industry. The consumer electronics, semiconductor, and steel industries have suffered significantly under this type of thinking. This quarterly profits mindset has been the driving force behind the trend of sending work outside. As long as this type of thinking continues, so will the practice of shrinking internal research and development capabilities, and the increased outsourcing of critical design work. If unchecked, there is no reason to think that the United States automotive industry will end up any differently then, say, the United States consumer electronics industry; little more then a marketing and distribution enterprise selling other nations' products.

The Japanese automobile companies are not concerned about short-term profits, but about long-term investment. They are investing money in facility modernization, improving production processes and product design. This long-term investment is positioning them well for the future, when they will be able to increase market share and thus inflict severe damage on the United States automotive industry.

The Japanese transplant trend is going to have a devastating impact on American suppliers such as Bendix, and this will also impact the American automakers in the long term. As the Big Three market share shrinks due to imports, so will the market share of their suppliers. Many of these suppliers are not financially strong enough to continue to provide the same level of leading edge research and development with continually shrinking volumes. This is because they will be forced to compete with the Japanese suppliers, whose prices do not directly reflect their research and development costs. Over time, this will lead to a significant technical and cost advantage for Japanese suppliers. American automakers should share the same fears as the semi-conductor and machine tool industries of being denied leading edge technology by foreign controlled suppliers.

This problem will be compounded by the United States automotive manufacturers as they change their focus from in-house research and development to outsourced research and development. The automakers must be careful not to lose their significant human resources knowledge base. By not having in-house experts who are able to manage projects and monitor suppliers' progress, they run the risk of losing control of projects.

Mindful of this risk, automakers must manage outsourced projects effectively. This is being done in large part by using outside design services that work on-site. By having teams of contract designers working in-house, managers feel they are better able to control complex projects, and help to assure the security of proprietary developments.

This relationship must be pursued with great caution because simply having outside experts in-house will not guarantee the development of, and access to, the latest technical innovations. The automakers will need to reverse the trend of suppliers (either on-site or off-site) developing important new technologies. If the Big Three continue this trend of relying more and more on suppliers for innovation, history will surely repeat itself and they will find themselves at the mercy of their suppliers.

However, contract engineers will become more valuable in the future for other reasons. As the number of engineering graduates continues to shrink, there will be fewer qualified people for the automakers to hire. The engineers that the automakers do hire should be developed as technical experts in whatever areas that are of importance at that time, with retraining occurring constantly. These highly trained in-house engineering managers will then become team leaders, assembling groups of both in-house and contract engineers, or 'rental experts', who will work on particular projects, with the team disbanding at the project's completion. These contract people will be technical experts in a narrow field, but must additionally be able to function as part of a broader but still focused group in order to be effective [47,48].

In order to manage these projects, both in-house and through outside vendors, the whole automotive organization will become more knowledge based. Automotive enterprises of the future will be composed of fewer middle managers, with primarily specialists who direct and discipline their own performance through organized feedback from colleagues, customers, and the corporate headquarters and tech centers. The enterprise will become much more information and knowledge based than it is today. As the automotive enterprises become better at sharing information over long distances, and further experience the coming shortage of engineering personnel mentioned previously, they will start to take advantage of engineering and design services on a global scale, sub-contracting to vendors in countries such as India, China, and Malaysia [47].

When properly managed, supplier relationships can be seemingly beneficial to both parties, a good example being General Motor's APV minivan development program. For the APV, suppliers worked with General Motors to develop new materials and processes, and shared in the financial risk as well. In return, General Motors has agreed to sole source from these suppliers for the APV, but not necessarily for future projects. Thus both sides have ownership in the success or failure of the APV, and suppliers are motivated to strive for continuous improvement in order to win future contracts.

While this relationship seems to be a success so far, it is too soon to really tell. The relationship between General Motors and the APV suppliers is the first ever where a significant number of suppliers have so large a stake in the project's success that their very existence depends on it, as discussed previously. It is too soon to tell if this relationship will be successful long term, but it must be closely watched, for it has the potential to repeat yet again the previously examined situation where Ford was at the mercy of Briggs. General Motors may run into the same types of problems sourcing the large plastic panels that it has neither the capacity or expertise to manufacture itself. Even though these supplier contracts are renegotiable, realistically there simply are no other suppliers that can make the capital investments needed to enter such a niche market. If the APV fails because of poor market acceptance, the real test of goodness of this relationship may never be known, for suppliers will not be the root cause of the failure. But, if it is a huge success and sells well for years, this car plant may well predict the future of modular outsourcing. If the APV suffers from supplier problems, it will be the most persuasive evidence yet that outsourcing is not the way to go.

The trend of modular sourcing has serious implications for traditional automotive suppliers, especially allied component groups such as Packard Electric, that have in the past enjoyed a somewhat captive market. Even if General Motors decides to do their own modular construction, as suggested previously, this still does not mean that they will buy wiring from Packard Electric. These allied suppliers must now sell themselves as second-tier suppliers to former competitors. Many of these competitors have been chosen by the final assembly plants as modular component manufacturers, and have final sourcing decision on lower tier component suppliers. Allied component manufacturers must now seek this modular business. In order to grow, they themselves should consider branching out into new areas. Some will themselves become second tier suppliers and get into businesses such as building components such as whole doors and headliners. Moving into the modular component arena is the only way that allied suppliers will be able to maintain and increase their product content levels in future vehicles.

Technologies deemed crucial to an automakers successful future must be planned and developed in-house, or if developed outside be very closely and carefully managed. They cannot be bought and simply made to work. American automakers must resist the temptation to use brute force and a blank check to attack their deficiencies in new technology areas. General Motor's buying, and very painful marriage with, EDS (Electronic Data Systems) to gain information data processing capabilities is a good example of what management can expect when it attempts to "buy" a technical advantage. The failure of General Motors to integrate EDS into its very different corporate culture, detailed in Keller's Rude Awakening [14], is on a larger scale what American automakers can expect if they find themselves having to once again buy out their suppliers in order to bring costs, or technical innovation, under control.

Conclusions

It is apparent that as automobiles have become more complex, the automakers have been unwilling to invest in the development and production resources needed to support this new complexity.

The automakers have instead turned to outside suppliers to provide the research and development services, production facilities, and human resources necessary to run their enterprises. These suppliers have increasingly been single source suppliers. Single sourcing is attractive because it encourages suppliers to invest heavily in new technologies, with the promise of a captive market. Additionally, single sourcing simplifies scheduling, and eliminates duplicate research and development efforts.

This trend has been easy to justify because, on the surface, it appears to facilitate the move towards modular build packages. This logic is flawed, however, because there is no reason that modular build packages cannot be designed and constructed in-house. Manufacturing in-house is the best single-source supplier relationship there can be, if it is managed correctly.

By outsourcing, the automakers are 'giving away' opportunities for value-added profit. They are sacrificing true control over the technologies of their products. As these automakers rely more and more on outside suppliers for design work (many times the SAME supplier), their products will lack individuality; they will eventually evolve into nothing more than commodities.

One can only conclude that the present outsourcing trends and practices are placing the future industrial prosperity, independence, and autonomy of the former big three automakers in great jeopardy. To counteract this, the automakers have no choice but to bring modular assembly work back in-house. They must invest in research and development, and modern manufacturing facilities. They must develop their human resources so that they are no longer dependent on outside concerns for the decisions that shape the very core of the enterprise. New manufacturing, investment, and human resource development strategies must be pursued vigorously.

The modern, multi-national automakers rest on the exploitation of their technologies. If they cannot control the development of these technologies, than they cannot control their own futures. By allowing outsiders to feed them technical innovations, any one automaker is at great risk of receiving only second generation developments, with the leading technologies going to competitors. The automakers must pay close attention to the management of these technologies. Even if they do not bring this technology development back in-house, they must carefully manage it to assure that they maintain their technological competitiveness.

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