Automotive Electronics in North America

Primary Report
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INTRODUCTION

OBJECTIVE OF THE STUDY

The objective of this study is to provide Dataquest clients with comprehensive and qualitative information, based on quantitative and statistically valid data, on the use and trends for electronic modules/systems, semiconductors, and components in the North American automotive market. It was undertaken with the intent that the report of findings be regarded as the definitive research document for this market for model years 1988 through 1995.

SCOPE OF THE STUDY

GEOGRAPHIC COVERAGE

The study focuses on the use of Automotive Electronics in North America. It encompasses all passenger cars and light trucks[1] produced in the United States, Canada and Mexico, whether for local consumption or for export. It identifies every electronic module/system used in every make and model of vehicle assembled in these countries, regardless of where the individual component was manufactured.

The component content of these electronic modules/systems is included in the analysis of component usage, again, regardless of manufacturing origin. The attempts to segregate module content by country of origin proved to be more difficult than had been envisioned; this study therefore analyzes the content of *all* modules used in vehicles produced in North America.

ASSUMPTIONS

The following assumptions were made from the outset.

1. To the extent feasible, all information is reported on a model-year basis (see explanation below on "model year" versus "calendar year").

2. Market-share information is based on *production* volumes, not registrations (sales units by vehicle), as production numbers more reliably indicate the potential available market for a given supply base.

3. The term "Automotive Electronic System," as it pertains to this study is confined to specific modules and sensors with electronic content as identified in the data. In general, a given Automotive Electronic System could also comprehend such items as wiring harnesses, external switches, motors, actuators,

1 This study defines "light-duty" (or "light") truck as possessing a gross vehicle weight (GVW) of 10,000 lbs. or less. Sport-utility vehicles (SUVs) fall into this category, as do passenger and cargo vans.

relays, etc. For the purposes at hand, the term "Automotive Electronic System" thus refers only to those items contained within a particular module's electronics package for each system identified. In most instances, the data contained herein refers to the market for "Modules/Systems," which more precisely defines the area under study.

4. "Captive" sources[1] are included in this analysis and are identified as such.

5. Categorization of vehicles, systems and components is, to a certain degree, unavoidably subjective, as different companies report data in different ways. Listings and definitions are provided for all categories utilized in this study.

6. All economic assumptions are explained in the appropriate sections.

DEFINITION OF TERMS

2WD/4WD - Two-Wheel Drive/Four-Wheel Drive

ABS - Antilock Braking System

AFTERMARKET - The market for products, parts and accessories sold for and/or installed on vehicles after the time of vehicle manufacture (as distinct from OEM).

BACKLIGHT - Rear Window

BAP - Barometric Absolute Pressure

CAGR - Compounded Average Growth Rate. Calculation formula is: [{(L/F)exp(1/N)} - 1]*100
wherein,
L = last value
F = first value
N = # of periods

CD - Compact Disc

CHMSL - Center High-Mounted Stop Light

CY (Calendar Year) - Jan. 1 to Dec. 31

DAT - Digital Audio Tape

EFI - Electronic Fuel Injection

ELECTRONIC MODULE - A discrete electronics package, that makes up a component of an ELECTRONIC SYSTEM (e.g., Engine Control Module, Cruise Control Module, Power Audio Amplifier)

ELECTRONIC SYSTEM - Collection of electronic and mechanical components, sensors, actuators, wiring, switches, etc. that make up a functional product (e.g., Engine Control System, Instrument Cluster, Audio System). Each Electronic System may include more than one Electronic Module. (The scope of this study is limited to the content of Electronic Modules, that do make up systems.)

ETR - Electronically tuned Radio

FFV - Flexible-Fueled Vehicle (i.e., a vehicle capable of running on alternative fuels in addition to conventional gasoline)

GPS - Global Positioning Satellite

HUD - Head-Up Display

JOINT VENTURE - A manufacturing or marketing enterprise involving more than one corporate entity (see "TRANSPLANT" below)

LCD - Liquid Crystal Display

MAP - Manifold Absolute Pressure

MPFI/MPI - Multiport Fuel Injection

MY (Model Year) - Varies by manufacturer, but generally the period from the beginning of

1 *A "captive" source is defined as a supplier owned by the OEM installer (e.g., Delco Electronics is "captive" to General Motors). In general, however, captive suppliers are not necessarily restricted from doing business with other vehicle manufacturers.*

October to the end of September the following year. This is the period during which a specific model-year vehicle is produced. Production ramp-up typically begins in August and phase down for model changeover in late June.

OEM - Original Equipment Manufacturer

PRNDL - Automatic transmission gear selector sequence, reading from left (Park, Reverse, Neutral, Drive, Low)

TBI - Throttle-Body Fuel Injection (single-point)

TRANSPLANT - A vehicle manufacturing or assembly plant located in the U.S. but owned wholly or partly by an offshore-headquartered manufacturer (e.g., Nissan's plant in Tennessee). Some TRANSPLANT operations are JOINT VENTURES, meaning that more than one manufacturer is involved (e.g., NUMMI plant in California - Toyota/General Motors 50/50).

VF - Vacuum Fluorescent

VM - Vehicle Manufacturer

WOT - Wide-open Throttle

DEFINITION OF CATEGORIES

To render meaningful analysis, the vehicles, electronic modules/systems and components need be categorized; so doing so facilitates examination of their respective behavior. The sections that follow describe how the various segments are defined for the purposes of this study.

VEHICLE CATEGORIES

Vehicles are categorized by size, type and market segment. The categories used are consistent with those adopted by The WEFA Group, a recognized authority on reporting automotive production and forecast data (WEFA has emerged from the combination of the Wharton and Chase Econometric forecasting groups. WEFA provides the basis for the data in *Ward's Automotive Reports*). For this study, vehicles are classified as follows:

PASSENGER CARS

Sporty Compact
Standard Compact
Specialty Compact
High Full-size
Standard Full-size
High Luxury
Sporty Luxury
Standard Luxury
Sporty Mid-size
Standard Mid-size
Standard Minicompact
Sporty Performance
Sporty Subcompact
Standard Subcompact

LIGHT-DUTY TRUCKS

Full-size Pickup
Small Pickup
Full-size Specialty Vehicle
Small Specialty Vehicle
Full-size Van (cargo)
Small Van (cargo)
Full-size Wagon (passenger)
Small Wagon (passenger)

ELECTRONIC MODULE/SYSTEM CATEGORIES

There are numerous ways to categorize vehicle electronic modules/systems. Many auto manufacturers, electronic module/system suppliers and component suppliers categorize systems differently.

In the course of researching this study, Dataquest conducted a subsurvey to determine how best to classify various systems. Dataquest respectfully proposes that the industry adopt the results of this study as a standard for reporting system categories. The following sections define Dataquest's recommendations for systems categorization. Although not exhaustive, the lists shed light upon the types of systems within each category. (Dataquest's Semiconductor Services Industry Group is now adopting these categories as their standard for reporting semiconductor application information.)

POWERTRAIN SYSTEMS

This category embraces, as applicable, all systems involved in the powertrain of the vehicle-engine, fuel system, ignition system, transmission, transaxle.

Examples:

Integrated Engine Controls
Stand-alone Engine Control modules
Fuel Injection Systems
Carburetor Control modules
Engine/Powertrain sensors
Ignition Systems
Spark Advance modules
Idle Speed Control modules
Voltage Regulators
Speed Signal Buffers
Transmission Control modules
Accessory Drive Control modules
Alternative Fuel Controls

ENTERTAINMENT/COMMUNICATIONS SYSTEMS

The Entertainment/Communications category embraces all products relating to audio reproduction and/or communications external to the vehicle.

Examples:

All Commercial Broadcast Radios/Receivers
Tape Decks
Compact Disc Players
Graphic Equalizers
Power Audio Amplifiers
Speakers
Cellular Telephones
Antenna Control modules
Antenna Amplifiers
Citizens Band Radios (CBs)
Remote Audio Control Panels
Headphone Controls

DRIVER INFORMATION/DISPLAY

The Driver Information/Display category embraces all instrument-panel systems that provide the driver information on the operation of the vehicle.

Examples:

Electronic Instrument Clusters
Head-Up Display
Electronic Compass
Electronic Temperature Gauge
Integrated Diagnostic System
Low Fuel Warning
Low Fluids Warning
Lamp Outage Warning
Brake System Warning
Voice Alert Systems
Trip Computers
2WD/4WD Indicators
Clocks
CRT Displays
Fuel Range Display
Service Reminders
Navigation/Location Systems

VEHICLE CONTROLS

This category embraces all vehicle-control functions not specifically listed under Powertrain Systems (above).

Examples:

Ride Height/Level System
Active Suspension System
Electronic Ride Control System
Anti lock Brake System
Traction Control System
2WD/4WD Control System
4 Wheel Steering System
Electronic Noise Control System
Collision Warning System
Collision Avoidance System
Electronically Assisted Power Steering
Cruise Control

BODY ELECTRONICS

Body Electronics embraces all electronics associated with vehicle lighting, in-vehicle data communications and any controls associated with movable body parts (e.g., sunroofs, windows, aerodynamic aids). Category also includes products used for multiplexing electronic information through the vehicle.

Examples:

Driver-Door Multiplex System
Steering-Wheel Multiplex System
Automatic Headlamp High-beam Dimmer
Headlamp Timers
Interior Light Delay
Light Reminder System
Automatic Headlamp-On System
Daytime Headlamp System
LED CHMSL
LED Taillamps
Electroluminescent Supply Module
Illuminated Entry System
Cornering Lamp Control Module
Automatic Sunroof Control Module
Power Window Control Module
Aerodynamic Aid Control Module

SAFETY, COMFORT, CONVENIENCE ELECTRONICS

The Safety, Comfort and Convenience(S/C/C) category embraces all devices pertaining to any area not mentioned in a foregoing section. S/C/C items relate to safety, security, environmental control and convenience.

Examples:

Keyless Entry System
Security/Antitheft System
Automatic Climate Control System
Air purification system
Memory Seating System
Memory Seat/Mirror/Steering Wheel system
Backup Alarm
Backup Distance Sensing System
Interval Wiper control
Automatic Wipers (rain actuated)
Backlight Timer module
Heated Windshield module
Automatic door locking system
Airbag control module
Passive seatbelt control module
Automatic Glass-tint gradation control
Electronic warning chimes
Automatic dim rearview mirror
LCD rearview mirror
Automatic Decklid/Hatch pulldown

MODEL YEAR/CALENDAR YEAR CONVERSION

The automotive industry reports data on either a Calendar Year (CY) or a Model Year (MY) basis. Although it varies with the manufacturer, the Model Year as is generally observed runs from October 1 to September 30. Tooling change usually takes place during late June and July, followed by new-model production. Model-year production typically winds down in June or July.

Minor albeit sometimes significant discrepancies occur in comparing Model Year with Calendar Year production figures. Consequently, it is desirable to develop an algorithm for converting Model Year to Calendar Year, and vice versa, so that fair and statistically valid comparisons may be made.

The Chart in Table 1 and the Graph in Figure 1 depict an historical comparison of Model Year versus Calendar Year production for North America. As the illustration reveals, the industry as a whole has done much better in recent years in matching production volumes to demand, resulting in closer correlation between Model Year and Calendar Year figures. As case in point between 1984 and 1988 there has occurred an average difference of only 2.9% between Model Year and Calendar Year production figures.

Because it is not possible to develop a simple model that yields results with greater accuracy when applied to the historical data, in this study Dataquest will use Model Year and Calendar Year Production figures interchangeably. For example, for Calendar Year 1990, Dataquest will use the same production volume forecast as for the corresponding Model Year 1990. It should be noted, however, that as available, actual Model Year data are cited herein.

Table 1

YEAR	MODEL YEAR VOLUME	CALENDAR YEAR VOLUME	CY-MY	% ERROR USING CY FOR MY	% ERROR USING MY FOR CY
64	7,892,090	7,744,888	(147,202)	-1.9%	-1.9%
65	7,882,679	9,335,208	1,452,529	18.4%	15.6%
66	8,606,166	8,604,726	(1,440)	-0.0%	-0.0%
67	7,666,898	7,412,610	(254,288)	-3.3%	-3.4%
68	8,402,870	8,848,507	445,637	5.3%	5.0%
69	8,440,765	8,224,267	(216,498)	-2.6%	-2.6%
70	7,595,411	6,550,077	(1,045,334)	-13.8%	-16.0%
71	7,221,290	8,557,878	1,336,588	18.5%	15.6%
72	8,589,049	8,827,706	238,657	2.8%	2.7%
73	9,915,802	9,667,118	(248,684)	-2.5%	-2.6%
74	8,125,488	7,309,763	(815,725)	-10.0%	-11.2%
75	6,523,880	6,740,584	216,704	3.3%	3.2%
76	8,114,376	8,537,759	423,383	5.2%	5.0%
77	9,159,100	9,293,674	134,574	1.5%	1.4%
78	8,995,418	9,153,299	157,881	1.8%	1.7%
79	9,526,024	8,418,369	(1,107,655)	-11.6%	-13.2%
80	7,085,480	6,416,885	(668,595)	-9.4%	-10.4%
81	6,639,954	6,280,045	(359,909)	-5.4%	-5.7%
82	5,447,135	4,973,870	(473,265)	-8.7%	-9.5%
83	5,768,893	7,112,352	1,343,459	23.3%	18.9%
84	8,102,269	7,777,721	(324,548)	-4.0%	-4.2%
85	7,975,390	8,186,040	210,650	2.6%	2.6%
86	7,890,392	7,829,697	(60,695)	-0.8%	-0.8%
87	7,375,359	7,094,992	(280,367)	-3.8%	-4.0%
88	6,903,518	7,129,420	225,902	3.3%	3.2%
TOTAL AVERAGE ERROR OVER 24 YEARS				6.6%	6.4%
TOTAL AVERAGE ERROR LAST 5 YEARS				2.9%	2.9%

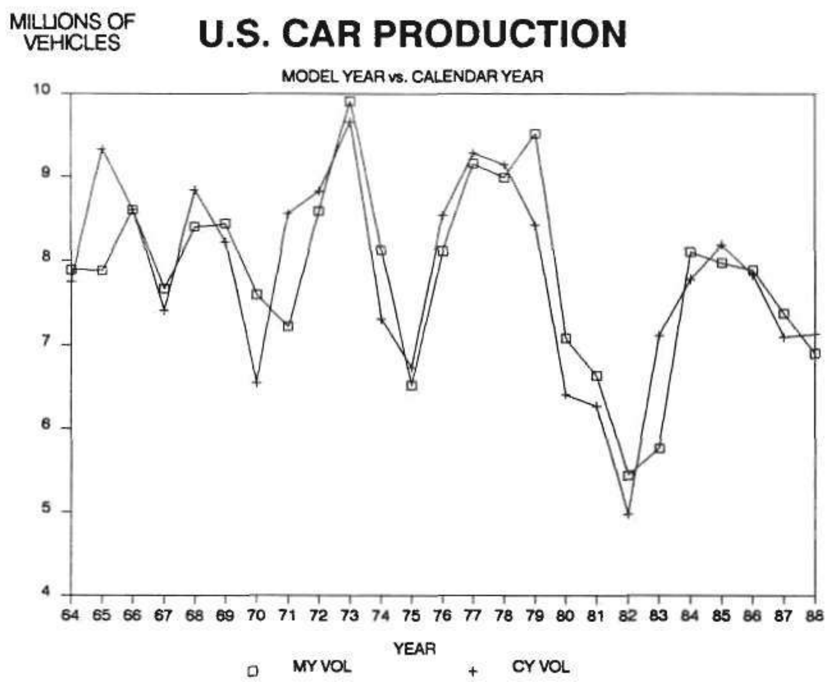

Figure 1

METHODOLOGY

The research for this study draws upon information obtained from a variety of primary and secondary sources. The assimilated information was used to create a massive database on Automotive Electronics. The sections that follow describe collection of this information and provide a detailed explanation of the database created, thereby forming the nucleus of the research.

DATABASE DEFINITION

Undertaking the study necessitated creation of a comprehensive database encompassing vehicle production, the installation rate of electronic modules/systems on these vehicles and the component content of said systems. The sections that follow explain the methodology used to create the final database.

DATABASE STRUCTURE

The database assembled with which to track the market for vehicle electronic modules/systems and components is a multidimensional database consisting of three major elements - Vehicle Production, Electronic Modules/System Usage and Component Usage (Figure 2 is a pictorial representation of the database structure.)

The vehicle production forecast portion of the database provides the volume basis for computing the remainder of the information needed. A vehicle forecast for each North American manufacturer was developed for MY88-95. MY88 was chosen as the point of origin because as the research task commenced it was the most recent for which published data on equipment installation rates was available.

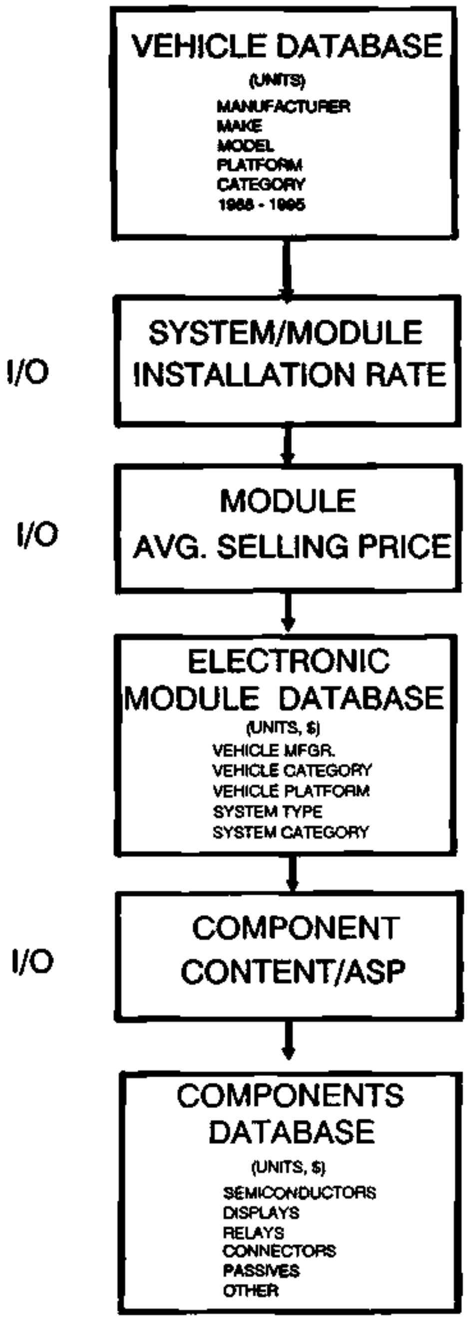

Figure 2
Overall Structure of Database

The vehicle forecast is an econometrically driven model derived from production-volume projection developed by The WEFA Group. The WEFA forecast provides Dataquest with a highly respected source of vehicle production data. However, minor adjustments were made to the WEFA numbers when superseding information was discovered in the course of Dataquest's research task.

The resident database built by Dataquest will be updated periodically to supply current information regarding vehicle forecast by make and model. The vehicle database can be summarized by individual auto make (manufacturer), by individual model, by vehicle category (e.g., luxury, compact, mid-size), and by manufacturer platform identification (where known). Vehicle production information also can be summarized according to country of origin (U.S., Canada, Mexico). Finally, the vehicle production forecast can be segmented into passenger cars and light-duty trucks.

The vehicle production forecast is qualified by an I/O factor that represents the installation rate of each system identified by individual make and model, yielding an Electronic Modules/Systems database. The I/O factors were ascertained through primary and secondary research described below (pp. 9-10). Multiplying the vehicle production database by the appropriate installation rate I/O factor results in an Electronic Modules/Systems database that denotes the number of units manufactured.

A second I/O factor, this representing the estimated Average Selling Price (ASP) of the electronic modules contained in these systems, is next multiplied by the Electronic Module/System database units, arriving at an estimated Electronic Module/System dollar value for the electronics modules' value. These I/O factors were ascertained through primary and secondary research efforts described below (pp. 9-10). The dollar values cited in this report *at this level*, refer to the wholesale, or OEM dollar value of the **System Modules Only.** Excluded are such peripheral components as wiring harnesses, external switches, actuators and the like.

For example, in an AM/FM/Stereo Cassette radio, the value shown represents only the radio. Purposely excluded are wiring, speakers, antenna and any other components unless specifically identified. In a system consisting of, say, a radio with a power amplifier and graphic equalizer, the estimated value of each item is stated. With respect to sensors, those most widely used are identified individually and are noted as separate line items.

The Electronic Modules/Systems database is summarized by type of individual system (e.g., cruise control, AM/FM radio), by system category (e.g., Powertrain, Entertainment) and, as applicable, by any other database category. The Electronic Modules/Systems database thus serves as the generator of the next level of detail, the Electronic Components Database.

The Components database is divided into (1) Semiconductor Components and (2) Other Major Components. For Semiconductor components, category breakouts are consistent with conventions established by Dataquest in reporting Semiconductor Industry data to clients. A list of these categories is contained in Table 2 (p. 9). Other Major Components are shown in Table 3 (p. 9).

DATABASE INFORMATION

The database used to create the foundation of this report resides at Dataquest headquarters in San Jose, California. It is Dataquest's intention to do periodic updates as statistically significant new data is discovered. Provided that client interest is sufficient to justify, an additional forecast year will be appended at the end of each calendar year, thereby perpetuating this original forecast into the future indefinitely. Moreover, as actual model-year data becomes known, earlier forecast estimations/projections will be revised accordingly.

The database assembled for this study is stored in an IBM PC/AT compatible. The software used to create and to maintain the database is VP Planner Plus™ Version 2.0, by Paperback Software International. VP Planner Plus is a spreadsheet program, similar to Lotus 1-2-3™. It differs most significantly in its unique, multidimensional database capability, making it especially well suited in maintaining large, complex databases such as this. It produces

Table 2

SEMICONDUCTOR CATEGORIES

- Integrated Circuits
  - Bipolar
    - ASIC
      - Cell Based
      - Full Custom
    - Memory
  - MOS
    - Microcontrollers
      - 4 bit
      - 8 bit
      - 16 bit
      - 32 bit
    - Logic
      - Standard
      - ASIC
        - Gate Array
        - Cell Based
        - Full Custom
    - Memory
      - DRAM
      - SRAM
      - EPROM
      - ROM
      - EEPROM/NVRAM
  - Analog
    - Amplifier
    - Voltage Regulator
    - Interface
    - Data Converter
    - Custom Std. Cell
    - Special Auto
- Discrete
  - Diode, Zener
  - Rectifier
  - Small Signal Transistor
  - Power Transistor
- Optoelectronic

Lotus[tm]-compatible spreadsheet files used to print and to graph the data contained herein. The entire database, consisting of (1) the vehicle forecast (passenger cars and light trucks), (2) the module installation rate I/Os, (3) the module Average Selling Price (ASP) I/Os, (4) the module component content I/Os, (5) the component Average Selling Price (ASP) I/Os, and (6) several "housekeeping" files, now occupies more than 32 Megabytes of hard-disk memory as of 1 May 1990. It contains several million individual data points; if printed out by each available breakdown, it would run nearly a thousand pages of condensed type!

Clients are welcome to request special reports and analyses from the database as part of the inquiry process. Upon request in writing, Dataquest will submit a proposal tailored to individual requirements. For particulars, contact Mr. Morris Kindig, (408) 437-8139.

Table 3

OTHER COMPONENT CATEGORIES

- Displays
  - VF
  - LCD
  - LED
  - CRT
  - Air Core Element
  - Other
- Sensors
  - Crank Position
  - Distributor Position
  - Cam Position
  - Throttle Position
  - Mass Air-Flow
  - Barometric Pressure
  - Manifold Pressure
  - Oxygen
  - Coolant Level
  - Temperature (air, coolant, oil)
  - Wheel Speed
  - Vehicle Speed
- Connectors
- Resistors
- Capacitors
- Indicators
- Relays
  - Low Current
  - High Current
- Other

PRIMARY RESEARCH

The information found in these pages represents the findings of extensive primary and secondary research efforts by Dataquest. In conducting the primary research, members of the dedicated research team employed the following survey instruments: personal interviews, telephone interviews and mail surveys. To ensure source confidentiality, the names of individuals and companies providing any relevant information, even that used only as "background," are withheld. As a group, those queried by one means or another represent the following constituencies:

- Automotive Industry Researchers, Analysts and Academicians
- Automotive Journalists
- Captive Electronics Manufacturers
- Electronic Component Manufacturer Executives
- Electronics Manufacturer Purchasing Executives
- Electronics Manufacturer Sales, Marketing Executives
- First Tier Auto Electronics System Manufacturers
- Retail Dealer Executives
- Second Tier Auto Electronics System Manufacturers
- Semiconductor Manufacturers
- Vehicle Manufacturer Executives

To supplement the personal interviews, a questionnaire was mailed to a representative sample of individuals in the supplier community. Its purpose was to aid in categorizing the many different types of electronic modules/systems.

SECONDARY RESEARCH

In addition to the aforementioned primary research, considerable secondary research was conducted to enrich the final report. Specifically, historical and current-year information pertaining to vehicle equipment-installation rates, available optional equipment and equipment pricing emanated from the secondary research. Major informational sources include:

Automobile
Automotive Electronics Journal
Automotive Engineering
Automotive Industries
Automotive News
Autoweek
Car and Driver
Cars International 1989
Edmund's New Car Prices
Electronic Buyers News
Electronic Outlook Corporation
Electronics
Electronics Manufacturers Promotional and Sales Literature
Mitchell's Service Guides
Motor Trend
Motor Vehicle Manufacturers Association Literature
Road & Track
Society of Automotive Engineers Technical Papers
Standard & Poor's Industry Surveys
The Hansen Report
The Wall Street Journal
The Power Report
The WEFA Group
Vehicle Manufacturer Promotional and Sales Literature
Ward's Reports
Ward's Auto World
Ward's Yearbook 1989

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MARKET ANALYSIS

The market analysis provided is divided in accordance with the three major elements constituting the database: (1) the vehicle market; (2) the market for systems/modules; and (3) the market within said systems/modules for electronic components. The section that follows on the Economic Forecast summarizes econometric assumptions that were made by The WEFA Group in developing the vehicle forecast used as an input to our database.

ECONOMIC FORECAST[1]

Although some economists argue that a national recession looms, The WEFA Group stands by its "baseline assumption" that no recession will occur in 1990. WEFA pegs the odds of a "near-term" recession at only 1 in 4.

WEFA sees a marginal expansion of the U.S. economy in 1990 by approximately 1.8% (compared with 2.9% actual in 1989) and real growth of 1.2%. Real growth of the GNP, meanwhile, is forecast at 2.3% for 1990 and 1.8% for 1991.

Fear of a recession could, nevertheless, prompt the Federal Reserve Board to tighten credit by late 1990, thereby precipitating an economic nose dive during the first three quarters of 1991. The Fed likely will ease credit by mid-1991, generating an economic uptick by late 1991.

The specter of a recession looms, however, for the rest-of- the-world economy. WEFA projects a real-growth decline for four consecutive quarters beginning first quarter 1991. Global recession is seen harming the U.S. economy, chiefly in terms of higher unemployment throughout 1991, peaking at 7.0% in quarters 1 and 2 of 1992.

Evidence is plentiful that consumers today are significantly less free-spending. The conspicuous consumption that marked the Eighties, especially among young, high-flyer professionals, is out; prudent purchasing and frugality are in.

The impending launch of the trade-barrier-free European Community (see "European Community", p. 105), coupled with the recent fall of Communism in Eastern Europe, could prove a mixed blessing for the U.S. economy. On the one hand, it doubtless will create new market opportunities for U.S. durable goods -- including automobiles. On the other, worldwide competition in both Eastern and Western Europe will be fierce. It remains to be seen whether U.S. OEM suppliers and VMs can move fast enough, adapt fast enough and successfully market their wares -- meaning world-class quality at competitive prices.

It would appear that if the U.S. does, in fact, move in earnest toward adopting gasoline-substitute fuels (see "Alternative Fuels," p. 132) for mainstream private transportation, it will come by government fiat and not by the weight of marketplace forces. Why? Because the price of gasoline is seen as remaining fairly stable for the next several years.

To wit, WEFA forecasts the Refiner's Acquisition Cost (RAC) of crude oil to average $18.25 per barrel for all of 1990 vs. $19.00 in the first quarter. WEFA projects a drop, to

1 Main information source for this section: The WEFA Group/Ward's Research, North American Light Vehicle Production Review, March 29, 1990

$17.56, for 1991, followed by a modest rise, to $18.62 for 1992. Bottom line: stable crude prices at least through 1992. For this reason, if alternative fuels are to gain popular acceptance near-term, it won't be because the pump price of gasoline is soaring. Rather, it will be because state and federal governments require it mainly in the interest of air-pollution abatement.

VEHICLE FORECAST[1]

North American[2] vehicle production is expected to rise approximately 9.9% by MY95 from MY88. Aggregate production volume for MY89 declined from MY88 by approximately 1.7%. MY90 is forecasted to be down further, at roughly 3.4% below MY88 and 3.3% below MY89. A modest rebound is expected for MY91, followed by another minor downturn in MY92. Full recovery is not foreseen until MY93 (See Figure 3, p. 23). Between MY90 and MY95, the projected compounded annual growth rate is 3.0%.

Top-Five Countries in Motor Vehicle Production

CY88

1)	Japan	12,699,803
2)	USA	11,190,452
3)	W. Germany	4,625,314
4)	France	3,698,465
5)	USSR	2,180,000

Total vehicles (cars, trucks, buses)

It is important to bear in mind that this forecast pertains to North American vehicle production, not sales. Vehicles marketed here but manufactured elsewhere -- "imports" -- are definitionally excluded. This forecast includes vehicles produced for export. While exports do not represent a significant portion of North American production today, it is anticipated that exports from the transplant manufacturers will increase over this period (See "Transplant Operations," p. 99).

Of particular note in this forecast is the market share growth of the so-called transplant manufacturers[3]. Their collective share is expected to grow from 8.2% of industry in MY88 to a projected 21.8% by MY95 (Figures 3 & 4, pp. 23-24). This figure represents the market share forecast for those "transplant" vehicles physically produced in North America as referenced to the total number of vehicles (passenger cars and light trucks) produced.

Likewise noteworthy is before CY88, most transplant vehicles were entry-level passenger cars and compact pickup trucks. No longer. In Marysville, OH, Honda now produces the upmarket Accord, Nissan's Smyrna, TN, plant is making an upgraded new Sentra, Toyota's Georgetown, KY, plant is building the mid-priced Camry, Mazda's Flat Rock, MI, facility is building the Ford Probe and Mazda MX6 and 626, the Diamond Star Motors joint venture is producing sporty Eclipse, Laser, and Talon models in its Normal, IL, facility, and Subaru's luxury model, the Legacy, is assembled in Indiana. This new trend toward higher-end and specialty vehicles by the transplant producers is certain to strengthen their ability to penetrate the stronghold traditional markets of the Big Three (General Motors, Ford, and Chrysler) and to influence the market for electronic modules and components, as up-market vehicles incorporate higher concentrations of electronic componentry.

Of all vehicles produced in North America in MY88, approximately 85% were assembled in the United States, 10% in Canada and 5% in Mexico. It is estimated that by MY95, 82% will be assembled in the United States (down 3 points), 13% in Canada (up 3 points), and 5% in Mexico (Figure 6, p. 26). As a nation, the United States currently ranks second among the world's motor-vehicle producers (see chart above). As a region, North America ranks first as the largest vehicle producer.

It also is important to consider production mix by vehicle category. In recent years, the largest-selling vehicle of all has been the half-

1 The data on which this analysis is based may be found in the Appendix, pages B-1 through B-4.
2 North America = U.S. + Canada + Mexico
3 Foreign- based companies with manufacturing operations in North America.

ton, full-size pickup truck. This phenomenon is unique to North America; pickups capture almost negligible market share in other world markets. Beyond the pickup, however, it is apparent from the market share values (Appendix p. B-2, and Figure 14, p. 34) that the bulk of the market comes from Subcompact, Minicompact, Compact, and Mid-size cars. Full-Size, Luxury, and Performance cars will experience a declining market share through the mid-nineties. This is significant, for as a rule, it is usually the Full-Size, Luxury, and Performance cars that account proportionately for the highest concentrations of electronics componentry.

Figure 8 (p. 28) illustrates the mix of cars versus trucks produced by the Big Three and the transplant operations. As previously noted, North American transplant manufacturers started in the early Eighties with low-end product. It is a foregone conclusion that before the turn of the century they will expand their offering to include more higher-end product.

It has been suggested that the transplant manufacturers may increasingly use their North American assembly facilities as a "launchpad" from which to export vehicles to Europe and other world markets. Given that most transplant operations involve Japanese manufacturers, these plants may afford them a means of circumventing the quotas imposed on Japanese-made vehicles by most of West Europe.

It remains to be seen whether such vehicles will be declared as "North American" or "Japanese" in origin. (For now, there is no European restriction on North American product.) The former vice-chairman of Chrysler Motors, Gerald Greenwald, has requested that the U.S. government mandate a minimum domestic content requirement on vehicles exported from U.S. soil to any European country. This request flies in the face of trade policies heretofore announced and championed by the Bush administration. The resolution of this potentially "hot" international trade issue could dramatically affect the production forecast numbers for the North American transplant manufacturers. (For a breakout of vehicle production forecast for cars and light trucks, see Appendix, pages B-1 through B-3.)

GENERAL MOTORS OUTLOOK

General Motors North American production is expected to drop from a MY88 level of 5,706,000 vehicles to a MY90 total of 4,955,000. GM's production is expected to rise slightly in MY91, however drop again in MY92. By MY95, it is forecasted to recover, to 5,265,000 vehicles. GM is expected to drop from a 44.1% market share of North American production in MY88, to a 37.0% share in MY95. GM's declining production and market share are attributable to several important factors.

The reorganization of the company in the mid-Eighties has proved to be a costly exercise for the giant automaker. Since that time, the individual car divisions have struggled for their own identities in the marketplace. Sales have suffered and exciting new models have not been forthcoming in keeping pace with the competition.

Another factor that could affect GM's competitive position is the way they have chosen to satisfy the legislated passive restraint requirement. GM has chosen non- electronically controlled passive-belt systems for most of their car lines, as opposed to airbags. With its major competitors heavily promoting the benefits of airbags, Dataquest predicts that GM will respond in kind by adopting airbags in a greater percentage of its vehicles in order to remain more competitive.

All of the Big Three, including General Motors, have felt the competitive pressures exerted by the transplant suppliers. This has been and will continue to be a factor in GM's eroding volume and market share.

FORD MOTOR COMPANY OUTLOOK

In contrast to GM, Ford is considered to have been the most successful U.S. automaker of the past decade. Beginning the Eighties with huge operating losses, then being forced to cut its workforce by more than 40%, Ford enters the Nineties profitable and as acknowledged pacesetter in productivity, quality and styling.

This performance positions Ford well for the remainder of the decade.

Ford executives are much less optimistic about their ability to forecast the increasingly stringent CAFE standards and accommodate these requirements into their own ponderously long (10-year) product design cycles.

Notwithstanding these difficulties, Ford is expected to loose only 2.7 percentage points of North American production market share (from 27.9% in MY90 to 25.2% in MY95) as opposed to 3.3% for GM in the same period.

CHRYSLER MOTORS OUTLOOK

Chrysler's current marketing strategy centers on changing the image of its offerings. Dictated by the reality of a CY90 first-quarter drop of 1.9% in market share (from the same period in 1989), Chrysler has chosen to target the huge sales gains in the U.S. market experienced by the transplants, which together jumped from 8.3% in MY88 to 15.8% in MY90, a rise of 90%!

Since the early Eighties, Chrysler chairman Lee Iacocca has confronted competition from the Japanese in his public statements. Facing the Nineties, Chrysler's challenge is much greater in that its customers have become better educated and more sophisticated in their buying patterns, and have experienced greater owner satisfaction with imported vehicles.

In his "Chrysler in the 90's Tour," Iacocca was quick to call attention to the fact that Chrysler sells 15 of the 59 models on the recommended list in Consumer Reports as opposed to only 7 list entries for Ford. Perhaps this alone is sufficient to explain the projection shown by this survey that Chrysler will loose the least production market share (only 0.2%) to the transplants between MY90 and MY95.

TRANSPLANT SUPPLIER OUTLOOK

The phenomenal penetrations of the U.S. market by the transplant producers, from 8.3% production share in MY88 to a projected 21.9% in MY95, is relatively easy to understand from the privileged position afforded by hindsight.

Beginning in 1981 with a long-range business plan, more- than-adequate financing and without the hindrances of worn, outdated equipment and cumbersome union contracts, the Japanese simply applied the methods developed during the U.S.'s own industrial revolution, and in the brief span of a decade went from zero U.S. production capacity to a total capacity of 1.5 million units a year in MY89. By MY95, based entirely upon existing plans, capacity will surpass 2.5 million units, representing over 20% of North America's vehicle production capacity.

With vast capital resources at their disposal, the real question is, what are the transplant suppliers planning for the future? Their further expansion in the next decade will be affected by several key issues, including U.S. environmental and trade policies, the condition of the U.S. economy and U.S. consumer attitudes toward purchasing "foreign" goods.

As indicated above, the transplant suppliers' outlook also will depend on their ability to successfully export vehicles from North America to other markets. From the steps they are taking, now they appear to be banking on it.

For further analysis of the vehicle production market, please refer to Figure 3 through Figure 17, pp. 23-37.

ELECTRONIC MODULES/ SYSTEMS

Based on our analysis, the total market for electronic modules/systems (as defined in this report) for this North American vehicle forecast is expected to grow 38%, from just over an estimated $4.2 Billion in MY88, to over $5.8 billion in MY95.

During MYs 90-95, the market is expected to grow by more than 29%, with a compounded average growth rate of approximately 5.2%. Figure 17 illustrates this growth by individual manufacturer.

Dataquest predicts that the greatest growth both in value and in share of market will occur in the categories of Vehicle Controls and Safety/Comfort/Convenience systems, due largely to the growth in applications of two major product areas, antilock braking systems and passive restraint systems, respectively. A combination of legislated and competitive forces in the market is causing VMs to incorporate both of these systems in increasing numbers. This gives rise to a "second wave" of growth in electronic content, similar to the "first wave" which occurred in the late Seventies with the incorporation of on-board engine- controls (See p. 110).

While most of the growth in value of this market during this period is attributable to the systems mentioned above, other product areas expected to contribute include: integrated engine-controls, keyless entry systems, lighting control products, security systems and other comfort/convenience products. The following sections summarize Dataquest's overview of each system category.

POWERTRAIN

The Powertrain category is dominated by engine-control systems. Because these products are installed on virtually 100% of the vehicles, this category is the most subject to change based on downturns in the market, as is evident from our forecast for MY90 and MY92 (Refer to Appendix C, pp. C- 23). Even though new and more complex powertrain products will be introduced in this timeframe, the growth in content will be modest compared with more substantial growth in other vehicle systems. Engine control systems, which represent the majority of the value in this sector, are continuing to evolve and become more sophisticated. Engineering efforts aimed at increasing component integration are bringing down parts counts and total cost. Thus, only modest growth is predicted for the Powertrain category. Between MY90 and MY95, the Powertrain category is expected to grow in value by $229M, amounting to a compounded annual growth rate of 2.4%.

Products to experience increased penetration in the Powertrain category include Distributorless Ignition Systems and Multi-point Fuel Injection Systems. Electronic Transmission Controls will be introduced during this period in greater numbers of applications.

Products to experience a decline in applications include Distributor-based Ignition Systems, Closed-Loop Carburetors and Single Point Injection Systems (TBI) as well as several other stand-alone modules whose functions will be integrated into the more sophisticated engine-controls (e.g. light drivers, idle speed control, spark advance).

Future emissions and CAFE legislation will place increased demand on future engine-control electronics for MY94 and beyond (See "Government Regulations", p. 117). To maximize fuel economy and, at the same time, to minimize tailpipe emissions, more sophisticated engine-management systems will be required.

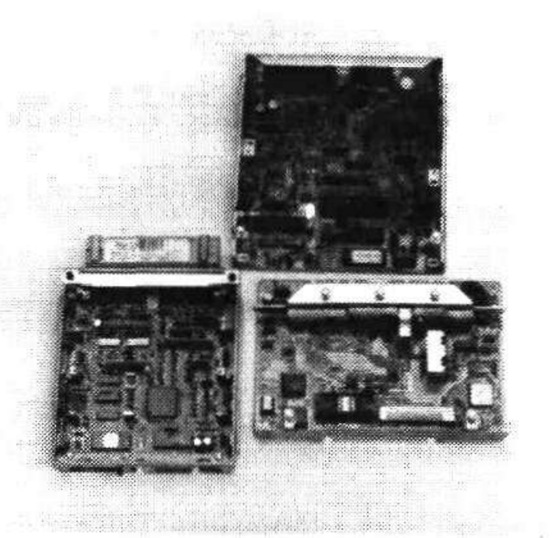
Dataquest predicts that presently available technology will be able to meet anticipated needs through the mid-Nineties. Both GM and Chrysler are producing engine-controls based on an 8-bit microcontroller architecture; to date Ford alone has gone to 16-bit. The more advanced 16- and 32-bit architectures are now under investigation by all VMs in an effort to understand how they might best meet future requirements. Although 16-, or 32-bit architectures would enhance vehicular performance, thus making it easier to meet proposed standards, Dataquest does not envisions notable change before MY95, for several reasons.

First, a tremendous investment already has been made in the software, support and development tools for the design and development of engine-control computers. Even if an architecture change should be required, Dataquest estimates it would take from three to five years for a widespread application of a new design to become a manifest reality. In addition, if a VM elected to make such a change during this period, it is likely that the change would be introduced gradually, on only a few car lines or engines initially, in order not to jeopardize their supply position should a technical or supply problem develop as production volume builds.

Second, it is estimated that change to a 16-bit architecture would represent only a modest cost increase whereas a 32-bit architecture would represent a significant cost increase over 8-bit architectures now in use, if introduced by the mid-Nineties (Note: Chrysler has designed a 32-bit machine into its advanced transmission control. To our knowledge, this is the only production application thus far of a 32-bit micro in an automotive system.). Unless it is determined that 8-bit based engine-control computers are simply not capable of performing the engine management task for a specific powertrain, Dataquest predicts that with Ford as the sole exception, 8-bit architectures will continue to dominate engine-control applications through MY95 for the North American manufacturers.

Third, 8-bit microcontroller designs have undergone substantive improvement in recent years. Both semiconductor manufacturers and their customers have re-engineered many of these products for optimized design-specific applications by customizing both the products and their manufacturing processes. This evolution of, or even proliferation of, "customized" versions of these workhorse products have made it harder for designers to justify "throwing away" the old designs and starting with a clean sheet of paper. Accordingly, embracing a whole new architecture becomes more difficult to rationalize financially.

From the standpoint of engine-controls, it would appear that U.S. VMs have a slight (2-3 year) technology lead over both offshore and transplant VMs. U.S. VMs, of course, are not eager to see this experience transferred via technology to foreign competitors. In more than one instance, a major system or semiconductor supplier has had its corporate hand slapped by a VM for offering variations on what was claimed to be proprietary technology to foreign customers.



Clockwise from top, Nissan, GM, and Ford engine control modules illustrate differences in packaging technology.

During the research conducted for this study, Dataquest examined several examples of current engine-control modules (see photo). From this analysis, it is apparent that the transplant module examined does not utilize latest methods in electronics packaging or design. Whereas most domestic VMs make use of surface-mount components, hybrids and large scale integration (LSI), the corresponding transplant module incorporates conventional through-hole designs, characterized by more discrete components.

Dataquest predicts, however, that the gap in technology between the domestic and foreign manufacturers will narrow in the next few years as technology requirements become increasingly globalized (See "World Standards" section, p.92).

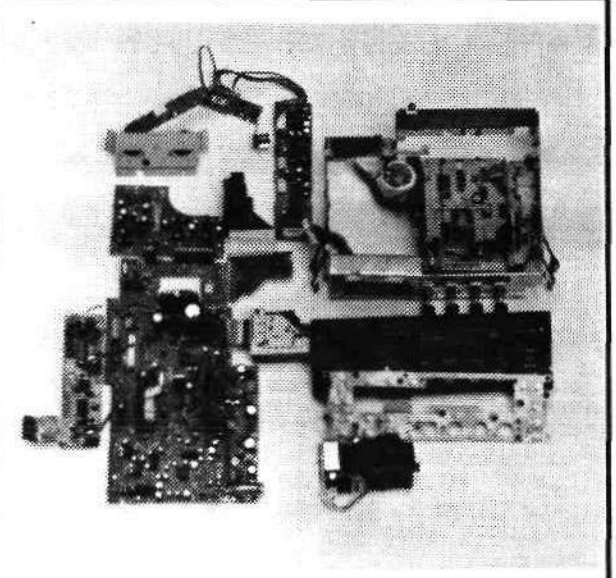
Notes: 1) For this report, we count only the Ford EEC-IV and its successors in the category of Integrated Engine Control. While other manufacturers also integrate engine functions, their modules are counted in the categories of either Multi-point EFI, Single-point EFI or Closed Loop Carburetor. This is done to permit a more accurate representation of system content based on product mixes. 2) For most Chrysler vehicles equipped with cruise control, the electronics are integrated with the engine-control module; this content is thus included in the Powertrain category. For all others, cruise-control values are assigned to the Vehicle Control category.

ENTERTAINMENT

The Entertainment category has undergone a radical transformation in recent years. No longer does the OEM car radio carry the connotation of being inferior to an aftermarket unit. In every respect – sound quality, features, appearance, and price – OEM audio products have moved upscale. In fact, AM-only and mechanically tuned radios are rapidly vanishing. Today, AM-FM stereo cassette combination radios constitute the largest single market share by type. The installation index exceed one-half of all passenger cars produced.

Virtually all radios are now electronically tuned. Mechanical tuning coils have been superseded by microcontrollers, phase-locked-loops (PLLs) and other custom integrated circuits, dedicated to performing such audio- related functions as noise reduction, graphic equalization, and tape transport control. In fact, many of the more sophisticated units incorporate not one but two microcontrollers, each designed to manage different functions within the entertainment system.

The trend to better audio quality and additional features comes in response to competitive pressure from the aftermarket, as well as from increased upscale OEM offerings by all VMs. In an effort to recover market share from aftermarket vendors, VMs also have made it more difficult to obtain and install aftermarket equipment by physically designing OEM system components to nonstandard sizes and by linking them electronically with other vehicle components (e.g., several North-America produced vehicles offer controls mounted in the steering-wheel hub to control various radio functions).



Car audio systems have become increasingly complex, as illustrated by this example with 12 circuit boards.

From the standpoint of electronics, what once was an evolution to the "one-chip" radio has become a packaging challenge to incorporate all of the components needed to implement today's full-featured entertainment system. Indeed, in many instances, the entertainment system is the most electronics-rich system in the entire vehicle. One particular AM/FM/stereo cassette radio examined as part of Dataquest's first-hand research was found to incorporate 12 individual printed circuit boards, 24 integrated circuits, more than 200 resistors and 300-plus capacitors! (photo left)

Dataquest predicts that the trend to more advanced features and to higher-quality audio components will continue. We believe, however, that redesigns will be undertaken in an attempt to reduce component counts, to solve thorny packaging problems and to provide a higher level of integration involving these items. Both cost and packaging limitations are the driving forces behind these efforts. It is rumored that one major VM is even considering incorporating a 32-bit microcontroller in an upcoming entertainment product. Also, the first production automotive application of single-chip Digital Signal Processors (DSPs) already is in a Japanese-produced car radio.

Similarly, the trend to entertainment systems that interact with other vehicle systems also will continue to evolve. From the VM's view, doing so affords added protection from aftermarket competition, as well as added opportunity to market a higher-priced, higher-profit product. From a technical standpoint, it is a logical evolutionary path for such systems as radios, CD players, cellular telephones and driver information systems to share such componentry as displays, touch panels, audio amplifiers and speakers. However, it is not expected that such fully integrated systems will command a significant market share before the mid-Nineties.

Extensive capability to design and to manufacture advanced entertainment systems is unique to the Big Three Vms. In other world markets, and as is true for the transplant producers, other VMs rely on outside vendors to develop and manufacture their audio equipment. Many other VMs do not offer factory-installed audio equipment, instead leaving the selection and installation of said equipment to the distributor or the individual dealer. The U.S. VMs have the advantage here and have begun using audio systems as an integral part of total-vehicle marketing. Although the Japanese have worked closely with outside vendors to develop similar "customized" audio systems for many of their vehicles, typically they do not factory-install them at rates comparable to that of North American domestic VMs.

VEHICLE CONTROLS

Surging demand for ABS systems is the chief reason for the Vehicle Controls area to experience explosive growth over this timeframe (See "ABS Overview and Trends," p. 87). While analogous to the engine-control system demand in the early Eighties, the ABS boom is not driven by legislative mandate. Rather, the demand is driven primarily by marketplace competition, fueled by safety-conscious, knowledgeable consumers, combined with demonstrable benefits this technology has produced (i.e., an important safety benefit now available at a reasonable price). Hailed as one of the most important automotive technology breakthroughs ever, ABS is projected to be commonplace on cars by the end of the decade, if not sooner. While ABS is propelling near-term growth in the Vehicle Controls area, other important systems that lie on the horizon will foster further opportunity in this realm.

Engineers are putting electronics to work in a number of other areas within the vehicle. Although these applications may not take off as quickly as is ABS, they will nonetheless create important new opportunities for vehicle electronics. Among them are advanced suspension controls for driver- adjustable suspension and fully active suspension, whereby the vehicle continuously adjusts itself to the road conditions for maximum safety, comfort and handling. Electronic noise-control systems are being investigated to replace mufflers by electronically canceling engine- and vehicle-produced noise. Result: a noticeably quieter vehicle.

Traction control is just now appearing on the scene as a sort of an "ABS in reverse." Electronics are used to apply power more evenly to the wheels to reduce or prevent wheelspin on slippery surfaces. Although it remains to be seen whether consumers are willing to pay for all of these advances, it is clear that most on-board innovations are in the sphere of Vehicle Controls.

Dataquest predicts that the Vehicle Control componentry will more than double, from an estimated $454M in MY90 to $947M by MY95. The compounded average growth rate (CAGR) in this period is estimated at 15.9%. Most of the growth to be realized likely will be in application of ABS.

DRIVER INFORMATION

Driver Information product penetration is seen increasing only slightly through MY95. Consumer reaction to expensive, electronic instrument displays has been mixed. Vehicles that once offered only electronic digital displays are now providing the consumer a choice of electronic, or conventional analog instrumentation. Such is the Corvette, the Cadillac Allante, the Buick Reatta and Riviera, the Lincoln Mark VII LSC and several others. Several studies indicate that as the baby-boomer generation matures, vehicles with digital displays will appeal to an aging population with deteriorating vision. Thus far, however, the market experience has not supported this finding. Between now and the mid-nineties, electronic instrumentation will remain no more than a niche market on selected high- line and "performance" vehicles.

Consumer demand for "old-fashioned," analog instrumentation has not suppressed the application of electronics to the dashboard, however. In growing numbers, conventional gauges seen today are of the air-core type, a technology that involves electronics. Driven by both cost and package-size constraints, instrument clusters are now incorporating electronics in place of mechanical and electromechanical devices. At the 1990 Society of Automotive Engineers Congress and Exposition, one semiconductor manufacturer was displaying a "one-chip" solution for air-core gauge applications, in which only one custom IC is required to drive a given gauge. Dataquest predicts that by MY95, nearly 6 in 10 vehicles produced in North America will incorporate electronically driven air-core gauge clusters.

Driver Information products are likewise playing a greater role in vehicle diagnostics. OEM diagnostic systems with increased capabilities are finding their way not only into luxury cars, but also into lower-priced, mid-size cars. Integrated diagnostic products such as low fluids warnings, lamp outage alerts and engine diagnostic systems are also on the rise.

Trip Computers have proved more of gimmick than a useful product. Even so, they have found a marketplace niche; Dataquest projects an installation rate of 9.3% in North American vehicles by MY95. While Navigational Systems have received considerable publicity of late, it is not expected that they will make a significant penetration into the North American Market in the time period addressed. Factors holding back their expansion include cost, ease of use, consumer acceptance and awareness, software infrastructure availability and the system's ultimate perceived value to the consumer (See "Navigational Aids," p. 112).

BODY ELECTRONICS

As measured in dollar volume, Body Electronics represents the smallest segment in North American automotive electronics, comprising an estimated $79.3M in MY90 and growing to $115M by MY95 (projected CAGR is 7.8%). One reason this category is not larger is explained by the fact that most of the componentry involves low-cost, simple systems. For example, most lighting controls fall into this segment for such functions as interior light delay, headlamp on reminder and various light timers. Multiplexing systems also are part of Body Electronics; however, their widespread application is not envisioned in the timeframe addressed by this study.

Body Electronics is expected to see continued growth both in products and in applications well into the Nineties. However, what growth Body Electronics does experience will be overshadowed by more substantial dollar growth both in Vehicle Control and in Safety/Comfort/Convenience systems.

SAFETY/COMFORT/CONVENIENCE

The Safety/Comfort/Convenience (S/C/C) category consists of a broad assortment of products which are associated with these three functional areas and which do not logically fall within any of the other aforementioned vehicle electronics categories. Examples include security systems, keyless entry systems, climate controls and memory seats. The product area that will impact this sector the most concerns passive- restraint systems, be they automatic seatbelts or airbags.

As of MY90, VMs are required by federal statute to equip an increasing proportion of their respective passenger-car fleets with passive restraints. Pending legislation would expand this standard to light trucks beginning MY94 (see "Government Regulation," p. 117). Although it is possible to meet such regulations without electronic controls (as GM is doing with many of its vehicles for MY90), competitive market pressure is forcing many VMs to incorporate airbags in increasing volume. Between now and MY95, the S/C/C sector is expected to grow from $545M to an estimated $948M, with a CAGR of 11.7%. Most of the growth will be in application of airbags and passive-belt systems.

Chrysler is the first American VM to equip all of its domestically produced cars with driver-side airbags, effective MY90. Chrysler is heavily promoting this first as a competitive advantage, one certain to spur further activity in this regard from other VMs. Not to be outdone, Ford subsequently announced plans to equip all passenger cars with both driver and passenger side airbags by MY94. GM is expected to increase its offerings in response to such competitive pressure. The net result is a projected installation rate for airbags of more than 65% by MY95.

Pressure is on for the industry to keep pace with stepped-up demand. Ford recently had to make the decision to ship Lincoln Town Cars to dealers with the passenger-side airbag deleted because of a temporary shortage from suppliers. Such problems are likely to be ironed out as the industry gears for high-volume airbag programs.

Besides airbags and passive belts, S/C/C is experiencing growth in other product areas, albeit not at nearly the rates projected for the passive-restraint devices. Other products seen gaining market share by MY95 are security/anti-theft devices and remote keyless entry.

Overall, the wholesale value of these systems/modules level will grow from a MY88 average of over $328.00 per vehicle, to a projected MY95 level of over $414.00 per vehicle. This amount is computed by dividing the total forecasted market value for those identified systems/modules by the number of total vehicles projected (combined cars and trucks) for this period. (Because the number is a composite average, it should not be used as an indicator of content for fully equipped vehicles, the dollar amount for which can run significantly higher.). See chart in Table 39 (p. 59) for graphic representation.

For a more refined analysis of the Systems/Modules market, refer to Figures 18-41, pp. 38-61.

Based upon Dataquest's findings, it would appear that the total dollar value of this market is below previous estimates. There are several reasons for this. First, it must be remembered that the market value identified is of *MODULES ONLY*. Estimates by others of the "Electronic Systems Market" usually include the cost of all related hardware and components(e.g., wiring harness, motors, actuators, external switches and relays). This study, by contrast, has identified strictly the value of the *ELECTRONIC MODULES* contained within these systems. Second, this study does not take into account an assigned value for OEM replacement parts. In any given model year, the market may include as much as 10% of the OEM value in replacement parts for service requirements. Because replacement parts are sold to different customers at different prices, they are purposely omitted from our analysis. Third, recent years has seen considerable price erosion at the OEM level for these systems. Contributing factors include competitive pressures from offshore suppliers and increases in manufacturing efficiencies owing to increased volume. The result is a slower expansion in the dollar value of the market. For example, a few years ago, engine-control modules cost VMs several hundred dollars each. Today, that number is estimated at under one hundred dollars and falling. Finally, by counting only the modules that go into vehicles built in North America, Dataquest does not count the export value of electronics shipped abroad, in cases when not factory-installed. Many other market estimates are based upon suppliers' estimated sales volumes, which often reflect a goodly amount of export business. By taking all of this into account, Dataquest believes this analysis to be a fair and accurate representation of real-world marketplace conditions.

COMPONENTS

Our analysis of components is divided into Semiconductors and Other components that make up these systems. Please refer to Appendix Sections G, H and I for component data. Also see Figures 42 - 70 for detailed analysis.

SEMICONDUCTORS

The total market for semiconductors within the automotive electronic systems/modules identified herein is estimated to have risen from $1.19B in MY88 to more than $1.3B in MY90. This growth has occurred despite the recent downturn in vehicle production due to increased application of automotive electronics on a per vehicle basis and the addition of such new systems as ABS, airbags, and passive belts. Between MY90 and MY95, the market is expected to rise by an estimated $571M, an increase of 43%. In this same period, growth in usage of automotive semiconductors is to occur at a CAGR of 7.5%. This fixes the value of automotive semiconductors by MY95 at nearly $1.9B.

For MY90, the market is seen as follows: 36.5% to General Motors, 34% to Ford, 15.8% to Chrysler and 13.7% to the Transplants. By MY95, however, GM is seen rising to 37.4%, whereas Ford and Chrysler will drop to 28.4% and 15.2%, respectively. Meanwhile, the Transplants will grow to 19% of the market (See Figure 42, p. 62). Ford's projected decline in market share is attributed to anticipated lower cost of its 16-bit engine-control microcomputer, a major portion of Ford's semiconductor makeup. While Ford's costs are expected to drop, other VMs are apt to see flat or modestly increasing costs as they slowly move to the more sophisticated microcontrollers already in Ford's repertoire.

In terms of application, for MY90 30.6% of the semiconductors are used in Powertrain, 13.5% are used in Entertainment products, another 13.5% goes to Vehicle Controls, 11.2% go into the Driver Information category, 10% are slated to be used in Safety/Comfort/Convenience equipment and only 1% will be used in Body Electronics,. By MY95, the mix is expected to change as follows: 35.2% Powertrain, 20.6% Vehicle Controls, 18.8% S/C/C, 13.6% Driver Information, 11.4% Entertainment and 2.3% Body Electronics. Again, the growth projected for Vehicle Controls and S/C/C is attributable primarily to increased application of ABS and passive safety restraints.

Dataquest projects that for MY90 an estimated 21.5% of this market will be owned by Delco Electronics, captive supplier to General Motors. The remaining market will be divided among the world's major semiconductor manufacturers, according to our estimated ranking of the suppliers (adjacent chart).

NORTH AMERICA AUTO ELECTRONICS MARKET

ESTIMATED SEMICONDUCTOR MFGR. MARKET SHARE

MODEL YEAR 90

Motorola	24.1%
Delco Electronics	21.5%
National Semiconductor	9.7%
Intel	8.3%
Texas Instruments	6.5%
Harris (GE, RCA, Harris)	5.6%
Signetics	5.4%
Hitachi	5.2%
Toshiba	3.7%
SGS	3.2%
All Others	2.5%
Sprague	1.7%
Cherry	1.4%
NEC	1.1%

In the course of Dataquest's research, the attempt was made to ascertain the projected usage of surface-mount versus conventionally packaged integrated circuits, resistors and capacitors. We estimate that for MY90, slightly more than 42% of all ICs used in automotive electronic systems use surface-mount packaging. The number is projected to grow to nearly 49% by MY95.

For a detailed breakdown by specific component areas, refer to Appendix sections G, H and I.

At the time of this writing, a detailed analysis of all sections of the Components portion of the database was yet to be completed. Updated analysis of these sections will be forwarded to all clients for insertion in this binder.

OTHER COMPONENTS

With respect to other major components used in automotive electronic systems, Dataquest has included in this research a top-level analysis of several important component areas. During the study of the semiconductor content of automotive electronic systems, we also made note of the usage of such related components as displays, relays, connectors, and types of wiring boards along with such passive devices as resistors and capacitors.

At this writing, the corresponding portion of the database was under revision, and therefore final analysis was not available for inclusion in this report. Revised data on this section is, however, included in Appendix sections G, H and I.

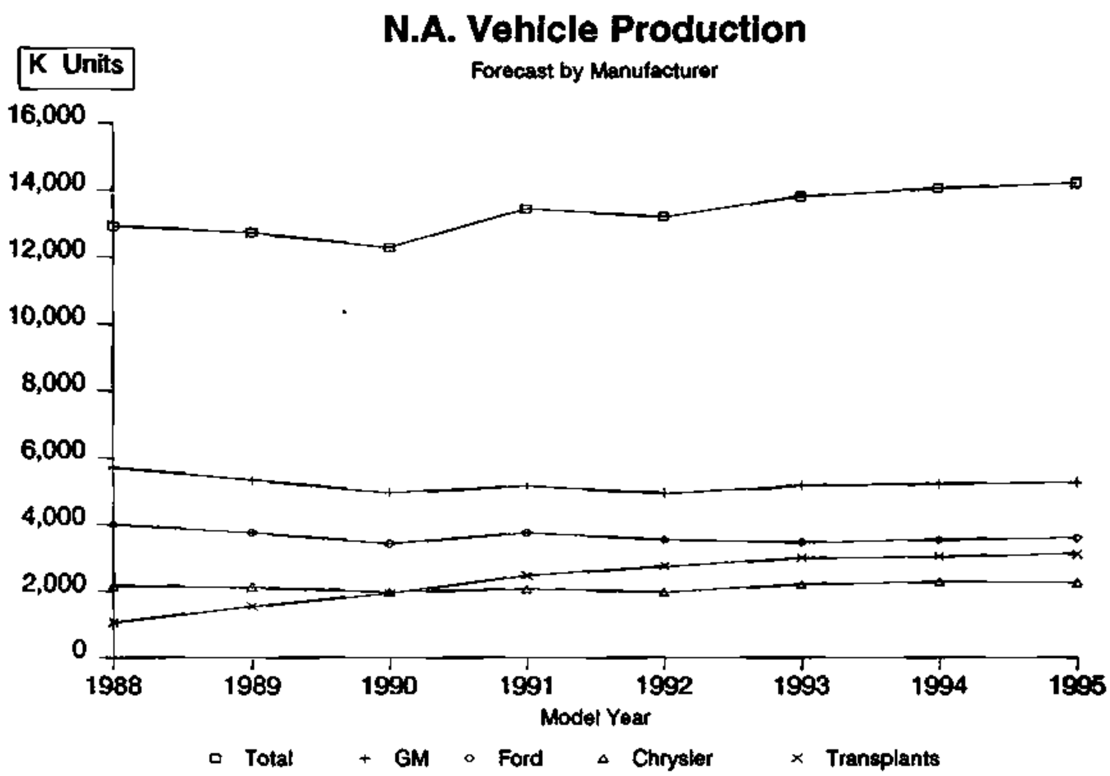


Figure 3

- **Market down-turns forecasted for MY90, MY92**
- **Total Market Compounded Average Growth Rate (CAGR) of 3.0% for MY90-MY95**
- **GM volume 5.7M in MY88, forecasted 5.2M in MY95**
- **Ford volume 4.0M in MY88, forecasted 3.6M in MY95**
- **Chrysler volume 2.2M in MY88, forecasted 2.3M in MY95**
- **Transplants volume 1.1M in MY88, forecasted 3.1M in MY95**

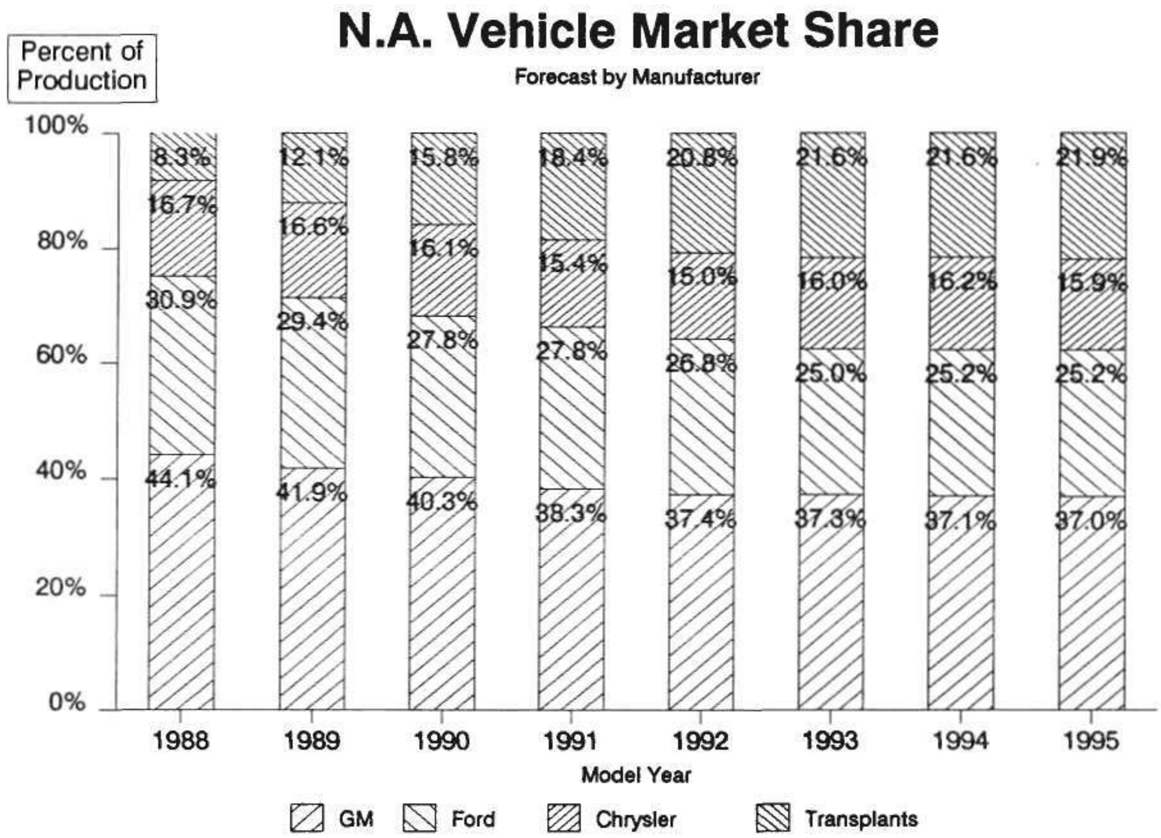


Figure 4

- **Transplant production market share growing from 8.3% in MY88 to a projected 21.9% in MY95**
- **GM production market share was 44.1% in MY88, projected to drop to 37.0% by MY95**
- **Ford production market share was 30.9% in MY88, projected to drop to 25.2% by MY95**
- **Chrysler production market share was 16.7% in MY88, projected to drop to 15.9% by MY95**

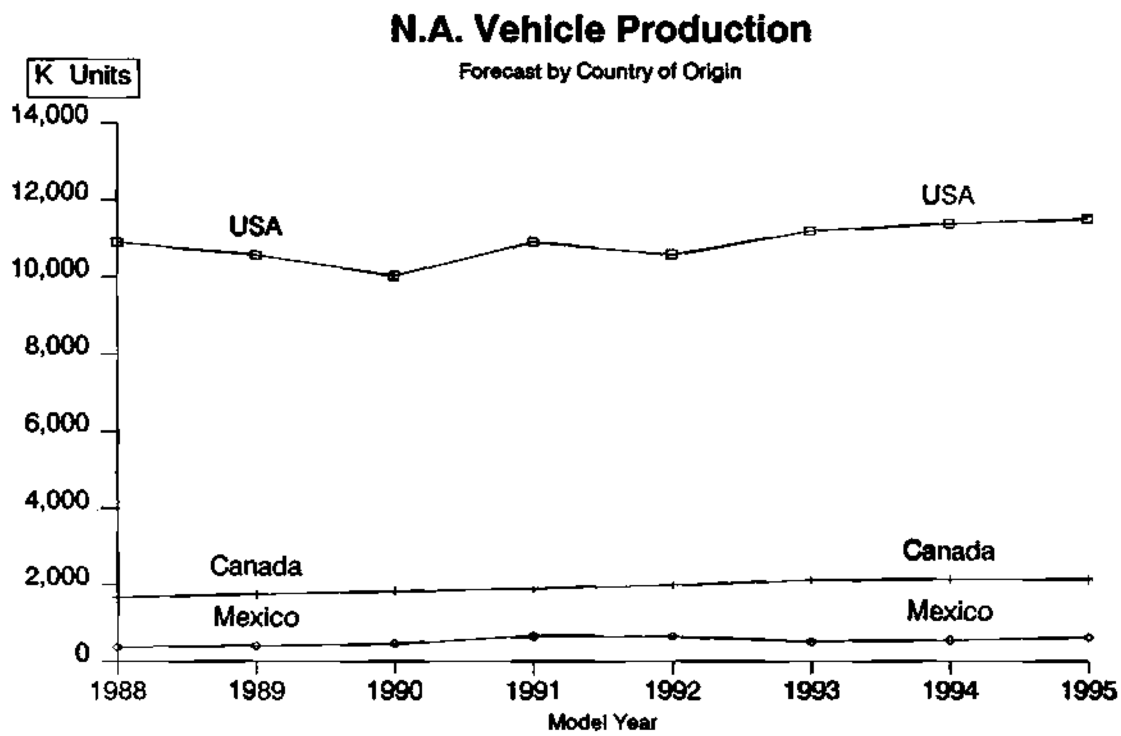


Figure 5

- **U.S. vehicle production projected to be 10.0M in MY90, 11.5M in MY95**
- **Canada vehicle production projected to be 1.8M in MY90, 2.1M in MY95**
- **Mexican vehicle production projected to be 0.5M in MY90, 0.6M in MY95**

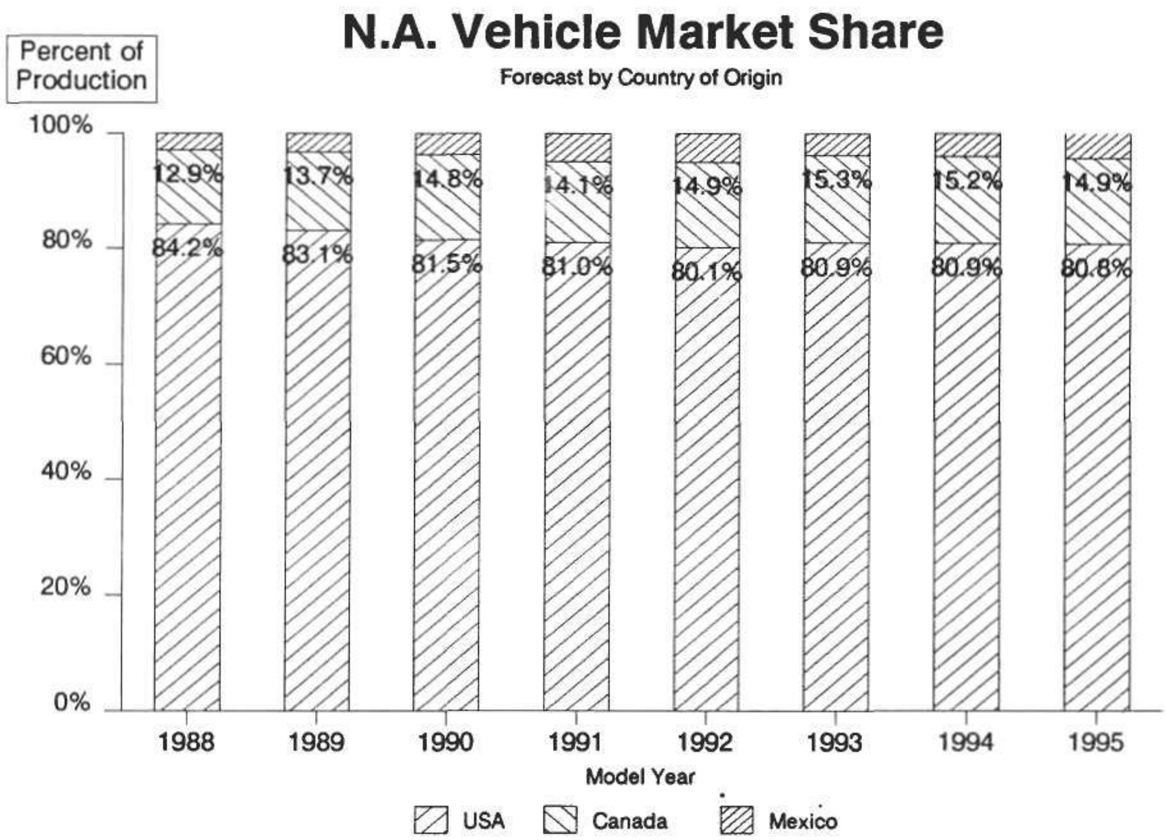


Figure 6

- **U.S. vehicle production represents an estimated 81.5% of North American output in MY90, down to 80.8% in MY95**

- **Canada vehicle production represents an estimated 14.8% of North American output in MY90, up slightly to 14.9% in MY95**

- **Mexican vehicle production represents an estimated 3.8% of North American output in MY90, up to 4.3% in MY95**

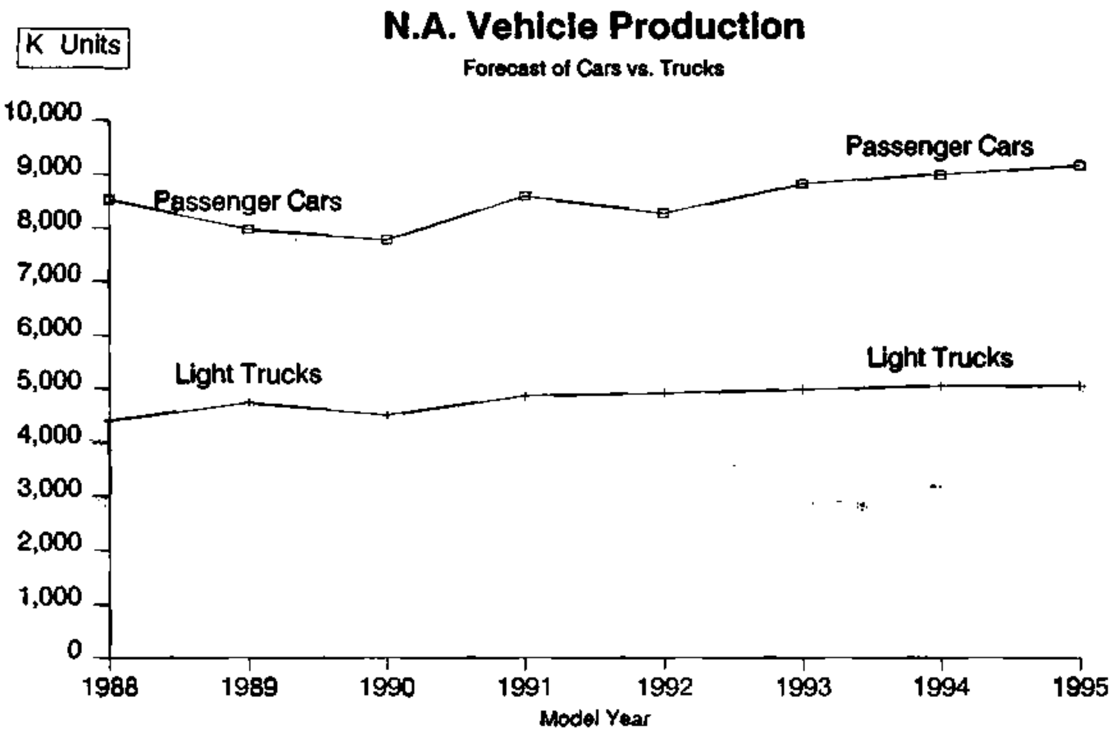


Figure 7

- **N.A. passenger car production to dip to MY90 & MY95**
- **N.A. passenger car production forecasted to be 7.8M in MY90, growing to 9.2M in MY95**
- **N.A. light truck (under 10,000 lbs. G.V.W.) production forecasted to be 4.5M in MY90, growing to 5.1M in MY95**

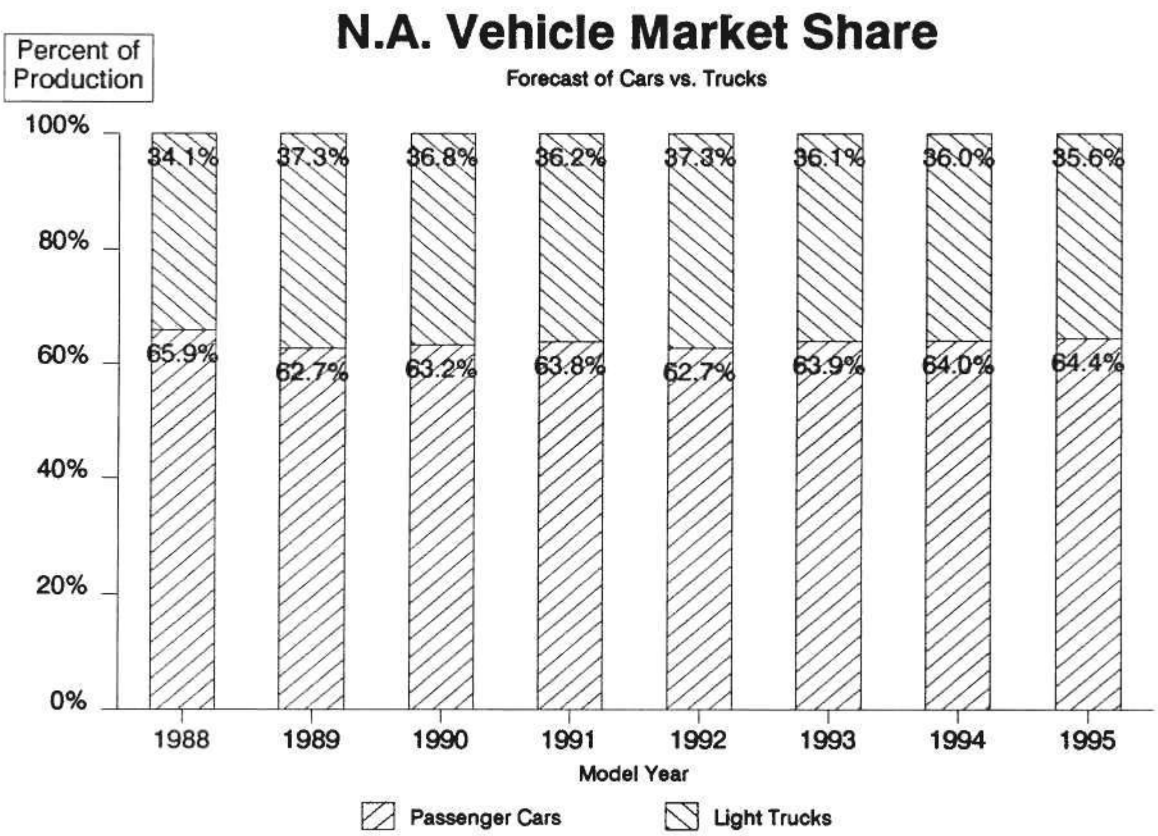


Figure 8

- **Passenger cars forecasted to be 63.2% of N.A. production in MY90, 64.4% in MY95**

- **Light trucks forecasted to be 36.8% of N.A. production in MY90, 35.6% in MY95**

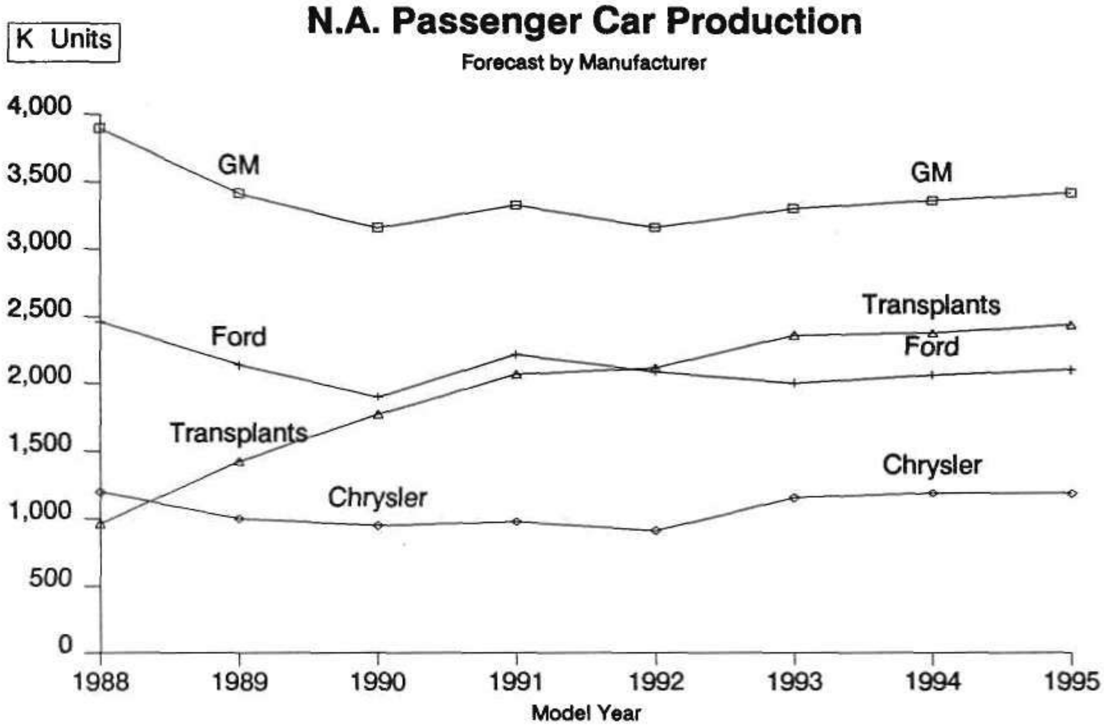


Figure 9

- **Transplant passenger car production projected to grow from 964K in MY88 to 2.4M in MY95**
- **GM passenger car production projected to decline from 3.9M in MY88, to 3.2M in MY90, and recover to 3.4M by MY95**
- **Ford passenger car production projected to decline from 2.5M in MY88, to 1.9M in MY90, and recover to 2.1M in MY95**
- **Chrysler passenger car production projected to decline from 1.2M in MY88, to 946K in MY90, and recover to 1.2M in MY95**

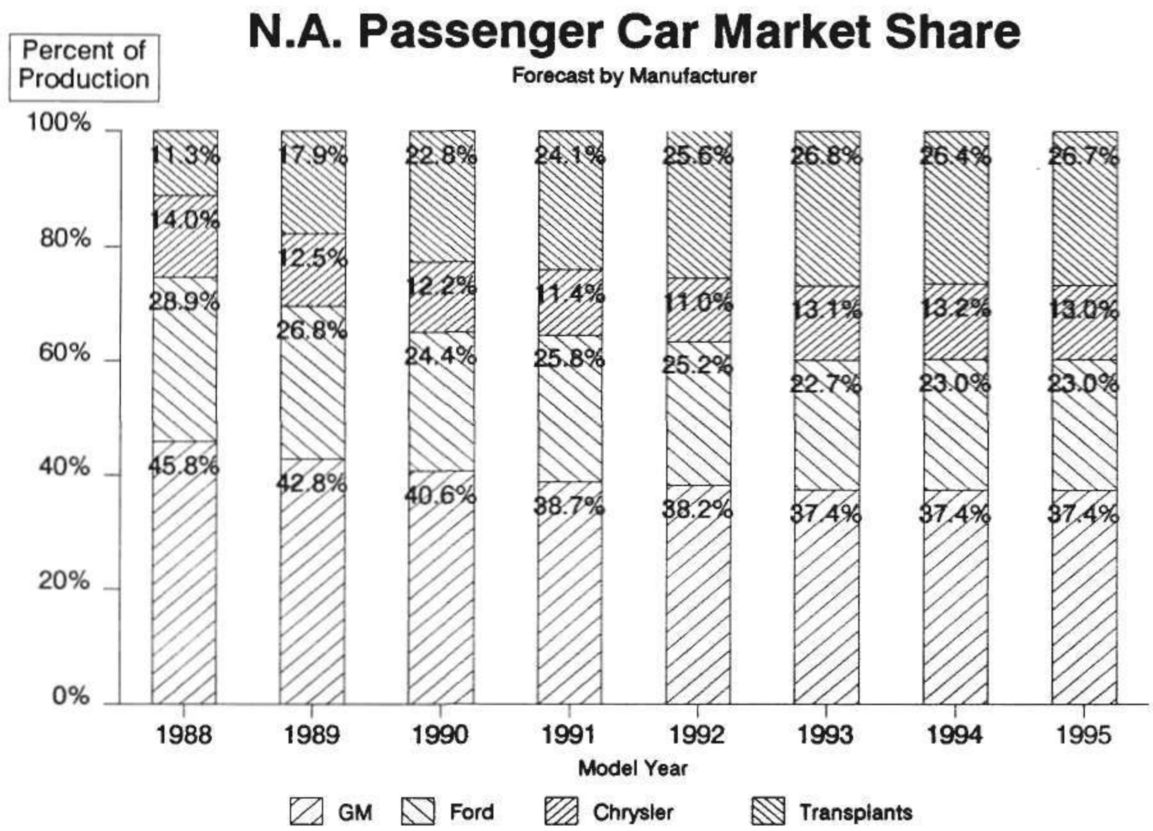


Figure 10

- Transplant passenger car production market share projected to grow from 11.3% in MY88 to 26.7% in MY95
- GM passenger car production market share projected to decline from 45.8% in MY88 to 37.4% in MY95
- Ford passenger car production market share projected to decline from 28.9% in MY88 to 23.0% in MY95
- Chrysler passenger car production market share projected to decline from 14.0% in MY88 to 13.0% in MY95

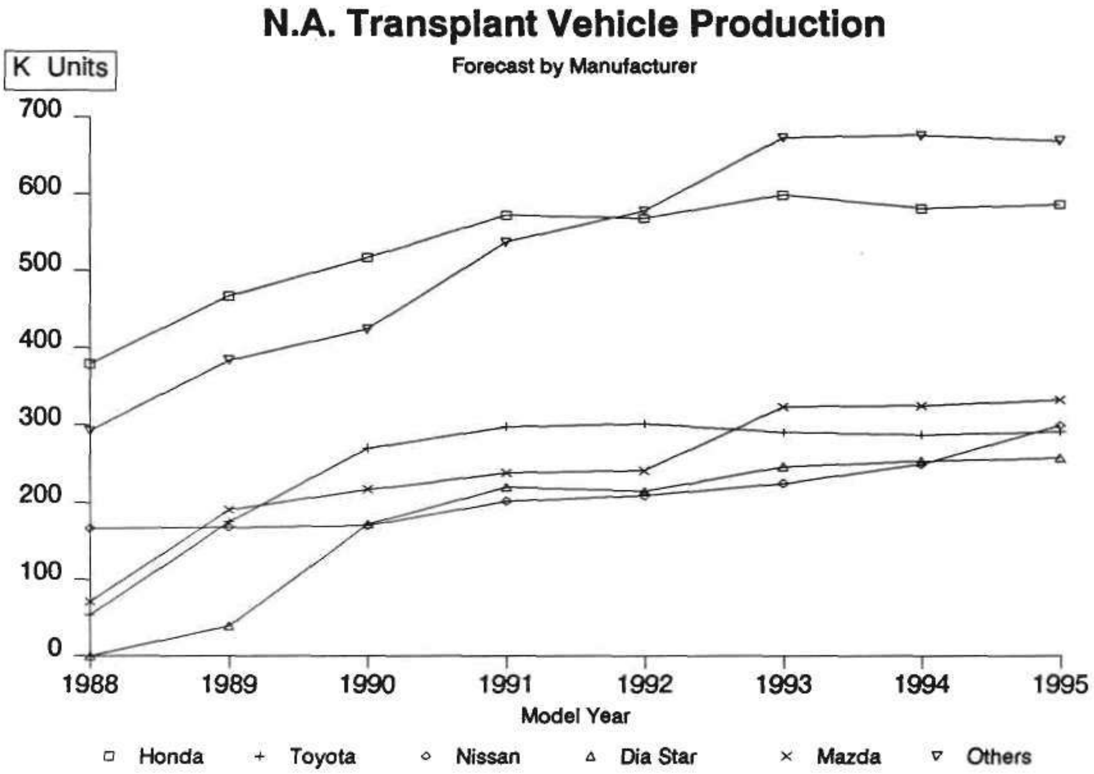


Figure 11

- **Honda leads the transplants, growing from an estimated 379K vehicles in MY88 to 588K in MY95**
- **"Others" include: CAMI (U.S., Canada), Hyundai (Canada), NUMMI (U.S.), Subaru (U.S), VW (Mexico), and Volvo (Canada)**
- **Forecast could increase with aggressive transplant export programs**

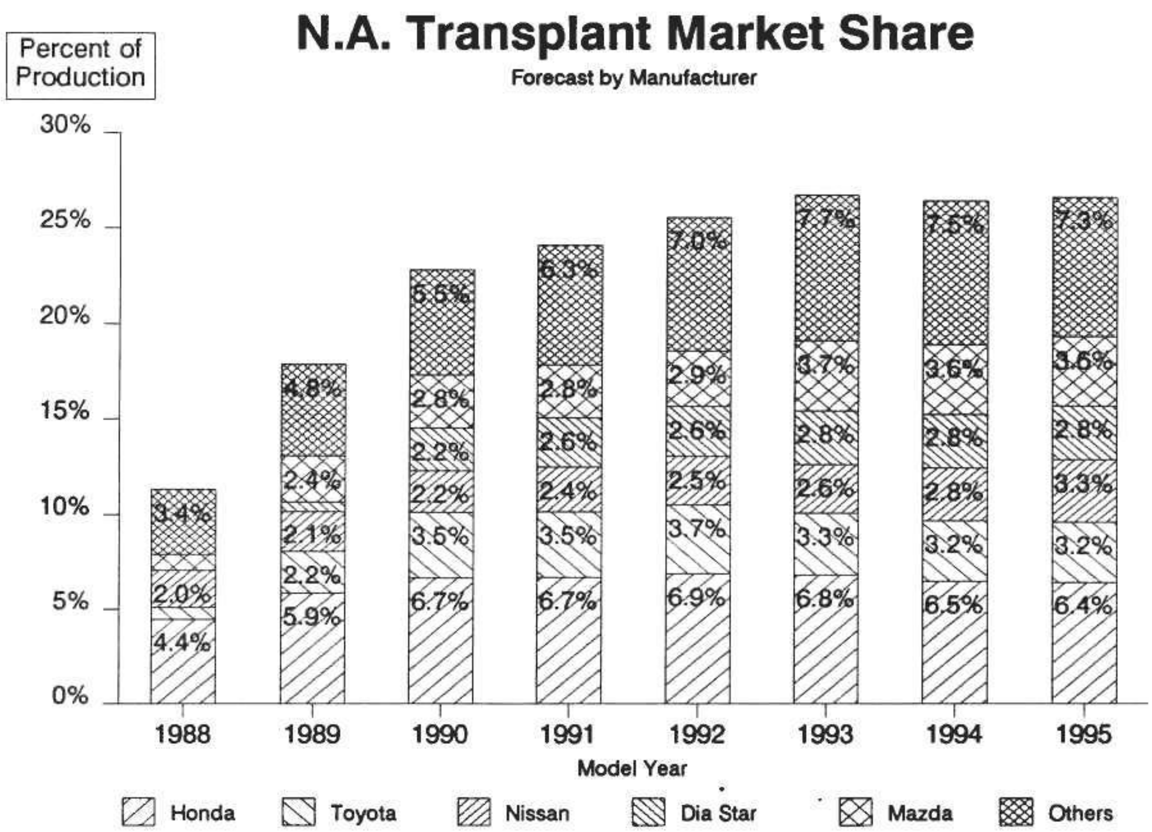


Figure 12

- Honda projected to have largest transplant market share, with 6.7% in MY90, dropping to 6.4% in MY95 as market saturates
- "Others" include: CAMI (U.S., Canada), Hyundai (Canada), NUMMI (U.S.), Subaru (U.S), VW (Mexico), and Volvo (Canada)
- Transplants to account for nearly 1/4 of passenger cars produced in North America by MY92

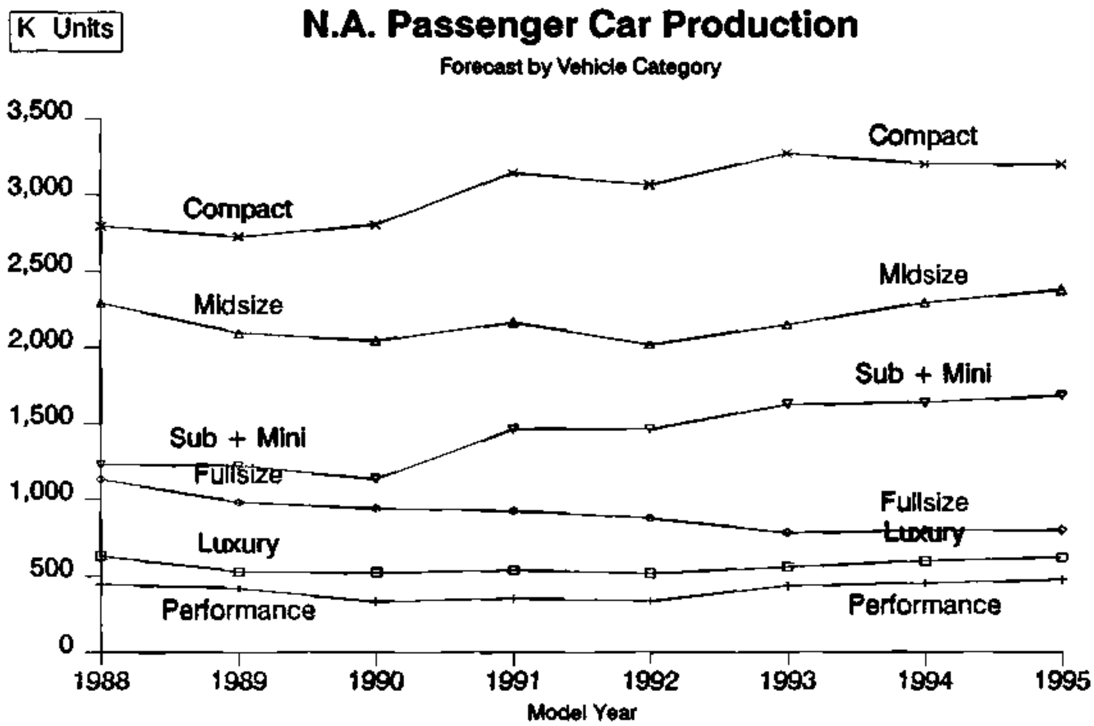


Figure 13

- Compact cars lead in passenger car production, growing from 2.8M in MY88, to an estimated 3.2M in MY95
- Midsize cars are #2 behind compacts with volumes expected to be 2.0M in MY90, growing to 2.4M in MY95
- Sub-compact and mini-compact cars growing from 1.2M in MY88 to an estimated 1.7M in MY95
- Fullsize cars declining from 1.1M in MY88 to an estimated 798K in MY95
- Luxury cars are expected to dip in MY90 and MY92, with recovery to 619K by MY95
- Performance cars are also expected to dip and recover to the 472K level by MY95

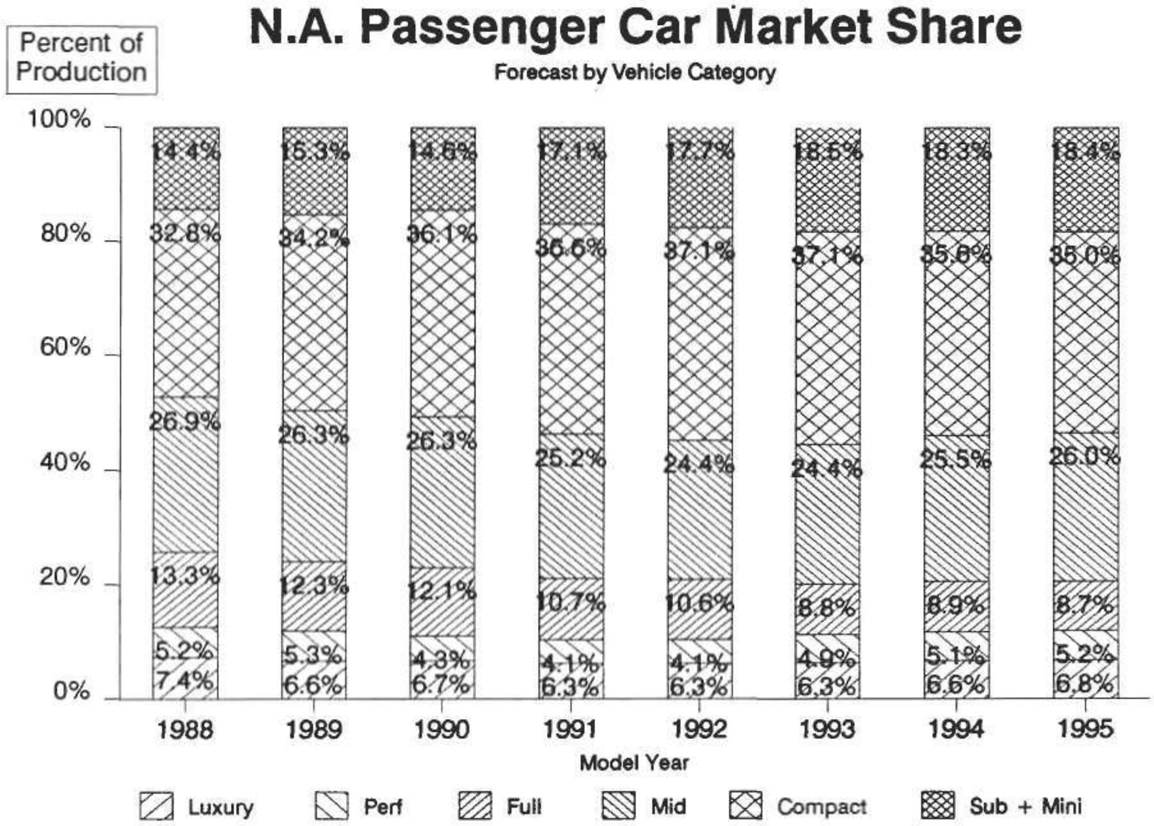


Figure 14

- Compacts make up the largest market share of the market with and estimated 36.1% in MY90, dropping to 35.0% by MY95
- Midsize cars are projected to hold 26.3% of the market in MY90, dropping to 26.0% by MY95
- Subcompact and minicompact cars together are projected to command 14.6% of the market in MY90, growing to 18.4% by MY95
- As a group, fullsize, luxury, and performance cars are expected to experience declining market share between MY90 & MY95

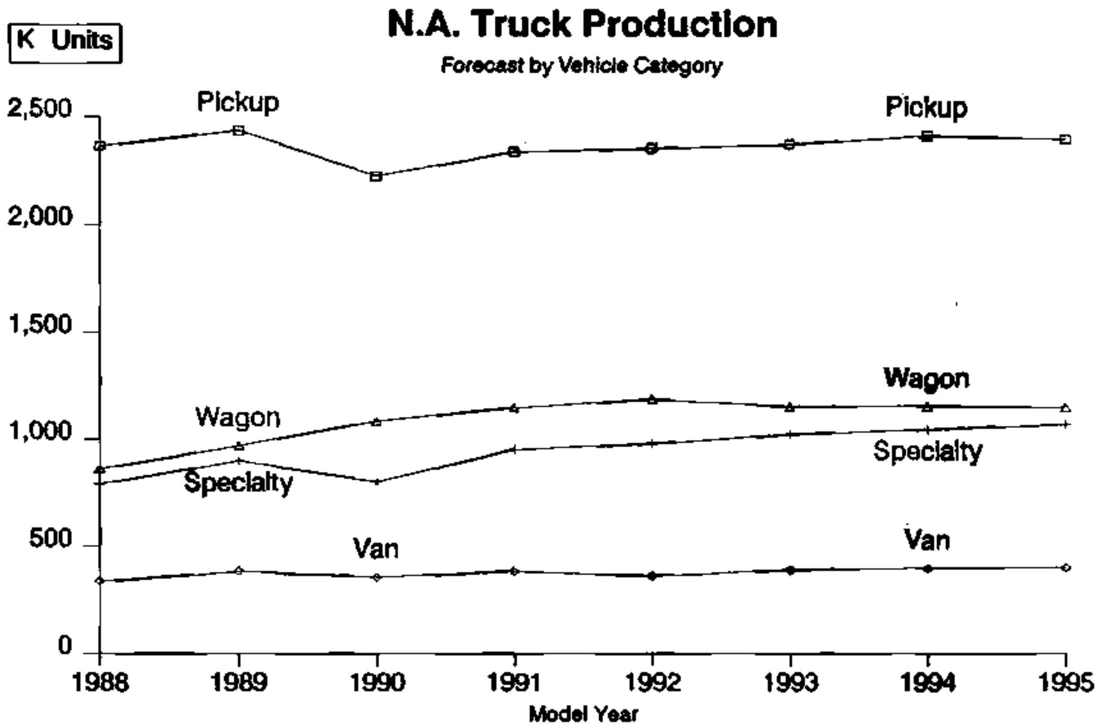


Figure 15

- **Best selling individual vehicle type is 1/2-ton, full size pickup truck**
- **Pickup production expected to dip in MY90 to 2.2M, recovering to 2.4M by MY95**
- **Wagons (passenger vans) are expected to grow slightly from 1.1M in MY90 to 1.2M in MY95**
- **Specialty trucks include Sport Utility Vehicles (SUVs). Segment is expected to dip in MY90 at 803K, with recovery to 1.1M by MY95**
- **Van production is expected to show continued growth from 305K in MY90 to 362K in MY95**

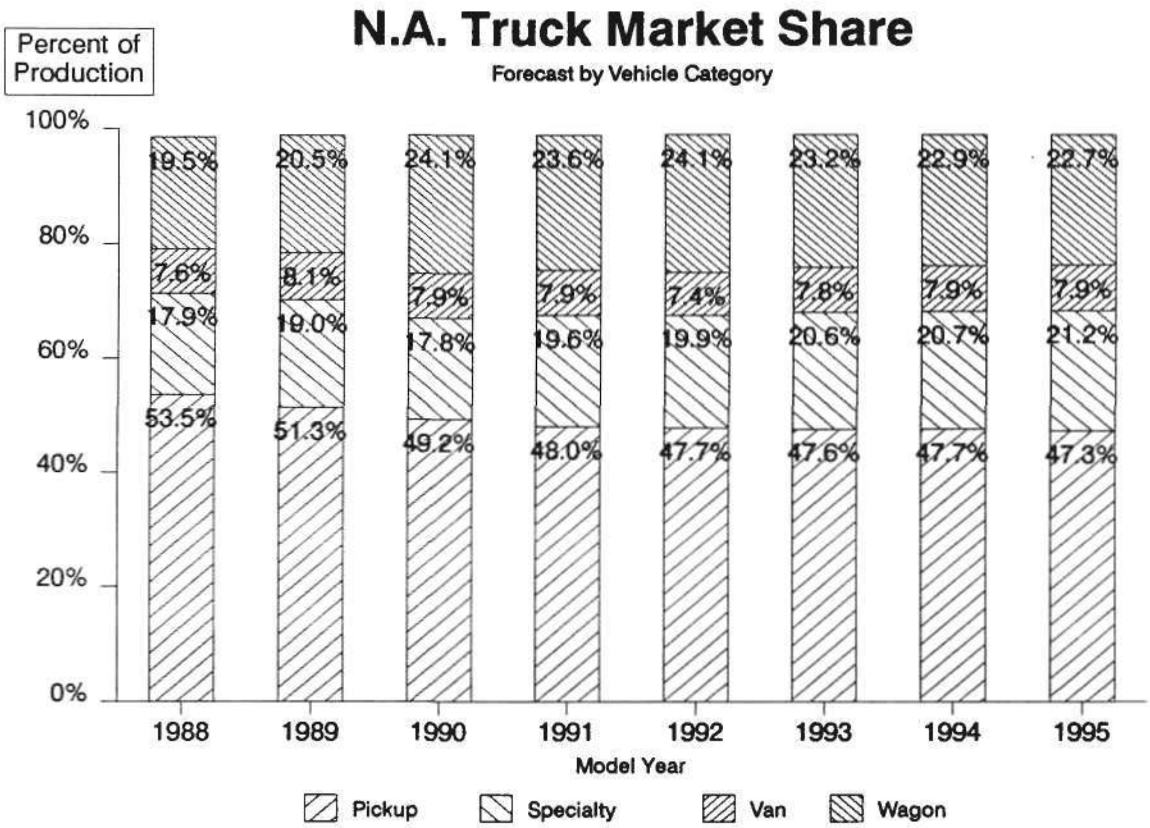


Figure 16

- **Pickups hold largest market share of truck production at an estimated 49.2% in MY90, dropping to 47.3% by MY95**
- **Specialty trucks are expected to grow from 17.8% market share in MY90 to 21.2% in MY95**
- **Passenger vans (Wagons) are predicted to surge in MY90 to a 24.1% market share. By MY95, they are expected to slip to 22.7% of truck production**
- **Cargo van market share is estimated at 7.9% for MY90, dipping slightly in MY92 and recovering to 7.9% by MY95**

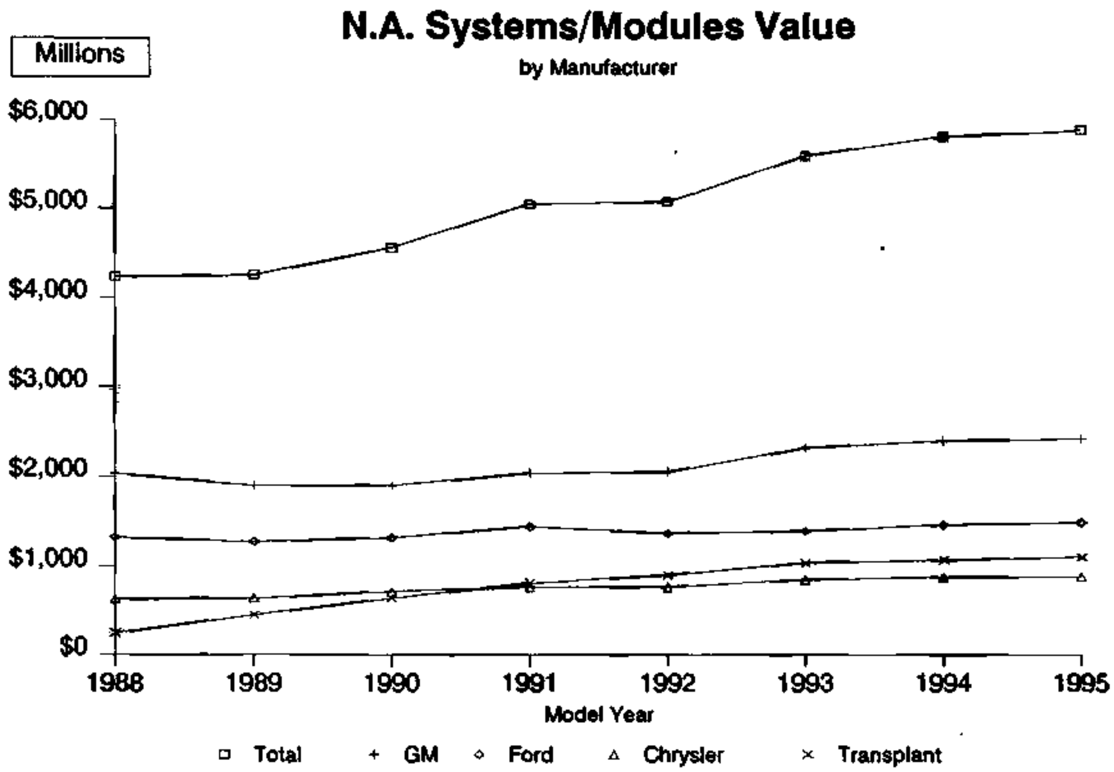


Figure 17

- **Total Market estimated at $4.6B in MY90, growing to $5.8B by MY95**
- **CAGR projected at 5.2% between MY90 and MY95**
- **MY91 projected to be up 10% from MY90**
- **Includes Passenger Cars & Light Trucks for GM, Ford, Chrysler, and 11 Transplant Suppliers**

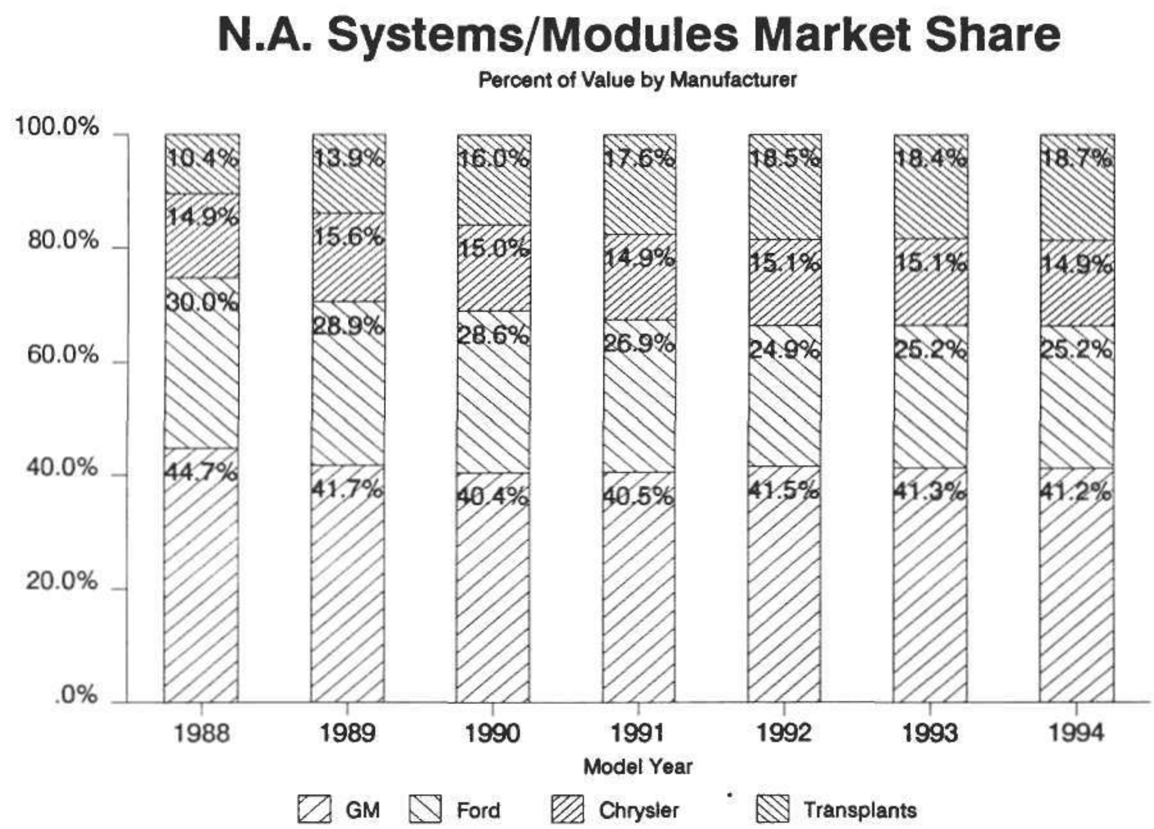


Figure 18

- **GM market share shrinking from 44.7% in MY88 to 40.4% in MY90, projected to be 41.2% by MY95**

- **Ford market share shrinking from 30% in MY88 to 25.2% by MY95**

- **Chrysler market share expected to remain flat at 14.9%**

- **Transplant share expected to grow from 10.4% in MY88 to 18.7% by MY95**

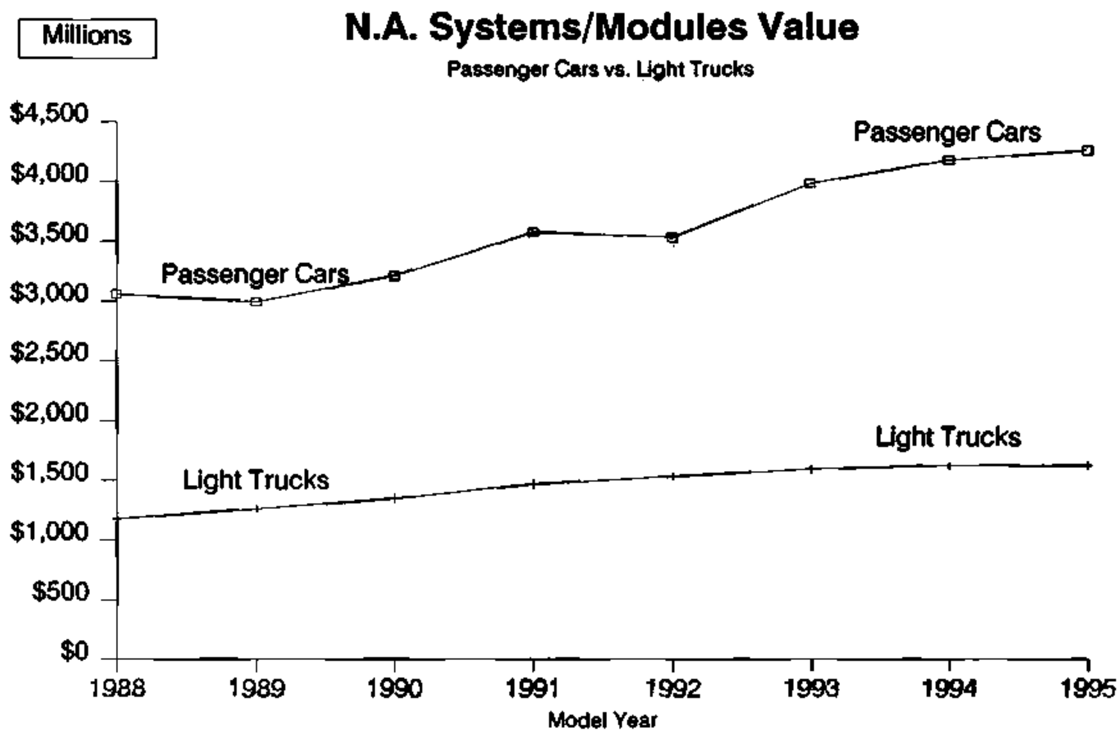


Figure 19

- **Passenger car electronics growing faster than trucks**

- **Passenger car electronics represent $3.2B in MY90, growing to $4.3B in MY95**

- **Light truck electronics represent $1.4B in MY90, growing to $1.6B in MY95**

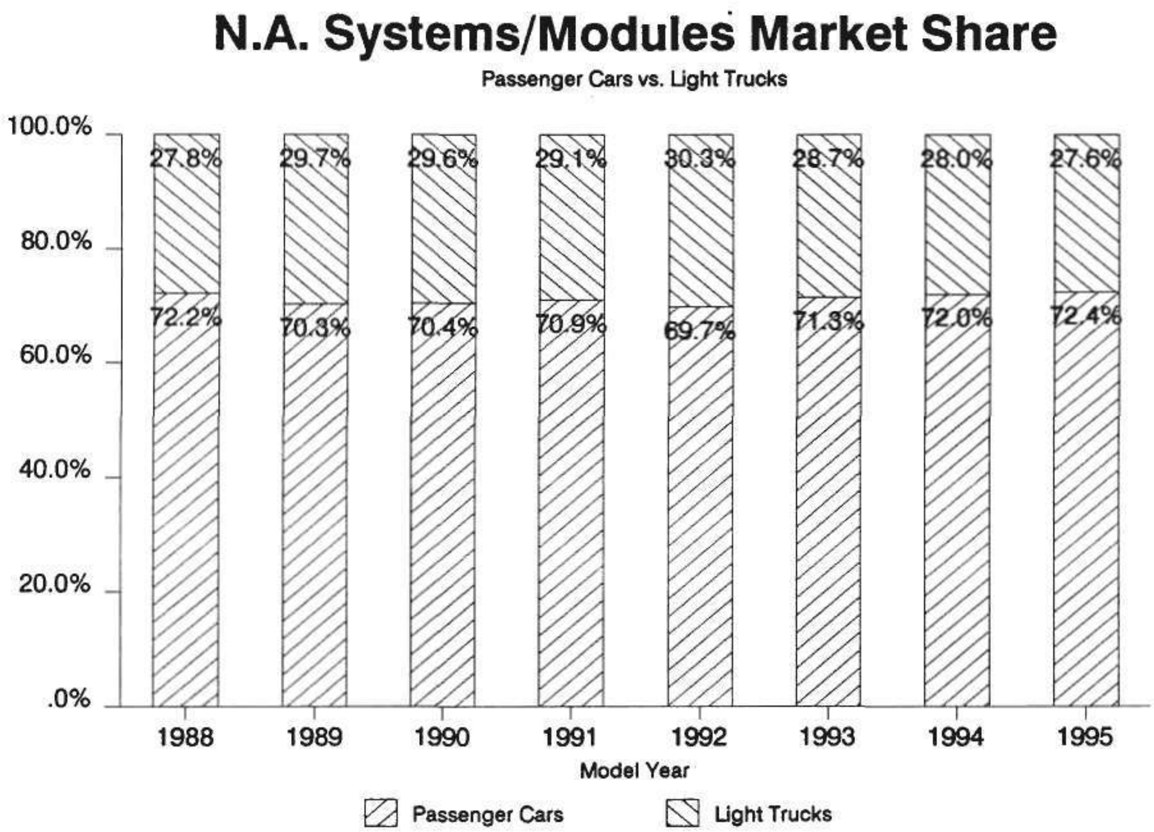


Figure 20

- **Passenger car electronics represent 70.4% of total in MY90, 72.4% in MY95**
- **Light truck electronics represent 29.6% of total in MY90, 27.6% in MY95**

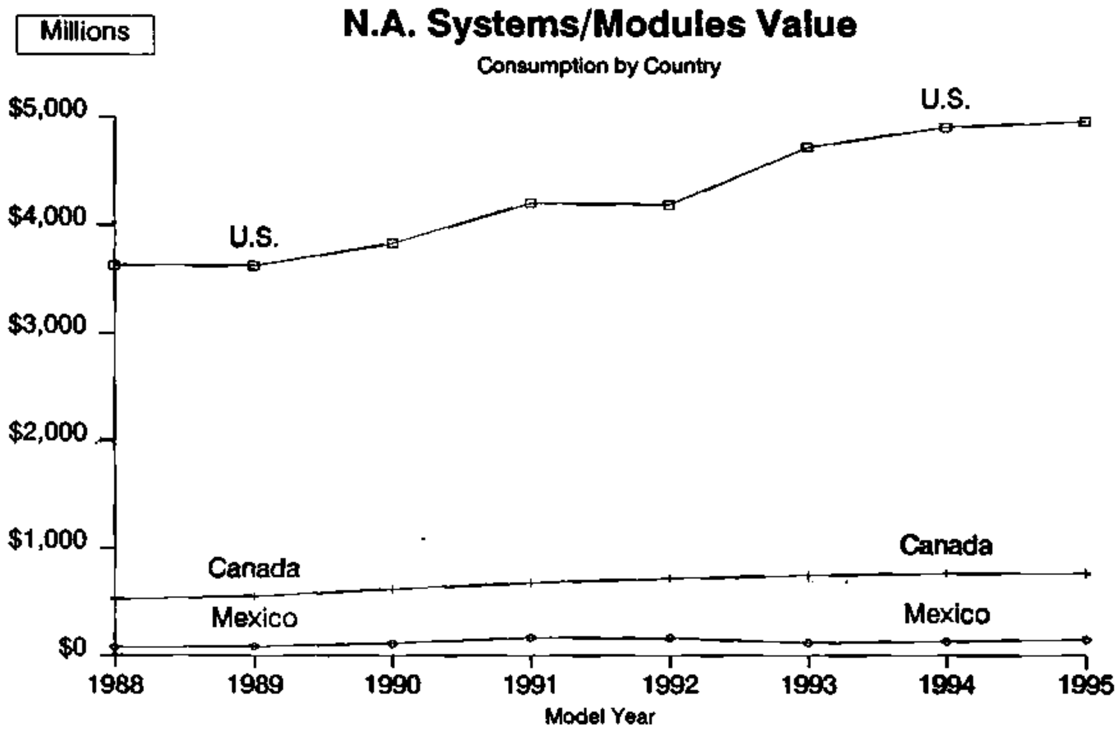


Figure 21

- **U.S. vehicle electronics estimated at $3.8B in MY90, $5.0B in MY95**

- **Canada vehicle electronics estimated at $538M in MY90, $602M in MY95**

- **Mexican vehicle electronics estimated at $112M in MY90, $151M in MY95**

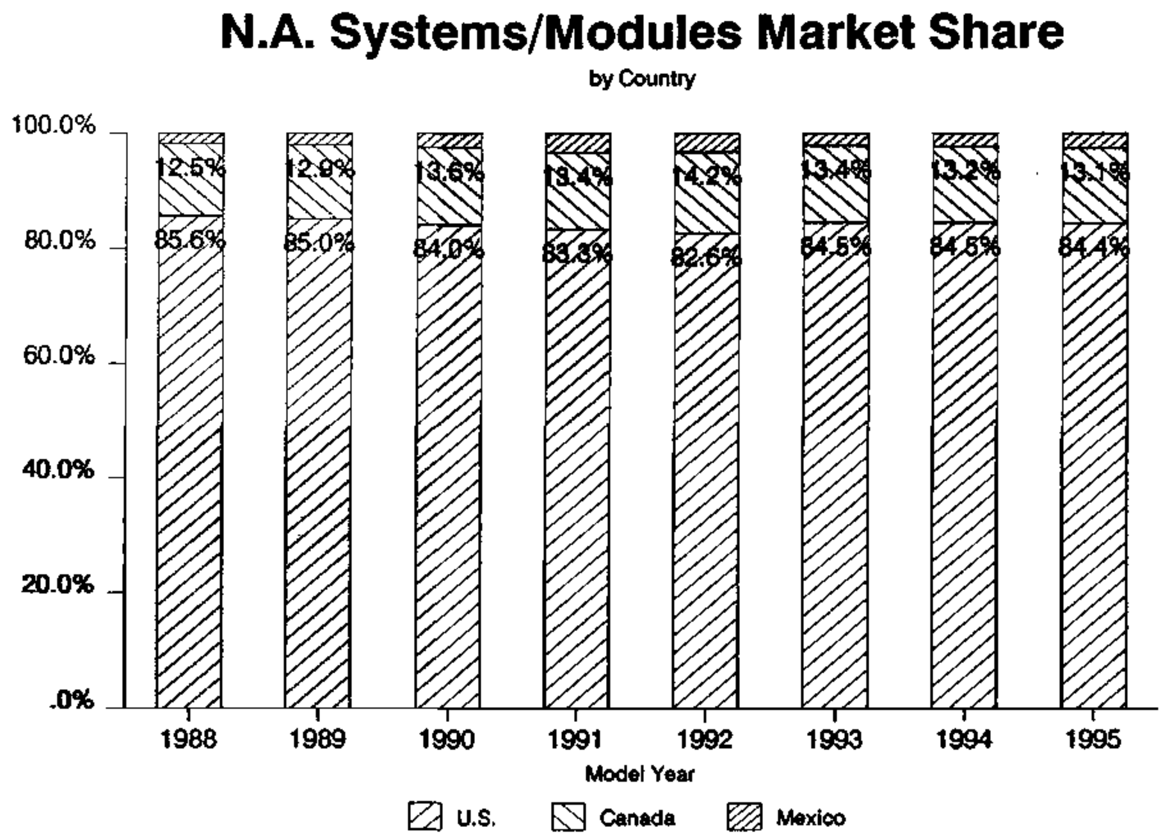


Figure 22

- **U.S. represents 84.0% of total N.A. vehicle electronics in MY90, 84.4% in MY95**
- **Canada represents 13.6% of total N.A. vehicle electronics in MY90, 13.1% in MY95**
- **Mexico represents 2.4% of total N.A. vehicle electronics in MY90, 2.5% in MY95**

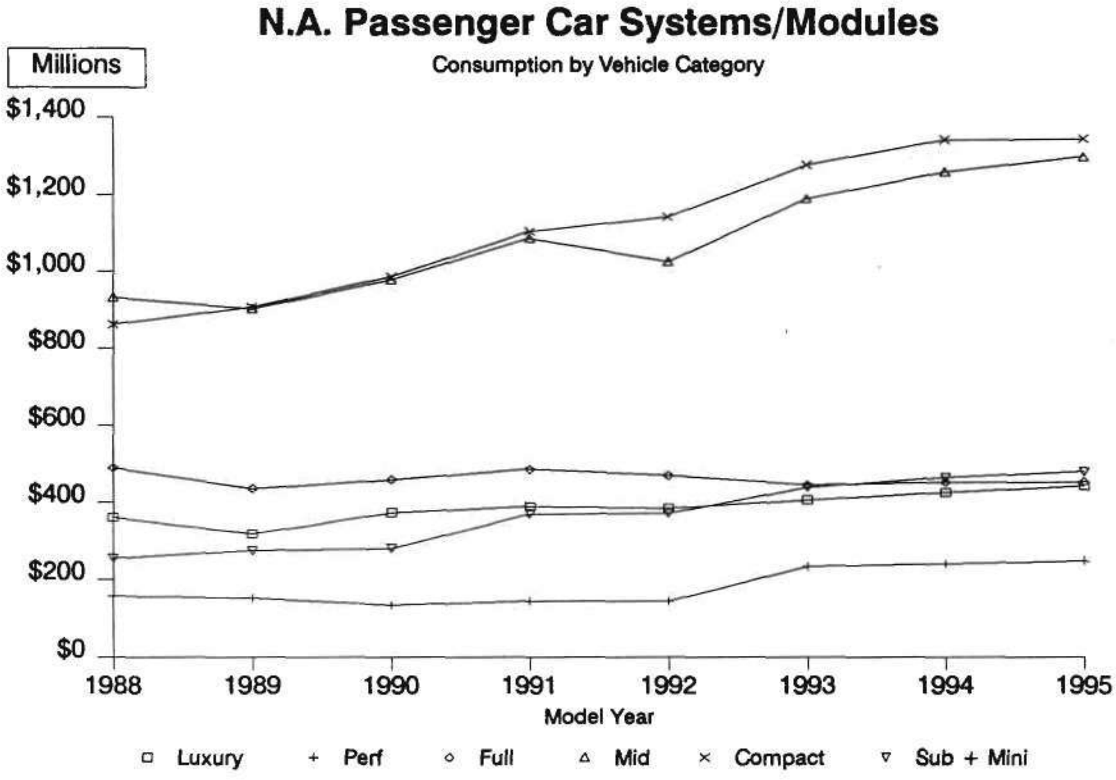


Figure 23

- **Compact cars represent the largest single market segment at $985M in MY90, growing to $1.3B in MY95**
- **Midsize cars are the second largest segment at $977M in MY90, growing to $1.3B in MY95**
- **Fullsize cars are expected to decline from $459M in MY90 to $452M in MY95**
- **Luxury cars grow slightly in electronics from $373M in MY90 to $442M in MY95**
- **Subcompacts grow from $261M in MY90 to $438M in MY95**
- **Minicompacts grow from $18.4M in MY90 to $80.9M in MY95**
- **Performance segment grows from $134M in MY90 to $247M in MY95**

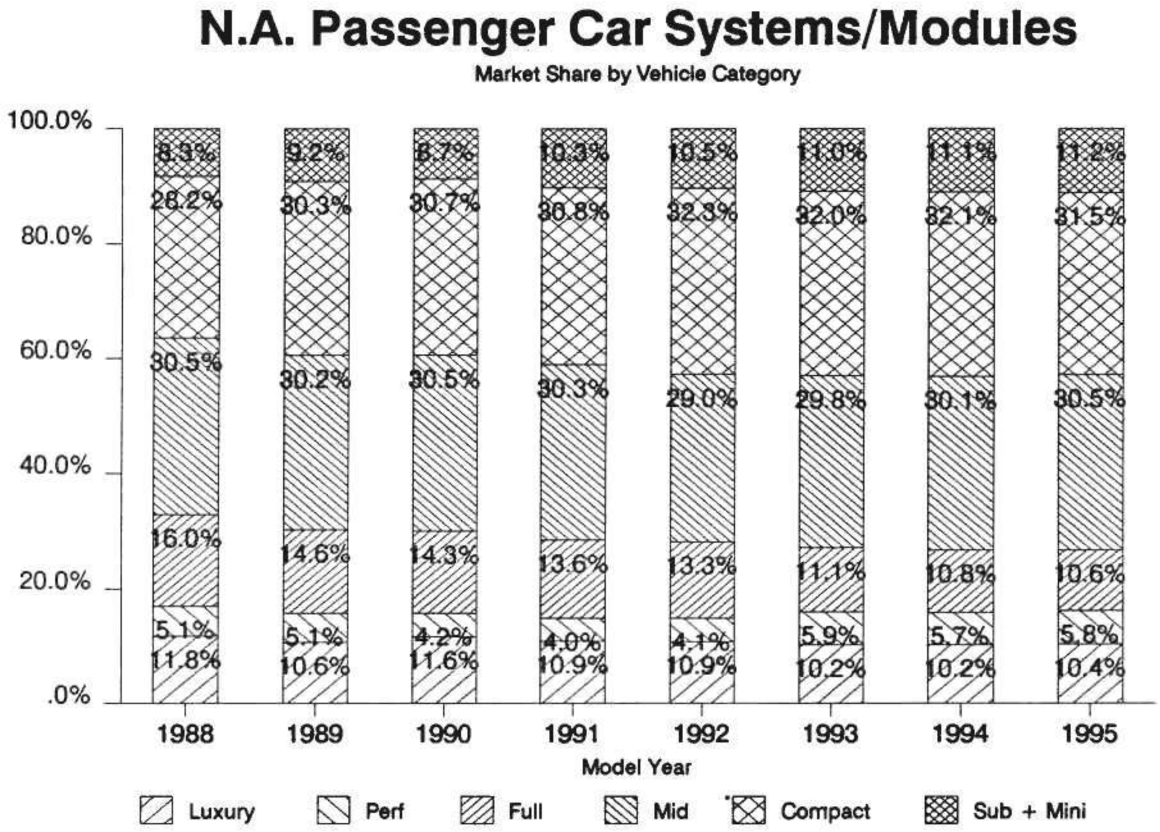


Figure 24

- Compact cars represent largest share of system electronics at 31.5% of the market in MY95
- Midsize cars are second with 30.5% in MY95
- Subcompact & Minicompact as a group are third with 11.2%
- Fullsize cars are fourth with 10.6%
- Luxury cars are fifth with 10.4%
- Performance cars are sixth with 5.8%

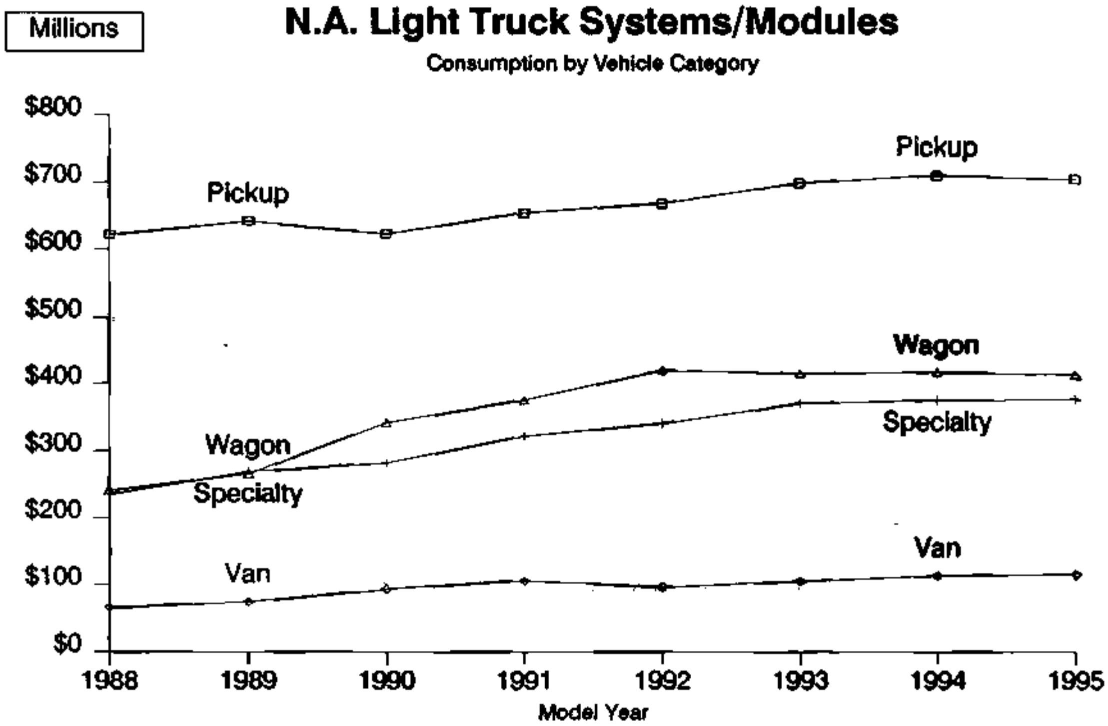


Figure 25

- **Pickups represent $623M in MY90, growing to $704M in MY95**
- **Passenger Vans (Wagons) are second largest at $341M in MY90, growing to $413M by MY95**
- **Specialty vehicles (4 X 4's, SUVs) growing from $282M in MY90 to $377M in MY95**
- **Vans (cargo only) represent $93M in MY90, growing to $115M by MY95**

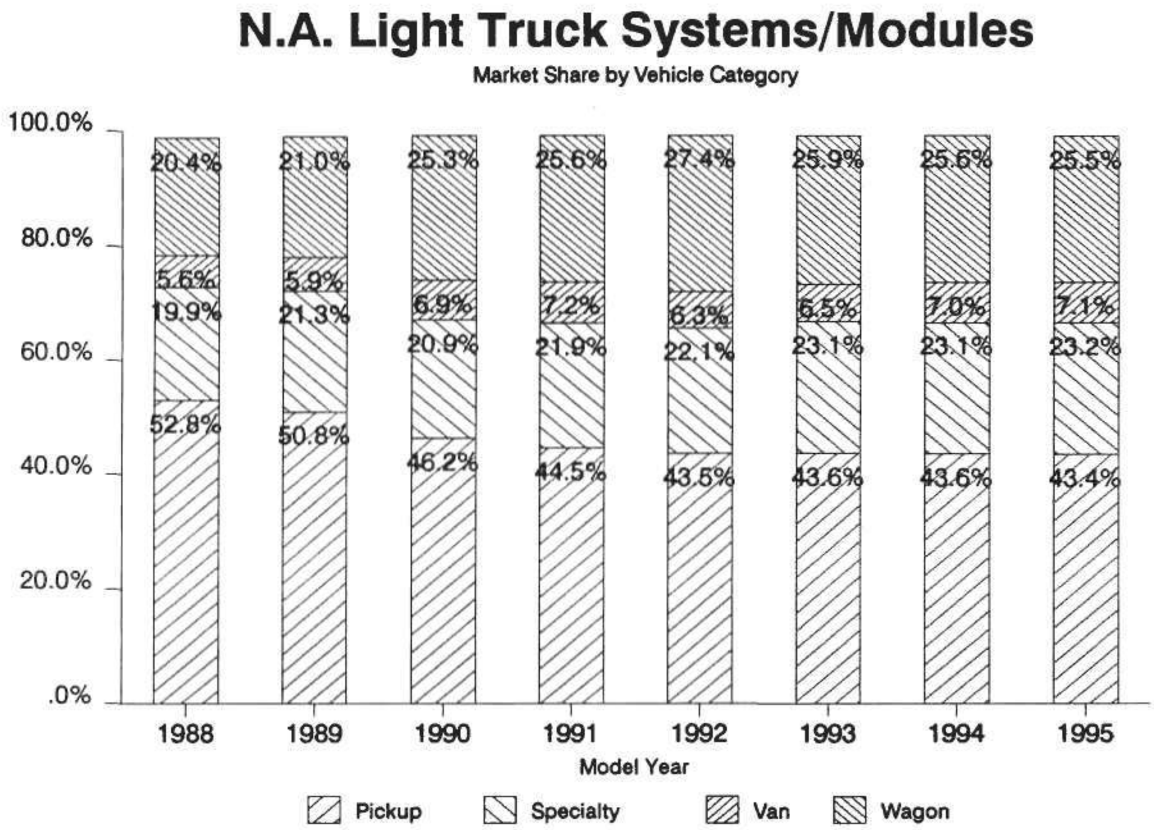


Figure 26

- **By MY95, pickups will retain largest sector of truck electronics at 43.4%**
- **Passenger vans (wagons) are projected as second at 25.5%**
- **Specialty vehicles will grow to 23.2%**
- **Cargo vans are estimated to represent 7.1%**

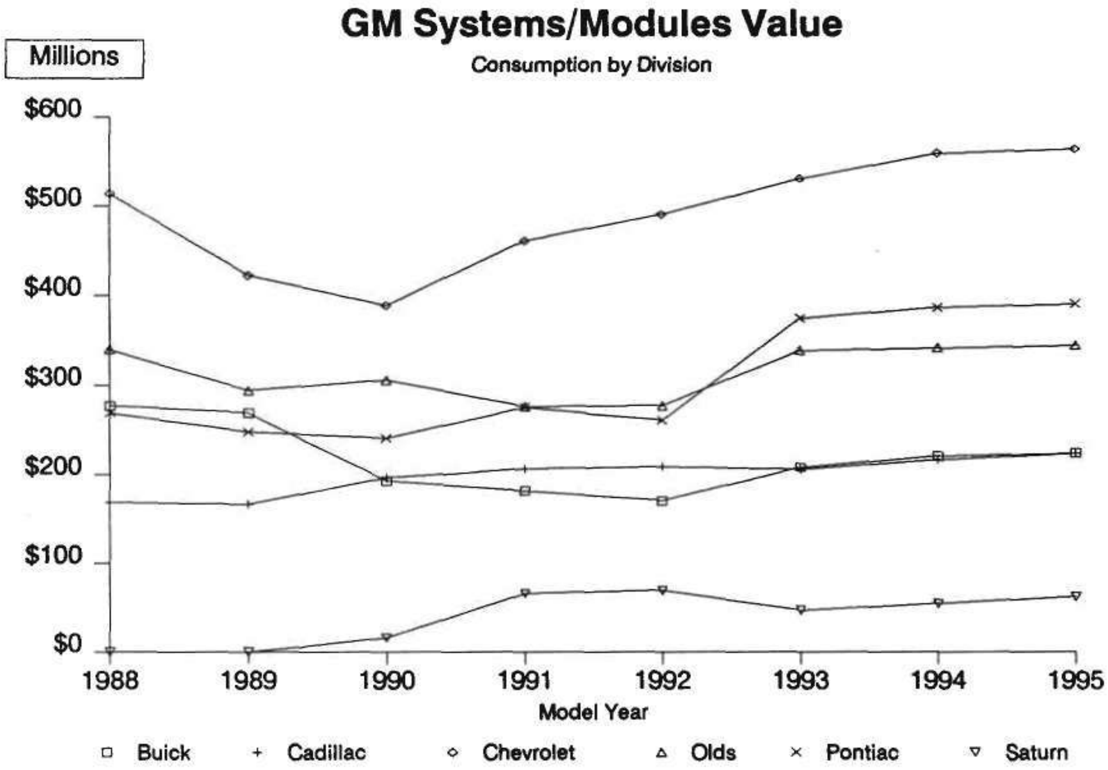


Figure 27

- **As largest GM line, Chevrolet shows most volatility in electronics (MY88 - $513M, MY90 - $388M, MY95 - $564M)**
- **Second largest consumer Oldsmobile, anticipated to be displaced by Pontiac in MY93**
- **Once-second, Buick falling to fifth... fewer cars, dropping electronics programs**
- **Cadillac steady due to high installation rates, flat volume projection**
- **Saturn expected to ramp up and fall back, low electronic content**

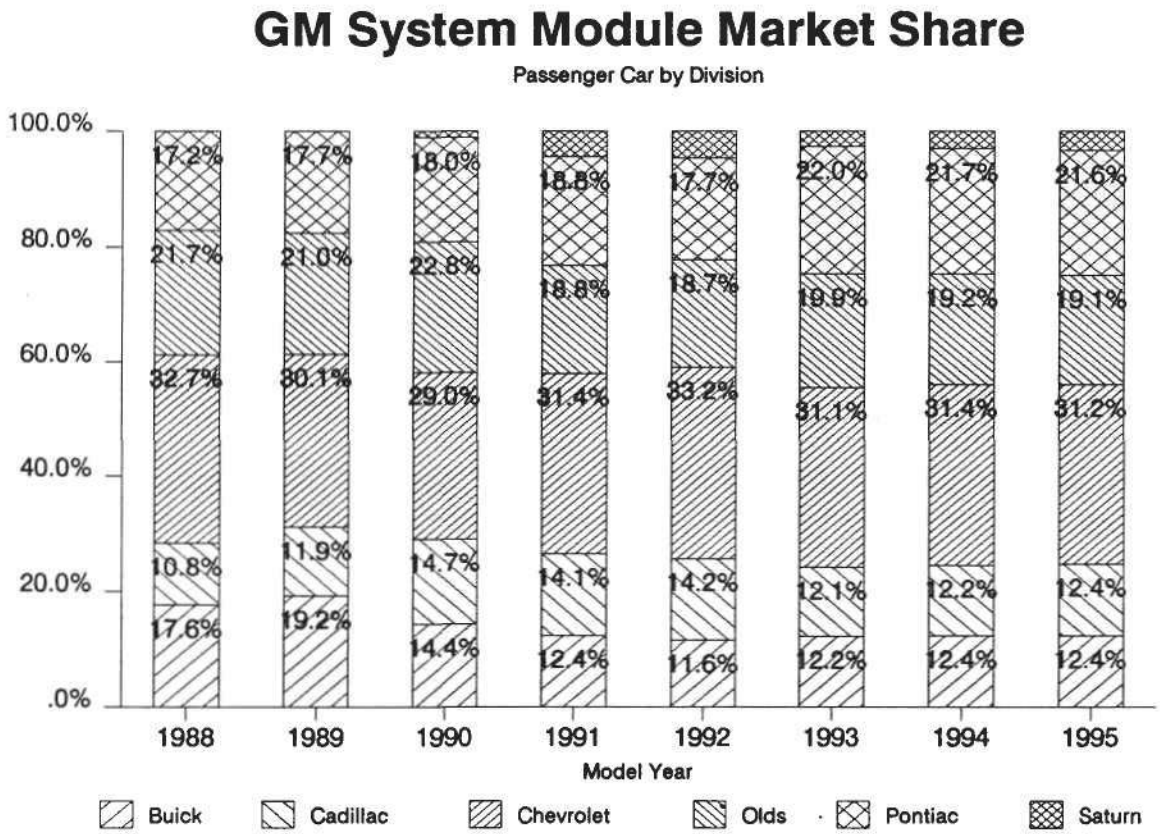


Figure 28

- Chevrolet to represent 31.2% of GM electronics in MY95
- Pontiac projected as second with 21.6%
- Oldsmobile estimated as third with 19.1%
- Cadillac and Buick tied for fourth at 12.4%
- Saturn last with 3.3%

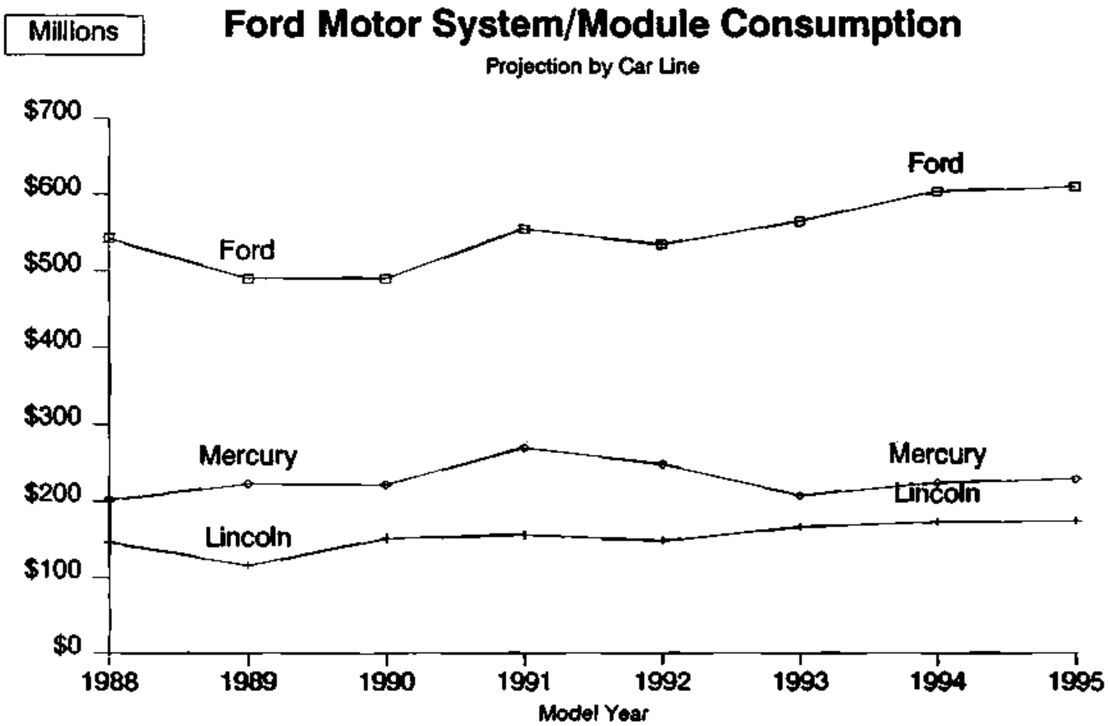


Figure 29

- **Ford car line electronics projected at $490M in MY90, growing to $610M by MY95**
- **Mercury division estimated to go from $222M in MY90, to $228M in MY95**
- **Lincoln to have modest growth from $150M in MY90 to $173M in MY95**

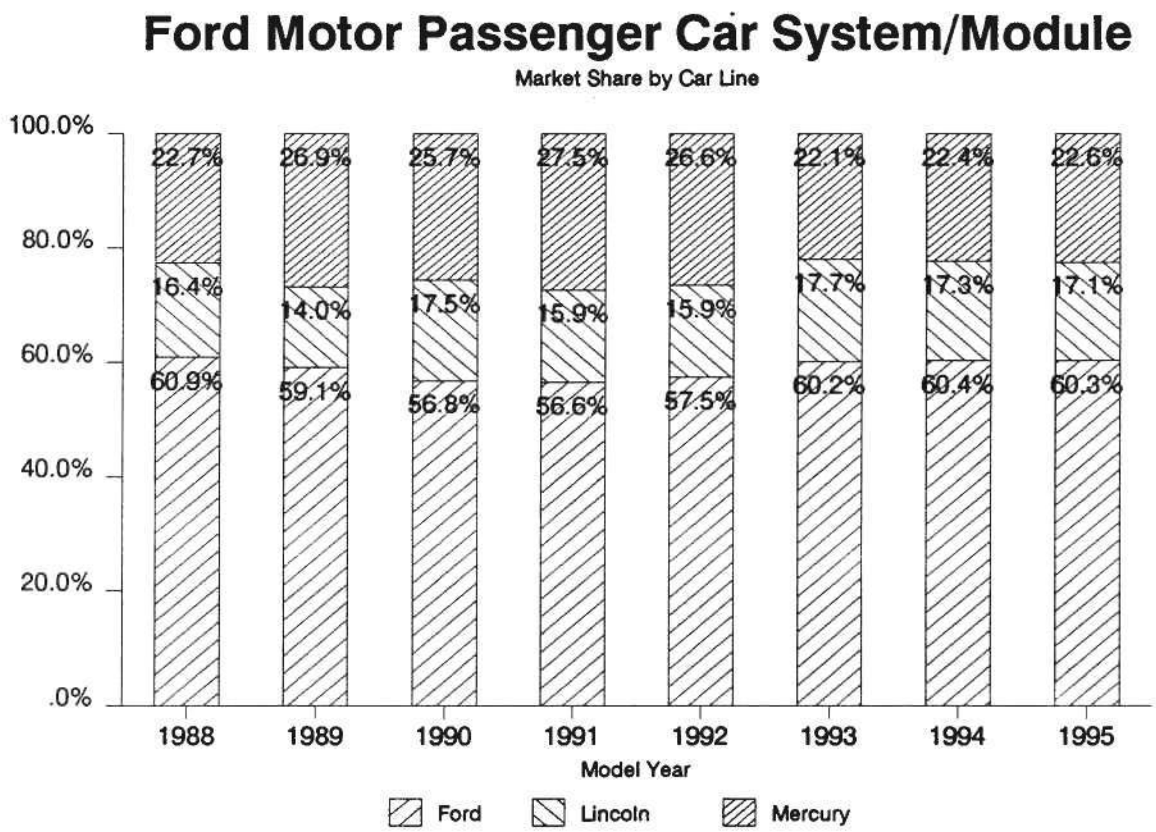


Figure 30

- **Total Ford consumption $1.01B projected by MY95**
- **Ford division estimated to be 60.3%**
- **Mercury division estimated to be 22.6%**
- **Lincoln projected at 17.1%**

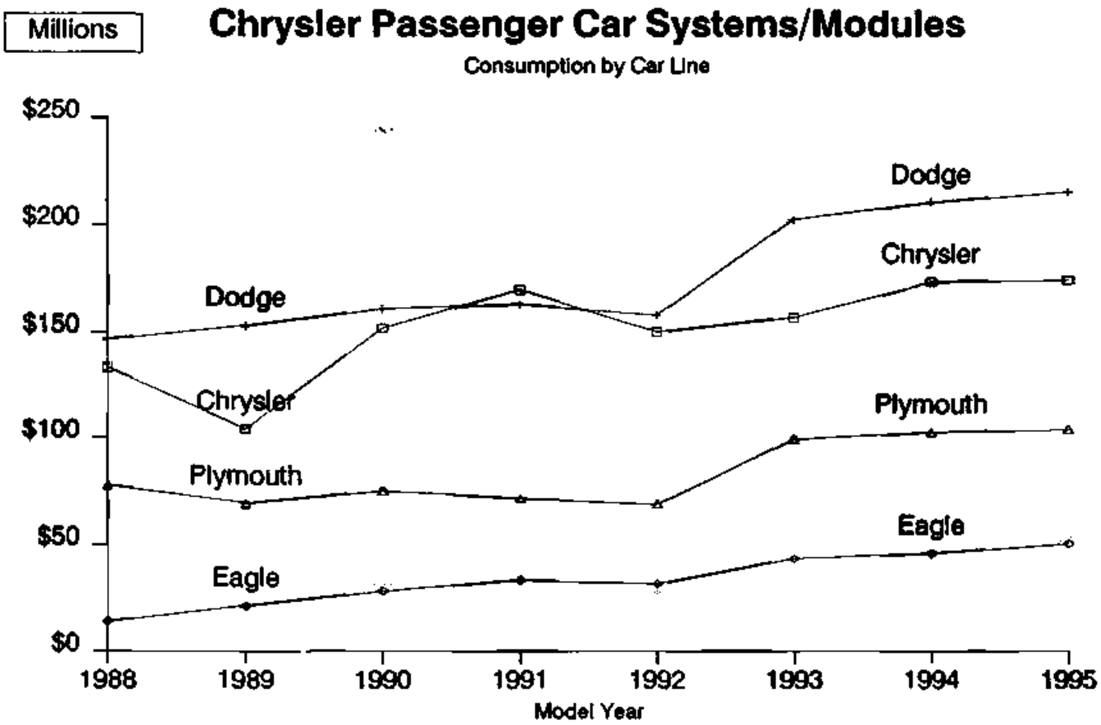


Figure 31

- **Chrysler line consumption volatile due to changing mix of vehicles (old lines dropped, new lines added)**

- **Dodge estimated to be Chrysler's largest electronics consumer in MY90 at $161M, going to $215M by MY95**

- **Plymouth to grow from $71.4M in MY90 to $104M by MY95**

- **Eagle line growing from $28.3M in MY90 to $50.2M by MY95**

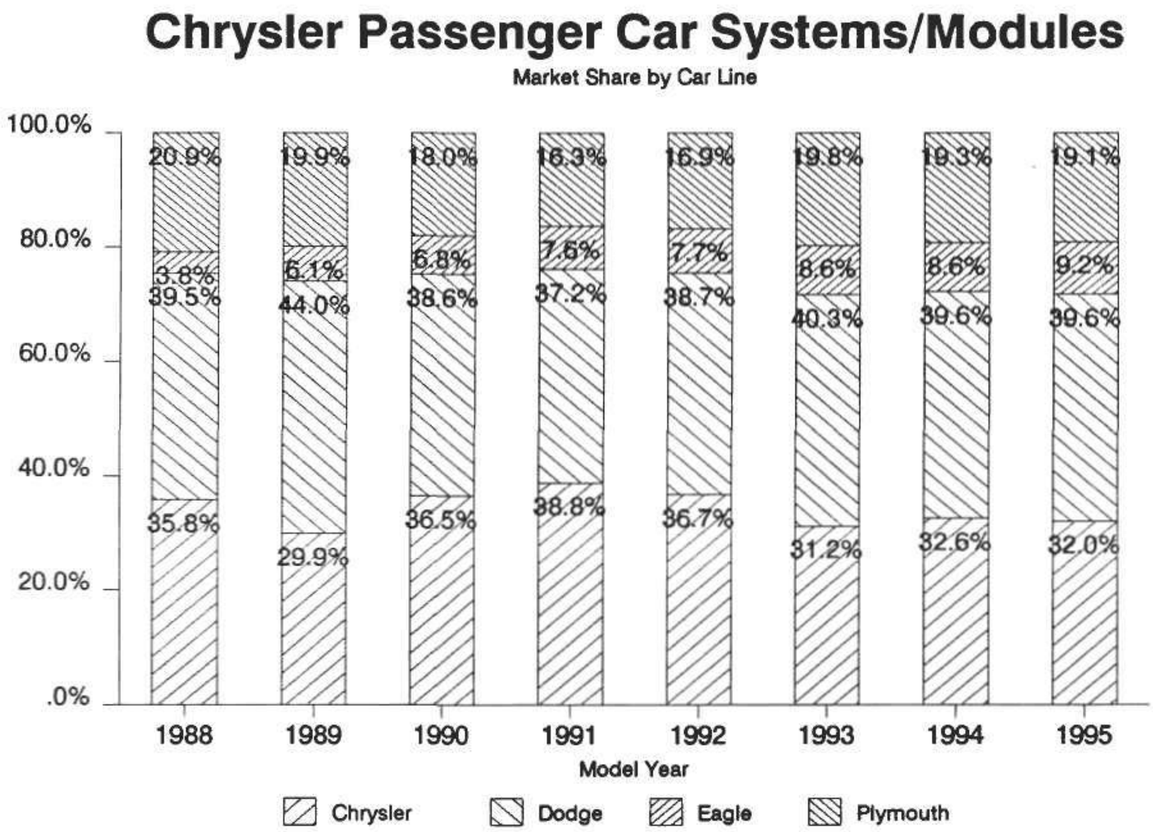


Figure 32

- **By MY95, Chrysler's estimated $543M in module consumption will be divided between:**
- **39.6% to Dodge**
- **32.0% to Chrysler cars**
- **19.1% to Plymouth**
- **9.2% to Eagle**

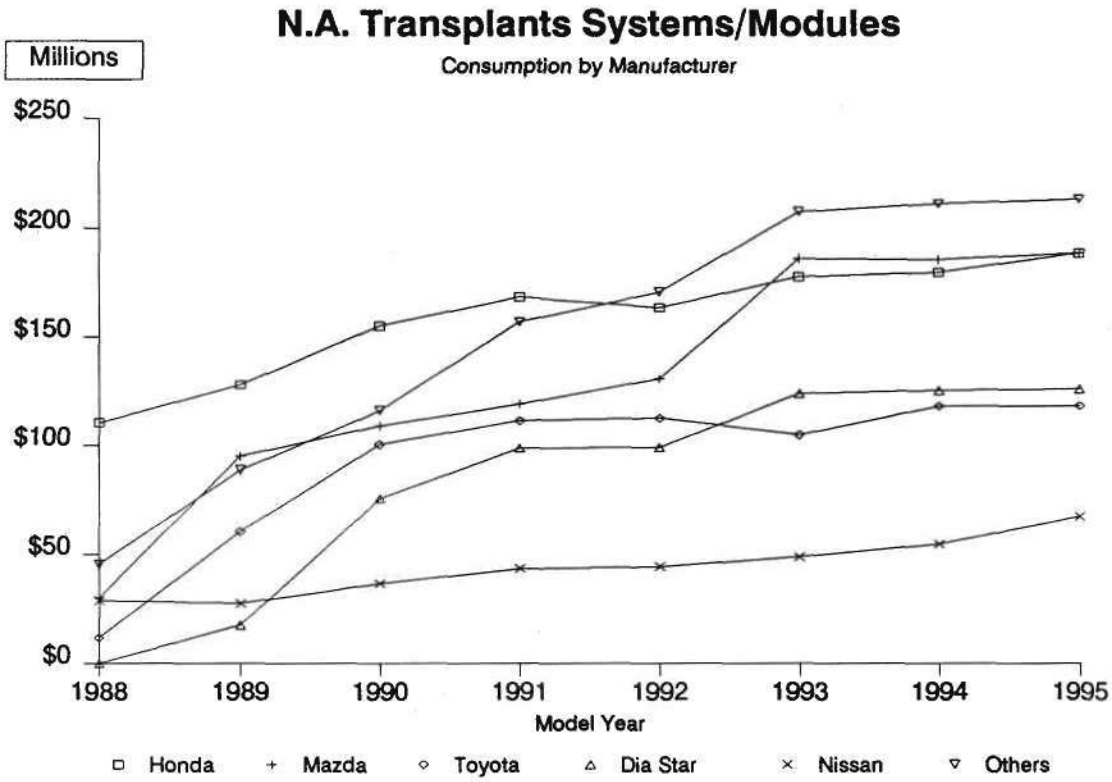


Figure 33

- Transplant electronics consumption is on the rise (MY90 - $592M, MY95 - $900M)
- Other category includes: CAMI, Hyundai, NUMMI, Subaru, VW, Volvo
- Ford Probe and Mazda MX-6 propels Mazda to tie with Honda as largest transplant electronics users by MY95 ($188M)
- 11 Transplant suppliers are: CAMI, Diamond Star, Honda, Hyundai, Mazda, Nissan, NUMMI, Subaru, Toyota, VW, Volvo
- In MY90, an estimated 85% of these modules are imported

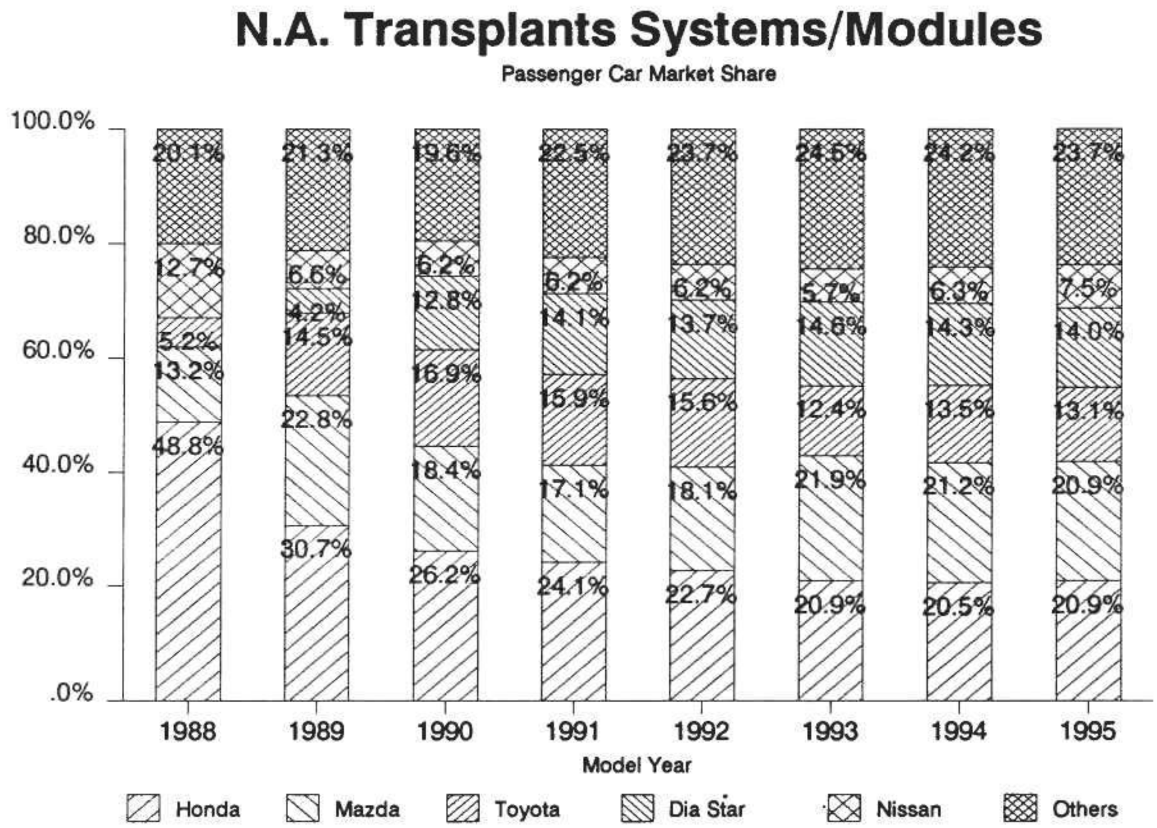


Figure 34

- **Transplants represent 18.7% of total N.A. electronics system dollars in MY95**

- **Over this period, market share expected to shift as new suppliers come "on-line"**

- **Honda represented almost 50% of the transplant consumption in MY88; estimated to be 20.9% by MY95, tied with Mazda**

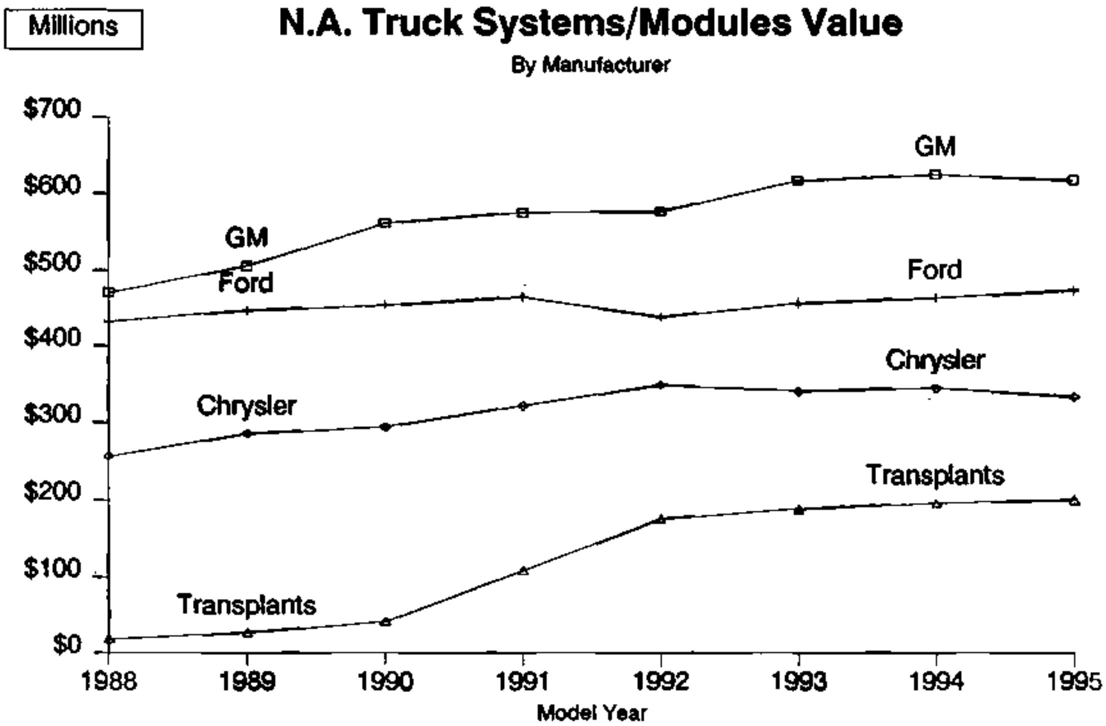


Figure 35

- GM (Chevrolet & GMC) expected to be largest user of electronics in light truckes (MY90 - $561M, MY95 - $618M)

- Ford second largest and expected to grow from $453M in MY90 to $473M in MY95

- Chrysler (includes Jeep) is projected at $294M in MY90, growing to $333M in MY95

- Transplants are expected to grow from $41.8M in MY90, to $199M in MY95

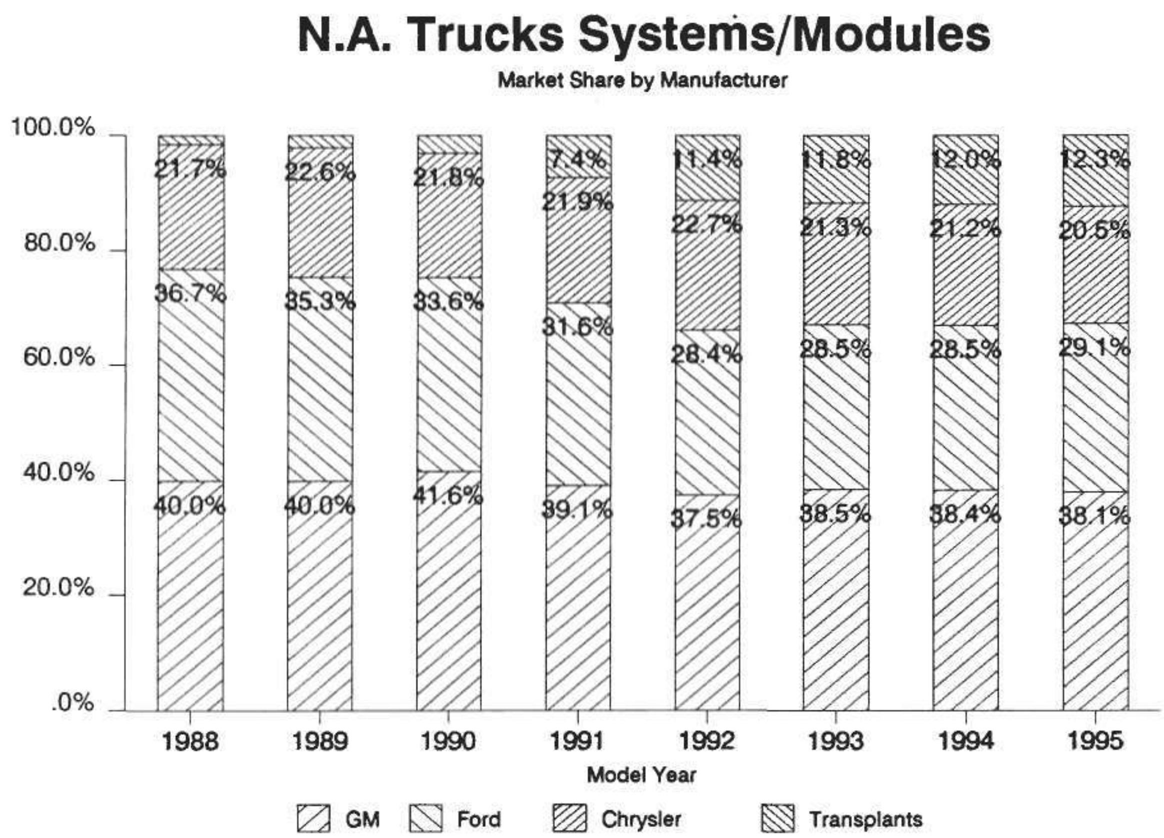


Figure 36

- **By MY95, the light truck sector is expected to consume $1.6B in electronics systems, consisting of:**

- **38.1% from General Motors**

- **29.1% from Ford**

- **20.5% from Chrysler**

- **12.3% from Transplants**

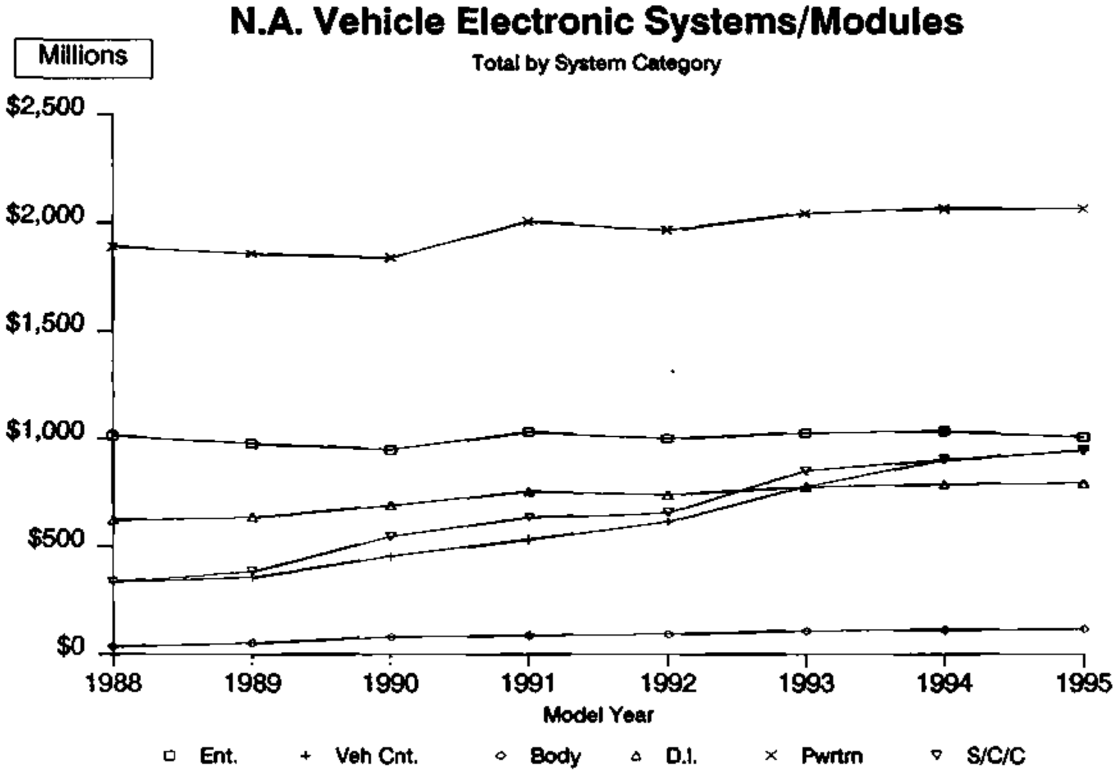


Figure 37

- Growth categories are Vehicle Controls (MY90 - $454M; MY95 - $947M) and Safety/Comfort/Convenience (MY90 - $545M; MY95 - $948M)
- Growth in these categories due to ABS, Airbags
- Powertrain to grow an estimated 12.5% from $1.8B (MY90) to $2.1B (MY95)
- Entertainment flat due to product upscaling offset by cost reductions
- Driver Information projected conservatively due to cool consumer reaction to electronic instrumentation
- Body Electronics includes many low-cost modules, will grow after MY95 when multiplexing spreads

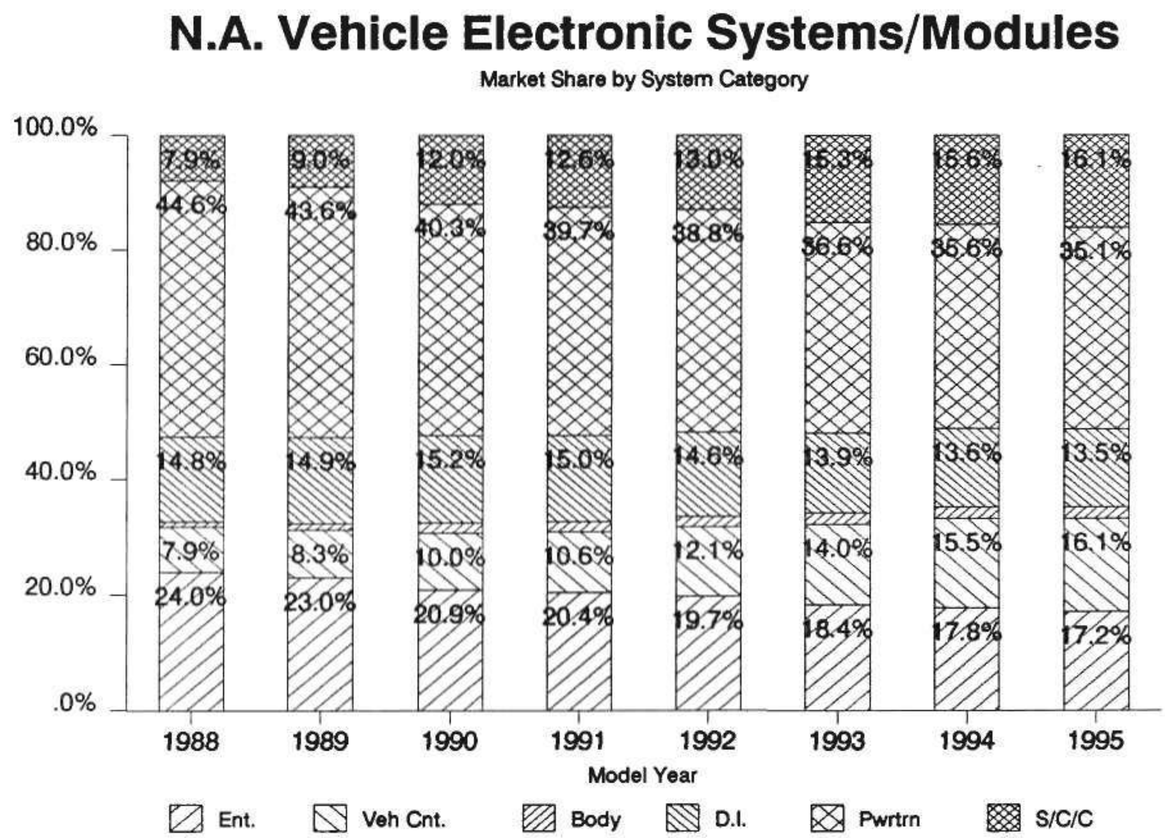


Figure 38

- Powertrain once represented over 50%, now 40%, predicted to be 35% by MY95
- Vehicle Controls growing from 10% today to over 16% by MY95 primarily due to ABS
- S/C/C growing from 12% today to tie with Vehicle Controls at 16% by MY95
- Entertainment market share falling from 24% in MY88 to 17% by MY95 due to total market expansion combined with cost reductions in entertainment products
- Driver Information not growing as fast as the market, going from 15% in MY90 to 13.5% in MY95

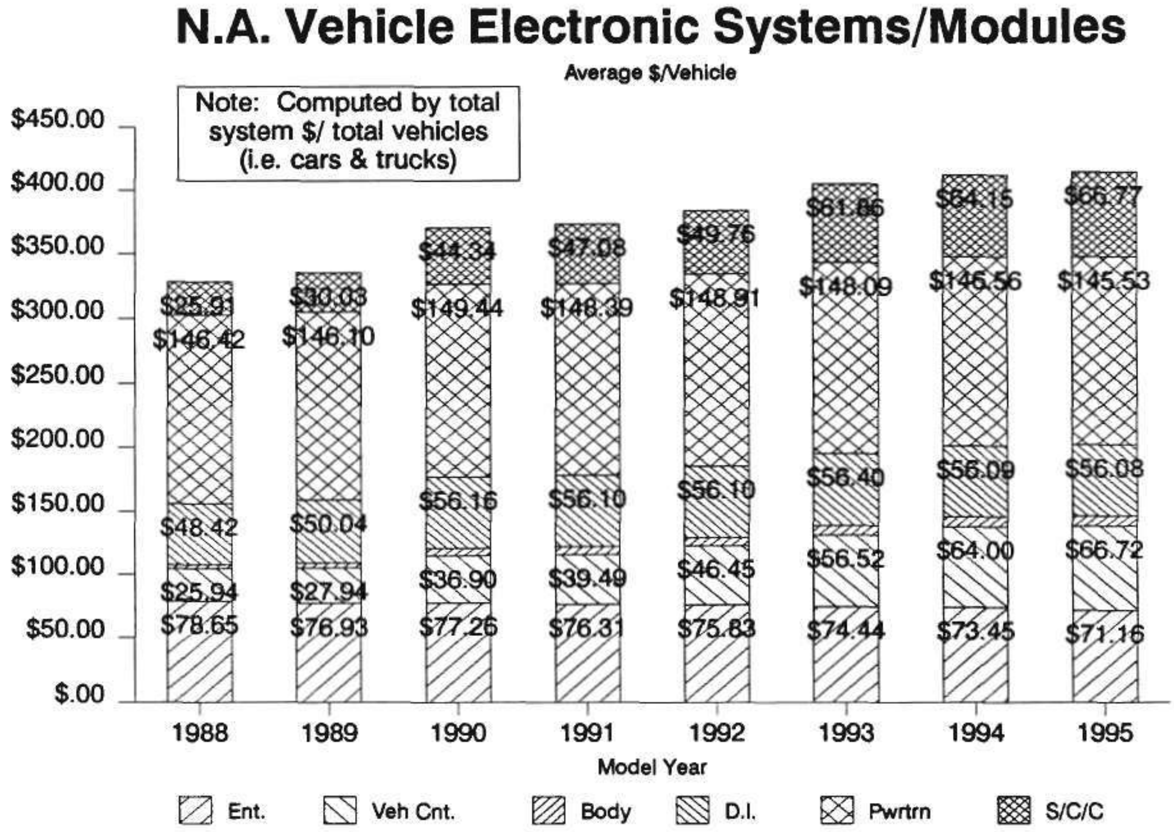


Figure 39

- **Average electronic content of N.A. vehicles continues to rise**

- **Totals are: MY88 - $328.21; MY89 - $325.03; MY90 - $370.54; MY91 - $373.76; MY92 - $383.95; MY93 - $405.03; MY94 - $412.14; MY95 - $414.39**

- **Computed by dividing total system dollars by total vehicles (cars & trucks) - not an indicator of content in fully equipped vehicles**

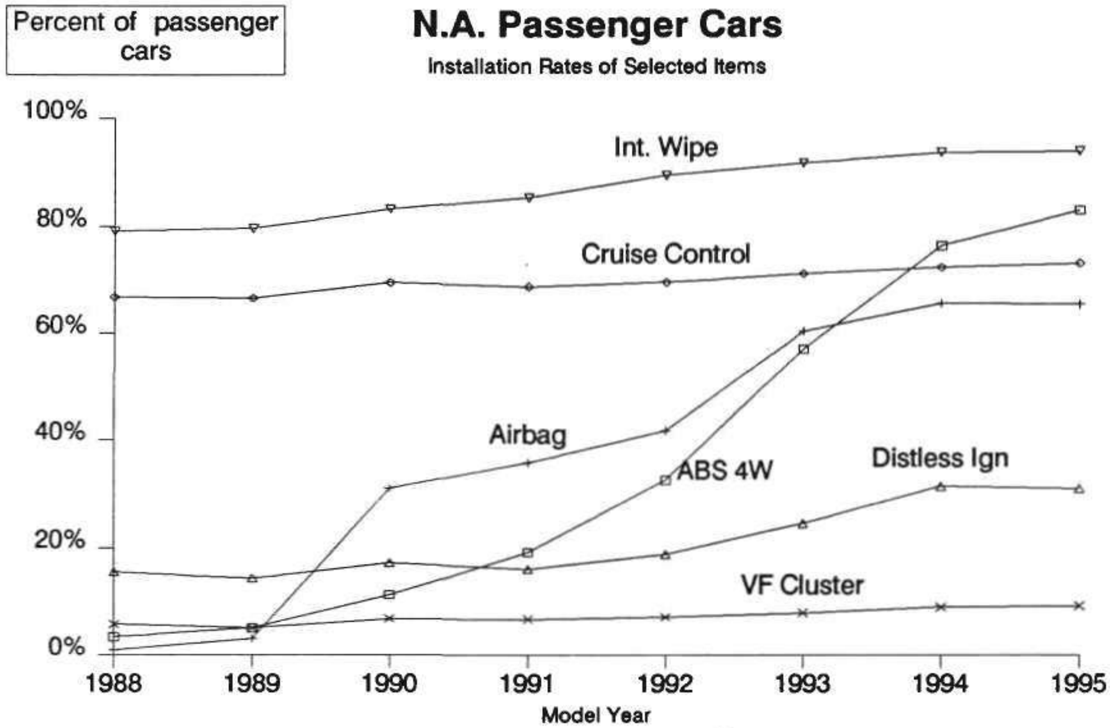


Figure 40

- Installation rates of ABS, Airbags expected to grow dramatically in the mid-90's
- Distributorless Ignition starting to grow, gradually replacing conventional distributor ignition
- Cruise control, interval wipers growing, but saturating
- Vacuum Flourescent instruments represent a "niche" market

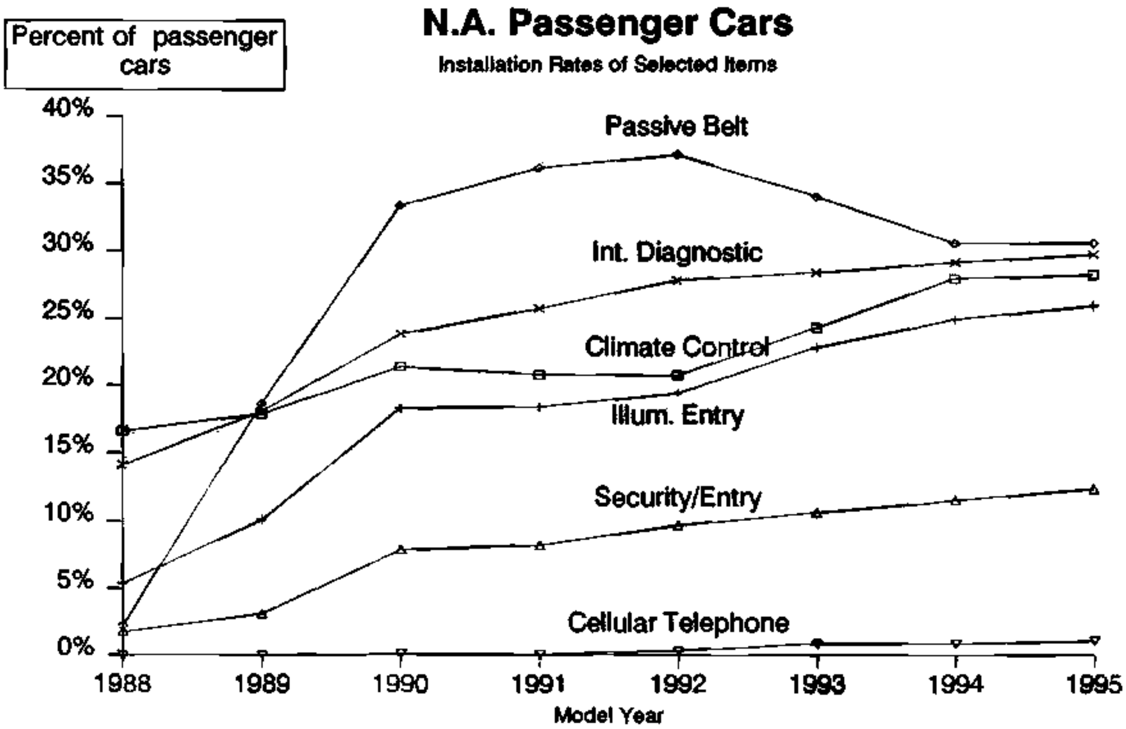


Figure 41

- **Passive belts expected to increase, then fall back as they are replaced by air-bags in some models**

- **Other projected growth products include illuminated entry systems, remote security/entry systems, integrated diagnostic displays, and climate control**

- **Cellular telephone is not expected to make significant in-roads at the OEM level by the mid-nineties**

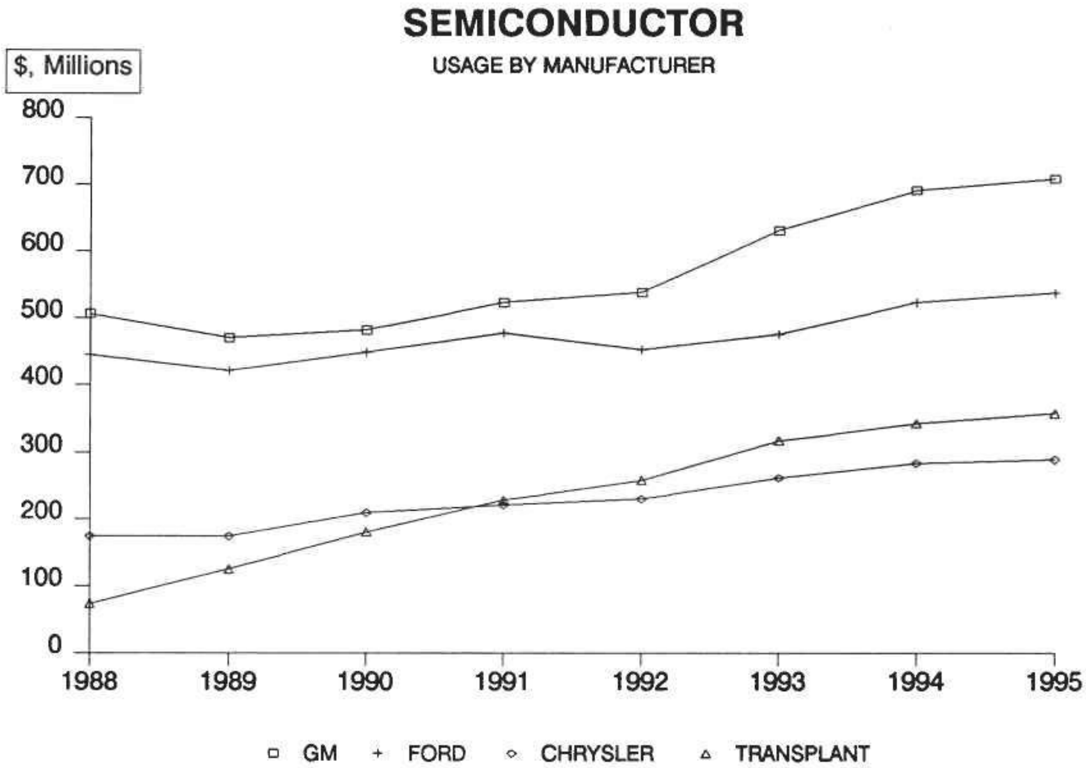


Figure 42

- **Total semiconductor market estimated at $1.32B in MY90, growing to $1.89B in MY95 at 7.5% CAGR**
- **14.7% growth for Transplants (pass Chrysler in MY91); 8.0% growth for GM; 6.7% for Ford; 3.7% for Chrysler**
- **Semiconductors represent 29% of systems/module value in MY90, growing to 32% by MY95**
- **Represents approximately 10% of U.S. Semiconductor Market**

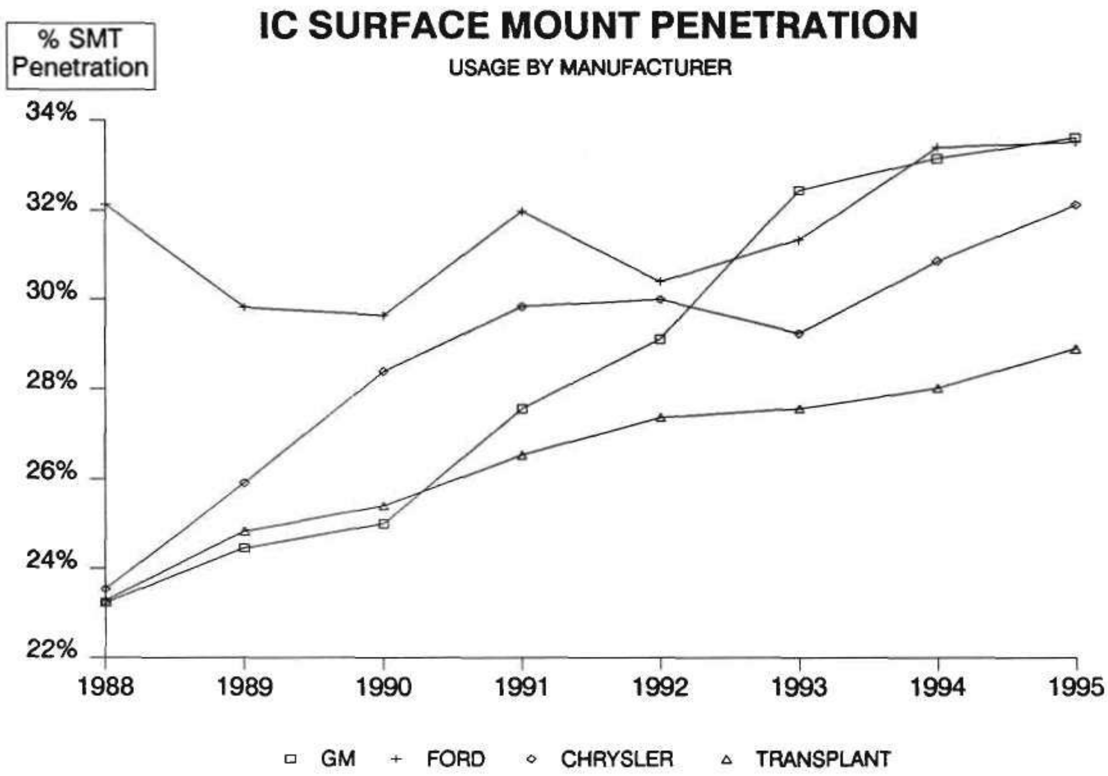


Figure 43

- **Ford has largest percent SMT at present**
- **GM to make largest percentage shift to SMT**
- **GM projected to equal Ford's SMT rate by MY95**
- **Cost not yet incentive**

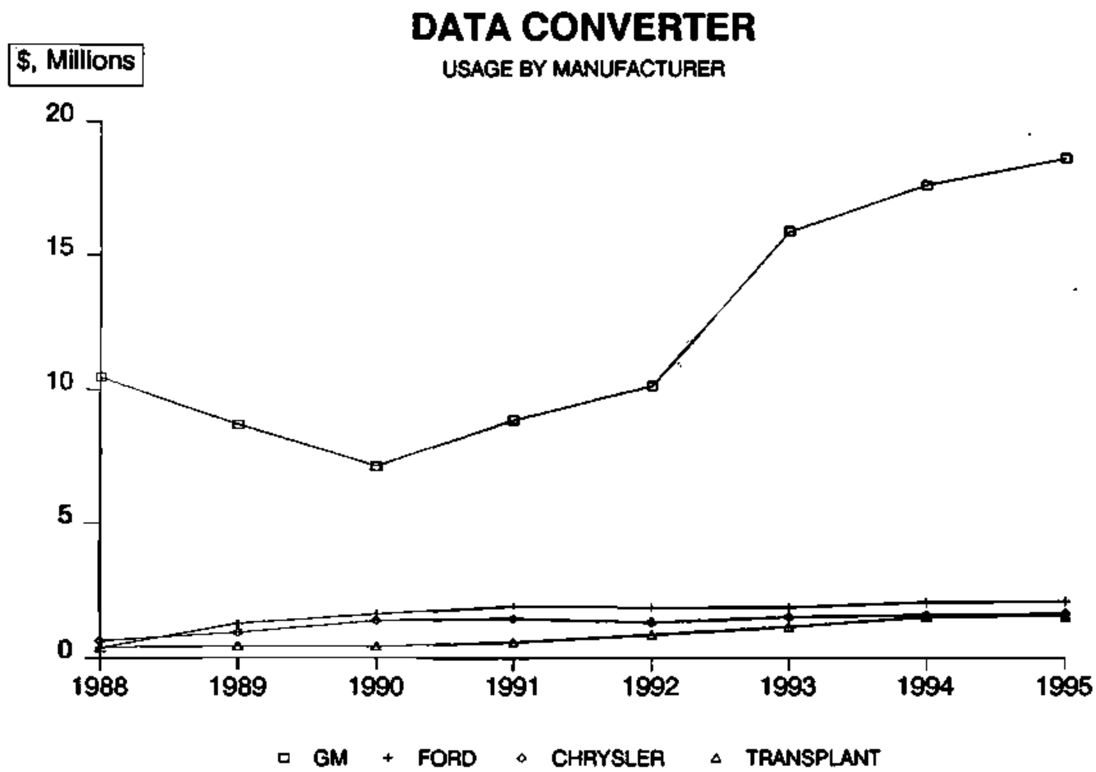


Figure 44

- **Only GM projected to use standalone A/D in engine control, others integrated or custom**

- **Other A/D applications include ABS, climate control, & compass**

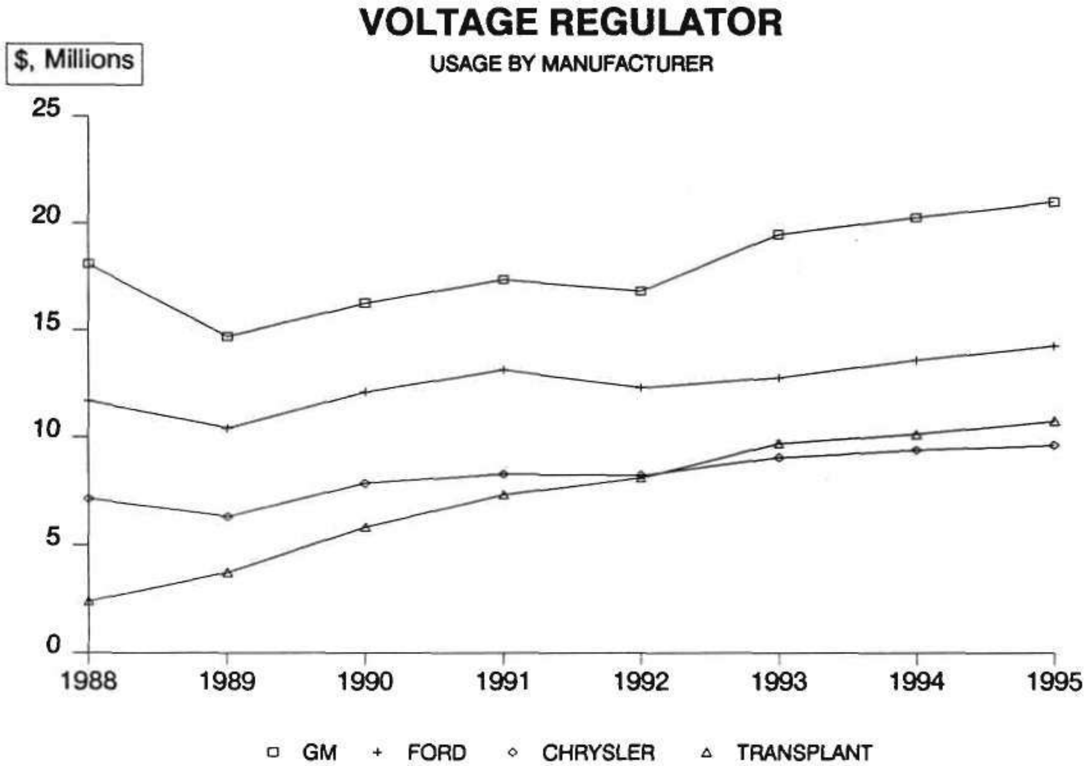


Figure 45

- Expected to grow from an estimated $42.1M in MY90 to a projected $55.6M in MY95
- GM expected to use $21M by MY95, 37.8% of total
- Total market growth MY90 - MY95; CAGR = 5.7%

SPECIAL AUTOMOTIVE LINEAR IC

USAGE BY MANUFACTURER

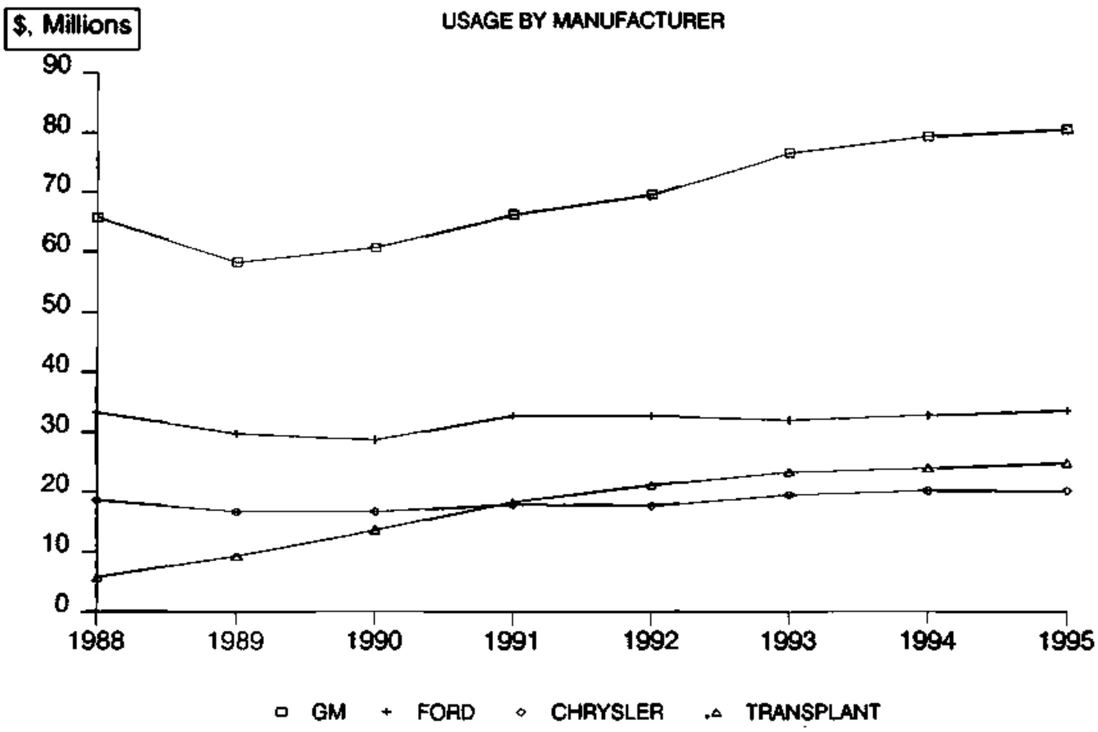


Figure 46

- **Automotive audio circuits, semi-custom products**
- **GM represents 51% of market by MY95**
- **Total market CAGR (MY90 - MY95) = 5.8%**

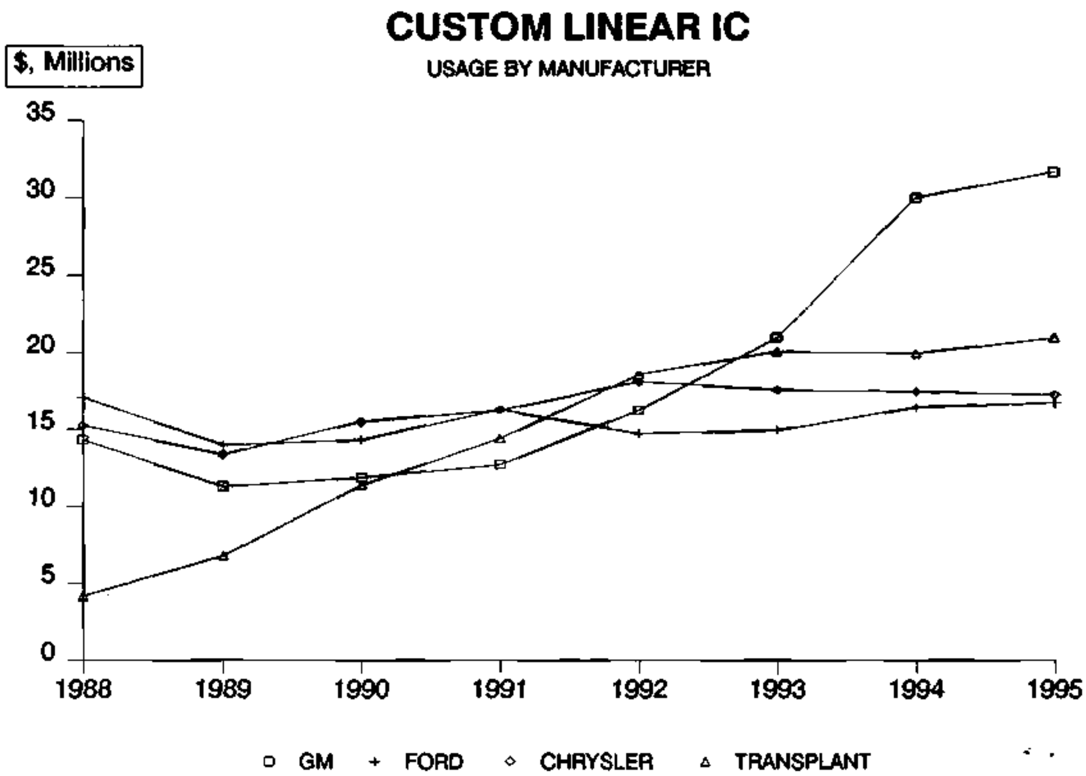


Figure 47

- **Full custom products for specific customer designs**
- **GM CAGR (MY90 - MY95) = 21.7%**
- **All other makes projected at CAGR of 10.3%**
- **GM to represent 36.5% of total market by MY95**

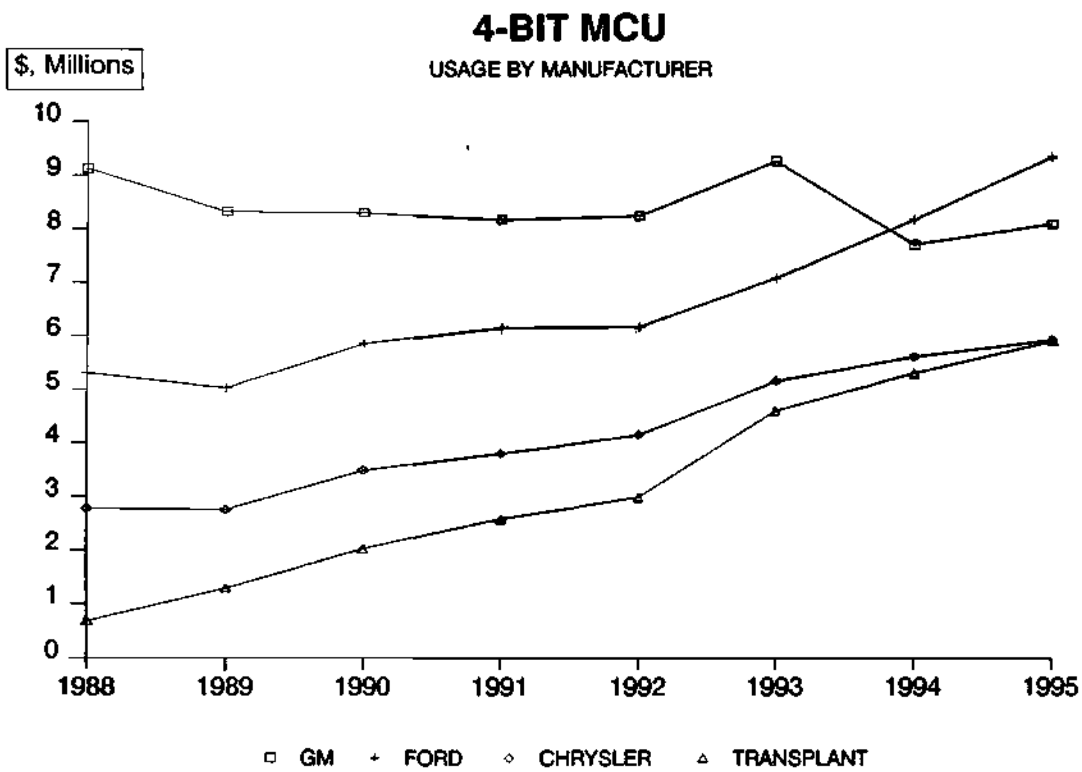


Figure 48

- **4-Bit & 8-Bit prices projected to equalize during this period**
- **Existing 4-Bit design-ins contribute to CAGR of 8.3% between MY90-MY95**
- **Most growth coming from radio applications**
- **Expect to be replaced by 8-Bit at next design change**

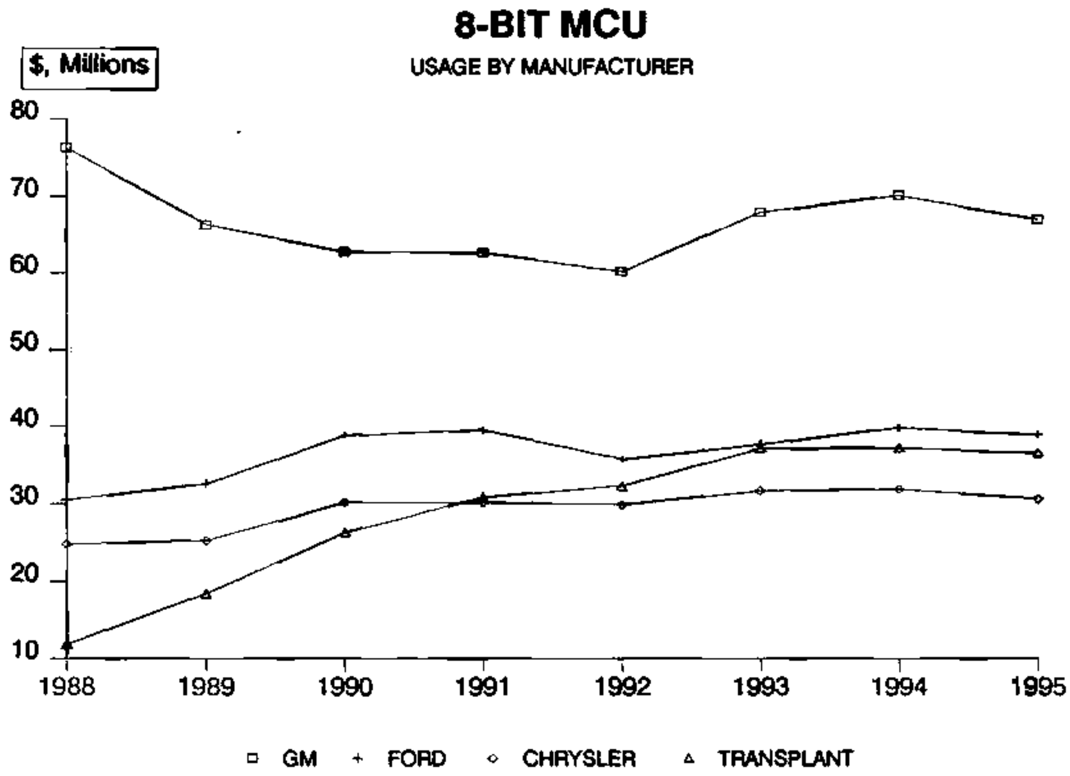


Figure 49

- **8-Bit market projected at over $173M by MY95**

- **Falling 8-Bit prices "flatten" market value, volume growing**

- **8-Bits expected to replace 4-Bits in product redesigns**

- **Transplants experience CAGR of 6.8% over MY90 - MY95**

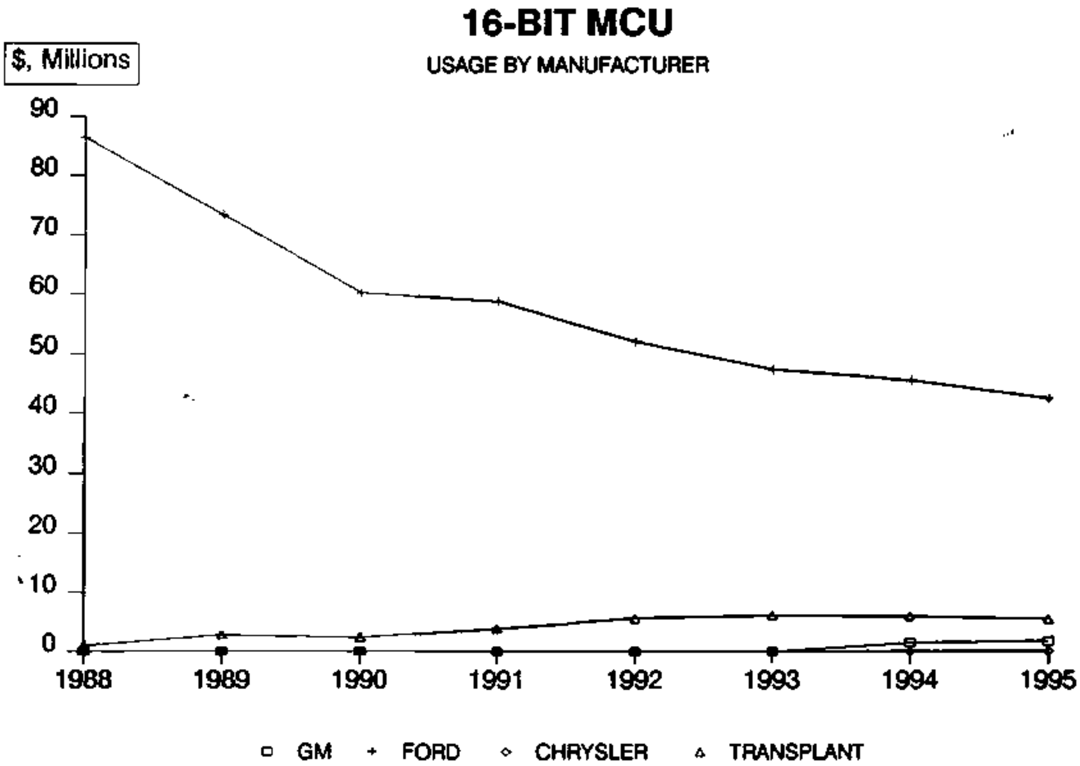


Figure 50

- **Prices for 16-Bit are expected to fall almost 30% by MY95**
- **Ford's volume usage of 16-Bit MCU's will remain relatively flat with a CAGR of 1.2% between MY90 - MY95**
- **Absolute value of the market will decline to an estimated $42.6M as prices come down.**

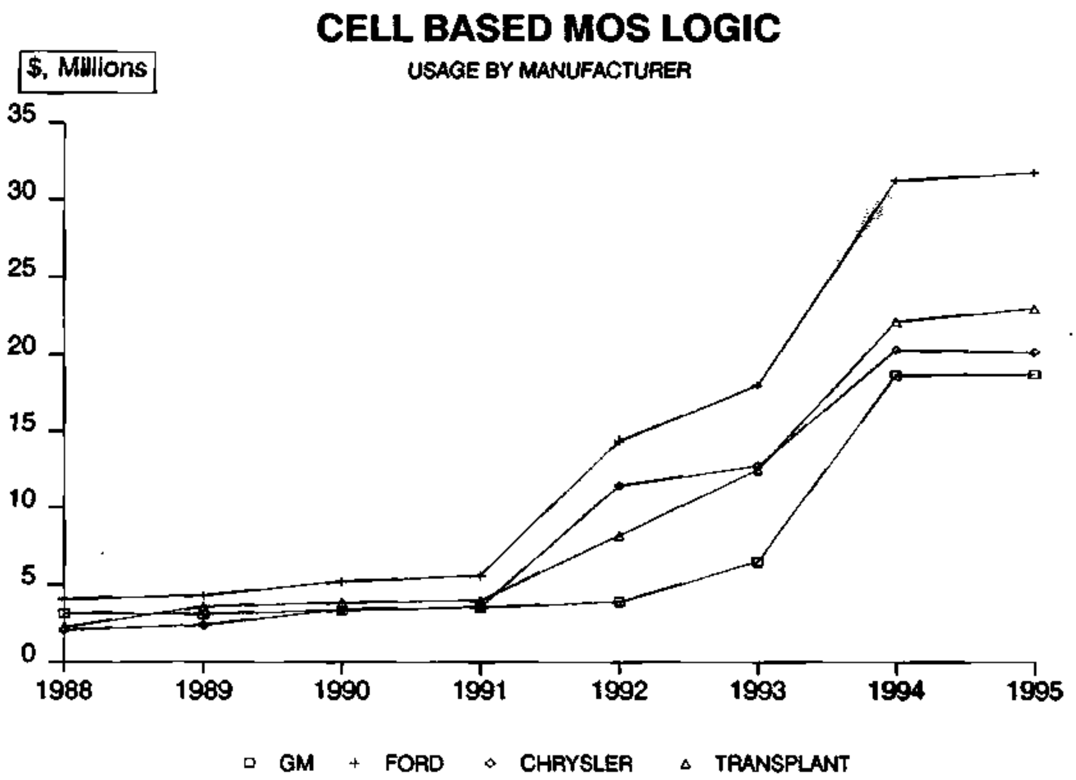


Figure 51

- **Total market expected to grow from $15.8M in MY90 to $93.6M by MY95**
- **Growth due largely to incorporation in ABS and air-bag systems, also growing rapidly over this period**
- **CAGR (MY90 - MY95) = 42.7%**

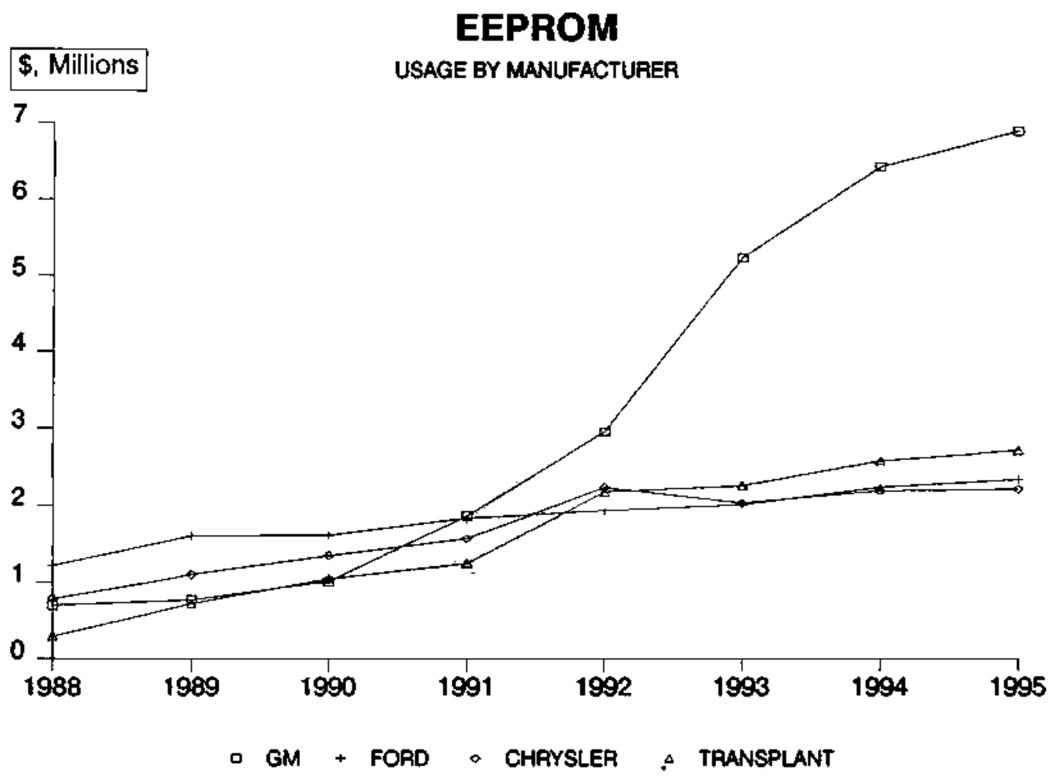


Figure 52

- Total usage expected to grow from $5M (MY90) to over $14M (MY95)
- GM to lead growth with CAGR of 47%
- Expected to replace some EPROM sockets
- Includes NVRAM for applications like compass, radio, odometer

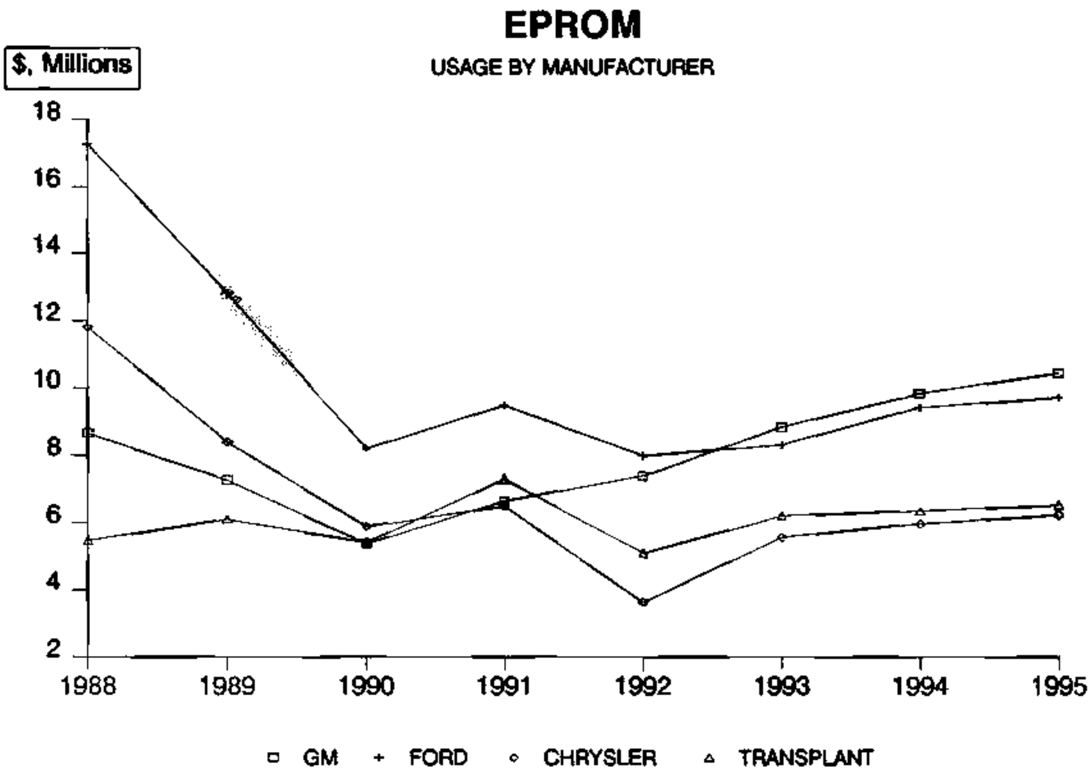


Figure 53

- **EPROM volume essentially flat, prices eroding**
- **With an average of 1 per car, subject to market fluctuations**
- **Total market forecasted to be $32.9M by MY95**

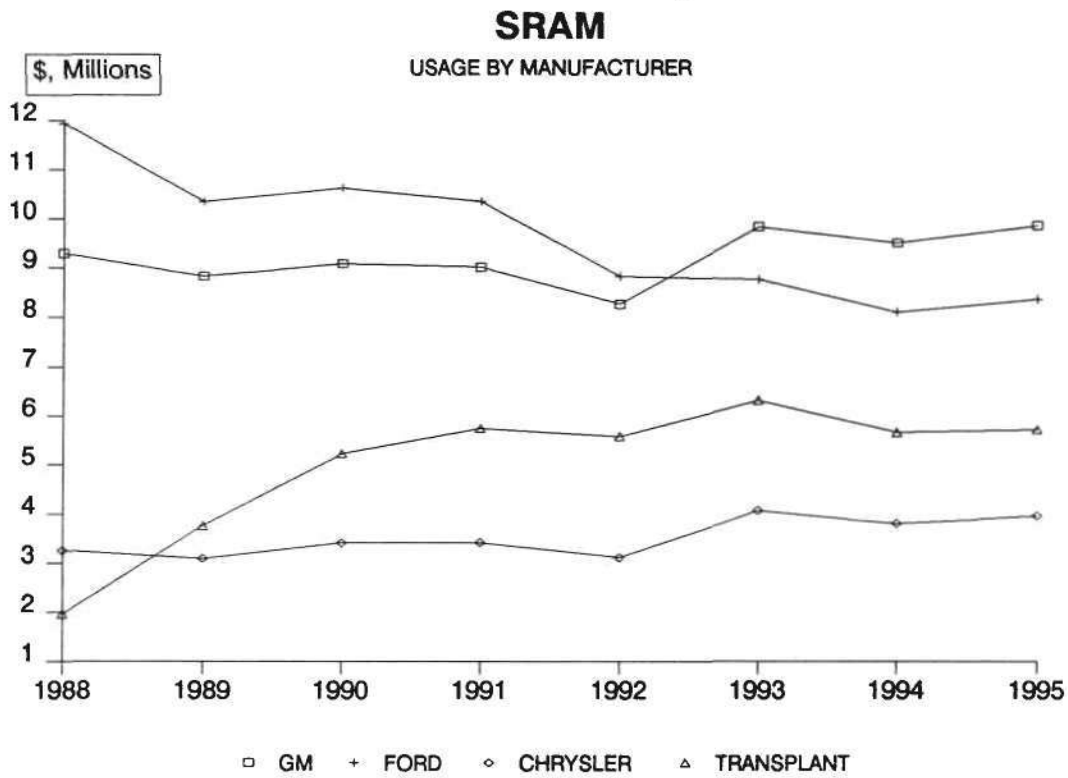


Figure 54

- **Total value of SRAM usage falls at CAGR of -0.3% between MY90 and MY95 due to price erosion**
- **Total quantity expected to rise at CAGR of 6.7% over the same period**

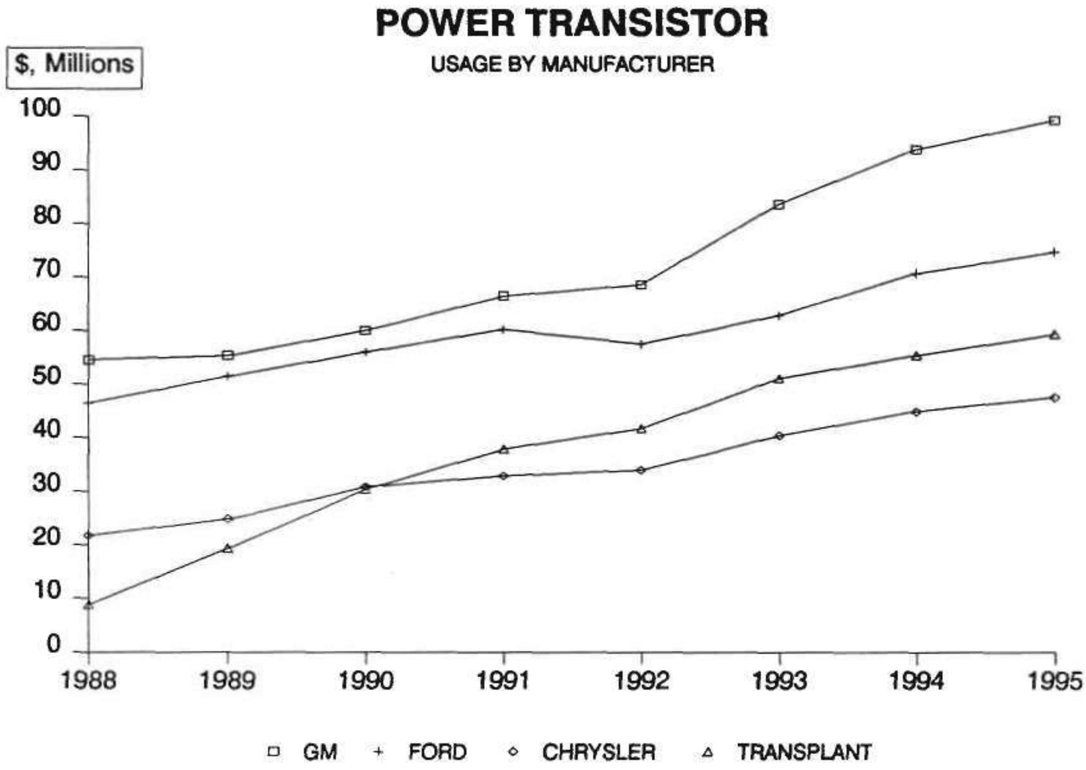


Figure 55

- **Total market expected to grow from $177.4M in MY90 to $280.6M by MY95**
- **CAGR = 9.6% over this period**
- **Transplants expected to grow the most with CAGR of $14.3%**

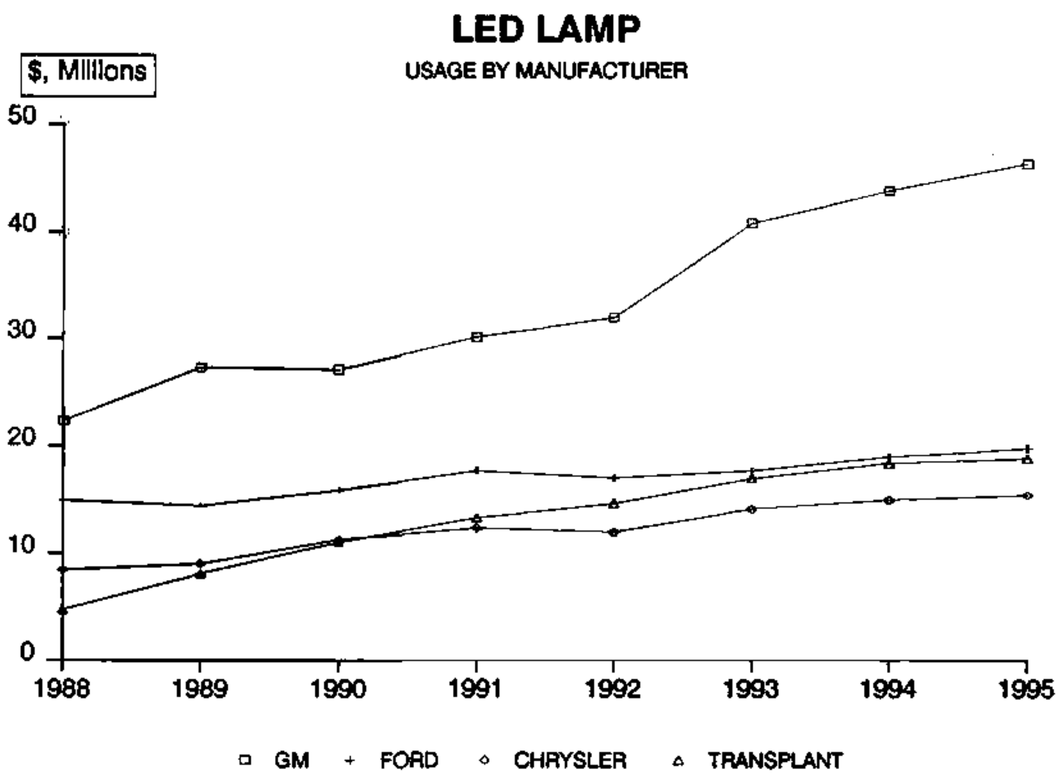


Figure 56

- **Expected to grow from usage of 65M units in MY90 to 100M units by MY95**

- **Entertainment grows from 24M units to 32M units**

- **Fastest potential growth area is LED CHMSL, with between 50 and 70 LEDs per unit**

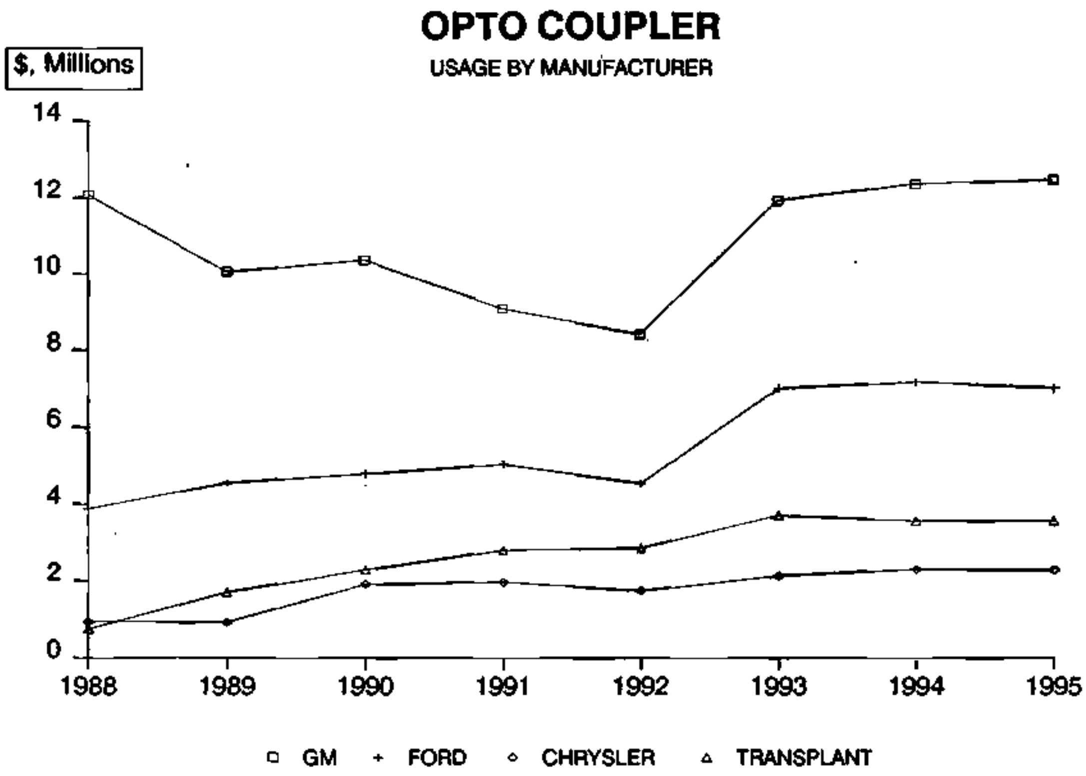


Figure 57

- **Used in tape transport mechanisms, often 2 per unit**
- **Estimated 21M units growing to 27M units by MY95 in Entertainment sector**
- **Used in suspension control, grows from 2.2M units in MY90 to 7.8M units by MY95**

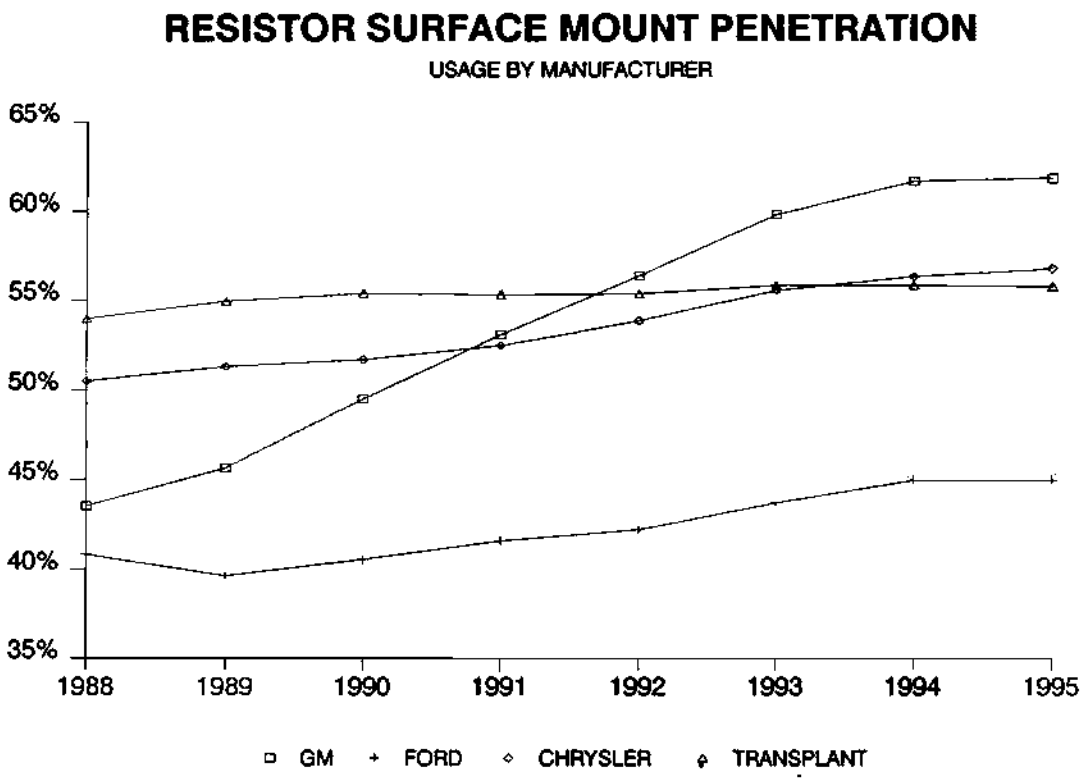


Figure 58

- **GM the most aggressive in moving to surface mount**
- **Transplants now using over 50% surface mount resistors**
- **Ford expected to use 45% surface mount resistors by MY95**
- **Chrysler estimated 56% by MY95**

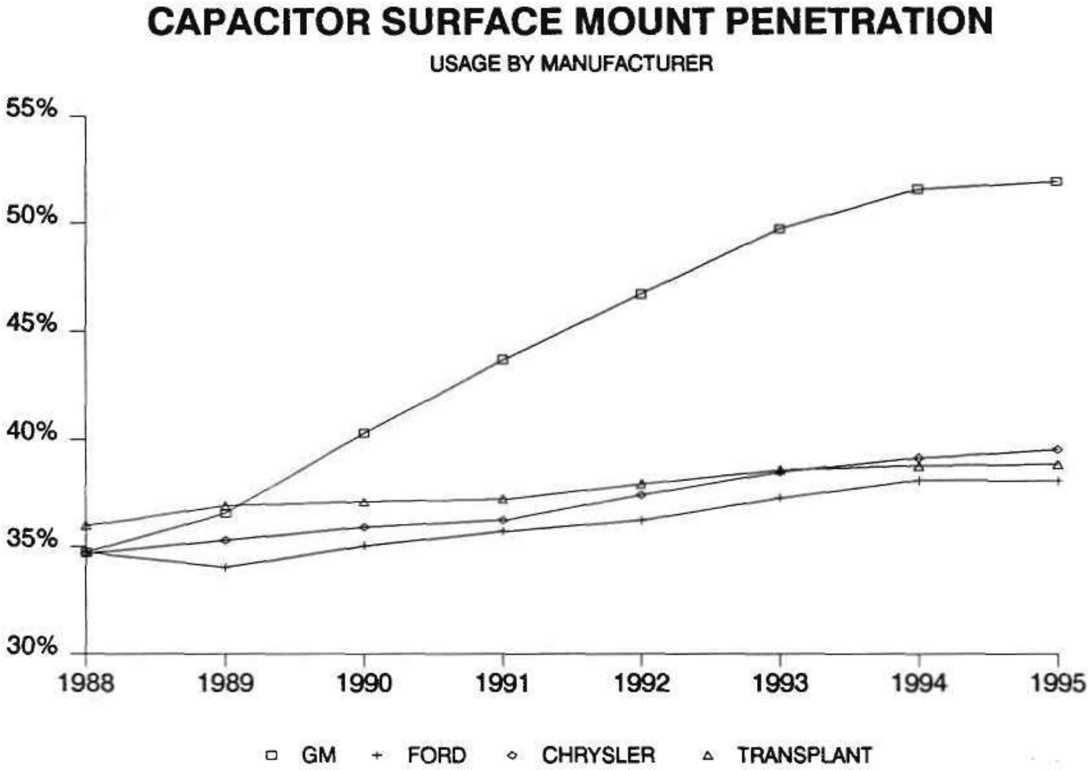


Figure 59

- **GM moving most aggressively toward surface mount, estimated 52% surface mount capacitors by MY95**
- **Others estimated to be at approximately 36% in same time frame**

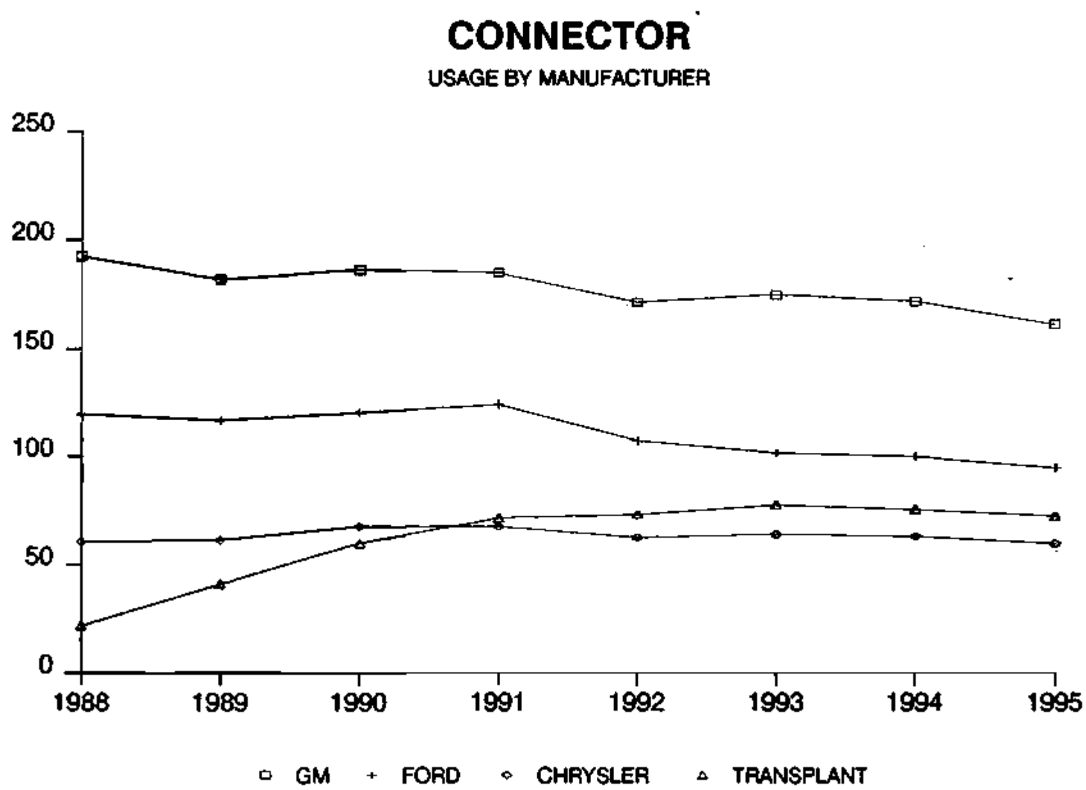


Figure 60

- This includes only connectors used within systems/modules, no external connectors
- Overall internal connector usage is projected to decline due to greater integration, fewer PCBs and moves to SMT for higher density
- Total internal connector CAGR is projected at -2.2% between MY90 and MY95

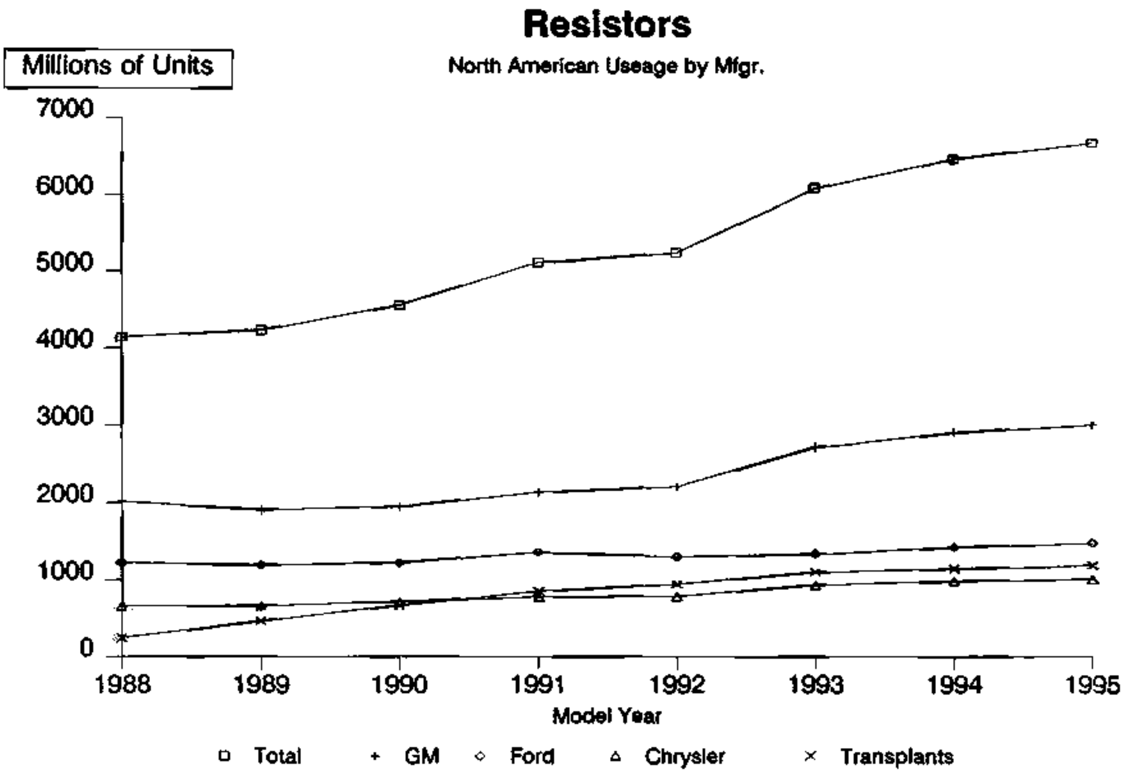


Figure 61

- **Usage growing with increased application of electronics to vehicles**

- **CAGR of 7.9% estimated between MY90 and MY95**

- **56.3% of market is projected to be SMT by MY95**

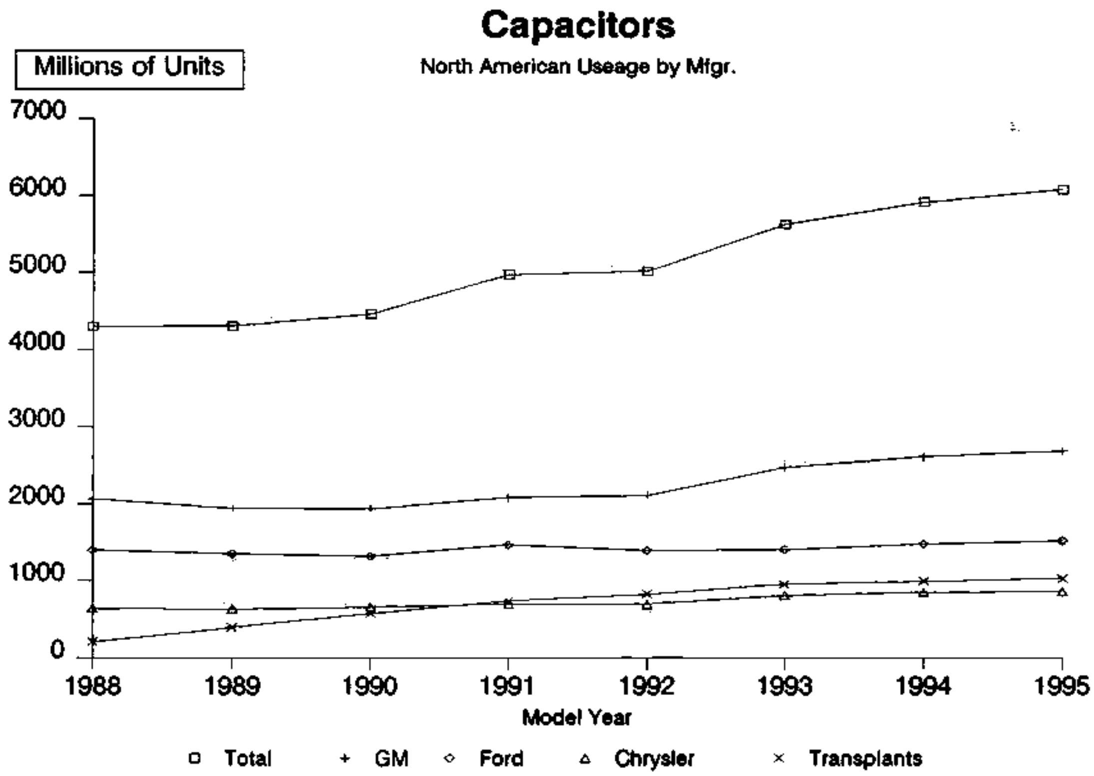


Figure 62

- **Nearly 6 Billion to be used in MY95**
- **CAGR of 6.3% between MY90 and MY95**
- **Growth within Transplant Suppliers increasing the most**
- **44.5% of market is projected to be SMT by MY95**

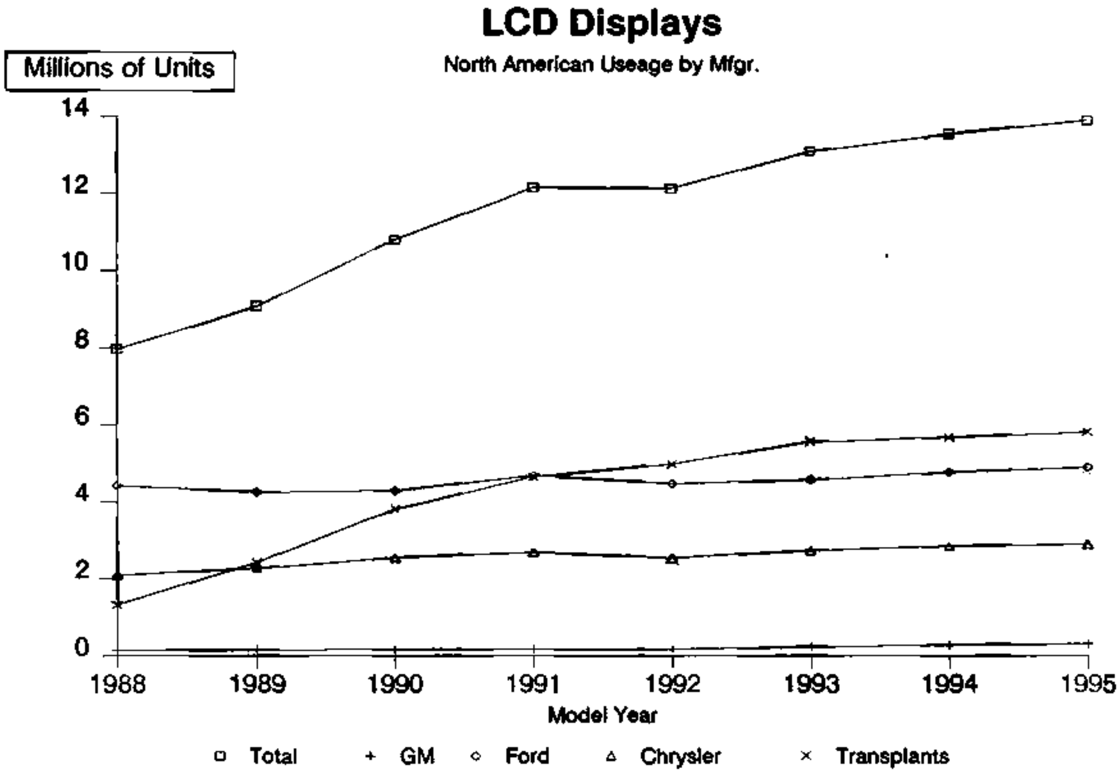


Figure 63

- **10M displays projected for MY90, growing to 14M by MY95**
- **Used primarily in clocks, radios, instrumentation**
- **Total market CAGR projected at 5.2% between MY90 and MY95**
- **GM usage growing the most with 13.8% CAGR between MY90 and MY95**

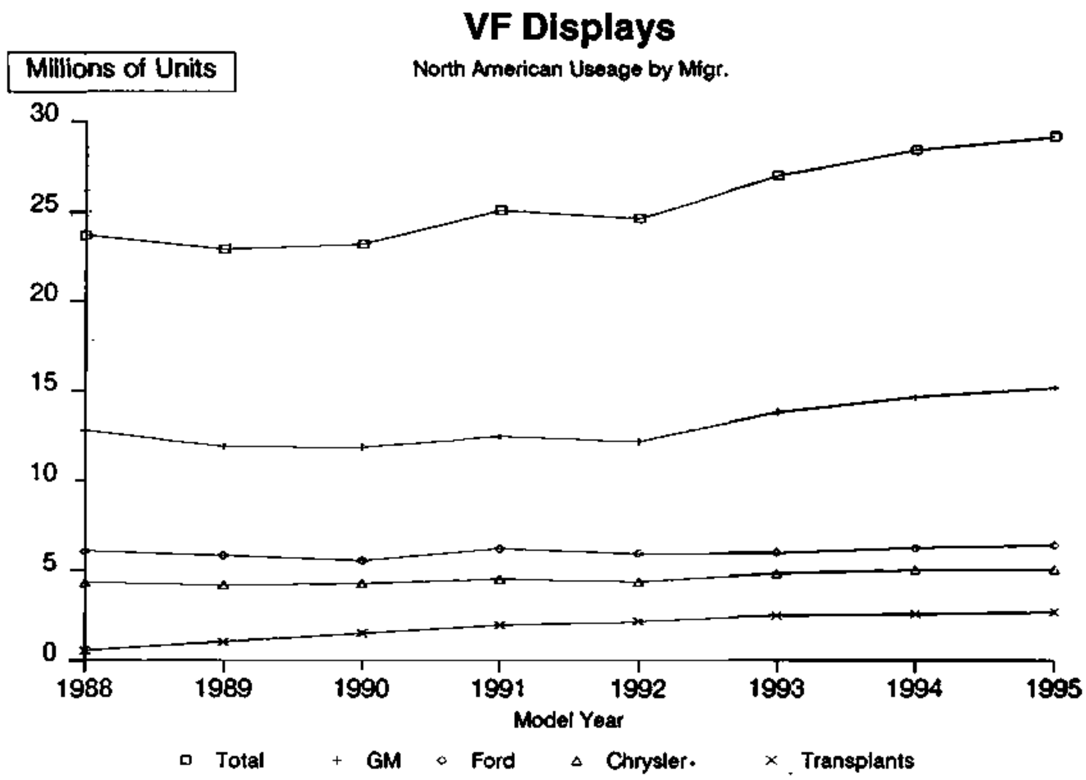


Figure 64

- **Total market growing from an estimated 23M units in MY90 to over 28M units in MY95**
- **CAGR of 4.7% projected between MY90 and MY95**
- **Transplants growing the most with CAGR of 12.1% between MY90 and MY95**
- **VF leads LCD by almost 2 to 1**

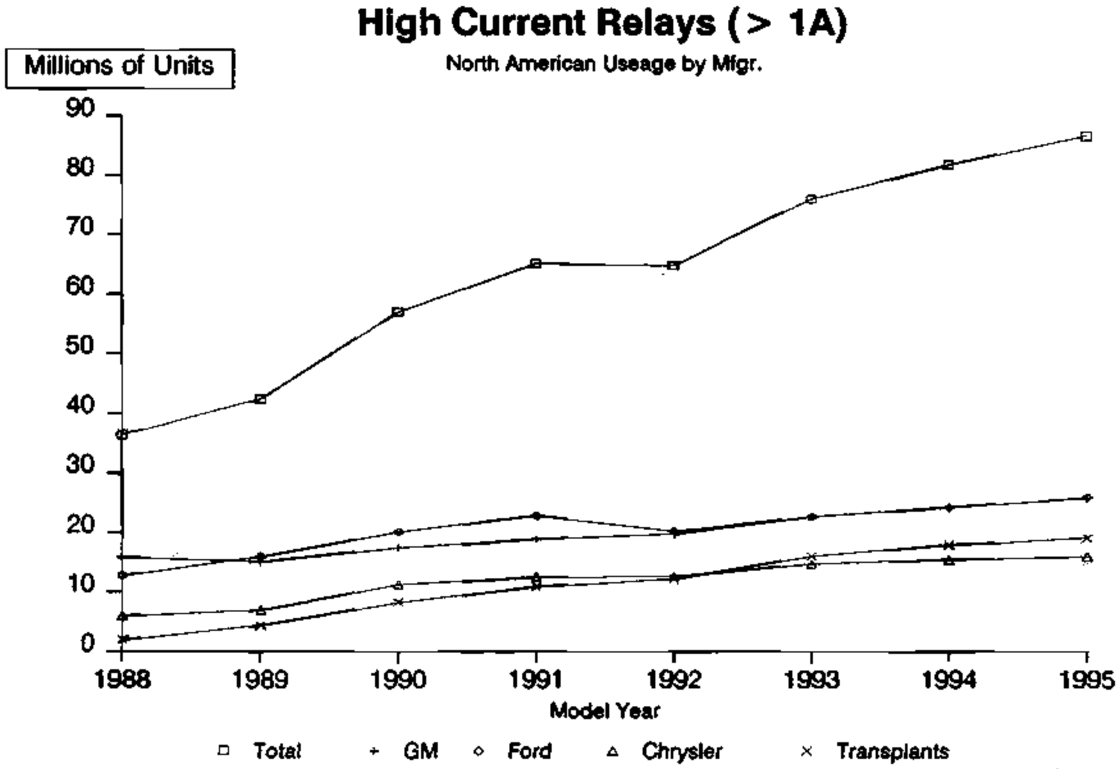


Figure 65

- **Relays growing due to increased electronic control of vehicle functions**

- **Includes only relays contained within electronic module packages – does not include external, standalone relays**

- **Estimated to go from 57M units in MY90 to 82M units by MY95**

- **CAGR is projected to be 8.7% between MY90 and MY95**

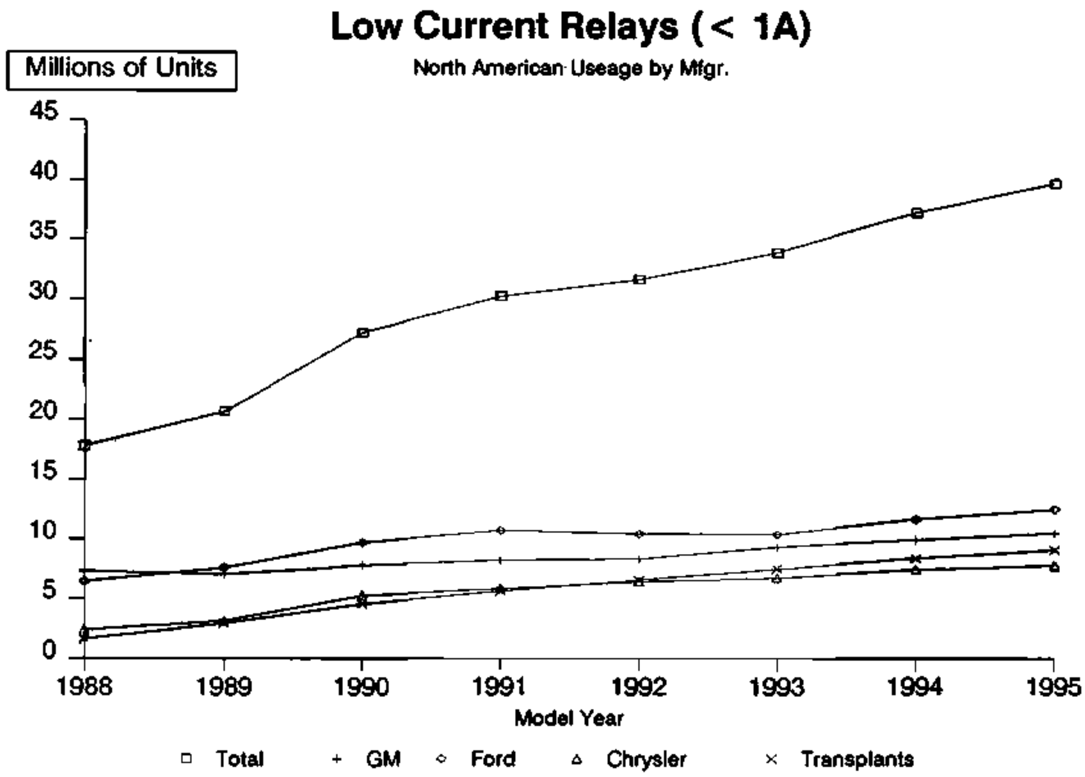


Figure 66

- Includes only relays contained within electronic module packages
- Growing from an estimated 27M units in MY90 to over 37M units by MY95
- CAGR estimated at 7.9% between MY90 and MY95

KEY TRENDS & ISSUES

In the course of our research, several specific trends and issues were identified as being pivotal to this market for the nineties. Dataquest summarized its findings in these areas in each of the following sections. These issues include; an overview of ABS trends, electronics packaging issues, the development of world standards, the concept of "doors-off" manufacturing, an overview of the North American transplant manufacturers, an outlook for Europe, the "second wave" of vehicle electronics, an overview of navigational aids, the outlook for legislation, manufacturers ties and alliances, the dominance of Japan, and a look toward the future at alternative fuels and smart highways.

ABS OVERVIEW & TRENDS

The proliferation of antilock braking systems (ABS) hinges on a quiet announcement by General Motors that the giant automaker intends to offer ABS on all its passenger vehicles by the 1995 model year. GM made that announcement in 1989, and soon afterward Chrysler released a similar public statement. These plans mark the most important single factor affecting ABS growth worldwide, because Ford, the Japanese, and the Europeans will have to match GM and Chrysler in order to stay competitive.

And there are other reasons for ABS growth. As antilock braking becomes more popular and widespread, it raises the twin specters of litigation and government mandate. Auto manufacturers feel that if they don't make ABS widely available voluntarily, litigation and legislative action will force them to do so. GM and Chrysler intend to make ABS standard on their upmarket lines and optional for all other passenger vehicles, including captive imports and transplants.

As of 1990, five major manufacturers, all with plants in the U.S., supply the North American auto industry with antilock braking systems: Bosch, Teves, Kelsey-Hayes, Bendix, and Delco Moraine. Lucas-Sumitomo also will enter the U.S. market soon. Kelsey-Hayes currently builds mostly rear-wheel-only ABS for light trucks and sport utility vehicles. The other four brakemakers produce 4-wheel ABS exclusively.

For 1991, K-H anticipates supplying 3.7 million 2-wheel vehicle sets of ABS. These will be sold to the U.S. Big Three plus Isuzu and Mazda for use on pickups and vehicles like the S-10 Blazer and Ford Explorer (nee Bronco II). K-H also has the capability to make 4-wheel ABS.

Bosch currently leads in 4-wheel ABS sales, producing 1.3-million ABS units in 1989. Teves will have the capacity by 1993 to produce 1.4 million vehicle sets in its new North Carolina plant. Bendix, which will sell some 500,000 sets of ABS in 1990, plans to supply 2.0 million ABS units worldwide by 1992.

GM's Delco Moraine Div. remains a relative latecomer to ABS and is just now gearing up for volume production. Delco Moraine's current and conventionally engineered ABS-III, of which only 30,000 units were built in 1989, will give way to a technologically different system called ABS-VI. ABS-VI is planned for a 1991-93 phase-in, with 2.5 million units possible by 1992. This projection, of course, will affect GM's current ABS suppliers, Teves and Bosch.

All five major ABS manufacturers talk about capturing 30% to 33% of the U.S. market by 1995. That projection alone stands as some indication of the competition ahead. And by 1995, it's believed that 87% of all cars produced or sold in North America will be equipped with ABS.

As ABS use expands, antilock systems will become simpler. Example: Bosch ABS in the early 1970s had some 800 components in its ECU. By 1978 that number had fallen to 140. It now stands at 70.

With simplification will come reduced prices. In 1978, Mercedes charged its customers just over $1000 for Bosch ABS. Delco Moraine recently put a price bogey of $300-500 to the customer for its forthcoming ABS-VI system. Even that will soon seem expensive. Teves now has a 4-wheel ABS under development, coded MkX, which it hopes to sell to its customers for around $150. Prices should level off at $250 or so per vehicle set by 1995 (consumer cost) as volume builds and supplier competition intensifies.

1989 ABS worldwide market shares (selected major suppliers)

Kelsey-Hayes	3,800,000*	62.7%
Robert Bosch GmbH	1,300,000*	21.4%
ITT Teves	600,000*	9.9%
Bendix	300,000*	5.0%
Delco Moraine	30,000*	.5%
Lucas Girling Ltd.	30,000*	.5%
Totals	6,060,000*	100%

Source: The respective companies *2-wheel ABS

Today's ABS evolution is still technology-driven, but that will soon change to developments being price-driven. ABS manufacturers are currently scrambling for new technologies and new ways to make ABS assembly and installation less expensive. However, as ABS technology stabilizes and antilock braking becomes more a commodity than a luxury, the supply and sale of ABS will hinge on price.

Rear-wheel-only ABS, almost universal on today's pickups and sport utilities, will give way to 4-wheel ABS as it becomes less expensive. (Kelsey-Hayes' 2-wheel ABS now costs about $75 to the OEM customer.)

Stand-alone "add-on" ABS is favored today by OEMs, a trend that most automakers see continuing through 1995. However, after 1995 it is possible that "integrated" ABS will gain the advantage as more car companies begin engineering and building their own systems.

Except for Honda, the Japanese haven't really produced much independent ABS R&D yet. However, with east/west partnerships, which all major Japanese automakers have entered or are entering, there seems to be considerable room for new ABS supplier/manufacturing combines that aren't even on the scene in 1990.

Bosch presently has licensing agreements and joint ventures with three Japanese companies: Nippon ABS, Nippondenso, and Akebono. Teves has similar ties with Nisshinbo. Bendix and Jidosha Kiki Ltd. are partners. Lucas Girling licenses Sumitomo, Aisin Seiki, and Tokico. The big Japanese automakers--Toyota, Nissan, Honda, Fuji Heavy Industries, Mazda- like to say that they build their own ABS, but that's open to interpretation.

Meanwhile, Lucas-Sumitomo just broke ground for a new plant in Lebanon, OH, with a projected output of 500,000 units a year. Lucas has no U.S. customers so far but currently offers both 2-wheel mechanical and 4-wheel electrohydraulic ABS in Europe.

Other independent ABS manufacturers--notably FAG Kugelfischer in Germany, Lockheed Antilok in England, and Wabco-Westinghouse in the U.S.– are gearing up to make inroads into the burgeoning global demand for antilock braking systems.

PACKAGING

Within the context of automotive electronics, the concept of packaging has three different connotations:

1) At the SENSOR level
2) At the MODULE or FUNCTION level
3) At the SYSTEM level

The evolution and design dynamics of each is based on separate fundamentals:

Functions exposed to the underhood environment (primarily sense and some control) are subject to one set of design criteria, whereas functions located within the more benign cabin/body environment (primarily control and memory functions) are subject to another. Design of their respective packages has, therefore, taken shape along appropriate paths.

Representative of a function of the first kind, is the soon-to-be-ubiquitous, silicon micromachined pressure sensor now used to measure such parameters as pressure, acceleration, air flow and temperature. The variety of applications continues to increase due to incorporation of signal conditioning electronics with the sensor die.

The basic pressure sensor consists of a thin diaphragm etched into the silicon die. Diffused on the diaphragm are regions of piezo-resistance. The output of such a sensor is a function of the location of the resistors, their values, resistive coefficients and the stress transmitted to the diaphragm from both the environment as well as the sensor package itself. In recognition of the stresses caused by packaging materials and processes, commercially available sensors are usually mounted on a silicon or glass base with a seal designed to protect the sensor from packaging stress.

In the case of pressure sensors, deliberate design consideration must be given to minimizing the propensity of any package to contribute to stress which results in variations in offset voltage. Practically, offset variations, caused by thermal stress transmitted to the sensor die are reduced by bonding the sensor die to its base by use of an adhesive known to have a low modulus of rigidity. Thus, it can effectively absorb the thermal stress caused by mounting sensors on substrates with high thermal expansion rates.

Other approaches to packaging for the underhood environment include those taken by Delco Electronics in its power hybrid ignition module. This module consists of a ceramic substrate bonded to a metal backplate that acts as a heat sink while maintaining torsionsal rigidity. The thick-film substrate fits within a glass-filled polyester housing that supports both the substrate and connectors.

Key to the modules' survival is the silicon gel that encapsulates the circuit. This RTV compound has flexibility and yield qualities that minimize thermal expansion stresses imparted to the components. In addition, the gel cushions the hybrid circuit against shock and vibration and provides protection against corrosion under sustained temperatures of greater than 375 degrees farenheit.

In the relatively benign cabin/body environment, packaging requirements are often driven primarily by size requirements. Often, reduction of 50% in size is achieved by replacing rigid PC boards and their associated interconnections with bendable, copper-clad epoxy laminates. Additional space is saved by maximizing use of surface mounted components.

Historically, the automotive industry was one of the first to recognize the value of replacing point-to-point wiring with flexible wiring harnesses. Nearly all VMs now use flexible circuits for instrument panel connections. However, without a parallel, evolving manufacturing infrastructure to support packaging progress, developments in this area would likely be sporadic and prospects for the doubling in forecasted growth for flexible circuits for auto electronics unlikely to be realized.

In the next decade, therefore, automotive electronics factories may very well have to take on a completely different approach to manufacturing. Development of a continuous fabrication and assembly process using flexible circuits already has been undertaken by Motorola Inc. The concept employs a flexible laminate moving in a continuous sheet through such process stations as etch, drill and surface mounting of components. In this continuous process, the flexible, copper-clad polyimide is wrapped around rollers and takeup reels.

Driven by the need for faster function execution time, designers have found ways to minimize interchip signal delay through the development of multichip modules. Developed primarily for the computer industry, this innovation may also ultimately benefit automotive electronics.

Functionally, a multichip module is an application specific electronic sub assembly, containing more than one discrete, active integrated circuit. This packaging concept provides direct connection of the IC die to a silicon substrate, thereby eliminating one level of packaging and interconnection. Given that connectors are the chief cause of vehicle electrical failures, this packaging technique strikes at the root of the problem as conventional connector, pin counts are expected to double by the mid 1990s.

Thanks to the multichip modules, ICs can be either wire bonded, tape automated bonded, or flip-chip soldered to the silicon substrate, these modules lend themselves to rapidly evolving manufacturing processes required by VMs of the nineties.

In one of these processes, Tape Automated Bonding (TAB), IC die are placed in apertures of a "tape" similar in structure and handling requirements to movie film. The die are then bonded to photoetched metallized pads on the tape. Once fabricated, the tapes' individual chips can be burned in and electrically tested, thus increasing final yields and avoiding costly rework of finished hybrids. The final step in the TAB process is the bonding of the outer leads of the tape to an interconnect substrate.

The main advantages of TAB are the ability to pretest and burn-in die prior to hybrid assembly and the associated cost benefits of the highly automated through-put rates. This process lends itself well to applications such as Honda's latest remote entry system in which a TAB circuit is mounted in the head of the ignition key.

t the system level, the aim of present packaging development effort is simplicity of wiring and conservation of space. Conventional wiring harness construction cannot effectively support the rapidly increasing electronic complexity being introduced into vehicle design.

Multiplex systems appear to offer a logical solutions to this problem. In a typical system, local control units are installed in their functional locales and connected to a central control unit, usually in or near the steering wheel. Optical/electrical converter modules, joined by optical fibers, act as interfaces between the central control unit and the function being both monitored and controlled.

Using half-duplex, bidirectional transmission, hundreds of devices can communicate with the central control unit. A classic candidate for such a system would be the top-of-the-line luxury car that can use more than 15 microcontrollers and over one mile of electrical wire. There is simply no more room to run cables through car doors. A multiplexed system would use two or three microcontrollers with a single wire or light conducting fiber multiplexed to a variety of smart modules that would perform control functions. Such systems have already been developed to a high degree of sophistication and reliability in both military and civil aircraft applications.

The Society of Automotive Engineers (SAE) is working to establish standardized data bus specifications for both automobiles and trucks. By 1992, initial circuits incorporating this standard (SAE J1850) should be in production. Other techniques are also being considered for this timeframe, such as CAN (Controller Area Network, developed jointly by Bosch and Intel Corp.), and others.

Dataquest predicts that by mid-decade there will continue to be a multitude of stand-alone control modules in each vehicle. A much-rumored central control computer has yet to become reality for logistical problems. One is that the industry is just beginning to consider the entire vehicle as an electronic "system" as distinct from a collection of individual "black boxes."

From an organization standpoint, most VMs are structured in a manner shaped by mechanical design requirements. The engineering groups working on engine controls rarely interact with those developing instrument panels, and so on. Although this situation is slowly changing, the fruits of these changes are not expected to be seen before the turn of the century.

In addition, the industry is still attempting to develop effective methods for dealing with electronic serviceability issues in the field. The complications for servicing that would be imposed by controlling all systems from a central computer are prohibitive.

At the individual system level, however, a continued expansion of functions and performance is foreseen. At the same time, greater integration at the component level will reduce module complexity, while increasing performance. Multiplexing techniques mentioned above will allow more systems within the vehicle to "share" data, thereby obviating redundant sensors and wiring.

The effect of these trends on vehicle electronic packages will create intensified demand for higher-density packaging techniques that do not impose either cost or reliability penalties over existing methods.

In general terms, the auto industry does not tend to "push" the state-of-the-art, but instead relies on proven techniques that can be produced economically and reliably in extremely high volumes. Therefore, Dataquest sees the auto industry continuing to monitor packaging developments introduced in other markets before rendering final judgment on their applicability to vehicle electronics.

TOWARD WORLD STANDARDS

Until the early Seventies, the automobile industry was predominantly national with respect to marketing boundaries. Nevertheless, motor vehicles made in America - as in Japan and as in Europe - were sold, or so the manufacturers claimed, "worldwide." To be sure, one could buy a Japan- built Toyota Corolla in England or France or America, just as one could buy - if one searched hard enough - a U.S.- made Chevrolet Monte Carlo in Japan or England or France. Similarly, such European prestige marques as Mercedes-Benz, BMW, Rolls-Royce and Jaguar were exported routinely to other nations. Some, like Jaguar, depended on sales in the U.S. alone for half or more of aggregate sales. However, nary a brand touted as an "international" product was designed and engineered from a truly global perspective. For example, the Monte Carlo sold in Tokyo was designed with the tastes and needs - and federally mandated safety regulations - of the American consumer in mind: big, soft ride, "full power," left-hand drive, etc.

The prevailing mind-set of vehicle manufacturers (VMs), from the design concept stage through to marketing, was that of "here is the car, take it or leave it." This was as true of U.S.-made cars sold to Americans, the primary, bedrock consumers, as it was of the consumer abroad. Sales of vehicles in export markets were viewed largely as so much incremental business, sales corporate bean-counters regard as lagniappe. Thus, decade after decade, the unwritten operating covenant among manufacturers everywhere was to "sell in one's own back yard."

This covenant was, to all intents and purposes, rendered null and void by the two oil embargoes of the Seventies. The double-barreled deed perpetrated by OPEC-cartel conspirators - the first in 1973, the second in 1978 - triggered profound and permanent change throughout the automotive community worldwide.

Things would never be the same again, for VMs or for suppliers. It was as though the "game" was ostensibly the same but the "rules" were completely new, completely unfamiliar, and, for many players, utterly perplexing. No longer could U.S. producers lay uncontested claim to the North American market it once had in its hip pocket. Seemingly overnight, "interlopers" from abroad had waged an offensive that caught U.S. VMs totally unawares, ill-prepared to protect their hitherto inviolate domain.

In assessing the post-World War II epoch, historians doubtless will identify the Seventies as a major turning point for the auto industry globally. Why? The Seventies were significant not only for the cataclysmic consequences of the two oil embargoes; in this country the federal government was increasingly interjecting itself by mandating regulatory statutes concerning end product. In 1975, memory of the first oil embargo still fresh, Congress passed a law requiring automakers to meet minimal fuel-economy standards for passenger cars - the so-called CAFE (Corporate Average Fuel Economy) statute (see "Government Regulations," p. 117). No longer could VMs turn out gas-guzzling mastodons with impunity; henceforth a fine would be levied for every unit produced whose combined city-highway fuel economy figure fell below the stipulated minimum. Moreover, those buying a fuel-gulper would pay a window-sticker surcharge. CAFE standards went into effect in 1978.

The federal government asserted itself in other areas as well - for example, safety and tailpipe-emission standards. As a result, gone were the days when manufacturers could turn out vehicles with a buyer-be-damned, environment-be-damned attitude.

Whether headquartered here or not, any VM wishing to market in America now had to comply with the newly issued regulations. For the first time, Uncle Sam was the back-seat driver, telling VMs what they could and could not do. Detroit started downsizing cars (and light trucks) not because it wanted to, but because it had to. By applying new technology and new features, cars became much more fuel-efficient. Witness that in 1978 the CAFE average industrywide was 18.0 mpg; a decade later it was about 28.0, a 56% improvement!

While Detroit was busy downsizing, the Japanese and, to a lesser degree, the Europeans, took advantage by introducing to American buyers "alternative" passenger cars that in general were, with little or no modification, significantly more fuel-efficient and significantly less air-polluting. (As case in point, the car that started Honda's ascent to stardom, the first Civic, introduced in 1973, met existing tailpipe-emission standards without need of a catalytic converter [required as of 1975].)

Prevailing marketplace conditions were ready-made for Japanese VMs. For decades they had been building small vehicles that delivered high mileage and produced relatively little pollution. By the early Eighties, demand for Japanese vehicles was so acute, especially on the two coasts, that many dealers had long waiting lists. Dealers typically were able to command above-sticker prices. (Thanks mainly to the Arabs, many dealers who carried Japanese brands became multimillionaires virtually overnight.)

But by the mid-Eighties, the bubble had burst for many Japanese-brand dealers. World production had outraced demand; suddenly, dealers were willing to dicker as waiting lists vanished and as inventory grew. Overall, however, demand remained robust; to wit, MY86 saw a sales-volume record in the U.S. of 16.3-million cars and trucks. But the U.S. marketplace was rapidly changing, from manufacturer/marketing-driven, as it had been since the days of Henry Ford ("any color you want so long as it's black"), to consumer-driven. After eight decades, tire-kickers in increasing numbers came to the realization that they did not have to "buy American" to get what they wanted. (Some buyers course contended that in order to get what they wanted, they had no choice but to opt for an import.)

As Americans' appetite for Japanese vehicles grew, the Japanese VMs eagerly responded by expanding their product offerings, ironically going upscale and larger with newly introduced models. And as more and more Americans began equating Japanese hardgoods in general - not just automobiles - with high quality, Detroit's once-exclusive domain of larger, higher-priced vehicles began to crumble.

No longer did most Americans associate Japan with cheaply made, tinny, "throwaway" merchandise. The consensus among industry professionals and auto journalists alike is that by the early Eighties, Japan had clearly leapfrogged Detroit in product quality and was close to parity with the best of the Europeans. By the late Eighties, many within these same two groups also shared the view that Japanese had emerged as world leader in price-dependent quality.

Not only is Japan widely acknowledged to be the leader in overall quality of finished hardware, it sets the world standard for start-to-finish product-cycle time, about three years on average compared with four to five in the U.S. and six to nine in Western Europe. Thus, not only are the Japanese producing world-class goods, they move through the product cycle faster.[1]

Although the product-cycle time keeps shrinking for all VMs, Japan is expected to maintain or, possibly, to widen its lead over the U.S. and Europe. Japan likewise has the edge in a related key manufacturing aspect: comparatively short production runs that are profitable. Insiders say that within the next few years, at least one Japanese VM will be able to launch profitable production runs of as few as 20,000 to 25,000 units for a single model.

Japanese VMs have risen collectively to the top [see "The Ascent of Japan," p. 127] for a combination of reasons: (1) lower manufacturing overhead costs, due in part to more complete robotization; (2) earlier and more successful integration of *kanban* (just-in-time delivery method required of suppliers; (3) higher standards regarding tolerance of defective supplier materials and of flawed end product; and (4) greater efficiencies achieved

1 Genuine world-class VMs experience 20 to 25 assembly-plant defects per 100 units compared with 70 to 80 for average VMs. World-class product-development time is 30 to 36 months from "blank canvas" through pilot production versus 45 to 50 months for average VMs. [Source: Booz-Allen & Hamilton, Inc.]

by the workforce, hence greater productivity.

As the automobile industry becomes increasingly globalized (meaning more manufacturing and marketing alliances and partnerships via mergers and buyouts, fewer free-world VMs and suppliers, and fewer economic and political trade barriers worldwide), competition will further intensify among all VMs not only in established, mature markets such as the U.S., Japan and Europe, but also in developing and Third World countries as they too become industrialized. (See "Global Alliances, p. 121)

As Communism crumbles in Eastern Europe, VMs from Western Europe, Asia and America vie for new business in what for them is virgin marketing territory of sizeable proportions - easily hundreds if thousands of units, perhaps millions, annually of incremental sales.

Within weeks of the fall of the Berlin Wall, U.S. and Japanese VMs were announcing manufacturing and marketing linkups with Eastern European counterparts for entree to such motor vehicle-starved places as Poland, Czechoslovakia, Hungary, Romania and East Germany. (See "Global Alliances," p. 121)

Neither to be overlooked nor discounted as the entire industry "goes global" is the dawn of the free-trade European Economic Community (ECC). Beginning in 1992, a dozen nations will participate in what essentially will be an unfettered marketplace. Its advent is certain to have profound and far-reaching effects on the automobile industry in both VM and supplier realms. To compete, indeed, to survive, VMs and parts suppliers everywhere will have to meet world standards at ever-higher levels. The target of "world-class quality" is dynamic. So too is technology. VMs that pioneer new technologies and make them cost-effective and of the highest quality will stand the best chance of experiencing marketplace success; those that do not face extinction.

Entering the new decade, we witness a rash of new manufacturing and marketing alliances among VMs and among suppliers (see "Global Alliances," p. 121). The bottom-line for the Nineties: "If you want to dance, find a partner."

External influences will come to bear significantly on marketplace dynamics. The world over, consumers grow increasingly product-sophisticated, therefore increasingly quality-demanding. More and more countries, whether acting independently or as consortiums, are getting tougher on pollution and toxic wastes from all sources.

Motor vehicles and the industry that produces

Cars rolling off the line at NUMMI are of Japanese design, assembled in Fremont, CA by a joint venture between General Motors and Toyota.

them are, of course, major contributors to health-threatening air and water contamination.[1] Our own Congress recently passed new Clean Air legislation that will force the industry to produce vehicles that are safer to operate and are less harmful to the physical environment. The EEC has adopted tough new uniform environmental standards,[2] and a number of European cities suffer worse air pollution - much of it from motor vehicles - than the worst of the U.S. cities.[3] As in Los Angeles, (see "Government Regulations," p. 117) cities in Europe and in Central America are adopting draconian measures to combat worsening air pollution from motor vehicles. In many cities around the world, driving restrictions are imposed.[4]

Meanwhile, the Japanese government is contemplating what would be the strictest NOx regulations in the world. There the EPA has called for reduced NOx levels in two stages: a 33% improvement to 0.6 grams per kilometer by 1994 for trucks under 1.7 GVW, followed ("within 10 years") by a 56% reduction, to 0.4 grams. For trucks in the 1.7 to 2.5-ton bracket, the range is a 35% to 65% reduction, and for trucks over 2.5 tons, the standard tightens more than double, from 38% to 17%.

Tailpipe emissions are the main, but not the sole, source of automobile-generated air pollution. There also are hydrofluorocarbon vapors (CFCs), emitted from freon-charged air-conditioning systems. A regulatory statute with international implications has been in effect since January 1989. This so-called Montreal Protocol, signed by 31 nations, is designed to control various CFCs and Halons. The U.S., U.S.S.R., Japan and the Common Market countries, which together account for an estimated 70% of global CFC use, were among signatories.[5]

As with emissions, the U.S. currently leads the world in government-mandated automobile safety standards. Newly proposed rules from the National Highway and Safety Administration (NHTSA) will extend certain standards now applicable to passenger cars only to light-duty trucks and passenger vans as well. Just as it becomes increasingly difficult, given the scale of economics, for any VM, no matter how efficient the production process, to intro-

1 *Automobiles are known to be a primary source of these pollutants: carbon monoxide, lead, nitrogen oxides, ozone and toxic emissions. Emissions of carbon monoxide and nitrogen oxides remain a problem even where catalytic converters have been introduced on automobiles - Australia, Austria, Canada, Japan, Norway, South Korea, Sweden, Switzerland and the United States - not to mention those where they have not. Catalytic converters have been a major boon. In the U.S., lead emissions fell by 96% between 1970 and 1987, thanks to the mandated device. [Source: State of the World, 1990 by Lester R. Brown, W.W. Norton & Co., 1990]*

2 *A) EEC members have agreed to curtail emissions of sulfur dioxide and nitrogen oxides. The SO2 protocol calls for a 30% reduction in emissions of their transboundary flows from 1980 levels by 1993. The NO2 protocol stipulates a freeze on emissions in 1994 at 1987 levels as well as further discussions beginning in 1996 aimed at de facto reductions. B) At least nine countries have pledged to reduce by 1995 SO2 levels to less than half those of 1980; Austria, Liechtenstein, Sweden and West Germany have all committed to a two-thirds reduction. On nitrogen oxides, 12 Western European nations have agreed to go beyond the freeze and reduce emissions by 30% by 1998. The United Kingdom is aiming for a 25% reduction of SO2 to satisfy Scandinavian countries downwind of Britain's coal-burning power plants. By 1994, Canada plans to have cut SO2 emissions to 50% of 1980 levels. C) In June 1989, the EEC Council of Environmental Ministers approved new standards for small cars that will be as tough as those now in effect in the U.S. Small cars will have to be equipped with catalytic converters. Although standards for large cars already are on the books, the EEC body is considering adopting stricter ones. Also, an EEC-wide speed limit is being weighed as another means of pollution abatement. [Source: Ibid.]*

3 *For example, in a recent year the number of days that the level of sulfur dioxide exceeded internationally recognized acceptable levels was 66 in Milan and 46 in Paris versus 8 in New York, the worst U.S. city listed. [Source: Ibid.]*

4 *Examples: In Florence, Italy, the heart of the city has been converted to a pedestrian mall during daylight hours. Central Rome is off-limits to normal vehicular traffic for seven hours a day, during morning and evening rush times. Budapest bans motor traffic from all but two streets downtown. Lagos, Santiago and, since fall of 1989, Mexico City bar all privately licensed vehicles from entering the city one day a week. [Source: Ibid.]*

5 *The Protocol requires developed nations to freeze consumption of the offending CFCs at 1986 levels by the middle of 1989, and to cut use 20% by mid-1993 and an additional 30% by mid-1998. This would put CFCs at 50% of the 1986 level. Moreover, beginning in 1992, production and consumption of Halons would likewise be frozen at 1986 levels.*

duce a vehicle for the domestic market only, so too it becomes increasingly important for VMs to pay heed to emerging legislation in individual nations and in multi-nation economic consortiums such as the EEC.[1]

1 As this was written, the President of Mexico, Carlos Salinas de Gortari (who happens to have an MBA from Harvard) proposed talks with President Bush in hopes of establishing free trade between the two nations. Were this to become a reality, all three North American countries would become a free-trade zone similar to the EEC. A free-trade agreement between the U.S. and Canada, which took effect January 1, 1989, calls for duties to be lowered or eliminated on 8,000 categories of consumer goods by 2000.

DOORS-OFF MANUFACTURING

A major development that may signal profound and sweeping change within the automotive industry is the concept of "doors-off" manufacturing. The concept itself goes beyond manufacturing per se; it can encompass engineering, design and development processes as well.

Practicing traditional methods, manufacturers heretofore have designed the components, then purchased from outside vendors raw materials and components used to assemble the vehicle piece by piece. To produce a door, for example, the manufacturer procures glass, steel, plastic trim panels, switches, wiring and other hardware from outside suppliers. Then, in the assembly plant, the door is assembled as one step in the total vehicle manufacturing process.

Using the "doors-off" concept, the manufacturer engages a subcontractor who provides to specification, a complete "turnkey" door - finished, painted, assembled, and tested. It requires only final installation on the assembly line.

The biggest single difference is that the responsibility for designing and sourcing the components, in addition to actually assembling the door is shifted to the vendor. The term "doors-off manufacturing" is not limited to doors. Indeed, the same concept is equally applicable to engines, transmissions, instrument panels, complete interiors and many other major subassemblies.

Advantages to manufacturers of the doors-off process include reducing the pool of suppliers they must work with and qualify. In addition, it reduces their investment in capital equipment and shifts financial burdens for development, work-in-process and inventory to the supplier. It also works in concert with the "just-in-time" manufacturing system (*kanban*), whereby completed subassemblies are delivered no sooner than needed on the final assembly line.

If the doors-off concept takes root, the manner in which the supplier might approach the manufacturer could be radically altered. For one thing, it changes the definition of the customer. Instead of dealing directly with the manufacturer, a component vendor might deal with a first- or second-tier supplier contracted to provide one or more of the major subassemblies. Such an arrangement would result in a much more involved, and, likely, more competitive, market for suppliers of raw materials, and subassemblies. Furthermore, it shifts the major burden of design and development work to the supplier. So doing will, by and large, create greater opportunity for the more-specialized "niche" vendors. The downside for the supplier is that the process shifts to him greater financial burdens in terms of underwriting the costs of development, raw materials and work-in-process, and finished-goods inventories.

A case in point in this regard is the Prince Corporation of Holland, MI. Prince has developed the capability to supply completed passenger cabin modules, featuring floor and overhead consoles. Prince supplies the consoles, which often contain electronic modules for lamp controls, compasses and inside/outside temperature display functions. Prince thus becomes a customer for the suppliers of such items as electronic components, sensors, connectors, lamps, and switches *in addition* to the traditional materials that go into a console - plastic, fabric, hardware, fasteners and trim items. Prince delivers its "turnkey" consoles, color-matched, tested and ready for installation on the VM's assembly line.

Frequently, Prince undertakes the design and development of these consoles on its own, thereby limiting the role of its customer, the auto manufacturer, to that of approval and procurement. As a consequence, the auto manufacturer's risk, investment and resources requirements are all lessened.

Expansion of the doors-off concept to areas incorporating electronics opens the door for new suppliers in this market. With first- and second-tier vendors controlling electronic subcontractor selection as opposed to the VMs or their in-house divisions, suppliers who have been previously unable to penetrate the VMs may now be able to become qualified vendors for these first- and second-tier suppliers.

At the first-tier supplier level, the doors-off concept will mean the expansion of resources and capabilities of the supplier. Traditionally, suppliers to the VMs have become quite specialized in their goods and services. In order to remain a first-tier supplier under the doors-off way of thinking, the supplier will need to develop additional skills and abilities to be able to broaden the range of products or services they provide to the VMs. In the example of Prince above, they expanded their capabilities to include electronics, and the ability of integrating other products and designs into their consoles.

At the second-tier level, suppliers that today deal directly with the VMs, may find themselves dealing with the first-tier suppliers under the doors-off concept. Deciding on whether to position oneself at the first-tier, or second-tier in the supply chain will be an important strategic consideration for auto industry suppliers in the nineties.

TRANSPLANT OPERATIONS

Although their marketing presence here had long been felt, it was not until 1982 - 25 years after the first Toyota was shipped here - that the Japanese opened a passenger-car manufacturing plant in the United States.[1] At a site six miles from where it had been producing motorcycles since 1979, Honda Motor Co. began turning out Accord sedans for U.S. buyers. Other Japanese vehicle manufacturers (VMs) followed suit in rapid succession, build and/or assembly facilities either as "solo" enterprises or as partners in joint-venture schemes.

Next came Nissan, establishing an assembly plant on 782 greenfield acres in Smyrna, TN. Initially, only compact pickup trucks were built there; Job 1 came off the line in June 1983. The first Sentra subcompact sedan rolled off two years later. Plans have been announced to supply stampings for the future joint-venture Ford/Nissan minivan, to be built at a Ford plant in Avon Lake, OH, starting in 1992. Ford has committed $900 million to the expansion, expected to create about 1,300 new jobs. In 1984, the historic General Motors-Toyota NUMMI (New United Motor Mfg. Inc.) joint-venture deal was signed,[2] resulting in the revival of an idled GM plant in Fremont, CA, for production of cousin cars, the Toyota Corolla and Chevrolet Nova (rebadged Geo Prizm as of MY89). Beginning in August 1991, a Toyota pickup truck will be added. Its projected annual build of 100,000 units promises to push plant output past 300,000 for the first time.[3]

Today, less than a decade after Job 1 Accord rolled off the line in Marysville, eight Japanese automakers (plus one South Korean, Hyundai) have manufacturing and/or assembly facilities in North America (see list below).[4] As of yearend 1989, Japanese VMs had invested an estimated $5.6 billion in U.S. and Canada operations alone.

These nine so-called transplants currently operating in the U.S. and Canada - not counting the two in Mexico (Volkswagen and Nissan) - produced an aggregate of some 1.3-million passenger cars and light-duty trucks in CY'89, approximately 15% of combined volume (and 22% of car volume!). Depending on the prevailing sales climate, collectively the transplants could account for an estimated 2.5-million units by mid-decade, 3-million or more by the turn of the century.[5] (It is projected, barring the unforeseen, that counting all Japanese-nameplate cars, regardless of where built, Japanese automakers could capture up to 30% of the total U.S. market as early as 1994. By then, the car-market share of the Big Three combined could drop by five to 10 points from the 68% held at yearend 1989.) Both Toyota and Nissan have divulged plans calling for at least half of their respective U.S.

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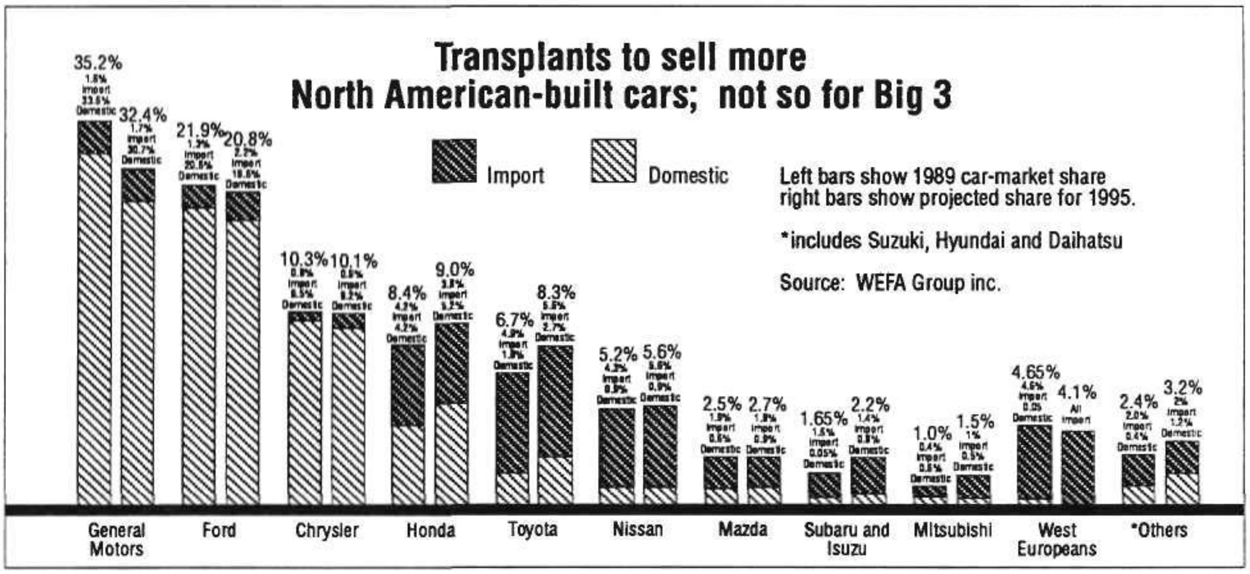
1 *Currently about half of all Hondas sold in the U.S. are natives of Ohio. Moreover, in an interesting twist, in 1989 the Marysville plant commenced a "reverse export," shipping Accord Coupes the homeland, where they have enjoyed surprisingly keen demand, in spite of, or perhaps because of, the left-hand drive. Now, the Marysville plant also assembles Preludes and Civics.*

2 *The deal, as approved by the Federal Trade Commission, has a 12-year life, meaning it expires in 1996. Because the plant is a money-loser, rumor is rife that GM will turn the entire operation over to Toyota, relocating assembly of the Prizm elsewhere or, conceivably, discontinuing the line. Since its debut in 1985, the Nova/Prizm has been a lackluster sales performer notwithstanding its consistent placement at or near the top of GM's internal audit of overall build quality.*

3 *A) Projected volume of 100,000 truck units per annum assumes peak line speed and two shifts. B) The $290-million capital project will enlarge plant to about 3.67M sq. ft., and increase of 22%.*

4 *Daihatsu has stated publicly its intention to begin manufacturing in the U.S. at an unspecified future date.*

5 *A) Figures cited do not include so-called captive imports, defined as vehicles produced off-shore for sale by dealers of U.S.-based manufacturers. B) U.S.-based transplant composite production volumes, car and truck combined; 1986 - 600K; 1987 - 700K; 1988 - 786K; 1989 - 1.3M; 1990 - 1.4M (projected); 1991 - 2.0M (projected).*



sales volumes by 2000 or earlier to emanate from North America-based factories. This goal already has been reached by Honda.

Further, it is expected that as the Japanese increase their transplant output, Europe will be very much on their marketing agenda, particularly in view of the start-up in 1992 of duty-free trade involving 12 Western European states (see "European Community, p. 105).

One reason the Asian automakers are aggressively boosting North American-plant capacity is that they can produce a given vehicle cheaper here than in the homeland. (The Government Accounting Office [GAO] says the transplants can build 200,000 vehicles a year using 2,666 hourly workers versus 4,236 workers at a typical Big Three plant for a like volume. The cost advantage is estimated to be $400 to $600 per unit over a comparable Detroit product.)

A second reason is that every unit produced on Yankee soil is exempted from the individual Japanese manufacturer's VRA- imposed quota,[1] which currently limits them collectively to 2.3-million units.

The transplants represent a potentially vast business opportunity, but thus far they have proved difficult for American suppliers to penetrate either because the procurement decisions are made in Japan, the contracts are awarded, whether fairly or unfairly, to Japanese-owned supplier companies in the U.S., or both. Although no one has a firm count, it is estimated that at present all told there are some 300 parts suppliers to the transplants. It is estimated that of them, approximately one-quarter are Japanese-owned or -controlled and that, on average, they buy some 60% of their parts from Japanese suppliers.

Regardless of source, the Japanese are steadily increasing local content. By yearend 1990 it is expected to reach an average of 67%. (At least two transplants, NUMMI [California] and Honda [Ohio] are targeting 75%.) Meanwhile, U.S. automakers are stepping up importation of components from Mexico and other foreign sources (see listing notations below).

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1 Stands for Voluntary Restraint Agreement, imposed (with a major nudge from the U.S. Congress) by the Japanese government on Japanese automakers. It started in April 1981 at 1,68-M units annually (April 1 - March 30) and now stands at 2.3M. The volume fixed is roughly proportional to the individual maker's previous year's sales volume in the U.S. of units exported from homeland plants. The VRA applies to passenger vehicles only; trucks are exempted.

UNITED STATES TRANSPLANTS

DIAMOND-STAR MOTORS CORP.

Location: Normal, Illinois
Launch: September 1988
Current product(s): Clone sport coupes Eclipse (Mitsubishi), Talon (Eagle Division, Chrysler), Laser (Plymouth); clone 4-door subcompact sedan Mirage (Mitsubishi), Summit (Eagle [Chrysler])
Future product(s): None announced
Annual capacity: 240,000
Hourly workforce: 2,400 (union)
Notes:

1) 50/50 joint venture between Chrysler and Mitsubishi (Chrysler owns 12.1% Mitsubishi).
2) Plant contains stamping, plastics operations.
3) Site is 636 acres.
4) As of fall 1989, local content approx. 60%

HONDA OF AMERICA MFG., INC.

Location (#1): Marysville, Ohio
Launch: November 1982
Current product(s): Accord 4-dr. sedan, 2-dr. coupe (compacts); Civic 4-dr. sedan (subcompact)
Future product(s): Accord station wagon (Summer/Fall 1990)
Annual capacity: 360,000 (1991 est.)
Hourly workforce: 6,200 (inc. salaried)
Notes:

1) First Japanese transplant operation in U.S.
2) Half of all Hondas sold in U.S. now built in Ohio (see above text).
3) Second Honda automotive transplant facility opened fall 1989 nearby, in E. Liberty, Ohio (see following entry).
4) At another separate facility in neighboring Anna, Honda plans to produce 300,000 engines in 1990 and 500,000 in 1991 in addition to 60,000 motorcycles and ATVs. Honda is only Japanese manufacturer in U.S. to cast its own engine blocks and aluminum wheels.
5) The 363,668 Accords and Civics built in 1989 at Marysville mark all-time record passenger-car car harvest from any one plant in U.S.
6) Export of Accord 4-dr. sedan to Taiwan begun 1986, 2-dr. coupe to Japan begun 1989. Plans announced to export forthcoming Accord station wagon to Japan and to Europe, making Honda second U.S. transplant to market product in Europe (Ford Probe is exported to Switzerland from Mazda's Flat Rock, MI, plant).
7) Parent has declared sales goal of 2.5M units worldwide by 1992.
8) Supplier base at Ohio auto plants has risen from 27 originally to 194 in 1990. Of them, an estimated 130 are either Japanese-owned or -controlled.
9) Honda says Accord will reach 75% local content in 1991, qualifying it for first time as U.S. in origin (i.e., as a "domestic" product).

HONDA OF AMERICA MFG., INC.

Location (#2): East Liberty, Ohio
Launch: December 1989
Current product(s): 4-dr. Civic sedan (subcompact)
Future product(s): None announced, although Acura model(s) rumored.
Annual capacity: 65,000 (1990); 150,000 (1991)
Hourly workforce: 950 (1990), 1,800 at capacity production (inc. salaried)
Notes:

1) East Liberty is Honda's 3rd plant in U.S., all in Ohio. Besides the other auto assembly facility, there is a motorcycle/ATV plant.
2) Second shift to be added spring 1990.
3) Plans announced to start shipment of unspecified number of Civics to Israel before yearend 1990.
4) Plant noteworthy -- and newsworthy -- as first "flexible" assembly plant in U.S., that is, can assemble multiple models with relatively little time needed for changeover. This capability also a) markedly diminishes capital investment requirements; b) allows Honda to produce profitable "niche" vehicles in smaller volumes; and c) further shrinks product-cycle time (Honda already leads the industry in this regard).

MAZDA MOTOR MFG. (USA) CORP.
Location: Flat Rock, Michigan
Launch: 1987
Current product(s): Mazda 626 4-dr. sedan, MX-6 2-dr. coupe; Ford Probe 2-dr. coupe
Future product(s): None announced
Annual capacity: 240,000
Hourly workforce: 2,800 (union)
Notes:

1) Only wholly owned transplant represented by UAW.
2) Ford owns 25% parent Mazda Motor Corp.
3) 40% of yield goes to Mazda.

NISSAN MOTOR MFG. CORP. IN U.S.A.
Location: Smyrna, Tennessee
Launch: 1983
Current product(s): Pickup truck (compact); 2-dr. Sentra sedan (subcompact); truck axles, Sentra engines
Future product(s): 4-dr. successor to Stanza (1992)
Annual capacity: 240,000 (1990); 440,000 (1993)
Hourly workforce: 2,600 + 900 salaried (1990); 5,400 total (1993)
Notes:

1) First vehicle built at Smyrna light-duty compact pickup truck [June 1983].
2) Sentra car added 1985, truck axle and Sentra engine assembly added 1989 (currently producing 4-cyl., 12-valve engines at rate of approx. 500 a day).
3) Plant undergoing $490M expansion to be completed 1993; will add 1.2M sq. ft. to existing 3.2M, for upgrade of stamping capacity, provide room for third vehicle in 1992.
4) Also by 1992, Nissan says Smyrna local content will have risen to 75%, qualifying vehicles as domestic-built.
5) Nissan says that by 1993 will have invested more than $1.2B in Smyrna since 1981 groundbreaking.

NEW UNITED MOTOR MANUFACTURING INC. (NUMMI)
Location: Fremont, California
Launch: 1984
Current product(s): Toyota Corolla, Geo (Chevrolet) Prizm (both subcompacts)
Future product(s): Toyota 4x2 compact pickup truck (August 1991)
Annual capacity: 240,000 passenger cars; 100,000 trucks
Hourly workforce: 2,300 (1990), 2,850-2,900 (1991) (union)
Notes:

1) Aiming for 75% local content by end CY90 (approx. 65% end CY89); would thus qualify products as definitionally domestic for CAFE-rating.

SUBARU-ISUZU AUTOMOTIVE INC.
Location: Lafayette, Indiana
Launch: September 1989
Current product(s): Subaru Legacy 4-dr. sedan, station wagon; Isuzu compact pickup truck; Rodeo 2/4wd SUV (fall 1990)
Future product(s): None announced
Annual capacity: 120,000 (1990), 240,000 (1995/6)
Hourly workforce: 1,700 (1990), 2,250 (1991), 3,200 (1995/6)
Notes:

1) Joint venture between Fuji Heavy Industries (Subaru) and Isuzu (51% Subaru).
2) Last of major Japanese automakers to build U.S. plant.

TOYOTA MOTOR MFG., U.S.A.
Location: Georgetown, Kentucky
Launch: May 1988
Current product(s): Camry 4-dr. sedan (compact); 4-cyl. engines at adjacent site
Future product(s): Camry station wagon (early 1992)
Annual capacity: 200,000 cars, 300,000 engines
Hourly workforce: 3,000; 3,500 (late 1990)
Notes:

1) $800M initial investment in greenfield plant.
2) Another $300M invested in adjacent powertrain plant opened 1989.
3) By 1991 plant also will supply many engine components, including pistons, valves, cylinder heads.
4) Starting 1992 will produce approx. 40,000 right-hand-drive Camrys for export to homeland.
5) 75% local content expected by 1991.

CANADA TRANSPLANTS

CAMI AUTOMOTIVE INC.

Location: Ingersoll, Ontario
Launch: April 1989
Current product(s): GM Metro (U.S.), Pontiac Firefly (Canada), Suzuki Swift (U.S., Canada) (all minis); GM Tracker, Suzuki Sidekick (4wd compact SUVs)
Future product(s): None announced
Annual capacity: 200,000 (120K cars, 80K SUVs)
Hourly workforce: 1,000 (yearend 1989), 2,000 (1990 target); union (CAW)
Notes:

1) 50/50 joint venture between General Motors, Suzuki.
2) Largest of the five offshore transplants in Canada in terms of investment ($500M), size (1.6M sq. ft.), production capacity (200,000 annualized, beginning fall 1990.)
3) Metal stamping plant on site.
4) Automaker meets requisite of Auto Pact under U.S.-Canada free-trade agreement, allowing duty-free access when vehicles produced reach minimum 50% N.A. content.
5) CAMI projects $200M in annual purchases of Canadian components plus unspecified dollar amount of U.S. components.
6) Product yield split 50/50 GM, Suzuki.
7) Second shift added spring 1990.

HONDA OF CANADA MFG.

Location: Alliston, Ontario
Launch: 1986
Current product(s): 3-dr. Civic hatchback (subcompact)
Future product(s): None announced
Annual capacity: 50,000 (1989), 80,000 (1990 est.)
Hourly workforce: 1,200 (inc. salaried)
Notes:

1) Sole supplier of Civic 3-dr. hatchback to North America; most remain in Canada

HYUNDAI AUTO CANADA

Location: Bromont, Quebec
Launch: January 1989
Current product(s): Sonata (compact sedan)
Future product(s): Unspecified sedan for Chrysler Eagle Div. (1991)
Annual capacity: 50,000 (1990), 100,000 (1992)
Hourly workforce: 600 (1,200 by 1991)
Notes:

1) Most of yield for U.S. distribution.
2) 6,500 Sonatas to be exported to Taiwan in 1990.
3) $121M adjacent stamping plant to open fall 1990.
4) Will employ 120 on two shifts, produce 32 separate body panels and parts.

TOYOTA MOTOR MFG., CANADA

Location: Cambridge, Ontario
Launch: December 1988
Current product(s): 4-dr. Corolla (subcompact)
Future product(s): None announced
Annual capacity: 50,000 (1990)
Hourly workforce: 1,000 (1990)
Notes:

1) Approx. 60% yield for U.S. distribution.
2) TTMC is Toyota's first wholly owned, full-process automobile manufacturing facility in Canada.
3) 900,000-sq.-ft. plant on 377-acre greenfield site.

VOLVO CANADA

Location: Halifax, Nova Scotia
Launch: June 1963; new facility opened fall 1987
Current product(s): 740 series (4-dr. sedan, station wagon)
Future product(s): None announced
Annual capacity: 8,000 (1990); 10,000 max.
Hourly workforce: 145 (+ approx. 30 salaried)
Notes:

1) AB Volvo's first plant outside Sweden.
2) Approx. 225,000 units produced cumulatively since 1963 launch; distribution roughly 30-40% to U.S., remainder to Canada.
3) In addition to this site, in 1987 Volvo GM Canada Heavy Truck Corp. opened new headquarters in Milton, Ontario.

MEXICO TRANSPLANTS

NISSAN MEXICANA, S.A. de C.V.
Location #1: Cuernavaca
Launch: 1966
Current Product(s): Sunny, Vanette, small pickup truck
Future Product(s): None disclosed
Annual Capacity: 100,000 (1990)
Hourly workforce: 3,000 + 2,000 salaried
Notes:

1) Approx. 50 mi. south Mexico City
2) Approx. 20% yield exported to Central, South America, remainder for domestic market.

NISSAN MEXICANA, S.A. de C.V.
Location #2: Aguascalientes
Launch: 1983
Current Product(s): 100K engines (1.6L 4 cyl.) for domestic market; 72K (2.4L 4 cyl.) exported to U.S. (Smyrna, TN plant); metal stampings (doors, roofs, etc.) for U.S. and domestic markets.
Future Product(s): Sentra assembly plant at Aguascalientes to be completed spring 1992.
@TPLIST = **Annual Capacity:** 96,000 initially; 192,000 projected
Hourly workforce: 400 + 800 salaried
Notes:

1) 300 miles north of Mexico City
2) Ground broken April 1990 on $250M new assembly plant; target start-up late 1992/early 1993. Second, $150M phase of expansion to commence 1995.
3) Most cars to be exported; 32,000 Sentras to U.S. by late 1993, 64,000 by 1995. Other markets: Japan, Latin America
4) Additional $120M to be invested to increase production capacity of engines, transaxles, metal stamping, aluminum foundry.
5) In January 1990 began exporting 5,000-6,000 engines/mo. Smyrna, TN, for use in pickups. Volume to reach 100,000 units/yr. eventually.
6) Tsuru (Sentra) was best-selling Mexico transplant model in CY89 with sales of 48,195 = 17.6% passenger-car market.
7) In April 1989, subsidiary became parent's first overseas base to achieve cumulative production of more than 1M units.
8) At capacity output of 200,000 units/yr., 30,000 to 40,000 to be exported to U.S., enabling Smyrna to decrease build of Sentra to 60,000 to 70,000 from 120,000 currently.
9, Nissan Mexicana turned out 84,598 units, giving Nissan top spot in Mexico for second consecutive year. Nissan also ranked first in market share in seven other Latin American countries to which Nissan Mexicana-built vehicle exported.

VOLKSWAGEN de MEXICO A.A. de C.V.
Location: Puebla
Launch: 1964
Current product(s): Beetle, Golf, Jetta, Kombi
Future product(s): Unknown
Annual capacity: 200,000 (1990)
Hourly workforce: 15,000 + 3,000 salaried
Notes:

1) Located 85 mi. from Mexico City.
2) Combined volume 800 units/day.
3) Beetle, Kombi for Mexico market only; 60K units/year of Golf, Jetta exported to U.S., Canada.

THE EUROPEAN COMMUNITY

The removal in 1992 of trade barriers will band a dozen Western European states[1] into an economic Goliath known as EC-92. If the abbreviation sounds like the code name for a new-model prototype, it is fitting. The ripple effect on the automobile industry - VMs and suppliers alike - will be profound and far-reaching, not just across Europe but across the globe.

The 17 states of Western Europe represent a vast market. Combined new-car registrations rose in calendar 1989 to 13.4-million units,[2] roughly 2-million more than in the U.S. At a time when sales in the U.S. were down, sales records were established in four nations, the United Kingdom, France, Italy and Spain. (West Germany remained the largest single market with 1989 sales of 2.85 million; Italy was runner-up with 2.36 million, the U.K. third with 2.30 million.)

Even before the collapse of the Iron Curtain in seven Eastern-bloc states, the Big Three had announced intentions to expand exports of North America-built vehicles to Europe. This year (1990), Ford begins sales in West Germany; Chrysler, which re-entered the Continent in 1988 after a 10-year absence, hopes to top 1989 sales of 50,000; and General Motors looks for an 80% jump in sales, to 27,000 units.

PASSENGER-CAR PRODUCTION BY COUNTRY

(Estimated monthly average X 1,000, 1987)

CZECHOSLOVAKIA	14.5
EAST GERMANY	18.1
FRANCE	248.5
ITALY	142.7
JAPAN	657.6
MEXICO	19.0
POLAND	24.5
ROMANIA	10.5
SOUTH KOREA	64.8
SPAIN	119.3
UNITED KINGDOM	95.2
UNITED STATES	590.4
USSR	108.3
WEST GERMANY	361.7
YUGOSLAVIA	25.8

Source: 1990 Information Please Almanac

The Japanese likewise already have a toehold in Europe. Of the major manufacturers, only Mitsubishi lacks production facilities in the EC. Rivals Nissan, Honda, Isuzu and Suzuki are producing there. Nissan built 77,000 vehicles in the United Kingdom in 1989 and another 86,000 in Spain. Toyota is erecting a plant in Britain that will have a production capacity of 200,000 cars a year.

Why the rush to invest? Because of the importance of the EC for motor-vehicle sales. Collectively, EC automakers produce more than a third of worldwide output. Car-ownership density is considerably higher than the world average - 332 cars for every 1,000 persons compared with 79:1,000 worldwide (in the United States it's 540:1,000).

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1 *EC members: Belgium, Britain, Denmark, France, West Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain. Collectively they represent a soon-to-be free-trade marketplace of 320-million people.*

2 *In CY89, the Volkswagen-Audi Group successfully defended its crown as Western Europe's 17-nation sales champion, delivering 2.02-million units, good for a 15.1% market share. Runner-up Fiat sold 1.94M, followed by Peugeot-Citroen (1.7M), Ford (1.56M) and GM (1.48M). Highest-volume of any of the quota-restricted Japanese brands was Nissan (380K), then Toyota (324K). The Japanese VMs' combined share slipped a half-point, to 10.8%. By comparison, Ford finished at 11.6% (up .3 points), GM at 11.0% (up .6 points). [Source: Motor Trend, May 1990.]*

In recent years, there has occurred a phenomenal binge of Japanese investment in Europe; more than 300 Japanese companies have set up plants. Cumulative direct investment in the EC as of yearend 1989 was said to have exceeded $35 billion, with nearly a third of it in Britain. One yen of every four "Japan Inc." invests abroad now goes to Europe; its investment in the U.S. is declining correspondingly. As many as 70% of all Japanese exporters (not just automakers) are boosting investment in the EC out of fear that once integrated after 1992, the EC might exact harsher demands of Japan.[1]

Now that the Eastern states have buried the hammer-and-sickle, new-business opportunities for the automotive community of Western Europe, the United States and Asia are further expanded. A "vast" market suddenly becomes one of gargantuan proportions.[2]

Despite nightmarish infrastructure problems, car sales in Eastern European countries have soared 59% in the past two decades to 42.7 million, a volume not to be dismissed.

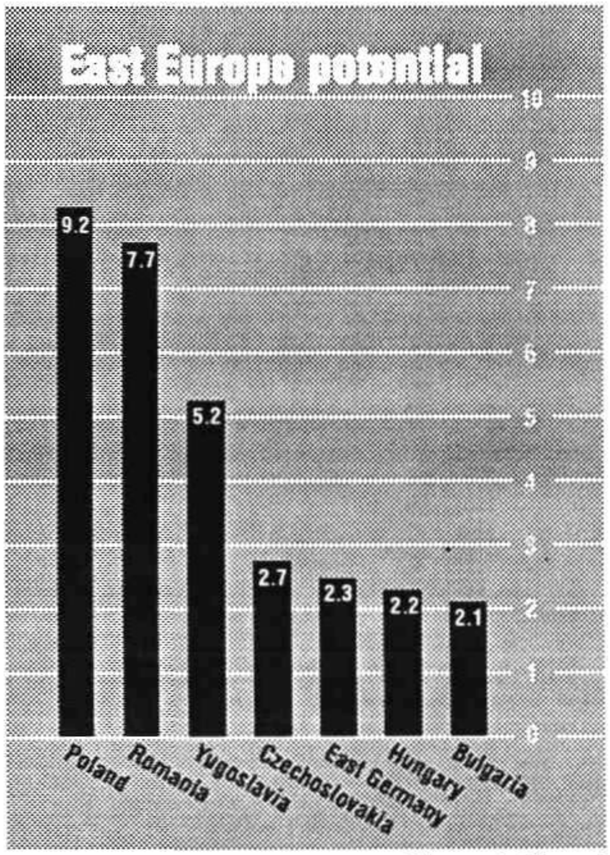

Chart shows how many more cars would be needed in each country to reach 350 cars per 1,000 people, the density of registration in West Europe. *Figures in millions.
*The U.S.S.R. would need 86.7 million more cars to reach that level.
Source: Central Intelligence Agency

Nor to be taken lightly is what is happening in the EC concerning 1) tightening of environmental controls and 2) harmonization of technical standards.

With respect to the former, see "World Standards," p. 92, footnote # X for particulars. Regarding the latter, as of 1989 the European Economic Commission (EEC) had set 44 "essential requirements" in the arena of regulation. Thus far, all but three have been translated into directives containing technical specifications (the three items yet to be covered are tires, weight and sizes, and windshields).

In the past, the U.S.'s National Highway Traffic Safety Administration (NHTSA) has been able to greatly influence technical specifications of European VMs. However, with the EC starting to flex its regulatory muscles, it is probable that after 1992 NHTSA will become a follower instead of a leader in setting internationally recognized standards.

The emergence of EC-92 sends a powerful message to suppliers as well. What is happening in the U.S. also will happen in post-EC-92 Europe. Increasingly, VMs and suppliers will become partners, "co-makers." The arm's-length or adversarial relationship of yesteryear

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1 *Source: Los Angeles Times, March 13, 1990.*

2 *Ford of Europe forecasts that by 2008, new-car sales in all of Europe - including the Eastern bloc - may be nearly twice as great as in the U.S. Western European nations will account for a projected 16 million, Eastern states another 7 million, for a combined 23 million. By contrast, Ford expects new-car registrations in the U.S. to rise in the same period to 13 million, only about 2-million more than in 1989. For VMs and suppliers, that's the good news; the bad news is that, says Ford, industrywide production capacity will soon exceed demand by 2.2-million cars. Ford sees Japanese transplant capacity in Europe of reaching 840,000 cars by 1995, resulting in the loss of 60,000 jobs in the European auto industry.*

is giving way rapidly to closer, more broad-based alliances whereby supplier and VM are equally and mutually committed to meeting or exceeding quality and performance standards observed worldwide.

Suppliers large and small must not just meet, but greet, the opportunities and challenges associated with a vastly enlarged role in engineering, design and technological development and in meeting performance requirements for cost, quality and service. In other words, it's a whole new ballgame for suppliers, especially for those courting new or added business in Europe.

Increasingly, suppliers everywhere will be called upon to fill design and engineering roles, not just makers of so many widgets "spec'd" by the VM. Suppliers that can play globally stand the greatest chance of winning new or added business; those that cannot face the distinct prospect of being left at the loading dock.

Following is a partial rundown of East-West deals either consummated or under discussion as of April 1990 (also see "Global Alliances," p. 121):

- **VOLKSWAGEN**, already heavily invested in Spain as a consequence of its recent acquisition of SEAT, will enter a joint venture - equity divided roughly 50/50 - with VEB IFA KOMBINANT to produce a car, likely a Polo derivative, beginning in 1993. (The IFA combine builds the paper-skinned, two-stroke Trabant, a car virtually unchanged since its debut in 1957.) VW says that by 1992 400K units will come off the line in Zwickau, East Germany [EG]. The first EG-assembled model goes on sale summer 1990. By yearend 1990 an estimated 30,000 4-stroke engines will have been produced for the Trabant.[1])
- **DAIMLER-BENZ** has signed a joint-venture deal with IFA involving truck manufacture. IFA is the sole truck producer in EG (about 40,000 units annually), Daimler is the world's largest truckmaker.) IFA reportedly is about 90% vertically integrated, has 24 production sites and employs some 50,000.
- **FIAT** has entered a licensing arrangement with another state-owned producer, FABRYKA SAMOCHODOW MALOLITRAZOWYCH (FSO) of Poland. Part of the deal is to sell cars through Fiat Auto, exporting about a third of its annual production of some 200,000 two-cylinder cars. FSO may look to Fiat to replace its oldest car, a 1968 version of the Fiat 125.
- This latest **FIAT** foray comes on the heels of a $4-billion deal hammered out in late 1989 with the Soviet Union to produce 300,000 small cars annually in the Russian city of Yelabuga. Job 1 is scheduled for 1994. The pact involves a co-op venture at a second Soviet factory where the partners will produce 900,000 engines annually, also starting in 1994. (Fiat's auto dealings with the Soviets dates from 1912. An estimated three-quarters of the cars made today in the USSR are based on Fiat technology.)
- As of March 1990, **PEUGEOT** was negotiating to build cars in the Soviet Union, while **GENERAL MOTORS** reportedly was pondering opening a plant there to produce engine components. The Peugeot deal is believed to involve assembly of its new luxury sedan, the 605 flagship, at the GORKOVSK AUTOMOBILE FACTORY in Gorki.
- In January 1990, **GM** announced a $100-million investment in Hungary for car and engine production. A month later its **ALLISON GAS TURBINE DIVISION** agreed to supply engines for a new commercial helicopter to be built in the Soviet Union.
- **ADAM OPEL (GM)** is scurrying to get about 25 service centers of its own in EG by summer, hoping to exploit the peak vacation period. Europe-based GM officials reportedly also are talking with other Eastern bloc states and with the Soviet Union on the

1 *Productivity in East Germany, though much higher than in Poland, Czechoslovakia or Russia, is estimated to be only about 40% of that in U.K., according to Nomura Research Institute, London.*

possibility of working to replace the VOLGA passenger car.

- In a separate deal, **ADAM OPEL** is said to be prepared to invest up to $600 million in "more or less buying" the woefully outmoded, 94-year-old factory in EG where the WARTBURG car is built. [Text in quotations from Automotive News, March 12, 1990, p. 51]

- After years of fruitless talks with the Hungarians, **SUZUKI** announced in January plans to build a new factory there that will turn out 15,000 small cars annually starting in 1992 and 50,000 by 1995 toward an eventual output of 100,000. Half of the parts are to come from Japan, the rest sourced locally. Suzuki says that although most of the cars will stay in Hungary, some may be exported. The deal is historically significant in that it is the biggest investment to date in Eastern Europe by a Japanese VM.

- **RENAULT** says it will produce its Trafic medium-range commercial van with BRATISLAVA AUTOMOBILE SAVODI at an existing plant in CZECHOSLOVAKIA. It struck a separate deal with Czech truckmaker AVIA to develop a range of new medium-duty trucks.

- **BMW** announced intentions to have opened by spring 1990 seven factory-sponsored service centers in EG.

- Several Japanese VMs were known to be ogling Eastern bloc penetration. The Japan Automobile Manufacturing Association (JAMA) says the Czechs are pushing hard for joint ventures with SKODA, the Czech automaker, and with truckmaker Avia.

- In spring 1991 manufacture commences in Austria of **CHRYSLER's** hugely successful minivan in a joint venture with Austrian vehicle maker STEYR-DAIMLER-PUCH. Alterations include provision for right-hand drive. The vehicle will be test-marketed first in the U.K. Output is expected to be in the 25,000-unit range. (Chrysler re-established a marketing presence in Europe in 1988 after a 10-year absence. That year it distributed U.S.-made product in West Germany, Holland, Belgium, Switzerland and Austria. In 1989 Chrysler sold 39,368 units in these five nations. France gets added in 1990, Spain and Italy in 1991.

- Only about 40% of the EC total car market is currently open to the Japanese. The U.K., France, Italy, Spain and Portugal restrict Japanese-made cars.

- **ISRAEL** says it may open its doors to Soviet-made cars.

- **PROTON SAGA** of Malaysia, once scheduled for U.S. distribution through the now-vestigial Bricklin enterprise (Yugo America/Global Motors/Proton America), is eyeing Europe. In 1989, the company, 30% owned by MITSUBISHI, saw sales of 10,170 units in Great Britain in its first year there. Proton officials hope to have a right-hand drive model ready for export to Europe by 1991. Proton currently produces about 90,000 units annually, good for a 65% share of the domestic market.

SALIENT ENVIRONMENTAL PROBLEMS IN EASTERN EUROPE

POLAND

- Estimated 60% of food grown in Krakow area deemed unfit for human consumption because of soil contamination by heavy metals.

- 95% of river unfit for drinking; 50% too contaminated for industrial use.

- Vistula River, itself biologically dead, deposits 6,400 tons of nitrogen, 5,000 tons of phosphorous, three tons of phenol, three tons of lead and undisclosed amounts of mercury, cadmium, zinc and other heavy-metal residue into the Baltic Sea each year.

CZECHOSLOVAKIA

- 70% of rivers polluted by mining wastes, nitrates, liquid manure, oil.

- 40% of all human-waste sewage untreated.

- 28% of nation's river water cannot support fish life.

- Women with newborns given priority access to scarce bottled water as tap water considered hazardous to infant health.

- 50% of all forests dying or dead from acid rain. (Soil covering the Erz, Riesen and Tatry mountain range is so acidic [Ph between 3 and 4] that aluminum trapped in the clay is disgorged to the surface.)

HUNGARY

- Nearly 40% of populace lives in areas where air pollution is above internationally recognized standards.

- 54% of human-produced sewage untreated.

- One of every 17 deaths attributed to disease associated with air pollution.

ROMANIA

- 85% of river water unpotable.

BULGARIA

- Experts predict Black Sea will be biologically dead by turn of century if present rate of contamination continues unabated.
-
- 34% of forests suffer defoliation from acid rain.

EAST GERMANY

- More than 125,000 acres of woodlands reported lost, "some" damage to 35% of forests and "severe" damage to another 20%.

- 60% of pine forests affected by acid rain.

AUTO ELECTRONICS: THE SECOND WAVE

It is now widely recognized that developments in electronics have profoundly shaped the impact that motor vehicles have had on the environment in the past decade. This circumstance can be traced back to the period between the end of World War II and the early fifties. During this time, America's thirst for the independence provided by automobiles as well as the power and symbolism of pure performance created the impetus to transfer a few wartime developments, including high specific outputs from internal combustion engines, to the commercial sector. Other wartime developments such as disc brakes, seatbelts and a deeper understanding of aerodynamic principals would, however, remain peripheral for at least another decade.

To satisfy mounting demand for performance, more of tetraethyl lead was required in motor-fuel formulations to pace the ever increasing digestive requirement of the internal combustion engine. Hindsight affords us the understanding that the lead residues contained in the exhaust of untold millions of vehicles was deposited into the atmosphere. Experience also has taught us that other, even more subtle baleful effects of vehicle exhaust from carbon monoxide and oxides of nitrogen content might be even more environmentally harmful.

Pernicious in other ways were air conditioners that reduced fuel mileage by 10% and to the emergence of performance-oriented fuel-injection systems that delivered 8 mpg (albeit at under 28 cents a gallon). It remained for an outside stimulus, OPEC, to provide the sobering shock that caused Americans to take a somewhat more realistic view of the automobile. As a consequence of the search for a quick solution, by 1973, the car-buying public experienced some of the most temperamental, troublesome, internal combustion engines since their appearance nearly a century ago.

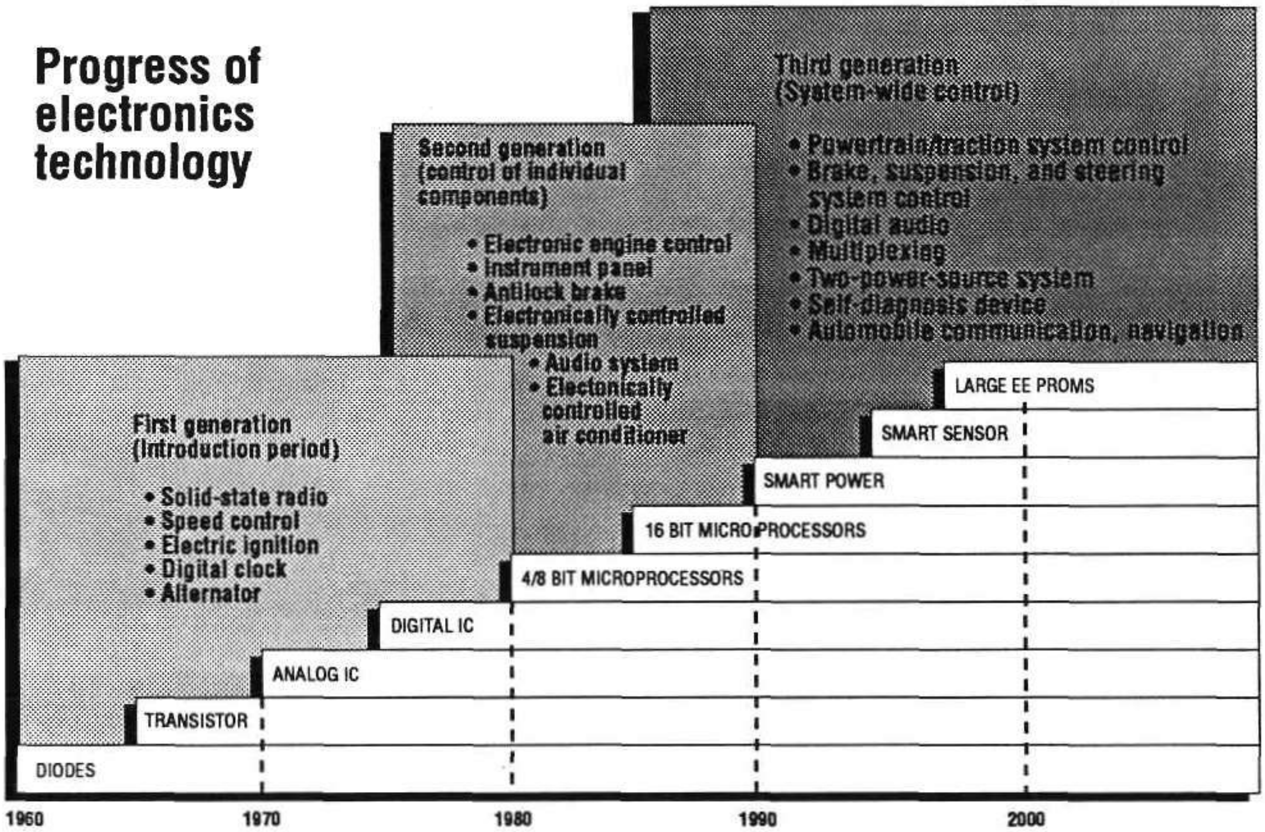
The "first wave" in automotive electronics can be marked by the combination of public outcry for clean-air legislation; the need to decrease dependence on foreign oil; experience in building rugged, cost-effective, electronic components; and the emergent availability of economical integrated circuits that could provide the computational power necessary for precise spark and fuel delivery without degradation of economy, performance or exhaust-pollutant output.

Stimulated by this first wave, the technology of employing control to fuel-delivery systems has evolved to the extent that today virtually all automobiles sold in North America employ some form of electronically monitored, fuel injection system.

To achieve effective feedback, sensors that detect throttle position, oxygen content of exhaust, manifold pressure and temperature feed data into an electronic control module that compares these inputs with optimum values stored therein and initiates a series of successive approximations which, in turn, adjust the fuel/air mixture. Current systems also integrate spark control and can even vary the timing of the voltage delivered to individual spark plugs.

Built on technology developed during the "first wave" in automotive electronics, it has now become possible to provide motorists with greater protection through new systems offering antilock braking as well as traction control and active suspension control. Antilock braking (see "ABS Overview and Trends", p. 87) has been available on many car models since the early eighties. Such systems sense wheel speed and maintain controlled braking to prevent wheel lockup. An extension of this technology is traction control, the electronic successor to mechanical self-locking, limited-slip differentials.

From the data contained in the Appendix section C, it should be obvious that what Dataquest defines as the first wave of automotive electronics (saturation of engine control devices) has stabilized at an installation rate of over 95%. Also obvious is the beginning of the "second wave" (driven by increased installation rates of ABS, passive seatbelt and airbag controls); less obvious because of the timeframe



Source: Mitsubishi Motors Corp.

studied is the advent of such other systems as traction control.

The "shock" (analogous to clean air and CAFE standards in the "first wave") that initiated the second wave is the legislation mandating the inclusion of either a passive restraint seatbelt or an airbag system on all MY90 and later cars sold in the U.S. (see "Government Regulation," p. 117). The "second wave" is expected to continue through the end of the decade, by which time it is anticipated that such systems as ABS and passive restraints will have achieved saturation levels similar to that of engine controls, near 100%.

Whether we will see a "third wave" is not yet clear. Potential exists in two key areas: a) in navigation and communications equipment necessary to implement a truly "smart highway" transportation system (See "Smart Highways," p. 137), and b) in further advances in engine control technology necessary to develop practical, alternative fuel vehicles (See "Alternative Fuels," p. 132). Although it is conceiveable that both of these areas could result in continued, substantial growth in automotive electronics, the timeframe in which these areas would result in actual manufacturing opportunities is near the end of this decade or beyond. Further, both depend on yet-to-be-decided legislation as well as government funding and support to be realized. History has shown, however, that similar legislation can stimulate substantial growth in OEM demand for automotive electronics.

> *- NOTE -*
>
> *There is an important semantic distinction between the terms "wave" and "generation" in the given context. "Generation," as used in chart above refers to the geneology or evolution of the technology; "wave" refers to the practical application of said technology.*

NAVIGATIONAL AIDS

Credit for devising what may be the first onboard navigational aid belongs to Ray Harroun. Legend has it that Harroun, an engineer and race-car driver, modified his 1911 Indianapolis 500 entry, a Marmon Wasp, into a single-seater. Doing so precluded room for the customary riding mechanic. While other drivers debated whether to lodge a formal protest over the absence of a riding mechanic to keep an eye out for approaching cars, Harroun, announcing that he would be his own navigator, promptly welded a 3" x 8" mirror onto a fender. Harroun, piloting solo, won the race handily and never looked back. He retired. Harroun's *ad hoc* contrivance caught on. Soon, rearview mirrors were a staple on all roadable passenger cars.

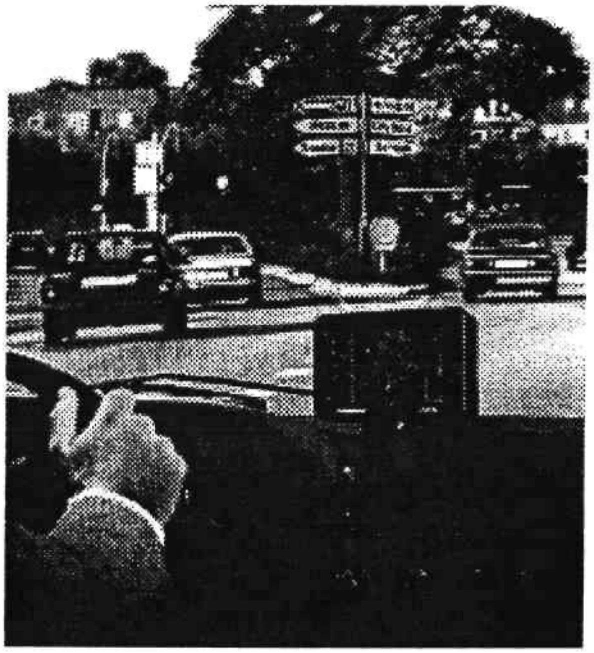
The rearview mirror as installed by Harroun has been brought in-cabin, of course, supplanted by the A-pillar mirror. For years, designers have pursued means of eliminating the sideview mirror altogether, as it contributes measurably to air drag, thus reducing speed and fuel economy.

A second major advance as a navigational aid came three years after Harroun's jerry-rigged mirror helped him ice the Indy. On the muggy summer morning of August 5, 1914, motorists nearing the intersection of Euclid Avenue and East 105th Street in Cleveland, OH, encountered something foreign: the world's first electric traffic light.

In the 79 years since Harroun's last hurrah, countless other navigational aids have been introduced. The general intent has been to a) lessen driver effort, b) make driving safer and/or c) facilitate getting from Point A to Point B. The advent of the microprocessor and attendant computerized electronics applications doubtless has done more in the past decade to advance the state of onboard navigational aids than all earlier inventions combined. Today's onboard navigational devices fall in either of two main categories: directional aids and location displays.

DIRECTIONAL AIDS typically employ the principle of dead reckoning.[1] Equipment generally consists of a microcomputer, a keypad and a mini-screen CRT unit. However useful, directional aids have been largely superseded by LOCATION DISPLAYS. The latter show the driver his current position via an in-vehicle display unit, usually as a designated point on a small monitor screen (CRT).

Most first-generation units are based on dead reckoning and offer no "best-route" advice. Examples are units marketed by Etak (Navigator) and Philips (CARIN). Second-generation units offer best-route advice as well as color CRTs and mapping data on removable, replaceable compact discs (CDs) in lieu of first-generation tape cassettes.



Bosch's TravelPilot is based on technology from Etak.

As of early 1990, the only navigational system actively marketed in the U.S. is produced by Etak Inc. of Menlo Park, CA. (Robert Bosch

1 *Using this method, distance traveled is calculated by averaging right and left wheels' respective running distance converted mathematically from wheel-mounted rotation sensor pulses.*

Inc. is a licensed distributor. A Bosch official says an Etak-based aftermarket system, marketed under the Blaupunkt brand name, may be available by late 1990. The West German-based parent company has been selling an essentially identical unit, called the TravelPilot, in the homeland since mid-1989. In the first six months, some 3,000 units -- at nearly $4,000 plus installation -- reportedly were sold in Europe. Bosch's initial market is commercial -- trucking, delivery and rental-car fleets.)

Etak uses map-matching enhanced by the dead-reckoning method to pinpoint vehicle location on the CRT, which continuously facsimilates vehicle position on maps of the surrounding vicinity. An arrowhead icon at the center of the screen represents the vehicle. As the vehicle is driven, the map rotates and shifts about the arrowhead, invoking pertinent information from a digitized database. The data is stored as vectors. Philips says its system provides actual routing guidance. It is being developed jointly by Philips, Renault and Sagem of France.

Japan too is committed to full-scale development of onboard navigation. Indeed, Japan probably leads the world in application of extant technology. Homeland-based electronics manufacturers have teamed with auto manufacturers to speed the R&D effort. For example, Clarion is paired with Toyota, Nissan with Hitachi (and Kanto Seiki Co.), Honda with Oki and Pioneer. (All three use data tied to AMTICS, a "smart-highway" system [p. 137].) Pioneer, in turn, has a link-up with Trimble Navigation Ltd. of Sunnyvale, CA. The joint venture they formed in October 1989, Pioneer Trimble Inc. (PTI), is preparing for production and marketing of a Global Positioning System (GPS) which reportedly will be available commercially in Japan before the end of 1990.[1] Trimble's system is the size of a car stereo and will be offered for both OEM and aftermarket sale.

Sumitomo Electric Industries Ltd. and Navico Navigation and Communications Co. have invested in applications of computerized road traffic control with emphasis on in-vehicle electronic information systems. Their jointly developed navigational system performs automatic vehicle location, traffic information display and destination guidance functions. It also can scan for short-time route based on real-time traffic-data input from AMTICS.
Mitsubishi Motor Corp. has developed the Mitsubishi Advanced Real-Time Information Autosystem (MARIA) to supply navigational functions, traffic-condition updates and data on destinations and points of interest. Designed primarily for use onboard transit buses, it features a 14-inch CRT interfaced with AMTICS. Matsushita Communications Industrial Co. Ltd. seeks to provide a complete in-vehicle information system using a single CRT for audio, video and telephone functions together with the vehicle's navigational system. It displays AMTICS traffic information on a small, dash-mounted color monitor. CD-ROM technology is used for digital map storage and an infrared touch-screen display.

Another Japanese electronics company, Toshiba, was trying as of April 1990 to find a VM partner with which to co-develop a navigational system custom-tailored to the VMs particular requirements. It reportedly would feature voice recognition, voice synthesis and self-positioning capability.

Toshiba has its marketing eye a couple of years down the road, by which time the Japanese government is to have its traffic information service infrastructure in place. Toshiba says its system, to sell for under $1,000, would appeal to perhaps 15% of Tokyo's 10-million licensed drivers.

Toshiba's Automotive Electronics Systems currently supplies 6-inch CRTs and 4- and 4.5-inch LCD displays for in-vehicle use. The CRT is the unit Toyota factory-installs in its high-line Crown series.
European investigations into short-range externally linked route guidance have been carried out mainly in West Germany. Several

1 *It was scheduled for introduction in June. The complete system, consisting of navigation device, CRT, antenna and audio unit, will list for about $3,160. Initial sales are estimated at 2,000 per month. The company says it has no plans to export.*

German manufacturers worked in the late Seventies and early Eighties toward devising both onboard navigational systems and externally linked route guidance. One such manufacturer is Bosch (see above reference).

The Dutch, meanwhile, are tinkering with a futuristic navigational-aid system aimed mainly at ameliorating traffic congestion. The system, to be operational in 1991, employs computers to constantly monitor the number of occupants in a given moving vehicle.

This is how it works: A black-box "brain," installed aboard the vehicle, is linked electronically to small gadgets placed in all the major transportation centers in Holland. The entire operation is linked, in turn, to a mainframe computer capable of tracking every motor vehicle in Holland around the clock. Any driver who ventures into corridors that are heavily trafficked during designated times is automatically levied a fine. The more occupants, the stiffer the fine.

Already, onboard navigational aids are available as OEM installations in Japan. Nissan offers a navigational system, combined with audio-visual paraphernalia, on two passenger-car models, the Cedric and the Cima.[1] Nissan's is a stand-alone system called Drive Guide.

Like Etak, Drive Guide uses a magnetic compass for direction, wheel sensors for distance and computerized location updating for enhanced accuracy. Moreover, the driver can key up other information, e.g., details on freeway interchanges, nearby department stores, lodging, golf courses and marinas. Unlike Etak, Drive Guide is CD-ROM-based. Its memory is sufficient to store all the operational data as well as high-resolution (335 x 210 pixels) street maps of metropolitan Tokyo, Osaka and Nagoya. Eventually, all major cities are to be added.

Toyota claims to be the first automaker to offer an onboard navigational system. It was introduced in 1988 as an option on the high-line Crown (not sold here).[2] Toyota's apparent head start notwithstanding, chances are that Nissan will be first to offer a navigational system on cars sold in the U.S., possibly before yearend 1990. Toyota and other Japanese automakers also known to be developing navigational systems are expected to follow suit. One is Honda, now putting the finishing touches on an inertial navigational system that uses a gyroscope akin to that used in aircraft. A commercial unit could be ready before the end of the year. (It is believed that General Motors will be the first U.S. automaker to offer an OEM navigational system, likely on the 1994 Oldsmobile Toronado.)

As if not to be outdone, at the 1989 Tokyo Motor Show, Mazda, Isuzu and Daihatsu all displayed concept cars equipped with navigational systems. A Nissan entry, the NEO-X, evidenced not only a navigational system, but also an infrared night-vision device in addition to such features as active suspension, permanent four-wheel drive and four-wheel steering.

In April 1990 Mazda began delivery of its new Eunos Cosmos luxury model, outfitted with satellite navigational system purported to be the first of its kind on the market.

Called GPSS (Global Positioning System with Satellite), it retails as a $4,200 option on the $30,000 Type E Coupe. It is said to be unique in that it combines dead reckoning with satellite navigation. Claimed accuracy is between 33 and 109 yards.

GPSS features a stand-alone sensing system that consists of a magnetic sensor, vehicle speed sensors attached to the rear-wheel driveshaft and wheel-spin sensors that compare the input from the front wheel to deduce

1 *Nissan reports that in the first nine months, 7,200 units of the two models combined were sold equipped with the multi-AV system, developed jointly with Sumitomo Electric Industries Ltd. It utilizes terrestrial magnetism and wheel rotation sensors.*

2 *Toyota says that of the 422,340 Crowns sold from September 1987 through the end of 1989, 81,680 (20%) were factory-outfitted with the optional navigation system, supplied by Toshiba. The 6-inch CRT features multimode instrumentation that includes a CD-ROM-based navigational system and an audio/visual panel that works both the TV and the sound system.*

correct turning information.

The dash-mounted, 5.5-inch CRT displays maps stored on a single CD-ROM. Fujitsu Ten supplies the CD changer, which also plays ordinary audio CDs. Likewise, the CRT can be used as a regular TV, provided that the vehicle is stationary. The main control unit, supplied by Mitsubishi Electronics, uses a dozen MCUs, including two 16-bit devices.

Mazda says its plans to build 1,000 Cosmos a month and predicts that 10-15% of buyers will go for the optional GPSS.

Because of limited production and questions of public acceptance, market penetration is likely to be slow, especially at a projected retail price of $3,000 or more. (An official at Bosch's U.S. headquarters predicts it will be "six or seven" years before we see them factory-installed in quantity.)

Surprisingly, the trucking industry could have a far-reaching influence on the practicality of at least certain types of navigational aids. Rockwell International is the latest of three companies to enter the arena of satellite-based communication with commercial trucks.[1] The two companies already actively involved are Qualcomm and Geostar.[2]

Rockwell says it hopes to have 50 to 100 prototypes ready for the U.S. trucking industry by August 1990. The company claims that individual trucks can be located within 100 meters of pinpoint accuracy. Once the satellite linkup is established by 1993, services are to include scheduled and unscheduled transmissions and variable-length messaging. Also planned are such customized trucker services as in-cab fax and data printers.

The long-haul outlook for navigational systems in general is encouraging. Dataquest projects that onboard navigational systems, OEM and aftermarket combined, could reach $300 million retail by 2000, $700 million by 2005, and as high as $1.6 billion by 2010.

Another driver aid soon to be marketed in the U.S., possibly as early as 1992 or 1993, is the electronically controlled collision-warning system. Known as NODS (Near-Obstacle Detection System), it employs a body-mounted microwave sensor (radar) capable of spotting an object up to 15 feet to the rear.

The technology involved, called machine vision, alerts the driver with an audible and/or visual signal when the vehicle nears an obstacle or when a vehicle is approaching too rapidly from behind. (So-called sleepy-driver alert systems already are in used by long-haul truckers. The systems are wired either to the driver's body or to the steering wheel. Should the driver start to doze, an alarm sounds.)

A variant collision-warning system, called SideMinder and developed by AutoSense of Englewood, CO, becomes operational when the driver signals to change lanes. Infrared sensors detect any object, whether stationary or moving, in the blind-spot zone, actuating a flashing red light on either side of the sideview mirrors while a dashboard-mounted alarm sounds.

The manufacturer claims that SideMinder will detect a potential blind-spot hazard up to 7 feet away on either side and up to 5 feet front and back.[3] A SideMinder prototype was first tested in 1987 on a Chrysler minivan. A year

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1 *Rockwell currently offers a nonsatellite communications system called Tripmaster, which monitors such functions as engine speed, idling time, fuel economy and whether preset speeds are exceeded. The data is fed into a computer at the end of a run. Introduced in 1979, 80,000 Tripmasters have been sold to more than 2,000 truck fleets.*

2 *Qualcomm, first with truck systems (June 1988), has some 7,500 Omnitrac units in field operation. Another 5,000, at about $4,500 per, are said to be on order. In the U.S., Qualcomm tracks trucks through a San Diego-based communications center, using Ku-band signals over GTE's GSTAR 1 satellite. In Europe, Qualcomm has nearly 200 vehicles testing its system over the EUTEL-STAT satellite. Out next, after Qualcomm, was Geostar's System 2C, operational since October 1989. It currently is on 2,000 trucks, with another 5,000 on order. The price is $4,500 plus a monthly fee of $45 for up to 900 messages.*

3 *The SideMinder system incorporates small electro-optical devices, about 1 inch in diameter, placed by each sideview mirror or within the taillights. The components project three to six pulsed beams of infrared light that fan out and sense objects in the blind-spot surveillance zone. Light reflected from the object is filtered and converted via a photosensitive semiconductor to an electric impulse.*

later, Ford tested the device on a Lincoln Continental. Chrysler may offer SideMinder on high-line passenger cars by 1995; Ford may introduce it on the Granada, an upmarket sedan sold in Europe.

Dataquest predicts that by mid-decade the technology will exist that could make adaptive, or smart, cruise control utilizing radar or optics a reality. And by 2000, the state-of-the-art could permit the first collision-warning systems to manifest second-generation technology. Dataquest further predicts that soon after the turn of the century, the necessary technology will be sufficiently developed to permit radar braking systems to become a practical reality. Radar, brakes and accelerator would link together to calculate when brakes should actuate automatically. Although speed, weather conditions and other relevant real-time data will determine when the system takes control, the driver still will be able to override the system, just as can be done with today's cruise control.

Whether or not these systems become reality will depend more on the willingness of the VMs to risk product liability lawsuits by introducing such devices, than on possessing the technology. Barring unforseen legislation protecting manufacturers, unless significant changes occur in the litigious nature of the public, and unless the present attitude of the courts toward manufacturers in product liability lawsuits changes, Dataquest sees the likelihood of VMs introducing such products into regular production vehicles for the U.S. market as extremely low.

Looking further to the future, the various navigational-aid devices now being field-tested or under development will be part and parcel of a so-called Totally Integrated Vehicle capable of two-way electronic communication with smart highways. One day, technology could permit real-world driving that would be as goof-proof as steering a rail-guided kiddie car at Disneyland provided the industry is willing to assume the liability risks associated with its public introduction.

GOVERNMENT REGULATION

In 1956, Ford Motor Co. introduced on its passenger cars a host of safety features, including what it referred to as a "deep-dish steering wheel" (recessed column). The buying public yawned. Ford's conclusion: "safety doesn't sell." Whether safety sells today is moot for in the intervening years legislators at both state and national levels have forced auto manufacturers to produce vehicles that are inherently safer to operate, are more crashworthy, are more durable and are more friendly to the physical environment. One of the first such regulatory actions came in 1966, when Congress passed a law requiring all passenger cars from that year forward to be factory-equipped with lap-type seat belts in the front compartment.[1]

Another regulatory milestone was reached in 1975 when Congress, in the wake of the first oil embargo, passed a law requiring all manufacturers marketing more than 10,000 passenger cars annually in the U.S. to meet specified fuel-efficiency standards known as CAFE (Corporate Average Fuel Economy). The designated standard started out at 18.0 MPG for MY78 and was to rise gradually, to 27.5 MPG by MY85 and beyond.[2] However, as was the general policy of the anti-regulation Reagan Administration (1981-89), federal agencies relented on CAFE and on associated eco-environmental matters. Accordingly, the National Highway Transportation and Safety Administration (NHTSA) actually rolled back the CAFE standard one whole integer, to 26.5 MPG for MY89. (For MY90, it was reinstated to 27.5 MPG. NHTSA ruled in April 1990 that the CAFE standard for light-duty trucks would be 20.2 MPG for MY91 and MY92. It currently stands at 20.0. The agency also ruled it is discontinuing optional standards that permit VMs to apply separate CAFE formulas for 2WD and 4WD fleets.)[3]

The era of regulatory reprieve may be over, however, as the Bush Administration seems bent upon tougher laws, particularly as regards fuel consumption and the environment. Further, the Democrat-controlled Congress is of a mind to tighten the screws.

On April 3, 1990 the Senate passed, by a vote of 89-11, a Clean Air Bill representing a compromise between the President's original proposal[4] and the Senate's stricter initial plan.[5] In a related and important development, the Senate Commerce Committee surprised VMs by voting 14-4 to require that passenger cars meet a *de facto* CAFE standard of 33.0 MPG by 1995 (20% higher than the 1988 level) and 40.0 MPG by 2001.[6] In addition, the commit-

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1 Today 33 states and the District of Columbia have laws on the books mandating use of safety belts, even though surveys show that the belts are used by fewer than half of all motorists.

2 The Federal Trade Commission estimates that a 10% increase in fuel efficiency results in a 3% increase in aggregate miles traveled. [Source: Automotive News, 11/27/89]

3 Entering the 1990 model year, of the Big Three, only Chrysler has registered CAFE credits. Ford and General Motors, both of which barely met the 1989 CAFE standard of 26.5 MPG, presumably will be more constrained concerning model-production volume and selection in 1990. [Source: Ibid.]

4 The President originally proposed, in June 1989, a new Clean Air Bill that would have forced VMs not only to produce but to sell 500,000 alternative-fuel vehicles in 1995, 750,000 in 1996 and 1-million a year from 1997 to 2004 in the nine U.S. cities with the worst air pollution: Baltimore, Chicago, Hartford (CT), Houston, Los Angeles, Milwaukee, Philadelphia, San Diego, Washington (alphabetical order). Yielding to pressure from automobile and oil industry interests, the White House later backpedaled, saying that VMs need only prove the capability of producing vehicles in the above-cited numbers, rather than actually build them. Retrenching further, the Administration finally said it would regard reformulated gasoline as satisfying the definition of "alternative fuel." [See "Alternative Fuels, p. 132]

5 The Senate measure would require that certain tailpipe pollutants be reduced by half by 1995, one year after a similar mandate in California is to take effect. A second round of emissions reductions would go into effect only if 12 identified cities still violate clean-air standards by 2003.

6 According to the American Petroleum Institute (API), which cites Dept. of Energy data, existing technologies could permit a cost-effective increase in CAFE to 32 MPG for 1995 without necessitating a "significant" downsizing of vehicles. If, however, the CAFE level were to be raised to, say, 39.6 MPG by 1995, then the pump price of gasoline would shoot to $3.94 a gallon (measured in 1989 dollars). [Source: Ward's Auto World, March 1989] tee amended the bill to give VMs credit for installing airbags on cars with a wheelbase of less than 100 inches and an EPA-certified fuel efficiency rating greater than 35 MPG.

As this report went to press, the House of Representatives was nearing a floor vote on its own Clean Air package. As voted out of the Energy and Commerce Committee, 42-1, on April 6, the measure, like the Senate version, would require all but nine of the 101 most-polluted cities to be cleaned up by 1999 or 2000. The House version forces the federal government to impose a mandatory cleanup plan on cities that fail to meet the deadline, whereas the Senate bill imposes a series of penalties.[1]

On auto-caused pollution, both bills require about a 50% cut in allowable tailpipe emissions by 1993 or 1994. The Senate bill mandates a second, more severe round of reductions if 12 key cities remain definitionally polluted in 2003; the House version calls for a second, stronger round only if the federal government should deem it warranted and "cost-effective."

Individual states, most notably California, are taking steps on their own to curb air pollution. California, which for many years had a tailpipe emission standard far more stringent than that imposed by the federal government, is making a concerted push to further reduce air pollution from all known sources, not just motor vehicles.

If, as is expected, the regulation proposed by the California Air Resources Board (CARB) goes into effect in September 1990, VMs doing business in the state will be required to market by 1994 a specified volume of alternative- or flexible-fuel vehicles. Moreover, oil companies would be required to sell alternative fuels at their service stations as a condition for continuing to do business in the state. (Interestingly, the findings of a special CARB committee indicated a probable best-case-scenario for substituting pure methanol [M100], not the 85% gasoline-15% methanol [M85] favored by most VMs.)

Assuming that the regulation goes into effect, VMs wishing to continue doing business in California - which accounts for approximately one of every 10 new-vehicle registration nationwide - will perforce hasten their collective R&D efforts toward fielding vehicles that comply. Here's how events would unfold:

Beginning in 1997, no fewer than one-quarter of passenger cars sold in California would have to emit 70% less of smog-forming hydrocarbons than required by the 1994 standard. By 1998, one-half of all passenger cars sold would have to meet the tougher standard. In effect, there would be two tailpipe standards, one for conventional gasoline-powered cars based on the 1994 standard and another for so-called low-emission vehicles (LEVs), which the state would require to be sold in California. The 1997 standard limits hydrocarbon emissions to 0.075 grams per mile (gpm) of travel. The 1994 standard limits them to 0.25 gpm. (Current federal standards set hydrocarbon limits at 0.41 gpm.) As time passes, the market share of LEVs would expand, it is projected, from less than 10% in 1994 to 100% of new cars sold in 2000.

By 2010, CARB projects, two-thirds of gasoline use in the state would be supplanted by cleaner-burning fuels. Heavy-duty trucks and off-road vehicles, among others, would continue to use conventional gasoline. As CARB envisions, there would be three categories of progressively cleaner cars: Transitional LEVs, LEVs and Ultra-LEVs. But even the transitional LEVs would emit only half as much smog-forming hydrocarbons as the cleanest new cars on the road in 1994. The LEVs would be 40% cleaner still, and the Ultra-LEVs would cut hydrocarbon emissions by half-again as much.

CARB reckons that for the first-generation of cleaner cars, the transitional LEVs, only minor modifications involving engine design and management would be needed for compliance. Indeed, the Board noted in its published report that at least one vehicle, the 1990 Nissan Sentra (built in Smyrna, TN [see

1 The House version would impose much stricter tailpipe emissions standards and mandate factory-installed onboard devices to capture gasoline fumes that otherwise would escape into the atmosphere.

"Transplants," p. 99]) already meets the hydrocarbon standard to take effect in 1994.

The second-generation LEVs would, however, necessitate further advances in control technology. Gasoline engines might be able to comply with the proposed standard if, for example, electrically heated catalytic converters actually work as well as early CARB tests indicate. If not, the Board reported, such substitute fuels as methanol and compressed natural gas (see "Alternative Fuels," p. 132) could meet the standard without need of an electrically preheated catalytic converter.[1]

Vermont, similarly concerned about worsening air pollution and global warming, has passed a law, effective with the 1993 models, that bans the sale of cars with air conditioners using chlorofluorocarbons (CFCs). (This widely used refrigerant is believed to harm the stratosphere's ozone layer, which helps to screen out the sun's potentially damaging ultraviolet rays. Already, Ford and General Motors have announced that the law will preclude from sale certain models.) It is likely that other states will follow the lead of California and Vermont by passing legislation of their own aimed at reducing, and, ideally, reversing the trend nationwide to deteriorating air quality.

Actions by both the federal government and individual states to curb air pollution contain a potentially profoundly important message for suppliers of engine-control componentry. Already, the Big Three have said that existing 8-bit controllers probably are inadequate to meet California's pending tougher standards. Considering that at least eight other states may adopt CARB standards and that European countries and Japan are clamping down as well, VMs the world over may well be forced to switch to 16-bit or greater technology.[2]

NHTSA proposed on January 4, 1990 that certain crash-protection standards now applicable only to the manufacture of new passenger cars additionally include light-duty trucks, vans and so-called multipurpose vehicles. The proposal (Standard 208) calls for 20% of all vans, light trucks, multipurpose passenger vehicles and small buses manufactured in MY94 to be equipped with factory-installed airbags or automatic safety belts, as applies to passenger cars effective MY90. The safety features would be required on 50% of the MY95 vehicles and on 100% by MY96.

Under the rule, vehicles that offer a driver's side airbag could have a manual safety belt on the passenger side and still meet the agency's proposed standard through MY97. But VMs that do not provide a driver-side airbag would have to install automatic belts on the driver's and front-seat passenger's side.

The measure would apply to the aforementioned with a gross vehicle weight (GVW) rating of 8,500 pounds and an unladen vehicle weight of 5,500 pounds or less. Included would be motorhomes, convertibles, open-body-type vehicles, walk-in van-type trucks and vehicles carrying chassis-mounted campers. Further, light truck and passenger cars with only two seating positions would have to be equipped to accommodate a child safety seat on the passenger side.

As with tailpipe-emission standards, California appears to be in the forefront of another, safety-related movement - antilock brakes. In April 1990 a bill was introduced in the state legislature (AB4342) that would mandate fac-

1 In March 1990 CARB began on-road durability testing of an experimental preheatable catalytic converter in two MY90 cars, a Toyota Celica and a Buick LeSabre. Each will be operated under everyday driving conditions for at least 10,000 miles. CARB officials, encouraged by early tests, say the modified converter - using heaters and air pumps - could conceivably satisfy the agency's ultra-stringent emissions rules proposed for 1997 without need to go to alternative fuels. Possible drawback: the technology could add more than $300 to the retail price of the vehicle.

2 As of MY90, only Ford utilizes a 16-bit microcontroller in its production engine management system. Other VMs are investigating both 16-bit and 32-bit architectures for their future systems.

tory-installed four-wheel ABS on all "private passenger cars" designated by the VM to be MY92 or later. The ruling also would apply to trucks and SUVs under 6,001 GVW. Non-compliance could cost the VM a fine of $500 for each unit sold. Should the measure pass, California would become the first state requiring ABS on motor vehicles offered for original sale. As yet, there is no federal regulation mandating ABS, and as of April 1990 no such bill had been introduced in Congress nor had NHTSA proposed enactment.[1]

The Treasury Department proposed in February 1990 adopting a new tariff category that would pave the way for the U.S. to assess 2-door and 4-door SUVs and minivans at the same rate. The rate probably would be lower than the 25.0% currently levied on light trucks, 2-door SUVs and vans with fewer than two rows of seats, but higher than the 2.5% charged on imported passenger cars, passenger minivans and 4-door SUVs. Treasury has petitioned a 19-nation advisory group on tariffs to adopt the recommendations internationally.

1 *Federal mandate or no, the big surge in ABS application is about to commence. Dataquest predicts an installation rate of over 80% by MY95 on passenger cars and light trucks built in North America. By then, General Motors and Ford are forecasted to install ABS on over 90% of their production, Chrysler more than 75%, and Transplants 45%. The retail price of ABS, standard already on many high-end vehicles, both domestic and imported, will fall to the $500 range by MY95 on those vehicles offering it as an option.*

GLOBAL ALLIANCES

The Eighties ended with a flurry of headline-making mergers, buyouts and newly forged operational alliances among automakers the world over. The final 60 days of 1989, marked by the sudden collapse of Communism in Eastern Europe, spawned a rash of new joint ventures linking Eastern Bloc automakers and suppliers and those of the Free World, the United States included.

This opportunity for business expansion by Free World VMs and suppliers comes at a time, ironically, when the clear trend has been toward consolidation of marketplace contestants. The biggest news in this regard in the Eighties, other than the recovery of once-moribund Chrysler Corp., was the purchase in August 1987 by then-resuscitated Chrysler of chronically downtrodden American Motors Corp. (Regie Nationale des Usines Renault had had controlling interest in AMC for nearly a decade.) In 1988 Volkswagen AG permanently shuttered its 10-year-old assembly plant in Westmoreland, PA, the first "transplant" in the U.S. (Its demise paralleled waning popularity of the Volkswagen brand here in the Seventies as buyers by the legion opted instead for Japanese-made goods.)

Despite the headlong rush by Free World interests into Eastern Bloc alliances[1], all signs point unmistakably toward further shrinkage of the player base in the years ahead.

In the late-Eighties, U.S. automakers, led by General Motors Corp., closed literally scores of assembly and captive- supplier plants as sales demand for Detroit-built vehicles softened, thanks largely to stepped-up demand for Japanese wares. (In calendar 1989, Honda Accord - half of which sold in the U.S. are now produced in Ohio - became the nation's best-selling model, either domestic or import. [See "The Ascent of Japan," p. 127]

Similarly, noncaptive suppliers to U.S.-based automakers are in a state of accelerating attrition. A decade ago, both Ford and General Motors each had thousands of suppliers; today, it is hundreds. Moreover, the Big Three, in moves that would have been unheard of not long ago, are entering joint ventures involving respective captive suppliers (e.g.: 1) Chrysler's New Process Gear in Syracuse, NY, and GM's Muncie, IN, Hydra-matic plant have merged to form New Venture Gear, Inc. It will produce new driveline products for each parent's use; hope is that it will win new business from European and Asian auto-makers; 2) GM, Ford and Chrysler have agreed to engage in joint "precompetitive" research into structural uses of composites in cars and trucks. The 12-year consortium was formed in 1988 under the U.S. National Cooperative Research Act of 1984.)

There are at least three main reasons in addition to such unprecedented co-op ventures between rival domestic VMs that help to explain why the noncaptive supplier base continues to shrink:

1) Higher quality standards imposed by assemblers (see "World Standards," p. 92);

2) Ever-fewer discrete parts required in final assembly (the trend to increased integration of electronics componentry [e.g., multiplexing] plays a major role in this regard).

3) Most of the sales declines experienced by the Big Three in recent years have come at the hands of Japanese-owned and/or -run "transplant" factories. Few, if any, American suppliers have been able to "crack the transplant nut," as these plants have relied chiefly on Japanese suppliers, whether captive in nature and whether situated here or in the homeland. Thus far, U.S. suppliers have been largely excluded.

To survive the Nineties, even big-contract,

1 Estimated 1988 population of seven-country Eastern bloc (including USSR) 408M vs. 356M for Western Europe. Total motor vehicles owned: Eastern Europe 39.7M, Western Europe 151.2M. Cars per 1M capita: Eastern Europe 87, Western Europe 376. (Source: Pemberton Associates, Warwickshire, England per Automotive News 4/16/90) diversified outside suppliers to domestic automakers must produce goods that consistently meet world-class standards. This means product not only of overall top quality, but also product lots virtually, if not literally, free of defect. The prevailing old-time attitude, "Return the bad units and we'll replace them" no longer washes. The new caveat, "Make every unit right the first time," has proved a rude awakening for many suppliers. Yet it is the newly coined price of admission in an industry that is rapidly becoming truly globalized both in manufacturing and in marketing (see "World Standards," p. 92) As for smaller suppliers, perhaps the best advice, even to those fiscally sound, is, "find someone somewhere to do something with" or run the risk of extinction. For many, the passport to survival may be summarized in one word: *partnering*.

Following is a rundown of major vehicle manufacturers (VMs) worldwide and their respective key tie-ups. (Affiliations listed alphabetically by manufacturer, U.S. companies first.[1])

CHRYSLER

BEIJING - 32% interest in joint venture with Beijing Automobile Works to build 4WD Jeeps in China. Involves Acustar deal to supply axles for at least 10 years.

DE TOMASO - 16% equity in Officine Alfieri Maserati SpA, 24% in Maserati. Controlling shareholder in De Tomaso Industries, Inc., Italy.

FIAT - 50/50 joint venture to take control of Alfa Romeo distribution in U.S.; permits Fiat to distribute Chrysler products in Europe.

HYUNDAI - Starting 1991, Chrysler to buy 30,000 Sonata sedans built by Hyundai in Canada. Cars to be rebadged for retail through Eagle Div.

GENERAL MOTORS - 1989 joint venture wedding New Process Gear, Syracuse, NY, and GM's Hydra-matic Div. transmission plant, Muncie, IN, to form New Venture Gear, Inc. Owned 64% Chrysler, 36% GM. Will build 4wd transfer cases, manual transmissions for both.

LAMBORGHINI - 100% ownership of Italian maker of superexotic sports cars.

MITSUBISHI - Starved for cash, in 1989 reduced equity share in Mitsubishi Motors Corp. to 12.1% from 21.6%. Each has 50% interest in Diamond-Star Inc., launched 1988. The joint- venture assembly plant in Normal, Ill. builds three clone sport coupes, Talon (Eagle) and Laser (Plymouth) for Chrysler, Eclipse for Mitsubishi dealers. Clone luxury sport coupes (c. $30,000), Mitsubishi GT 3000 and Dodge Stealth, due off line starting fall 1990. Mitsubishi buys Chrysler- made automatic transmissions for compact pickup built in Japan and sold in U.S. by Dodge dealers as Ram 50. Chrysler buys V-6 engines from Mitsubishi.

RENAULT - As part of 1987 AMC buyout arrangement, assembles Renault-designed Premier in Canada under license agreement for sale in N.A. Regie Renault has Jeep distribution rights in France, Italy. Latest joint venture (1989), ARCAD, to produce in Spain small Jeep for sale in Europe and possibly in U.S. #Job One target 1992. Vehicle expected to compete with Suzuki compact SUV.

STEYR-DAIMLER-PUCH - Tentative agreement early 1990 with Steyr to assemble Chrysler minivans at initial annual rate of 25,000 at Steyr plant in Austria, starting 1991. Target annual rate 100,000 units within five years. (Chrysler has lacked manufacturing presence in Europe since 1978.)

1 *List, link-ups not exhaustive. Information gleaned from various periodicals and documents in public domain; current as of May 1, 1990. Principal sources: various Ward's Communications publications; Crain's Automotive News; Autoweek; The Wall Street Journal.*

FORD

AC - 51% interest in AC Cars Holding Ltd., U.K.-based low-volume builder of specialty sports cars.

ASTON MARTIN - Estimated 75% interest in Aston Martin Lagonda, U.K. maker of limited-production ultraexpensive sports and specialty cars.

DE TOMASO - Supplies engines for Pantera sports cars.

FIAT - Merged with Fiat's U.K. truck-making and distribution subsidiaries to form joint venture, IVECO Ford. Each owns 48% interest. Ford and Fiat also each own 24% of Van Doorne's Transmissie BV, Dutch developer and maker of CVTs. Supplies Fiat with CVTs from plant in France.

JAGUAR - Bought 100% Jaguar PLC in 1989.

KIA - Owns 10% Kia Motors Corp., S. Korean maker of minicar retailed in U.S. through Ford dealers as Festiva.

MAZDA - Owns 25% Mazda Motors Corp. In Flat Rock, MI, joint-venture factory, Mazda assembles pair of coupes off Mazda 626 platform - MX-6 for Mazda, Probe for Ford. In 1989 added 626 sedan to line. Produces engines for use in all three vehicles. Mazda supplies engines for Japan-engineered 1991 Ford Escort/Mercury Tracer[1]. Will produce clone of 1991 Ford Explorer compact SUV, badged the Navajo, for sale by U.S. Mazda dealers. Shared equity (34%) with Mazda (39%) in Autorama Inc., exclusive marketer of Ford products in Japan. As of Feb. 1990 reported to be negotiating possible additional joint venture with Mazda, likely involving 1995 replacement for Ranger compact pickup, now built at Ford plant in Louisville.

NISSAN - Joint venture at Ford assembly plant Lorain, OH, to build Nissan-designed minivan for U.S. market, beginning 1992. Co-developing production of 4wd SUV at Nissan plant in Barcelona. Job One target 1993.

SUZUKI - Taiwan-based affiliate Ford Lio Ho Motor Co. will make and sell minitrucks and minivans for Suzuki in Asia. (Ford rumored to be seeking means of entering mainland China market using Lio Ho as wedge.)

VOLKSWAGEN - In 1987 merged Brazilian manufacturing operations with those of Volkswagen AG to form Autolatina (49% Ford equity). Separate retail networks maintained. Talks reported but unconfirmed regarding European joint venture to develop and produce MPV starting 1993.

GENERAL MOTORS

DAEWOO - 50% equity interest in S. Korean automaker. Principal product is GM Opel-derived, Daewoo-built subcompact sold by Pontiac dealers as Le Mans.

ISUZU - 38% ownership. Imports Isuzu-designed and -built Storm, sold by Chevrolet dealers under Geo badge. In Japan, Isuzu markets Opels, produced by GM Europe. GM, Isuzu swap engines and other components. New Joint venture in U.K, IBC Vehicles Ltd, to produce Isuzu 4wd pickups beginning 1990; to be marketed by GM throughout Europe. Other joint-venture activities in Australia, the Philippines, W. Germany.

LOTUS - 100% ownership of legendary U.K. sports-car builder.

RABA - Signed agreement early 1990 for 67% stake in joint venture with Hungarian Railway Carriage and Machine Works (RABA), state-owned truck and parts maker, to produce 25,000 small cars, 100,000 engines by 1995 latest, mostly for export to Western Europe for use in several GM models. Production start-up target 1992.

1 *Escort assembled at Wayne, NJ, and Hermosillo, Mexico; Tracer assembled exclusively at Hermosillo.*

SAAB-SCANIA - Acquired 50% stake December 1989 in automotive division for $500 million. Likely first product of newly formed joint venture, named Saab Automotive AB: new Saab-badged model, possibly upmarket of 9000 flagship.

SUZUKI - 5% equity share. Together own CAMI, Canada-based assembly plant that produces clone compact sport-utility vehicles (SUVs), Tracker for GM, Sidekick for Suzuki. In Japan, Suzuki markets Pontiacs, Chevrolets built in U.S.

TOYOTA - Paired 50/50 with Toyota Motor Corp. in Fremont, CA, joint venture assembly plant, NUMMI (New United Motor and Manufacturing, Inc.), formed 1984 for 12-year period. NUMMI builds clone subcompacts, Corolla for Toyota, Prizm for GM (sold through Chevrolet as part of Geo line). Pickup truck assembly for Toyota to commence Aug. 1991. Paired with Toyota in newer joint venture in Australia, where in 1988 formed United Australian Automotive Industries Ltd. (UAAI), merging respective automaking operations. UAII to produce Corolla, Camry for Toyota, Holden's Commodore for GM in Australia.

VOLVO - Merged Class 8 truck operation with Volvo N.A. Heavy Truck to form Volvo GM Heavy Truck Corp., owned 76% by Volvo.

WARTBURG - In March 1990 announced plan to invest up to $600-million in E. German joint venture between Automobil-Werk Eisenach (AWE), which builds the Wartburg, and Opel AG. To make components and up to 150,000 cars annually at Eisenach factory.

NOTABLE ALLIANCES INVOLVING FOREIGN-BASED AUTOMAKERS

DAEWOO- Joint-venture agreement with SUZUKI to produce, distribute badge-engineered spinoffs of Suzuki Alto minicar and Carry minitrucks in S. Korea beginning 1991. Capacity production target 240,000 units per annum.

DAIHATSU - Reached agreement February 1990 with FABRYKA SAMOCHODOW OSBOWYCH (FSO), producer in Poland of Fiat 125-based cars, to provide FSO with knockdown kits for assembly of 1.3L Charade minicar. Target start early 1991.

DAIMLER-BENZ- 50.1% interest in Mercedes-Benz South Africa, which under license from HONDA produces Honda Ballade/Concerto cars for local consumption. Announced March 1990 joint-venture plan with MITSUBISHI to selectively co-develop and/or cross-market aerospace and electronics products in addition to motor vehicles. Involves sharing of respective technological expertise. In February 1990, bought majority stake in FABRICA AUTOTRANSPORTES MEXICANA, Mexican truckmaker. Paired with MAN AG, W. German truck and heavy-equipment producer, to gain control of ENASA, Spanish state-owned maker of commercial vehicles.[1]

FIAT - Owns ALFA ROMEO, AUTOBIANCHI, FERRARI, IVECO, LANCIA; controls 49% Maserati SpA, 51% Innocenti Milano SpA. Joint venture with Maserati SpA to build Fiat Pandas in Italy. Joint venture with Innocenti Milano to market Fiat- based Yugo Floridas build in Yugoslavia; in exchange, Innocenti may sell Fiat Panda and Poland-built Fiat 126 in Western Europe. Subsidiary Alfa Romeo SpA may help develop future MASERATI cars and supply certain components. Partnered with PEUGEOT in

1 In addition to those noted here, since Jan. 1990 Daimler-Benz has entered or announced collaborative schemes with a) United Technologies, owner of Pratt & Whitney, on commercial jet engines; b) Aerospatiale of France, forming world's second-largest helicopter maker (Sikorsky of U.S. is #1); c) E. Germany's big lorry and railway-wagon makers.

making commercial van in Italy; separate distribution. Scheduled to reopen two plants to produce with Peugeot light-duty utility vehicle starting 1993. Said joint venture, SEVEL, currently builds Peugeot J5, Citroen C25, Fiat medium-duty commercial van. New deal with FABRYKA SAMOCHODOW OSBOWYCH (FSO) of Poland, to build and distribute Fiat Uno derivative, starting 1990. Talks under way early 1990 whereby Fiat would supply FSO with tooling to produce Fiat Tipo 4-door hatchback at plant near Warsaw. Owns 15% ZAVODI CRVENA ZASTAVA, maker of Fiat-derived Yugo car. Owns 30% new joint venture with Soviet Union to produce at plant in Yelabuga 3- and 5-door hatchback spinoffs of Uno. Job One target late 1991.

HONDA - 20% equity share in ROVER GROUP PLC. Will share with Rover production of cars from new U.K. assembly plant at Swindon, Wiltshire, where Accord-sized Syncro due late CY92; separate versions to be sold in respective local markets. Previously co-developed with Rover luxury sedans marketed separately as (Acura/Honda) Legend, Sterling/Rover 800. More recently co-developed smaller Concerto/200 series for distribution in respective local markets. In addition, supplies Rover with components.

ISUZU - Joint venture with FUJI HEAVY INDUSTRIES in Lafayette, IN, where Subaru-Isuzu Automotive Inc. (SIA) builds Isuzu-brand small trucks and Subaru cars. Fuji has controlling interest (51%).

MAZDA - Owns 8% KIA (S. Korea). (See notation under VOLKSWAGEN.)

MITSUBISHI - Owns 15% HYUNDAI (S. Korea), 30% PROTON (Malaysia). Joint venture with SUZUKI to develop COE truck for Indonesian market; production to commence 1991.

NISSAN - 4.5% stake in FUJI (Japan), 25% YUE LOONG (Malaysia). Plant in Mexico supplies engines to VOLKSWAGEN plant in Mexico.

PEUGEOT - Rumors (March 1990) of possible link-up with FIAT.

RENAULT - Equity-exchange deal with VOLVO February 1990 (see VOLVO entry). Sold full stake (45%) in American Motors Corp. to CHRYSLER Corp. August 1987. Chrysler continues to assemble Renault-designed Premier and Monaco 4-dr. sedan under license at Bromont, Ontario, Canada plant built by AMC. Has Jeep distribution rights in France, Italy. Joint venture with Chrysler, called ARCAD, to launch production of small Jeeps (Renault JJ) in Europe, North America in 1992. Buys axles, other components from GENERAL MOTORS. Jointly designs, produces components with PEUGEOT. The two are partners in engine-making venture known as PRV (the third party, Volvo, withdrew in 1989). Scheduled to buy 4-speed automatic transmissions from VOLKSWAGEN.

SSANGYONG - Owns 80% PANTHER (U.K.).

SUZUKI - 1988 agreement with DAEWOO (S. Korea), to produce, distribute clones of Suzuki Alto minicar and Carry minitrucks in S. Korea. Output to begin 1991; minivan production to follow. 40% stake in MARUTI UDYOG, joint venture with India; product built, the Maruti 800, is a version of 3-cylinder Suzuki Alto, exported to various world markets. 1990 yield target 115,000 units.

TOYOTA - Owns 15% DAIHATSU (Japan); 50% stake in joint venture in U.S. with General Motors (NUMMI).

VOLKSWAGEN - Owns 80% SEAT (Spain); expected to acquire remainder by end 1990. Deal with WARTBURG (E. Germany) whereby Wartburg to produce 1.3L engine for VW Golf. VW entitled to third of output in exchange for tooling, technical assistance. In 1988 formed FIRST AUTOMOTIVE WORKS (FAW), a joint venture with Chinese government to produce in China Audi 100 kits. Estimated 1990 output: 6,000 units, to rise to 30,000 by 1992. Entered into another agreement with FAW in April 1990, to build Golfs and Jettas for local and export markets. Output to start 1991 with 2,500 cars assembled from semi-knockdown kits. Regular production to begin 1993; capacity of 150,000 units annually to be reached by 1996. In separate joint venture, SHANGHAI VOLKSWAGEN AUTO CO. LTD., which since 1985 has produced the Santana, predecessor to Passat (Quantum) sedan. In 1989 built 15.7K, all for government and business officials. Capacity to reach 30,000 units by end 1991. In 1987 merged Brazilian manufacturing operations with FORD to form AUTOLATINA (see entry under FORD). Pending agreement reported April 1990 with MAZDA to joint-market VW T4 van (due late 1990) in Europe; in turn, VW would produce and market in Europe a VW-badged version of next-generation Mazda MPV (debut date unknown). VW dealers might additionally sell a Mazda-built light truck.

VOLVO - February 1990 agreement with REGIE RENAULT to exchange 45% equity in respective truck and bus units. Also acquires 20% parent Renault, including automobile operations, with option to raise stake to 25% within three years. In turn, Renault buys 25% stake in Volvo Car Corp. from AB Volvo plus another 10% through open-market purchase. (Deal excludes GM tie with Volvo Truck, *op. cit.*)

THE ASCENT OF JAPAN

In the late Sixties, Henry Ford II, chairman of Ford Motor Co., was asked by a reporter if he was concerned about Japanese automakers as a player in the U.S. marketplace. He replied: "We [Detroit] will push the Japanese back to their own shores." At the time, Japanese makes held a composite market share of approximately 10.0%. Two decades later, Lee A. Iacocca, chairman of Chrysler Corp., was asked by a reporter about the mounting Japanese challenge. He replied: "The Japanese don't know when to let up." At the time, Japanese makes held a composite market share of approximately 25.0%. Are the Japanese likely to "let up?" Observes one industry analyst[1], "The domestics have to realize [that] the battle has just begun."

* * *

In 1947, two years after World War II ended, Japan produced a total of 11,320 motor vehicles. Every one built was consumed domestically. Export volume: zero. That same year, U.S. automakers had regained full assembly-line speed. Demand, at near-burst level after four years of suspended civilian production, far outstripped supply. Dealers could have sold their inventories several times over.

The 10 major VMs turned out 4.8-million passenger cars and trucks, 82% of the world total. (For every vehicle Japan produced, 424 rolled off American assembly lines. Far and away, "Detroit" was the premier, unchallenged motor-vehicle producer globally. Numerically, America's supremacy was nearly laughable. The world's second-largest producer in 1947 was the United Kingdom. All told, British VMs assembled 441,284 vehicles, an impressive volume but fewer than one-tenth of what Detroit could count. Third-highest was Canada, and all 242,107 of the units produced there came out of factories constructed, owned and run by American companies. It was as if Detroit had "colonized" Canada, a point that would prove worth remembering four decades later.

By 1957, a decade hence, Japan's aggregate yield had risen sixteenfold, to 182,000 units. Even so, the volume fairly paled in comparison to America's 7.2 million! Though still a minor player, by now Japan was embarked upon a mission that would permanently change the direction of its auto industry and would work eventually to reorder the world hierarchy of producers.

It was during this momentous year (1957) that both of Japan's largest VMs, Toyota and Nissan (known here then as Datsun), dipped their big toes into U.S. sales waters. Their respective passenger-car offerings - the Toyopet and the Bluebird - two family sedans that were enjoying sunny sales in the homeland, met with a chilly reception.

Understandably so. By now, the Volkswagen Beetle was nearing its 10th anniversary of U.S. sales. It was solidly entrenched as America's favorite import brand. Indeed, "The Bug" was on its way to cult-car status. The Toyopet Crown, unveiled here in 1957, was a phenomenal flop. So dismal was its showroom draw that after 14 months and only 288 units retailed, it was quietly withdrawn from the U.S. market. Although sales of the Datsun counterpart were nothing to crow about - a mere 52 units found takers in 1958, the first full year - the parent company hung in despite experiencing indifferent sales for an entire decade. Was VW unbeatable?

Toyota re-entered the U.S. passenger-car market in 1965 with an entirely new model, the Corona. The Japanese had done their homework. The car proved itself far better suited to U.S. road conditions and to the needs and tastes of American buyers than had its forebear. Although no overnight success, the boxy, frumpy, four-door sedan soon became a serious challenger to the German juggernaut. Within only four years, Toyota sales catapulted to 100,000 units, thanks largely to the rising popularity of the Corona.

1 Christopher Cedergen of J.D. Power and Associates

Between 1967 and 1971, Japanese car and truck exports to the U.S. grew tenfold, from 82,000 to 814,000 units, aided by Stateside marketing start-ups of Subaru, Mazda and Honda. It was during this period that Nissan dispatched to our shores a wolf in sheep's clothing, the original 510 model. The motoring press hailed it as "the poor-man's BMW 2002"; it stickered for a third less, and performance was nearly as good. Mechanical reliability was as good, if not better. (It was noteworthy too as the first import designed primarily for the American market. The high-water mark for the Beetle in the U.S. came in 1970, when more than half a million were delivered. Thereafter, Toyota and Nissan (Datsun until the early Eighties) sales fortunes soared as VW's soured.

A year later, in 1971, Japan finally eclipsed Europe as the highest-volume exporter of motor vehicles to America; by 1975, Nissan had wrested from VW the mantle as best-selling import. Two years hence, the Beetle hardtop, outdated and no longer inexpensive, vanished from the U.S. marketplace.[1] (The convertible version survived another four years, until 1979.)

When the first oil embargo sneak-attacked in 1973, Japan was ready. It had the right product at the right time: inexpensive, reliable, low-maintenance, high-mileage "econoboxes" that enabled growing numbers to putter past the long lines of gas-gulpers Detroit was famous for ... and which Detroit continued to produce even after the first embargo.

The second embargo (1978) emboldened another phalanx of Japanese VMs - Mitsubishi, Isuzu, Suzuki and, lastly, Daihatsu - to seek their fortune in the world's richest and largest auto market. Collectively, the Japanese "car-tel" was on a roll. Sales were blossoming not only in the U.S., but also in the homeland, thanks to the ever-increasing strength Japan was gaining as an international economic power.

By 1980, only 35 years after the Allied forces had brought the nation to its knees, Japan had risen from the scrapheap to overtake the United States as the world's leading producer of motor vehicles. The scoreboard that year showed 11,042,884 for Japan to 8,010,374 for Detroit, a margin of 39%.

The Japanese were making such inroads into the U.S. market that, under pressure from Detroit, Congress inveighed upon Japan to impose "voluntary" restraints on the total volume of homeland-produced passenger cars its VMs could export here. The sanction, known formally as the VRA (Voluntary Restraint Agreement), went into effect in April 1981. The cap: 1.68-million units (subsequently raised to 2.3-million, where it stands for 1990-91).[2] Actually, the VRA has been rendered largely academic, as in recent years, Japanese producers, seeking a means to circumvent the export limit, have opened U.S.-sited assembly plants. (In 1980, the number of such so-called transplant factories [see "Transplants," p. 99], was zero; by 1990, however, seven of the nine Japanese VMs had a manufacturing presence here, operating either their own "solo" plants or teamed with a U.S. or another Japanese company.) In all, these transplant operations assembled nearly 1-million passenger cars and light-duty trucks in CY89 - an output roughly equal to Chrysler's corresponding 12-month passenger-car yield and to Canada's entire motor-vehicle crop.

Overall transplant output is certain to increase year by year as assembly lines gain full-production speed, as plant-manufacturing activity expands further and as "Japan Inc." probes ever deeper into the lucrative U.S. marketplace. By the mid-Nineties, total capacity potential is expected to approach 3.5-million units - fully one-fifth of the entire U.S. combined car-and-truck market in 1989.

There are several reasons why the Japanese will rely increasingly on North America-based production:

1) It is estimated by our own government

1 The Beetle is still produced in Mexico, strictly for the domestic market. None are exported.
2 The VRA year runs from April 1 through March 30.

(GAO) that the total cost involved for the Japanese to produce and deliver a given individual vehicle in America is considerably cheaper than for the Japanese VMs to export for sale here a like vehicle produced in the homeland. The Japanese reportedly can build a like U.S.-built vehicle $500 to $800 cheaper than can any of the Big Three. Why?
A) Younger, predominantly nonunion workforce;
B) Lower fringe-benefit and pension overhead;
C) More-efficient, more-modern manufacturing techniques.

2) It is known that the Japanese desire to sell more vehicles in Europe. Current import quotas severely hamper their access. As yet, there are no such barriers on vehicles produced in the U.S. Hence the energized drive to expand North American production capacity.

As the new decade dawns, nearly one passenger car in three newly registered in the U.S. wears a Japanese nameplate (including so-called captives); overall, one vehicle in four (vans, SUVs and light-duty trucks combined) are of Japanese lineage.

The Eighties drew to a close with retail inventories bulging, even for some historically fast-turn Japanese brands. So product-overloaded were most dealers, especially those carrying domestic brands, that each of the Big Three announced massive plant layoffs and temporary plants closures in an effort to shrink swollen inventories. Collectively, 42 of the domestics' 62 assembly plants were shut down, idling 142,000 hourly workers. Although the Japanese too were feeling the effects of a stagnant marketplace, those with manufacturing sites here nonetheless forged ahead with previously announced plans to *expand* manufacturing operations.

Yearend 1989 saw Detroit in retreat. Two domestics, General Motors and Chrysler, had lost market share. Chrysler finished down 3.4 points, 10.3%, while GM skidded 1.2 points, to 34.8%, from year-previous figures. Ford defied the odds, closing the year up marginally, to 22.0% marketshare versus 21.6% in 1988. (Though still the world's largest automaker, GM ended 1989 with a corporate marketshare 10 points lower than a decade earlier.)

Meanwhile, Japan Inc., soft sales notwithstanding, was revving into high gear, bent upon capturing greater market share, which, during the Eighties, rose roughly 5 points, to 25%. Several Japanese VMs - Toyota, Nissan, Honda and Mitsubishi - have announced plans to augment their respective retailing networks here at a time when the ranks of new-car dealerships continue to dwindle. (The immediate past president of the National Automobile Dealers Association went on public record as predicting that during 1990 and 1991 the dealer count would diminish by 10%.)

The Japanese enter the Nineties in a most enviable position. They are widely regarded both within the industry and by the general public as being on the leading edge not only in product quality (per the Power and *Consumer Reports* size-ups, among others), but also in introducing functional new technology - specifically, in state-of-the-art engine designs, powertrains, suspension systems, steering systems and entertainment/safety/comfort systems.

As of the 1990 model year, Japan's two largest VMs - Toyota and Nissan - are newly represented here in the luxury-model segment. Each has introduced an upmarket line in the $25,000-to-$40,000 range. Their respective flagships are judged by the motoring press to be as good as, if not better than, the best Europe currently has to offer. Moreover, it is estimated that because of advanced manufacturing methods, Toyota and Nissan are able to produce their luxury cars for a third or greater less than can either Detroit or Europe.

It is predicted that the Japanese collective market share will continue to rise, possibly to as much as 35% to 40% by 1995. Whatever growth is in fact realized is expected by most industry analysts to come mainly at the expense of the domestics. Accordingly, they see the Big Three's composite share to skid by another 5 to 10 points by 1995, to between 58% and 63% versus 68% as of yearend 1989.

In North America, the so-called traditional domestics (i.e., the "Red-White-and-Blue" VMs) are building at a combined annualized rate of approximately 9.3-million cars and light-duty trucks; their output by 1995 is expected to fall to 8.6 million and to 8.5 million by 2000. Meanwhile, U.S.-sited plants in which Japan Inc. has full or partial ownership will throttle up production numbers, to as high as 3.5 million by 1995 and, conceivably, upwards of 5 million by 2000.

Best estimates are that already no fewer than 350 supplier companies - most of them Japanese-owned or controlled - are serving the transplants factories. Whether more or less of the supplier business, including electronics, is awarded to American companies in the future looms as an economic-political issue of major international proportions.

The ripple-effect ramifications for the auto industry in general and for suppliers in particular are enormous as the Japanese continue their push not only in this country but in other world markets as well. One such "other" market known to be high on Japan's agenda is Europe, especially now that the fall of Communism has opened Eastern-bloc states to outside trade.

Japanese VMs already have a sizeable presence in the European Community. Although five of the 12 nations constituting the EC impose quotas in one form or another on Japanese cars, 1.7-million were sold there in CY89, a market share of 11%, about the same as for Ford and General Motors separately.[1] (In the EC countries without import curbs, the Japanese have fared much better - 40% of the market in Ireland, 25% in Sweden, 15% in West Germany.[2])

The collapse of Communism notwithstanding, Japan is hedging its bet in Europe by expanding production there as rapidly as possible. Honda, Nissan, Isuzu and Suzuki are already manufacturing in Europe. Last year, Nissan built 76,976 cars in Britain and another 86,181 in Spain. Toyota is building a plant in Britain with a planned volume capacity of 200,000 cars a year. Mitsubishi, for one, has indicated a desire to invest in an assembly plant in East Germany.

It is estimated that Japanese production in Europe by 1998 could exceed 1-million units annually. The Economist Intelligence Unit, a London-based research organization, says that Japanese cars produced in European plants could absorb as much as 60% of Europe's projected annual growth of 2%.[3]

Although U.S. VMs have made huge strides toward improving product quality in the past decade, it is generally acknowledged that the Japanese lead the world.[4] They likewise lead the world in brevity of product-cycle time (roughly three years vs. four-plus for the U.S. and five-plus for Europe). Moreover, thanks primarily to advanced production methods (*viz.*, heavy usage of robotics), the Japanese can assemble a vehicle faster than anyone else (19 man-hours at plants in Japan and the U.S.) compared with 31 for U.S. makers, 36 for the Europeans.[5]

Further, the Japanese have shown the world that it is indeed possible to manufacture in an atmosphere free of rancor and strife between labor and management. There are no "hourly workers" in Japanese factories, only "associates," and virtually no caste system, as is the rule elsewhere.

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1 *By comparison, in CY89 2.6-million Japanese cars were sold in the U.S., a market share of 25% (28% including "captives," i.e., Japanese-made cars marketed by U.S. VMs).*

2 *A) Two EC members, France and Italy, are leading the fight to keep the quotas in place even after 1992, when existing duties are lifted, creating a unitary, free-trade market of 320-million consumers. B) France limits Japan to 3% of total sales, Britain to 11%, Italy and Spain to less than 1%. (Fiat sells 68% of its cars in Italy, Peugeot 43% in France.) C) Two other EC states, the U.K. and West Germany, advocate a completely liberalized auto market to which Japan and any other nation would have unrestrained access.*

3 *Source: Fortune, January 29, 1990*

4 *The April 1990 Consumer Reports awards a 3.83 grade-point average to Honda products, 3.3 to Toyota's, 2.80 to Nissan's, 1.30 to Chrysler's, 1.15 to Ford's, .75 to General Motors'. (Perfect score: 4.00)*

5 *Source: Fortune (ibid.)*

Formidable as it is now, Japan is certain to gain added might in North America and in Europe in years to come as more constituent builders expand their respective product lines to include offerings in two key categories: luxury and ultraperformance sports cars. Honda, Toyota and Nissan are represented in the former (Acura, Lexus, Infiniti), and before yearend 1990, Honda will introduce a so-called supercar, code-named the NS-X, whose performance is said to compare with that of a Ferrari. It is expected to carry a sticker price of $55,000 to $60,000, half that of the least expensive Ferrari.

In light of a) the progress they have made in the past two decades and b) new product known to be in the pipeline, it cannot be gainsaid that Japan is poised to become the world's pre-eminent motor-vehicle producer by the turn of the century, if not sooner. Decades down the road, historians may look back on the 20th century and identify the point at which global dominance shifted from American to Japan as the early Seventies, when the first oil embargo took place. From this time forward, America's status and marketplace fortunes have continued to wane while Japan's have waxed.

Just as America has lost - or perhaps conceded - other manufacturing industries to the Asians (electronics notably among them) the wheels are in motion, likely irreversibly, for Detroit's role as a producer to further decline. By 2000, the "Big Three" in this country could well be reconstituted as Honda, Toyota and Nissan, thereby relegating U.S. companies largely to the role of marketer instead of manufacturer.[1] If the first three-quarters of this century was "owned" by American automakers, then the final quarter - and perhaps beyond - may well prove to be Japan's time in the sun.

1 *As we went to press, the rumor - unconfirmed - was circulating that Honda was considering relocating its permanent world headquarters to Ohio, where it already has three plants.*

ALTERNATIVE FUELS

General Motors Corp. has on the 1990 auto-show circuit a concept car call the Impact (see photo). The plastic-bodied, 2-door, rear-skirted coupe has a Cd of an astonishing .19, well below that of any of today's production vehicles. GM claims a 0-60 mph acceleration time of 8.0 second, not whippet-like but very respectable.

What makes the Impact newsworthy, however, lies underhood - an electric motor. GM says conventional lead-acid batteries in the car will propel it up to 124 miles at freeway speed without need of a recharge... on ordinary household current (110 volts). This is roughly twice the non-stop cruising distance of any previous battery employed in an experimental vehicle.

Will General Motors' electric vehicle, the Impact, see production?

On the eve of Earth Day 1990, GM surprised the auto world by announcing its intentions to mass-produce the Impact. Officials provided no details, however, on several key items, *vis.*, production timetable, build volume, estimated cost, etc. In the absence of such information and in the light of GM's failure to deliver on promises of a mass-produced electric vehicle[1], some industry observers were skeptical that GM actually intends to commit the Impact to production in quantity.

Other Doubting Thomases note that although the car does offer vastly improved range and acceleration, using a lead-acid battery is hardly a breakthrough advance. The 320-volt battery is heavy (870 pounds, more than one-third the stated curb weight) and would need to be replaced every 20,000 miles or so, at a cost in today's dollars of about $1,750.

One independent analyst, factoring in the cost of the battery, computed the equivalent purchase price to be about $32,500, probably far too much to interest all but well-healed collectors, electric-car *aficionados*, environmental evangelists and the like. For the same price, you could, for example, buy five high-mpg Hyundais. Moreover, once the kilowatt usage is factored in, the total operating cost works out to be roughly twice that of a gasoline-powered car.

How sincere and how serious GM is remains to be seen, of course.[2] Since the original announcement on April 18, 1990, GM has already done some backpedaling, indicating that production would not commence until battery life can be at least doubled, to 40,000 miles. Interestingly, it is known that Isuzu, a GM affiliate, has been working for two years on a new-wave battery. Isuzu scientists reportedly have developed an electric power storage

1 *In the late Seventies, at the peak of the second oil crisis, General Motors announced intentions to build 100,000 battery-powered cars annually by 1984, and furthermore, that by 1990 a tenth of its total production volume would be in electric cars.*

2 *Ford and Chrysler, in addition to several foreign-based VMs, are known to be conducting serious experiments with electric prototypes. So too is a small, two-year-old company known as American Motion Systems, Inc. (AMS), of Camarillo, CA. Its founder, Dan McGee, has invented a new variety of electric engine, one which he claims offers extended travel - up to 500 miles. Moreover, it eliminates several major components, including transmission and brakes. The engine differs in that it is a turbine, powered most likely by grain alcohol. McGee says the electric turbine produces safe speeds of rotation about five times greater than present electric-motor technology while reducing materials requirements by 60%. The elimination of major components would reduce the overall weight of today typical mid-sized sedan to about 2,000 pounds, without sacrifice of power, fuel economy or handling characteristics, according to McGee. He says the engine easily meets 1997 EPA standards for emissions. [Source: UPI wire story in San Francisco Examiner, April 15, 1990]*

system with 40 times the so-called cranking power (peak load) of a conventional lead-acid battery.

Project partner Fuji Electrochemical says output density (watts per kilogram) is 20 times greater than for a lead-acid battery, that its weight is 1/20th of same, and that the unit can be recharged in 30 seconds or less! The power unit is said to use activated charcoal as its energy source, which is cheaper than the lead-acid battery.

The Impact is by no means the only breaking, if not breakthrough, development involving futuristic technology. The day after GM announced the green-light decision on the Impact, Southern California Edison Co. and the Los Angeles Department of Water and Power revealed plans to build a road that transfers electric power from underground cables to cars and buses on the surface, without physical contact.

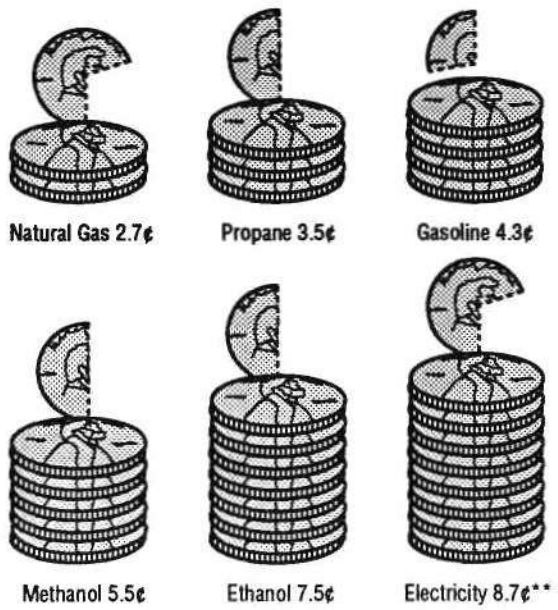
The $2-million demonstration project, in a new residential development called Playa Vista, entails burying cables beneath 1,000 feet of roadway. The cable would produce a magnetic field at the road's surface. A metal plate on the underside of a specially outfitted car would convert the magnetic force back into electricity to recharge the car's battery. (The cost of laying the cable is estimated at $200 per participating vehicle per year.)

The vehicle would run on ordinary rubber tires and would not look noticeably different from a standard gasoline-powered model. But the undercarriage metal plate would descend to within 1.5 inches of the road's surface when the power was available.

It is claimed that the technology could make the cruising range of electric vehicles virtually unlimited, especially if big highways and major arterials were "energized."

The impetus for developing gasoline-substitute, or "alternative-fuel," vehicles is by no means marketplace-driven. It's mandate-legislation driven, most recently in the form of the 1990 Clean Air Act, which, together with other laws already on the books, forces auto manufacturers to seek - and to find - practical solutions aimed, among other things, at reducing 1) the nation's dependence on foreign oil (now exceeding 50%) and 2) tailpipe emissions. (See "Government Regulation," p. 117)

Alternative fuel costs



Costs per mile of operation
**Includes battery amortization
Source: California Energy Comission

Accordingly, a number of major VMs worldwide, including each of the Big Three, have developed prototypes that do indeed run on substitute or reformulated (cleaner-burning) fuel, and each says it can produce a car that automatically adjusts to different mixtures of gasoline and/or methanol. These so-called flexible-fuel vehicles (FFVs), it is said, only need sufficient lead time for engineering and tooling before production can commence in earnest.

In March of 1989, the South Coast Air Quality Management District voted to require all cars to run on electricity or other "clean fuel" by 2007. The Los Angeles Basin thus has become the hot test bed for real-world experimentation with alternative fuels and alternative vehicles. Southern California has gained this prominence because of its human and vehicular densities and its consequent air pollution, EPA-rated as worst in the nation.

One of many alternative-fuel prototypes undergoing a 12-month test, through spring of 1991, is a Toyota Corolla FFV. The 1.6 liter, 4-cylinder EFI engine has a comparatively high compression ratio of 9.5:1. The modified engine uses corrosive-resistant metals for "key parts." A capacitance-type alcohol sensor measures methanol levels in the fuel mixture and relays information to the ECU (engine control unit), which, in turn adjusts fuel injection and ignition timing accordingly.

The overriding reason that this Corolla and other FFVs are being tested is the specter of regulatory mandate. To wit, the California Energy Commission has stated it wants no fewer than 5,000 fully driveable FFVs on California roads by 1992.

Although other kinds of alternative fuels are being field-tested - hydrogen, methane (natural gas), propane (liquid petroleum gas), ethanol (grain alcohol) and reformulated gasoline - what seems likeliest to emerge as the gasoline substitute of choice is a chem-lab concoction of methanol and gasoline. The favored mixture, consisting of 15% methanol and 85% gasoline, is dubbed M85.[1]

Another candidate, one being strongly pushed by the oil industry, is reformulated gasoline. Oil industry people contend that reformulation of gasoline makes most sense economically and practically because 1) the distribution system is in place and 2) no redesign or retooling of engine or fueling systems is needed. Environmentalists counter that reformulation is but a token gesture, a Band-Aid approach to the serious and worsening problem of air pollution (see "World Standards," page 92).

(In April 1990, Shell Oil Co. introduced in 10 U.S. cities - including all nine identified by the EPA as having the dirtiest air - a reformulated "green gasoline" claimed by Shell to meet the stricter tailpipe-emission standards proposed for 1992 in California [see "Government Regulations," page 117]. Shell thus joins a growing parade of oil companies in test-marketing a cleaner-burning gasoline. Others include Atlantic Richfield (ARCO), Phillips, Exxon, Amoco, Mobil, Citgo, Marathon, and Sun Oil (SUNOCO). To date, Shell's pilot program is the broadest geographically.[2]

Politics, vested interests, "infrastructure" and expedience aside, one of the most compelling arguments for so-called flexible fuel is that no driver action is required other than to buy the fuel of one's choice, depending on availability at any given time. Moreover, only one fuel tank is needed.

The "flexibility" in "flex fuel" refers to an electronic sensor that finely measures the amount of alcohol in the fuel in the tank. The sensor sends a signal to the microprocessor or onboard computer, which in turn adjusts the fuel flow and spark timing to optimize whatever mixture is in the tank.

The oxygen sensor used on today's gasoline vehicles to control air-to-fuel ratio does the final trimming to ensure that the engine always operates as close to stoichiometry[3] as is possible, irrespective of the fuel used.

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1 *Published results of a Delphi survey by Camden Corp., a research firm that works closely with the U.S. Dept. of Energy, indicate that if gasoline were to be pump-priced at $1.50 a gallon in 2010, 5% of all automobiles would be methanol-fueled as would be 4% of light trucks and 2% of heavy trucks.*

2 *A) Shell's new gasoline, marketed as SU2000E, replaces the company's premium grade at more than 2,000 service stations in the 10 cities involved: Baltimore, Chicago, Hartford (CT), Houston, Los Angeles, Milwaukee, Philadelphia, San Diego and Washington. Shell said in published reports that it expects SU2000E to cut tailpipe emissions by up to 10 percent in Los Angeles and Houston, the two cities with the worst air quality (as ranked by the EPA). SU2000E cuts hydrocarbons by 13% and carbon monoxide by 10%, while giving off slightly more nitrogen oxide (+2%), according to company officials, who note that engine performance ("driveability" characteristics) is unaffected. The Shell substitute additive, called methyl tertiary-butyl ether (MTBE), is used in lieu of butane (a known carcinogen) to reduce volatility while boosting octane. B) The vice-president of marketing for Marathon has been quoted as saying, "Methanol will be the fuel of the future. But reformulated gasoline will be the predecessor to alternative fuels like methanol." [Source: Automotive News, April 16, 1990].*

3 *Stoichiometry is defined as "the calculation of the quantities of chemical elements or compounds involved in chemical reactions." [Random House Dictionary of the English Language, Second Edition, Unabridged, 1987] Relative to engine control functions, it means that the engine is operating at an air-fuel mixture value that is as close as possible to the most efficient point for 3-way catalyst in the engine's exhaust. Thus peak efficiency and lowest emissions are ensured.*

Pros and Cons of Various Alternate Fuels
(List, Arguments Not Exhaustive)

FUEL	FOR	AGAINST
HYDROGEN	1) Potential for very low emissions (water is only by-product) 2) Burns readily over broad range of air-fuel mixture ratios 3) Desirable thermodynamic properties	1) Much R&D remains 2) High production costs 3) Likely storage problem 4) Fear factor by general public ("Hindenburg remembered")
ETHANOL	1) Potentially a good spark-ignition engine fuel, either in pure form or mixed with gasoline as extender 2) Can be produced from indefinitely renewable-biomass sources - e.g., corn, sugar 3) Requires relatively minor vehicle modification (roughly half the cars in Brazil run on ethanol)	1) Very expensive to manufacture (3 to 4 times cost of gasoline) 2) Only 2/3 energy content of gasoline, thus reduced cruising range 3) Comparative low volatility makes for hard cold-weather starts
REFORMULATED GASOLINE (i.e. gasoline with substantially lowered concentrations of emission-producing benzene, aromatics, olefins, sulfur & vapor pressure but with higher octane ratings - in short, "cleaner-burning" gasoline)	1) Politically far more palatable to oil industry than any other option 2) Technology, infrastructure in place to produce in relatively large volume 3) Requires only minor modification of vehicle 4) Benefits for all cars & trucks, especially pre-catalytic converter era vehicles 5) Likely far better public acceptance than for any other AF candidate	1) Uses rapidly diminishing fossils, thus only a stop-gap or partial solution 2) Only modest reduction of tailpipe and evaporative emissions 3) Delivered price (at pump) a question mark
METHANOL (see text above, page XX)		
LIQUEFIED-PETROLEUM GAS (LPG)	1) Here now and in limited use, mainly specialized applications here and abroad (e.g., govt. vehicles, taxis, small buses, lift trucks) 2) Low carbon monoxide emissions and hydrocarbons formed less damaging to ozone layer than is gasoline 3) Can be liquefied at moderate pressure, yielding decent cruising range 4) Mixes readily with air, assuring easy starting and low cold-cycle emissions 5) High octane rating	1) Very limited supply. As by-product of refined petroleum, limited to 2%-3% of U.S. fleet 2) Like gasoline, obtained from non-replenishing fossils 3) Requires different fuel metering - engine management system
NATURAL GAS (METHANE)	1) Outstanding spark ignition 2) High octane rating (c. 130) 3) Burns cleanly and thoroughly; produces less CO_2 per unit of power delivered than gasoline because of higher hydrogen/carbon ratio 4) Huge cost advantage 5) Abundant supply; distribution system in place nationwide	1) Like that of hydrogen, main drawback is onboard storage - combustibility hazards 2) Cruising range lower than that for gasoline 3) Requires different fuel metering - engine management system

One of the big breakthroughs for methanol use came in 1986 when a practical cold-start system was developed that meets the industry standard for cold starts at -20 degrees Fahrenheit. (The proprietary system reportedly uses variable electronic fuel injection combined with a sensor to measure fuel composition.)

But the fuel of the Nineties, nudges from Washington to adopt substitutes notwithstanding, will be that which has prevailed virtually unchallenged for the past eight decades - ethyl gasoline.

How quickly and how extensively alternative fuels come into everyday use in private and commercial transportation most likely will be determined mainly, as has been the case since the first oil embargo of 1973, by the prevailing barrel price of crude oil as fixed by OPEC.

For so long as gasoline is perceived by the majority of Americans to be acceptably priced, there is little or no incentive either by the general populace or by public officials at the federal level to push in earnest for an alternative to gasoline, notwithstanding the growing dependence on foreign sources and notwithstanding the demands from increasingly vocal and increasingly powerful environmental groups to cease fouling the air we breathe.

For automakers, the biggest single incentive thus far to get moving on development of alternative-fuel vehicles is the Alternative Motor Fuels Act of 1988. This Act recognizes the FFV as a potential nonpetroleum use, thus according it favorable treatment in calculating each manufacturer's Corporate Average Fuel Economy (CAFE). (See "Government Regulations," p. 117)

If we do in fact see genuine alternative-fuel vehicles (as distinct from vehicles using reformulated gasoline) in private-fleet use in appreciable numbers, Dataquest believes - based on research and first-party interviews with government officials, involved industry professionals, academicians and proprietary-interest entrepreneurs - that the probable scenario to unfold as follows. First we will see conventional FFVs, then (once the infrastructure is in place) gasoline-tolerant methanol vehicles (GTMVs), then vehicles dedicated to run either on M85 or M100 (pure methanol).

Should the day come when alternative-fuel vehicles are welcomed - or, more likely, forced - into the marketplace, as distinct from being a government-mandated "S.O.P." or a be-the-first-on-your-block novelty, there will an impact on the electronics required to manage these multi-fuel systems. To date, the vehicles under test in the field make use of modified engine control modules with multi-fuel capability.

One key to this technology is the development of low-cost, accurate, and reliable multi-fuel sensors, which can determine the composition of the fuel being used. While a few commercial sources for such sensors now exist, they are still expensive by automotive production standards. The capability of recognizing different fuels, and adjusting the engine to meet performance and emissions standards will increase the complexity of the engine control from today's levels. Additional memory will be required to store a variety of control algorithms which may be selected based on the fuel mix.

As manufacturers get further down the learning-curve on FFVs (i.e. by the late-nineties), then adaptive controls may be called upon replace the look-up methods now used in most engine management systems. Such an approach will press the limits of today's technologies as greater processing power and speed will be required to realize truly adaptive controls. It is anticipated that by this time, there will be tremendous new opportunities for engine control electronics capable of adapting to a new world of multi-fuel vehicles.

SMART HIGHWAYS: LANDSCAPING THE FUTURE

The United States has more registered passenger cars than any other country - some 135-million, one for every 1.2 licensed driver. Roughly 110-million commuters, double the volume of 1950, jockey for ever-diminishing space on freeways and surface streets. As the ranks of motorists continue to escalate, so too, of course, does traffic congestion.

Highway traffic volumes are forecast by the U.S. Department of Transportation (DOT) to double on America's highway network by 2020, to 3.8 trillion vehicle miles of travel compared with 1.9 trillion in 1988. DOT statistics indicate that 2-billion vehicle hours of delay a year owe to traffic congestion, resulting in an estimated $73-billion loss to the nation. (Elimination of such a dollar loss for just two years would save enough money to build anew, in today's dollars, our entire 44,600-mile interstate highway system.)[1]

However bleak the outlook may seem, relief, if not a remedy, for swelling traffic congestion may lie on the horizon. Like other countries, America is creeping toward development of what is called the "smart," or "intelligent," highway system. It has four chief components:

(1) A navigation system [see "Navigational Aids," p. 112] installed aboard the vehicle;
(2) A traffic control center that monitors vehicular flow into, out of, and within urban areas;
(3) Two-way communication between vehicle and traffic control;
(4) Sensors embedded in the pavement to detect traffic density and real-time vehicular speed.

Research toward developing smart highways in America is slow getting started and is meagerly funded by the federal government - $100 million a year, a pittance compared to what other nations are investing. Here, the bulk of the R&D activity lies in the hands of academicians. For example, a group at the University of California at Berkeley is working on highway electrification as a source of vehicle power. Both at the University of Michigan and at Texas A&M University, other proprietary groups are conducting experiments for possible future smart-highway application.

The federal government's biggest dollar involvement to date concerns a 13-mile stretch of southern California's often- gridlocked Santa Monica Freeway (I-10). By spring of 1990, this stretch and feeder arterials was to be launched as the nation's first "Smart Corridor." Sensors embedded in the pavement send a continuous signal to a traffic control center, which, in turn, electronically adjusts the timing of freeway-ramp metering signals. Eventually, satellite-based "eyes" may track individual vehicles.[2]

Linked with the Smart Corridor is a separate Pathfinder project, a demonstration experiment along this same segment of the Santa Monica Freeway. Central to Pathfinder are 25 1989 Oldsmobile Delta 88 sedans provided by General Motors, a Pathfinder co-sponsor together with the California Department of Transportation (CalTrans) and the Federal Highway Administration. Each car is outfitted with an onboard navigational CRT, the Etak Navigator, from Etak, Inc. of Menlo Park, CA.[3] (See "Navigational Aids," p. 112) Chief immediate goals of field-testing are to ascertain what benefits, if any, accrue to the driver

1 According to the Federal Highway Administration, the number of vehicle miles traveled on urban freeways annually between 1984 and 1987 increased 22%. During this time the miles of new urban freeways increased only 5%. Total hours of delay on freeways rose 57% between 1983 and 1985, and was projected to rise 400% by 2005. Meantime, no new major road construction is foreseen.

2 Benefits of advanced traffic-management systems, based on measurements of 180 surface-street intersections in Los Angeles: 20% reduction in delays; 35% reduction in stops; 10% reduction in emissions; 12% reduction in fuel consumption; 13% reduction in travel time. [Source: Smart Cars, Smart Highways, Highway Users Federation.]

3 Adapting technology developed by Etak, General Motors will offer a Delco Electronics- manufactured dead-reckoning map-matching navigation system called NAVICAR at an unspecified future date.

and the overall costs of the communication system. General Motors says that Pathfinder could cover Los Angeles by 1994 and spread nationwide to as many as 50 cities by 2004.

As the Smart Corridor-cum-Pathfinder project was ramping up, in April 1990 the DOT announced details of another IVHS project - TravTek - in Orlando, FL. It is to be conducted jointly by agencies of federal, state and local governments.

As with Pathfinder, General Motors will be involved, supplying vehicles equipped with navigation systems for the two-year road project, which could commence as early as October 1991. Of the 100 cars GM will provide, 75 will go into local rental fleets (Disney World and Tupperware Museum are major tourist attractions) and 25 will be placed with local high-mileage drivers.

The project carries an estimated pricetag of $10 million, one-quarter of which the co-sponsoring Federal Highway Administration will fund.

Reportedly, two rival CD-Rom-based navigational systems will be employed: Etak's and that made by Navigation Technologies of Sunnyvale, CA. Each will use a 6-inch color CRT mounted on the dash. Data will be transmitted between the cars and a control center via a VHF FM system operating at 800 Mhz. The cars also will be outfitted with cellular phones. GM is to have overall responsibility for the project.

The University of California at Berkeley, meanwhile, is engaged in what to date is the nation's most ambitious "ivory-tower" project involving IVHS[1] technology. Called PATH, it features as major elements highway electrification and automation, including numerous automatic vehicle control (AVC) concepts.

The six-year project, begun in 1986, has a budget of $56 million. PATH consists of three main field-test phases:

1) Santa Barbara electric bus project, to complete development of roadway electrification.
2) A 6-year, $40-million R&D project to bring electrification and automatic technologies to fruition by the mid-1990s on HOV-type facilities.
3) A 12-year, $600-million national consortium spearheaded by California, Texas, Illinois and Michigan.

Texas A&M University is in the second year of a developmental project funded entirely by the state's Department of Highways and Transportation. Work is being done on an autonomous vehicle controlled by two stereoscopic cameras linked to a compact, onboard computer (386/20 Compaq). A camera is mounted over the front seat of a Dodge minivan. The vehicle can brake, stop and start the engine from a cold start, all automatically. It also has collision-avoidance capability.

A Texas A&M program official says the state has committed $400 million to establish traffic-management centers in six cities - Dallas/Fort Worth, Houston, San Antonio, El Paso and Austin. The timetable, he says, calls for four to five miles of Hwy. 75 in Dallas to be "smart" by 1992 along with about 40 miles of roadway in Houston. The university also is involved in a related, $1.5-million project to develop state-of-the-art freeway-design operations.

In April 1990, the Illinois University Transportation Research Consortium - composed of the University of Illinois at Chicago, Northwestern University, and the Illinois Institute of Technology - announced plans to launch a 200-square-mile IVHS project on Chicago's northwest side.

It would link thousands of navigator-equipped passenger cars and commercial and municipal vehicles to a traffic management center via Cover Plus, Motorola Corp.'s 800-MHz land-based mobile radio system.

In addition to using the vehicles themselves to collect data, the Chicago experiment, as yet

1 IVHS stands for Intelligent Vehicle Highway System. The technological components it embraces seek to improve 1) highway safety; 2) vehicular operating efficiency; 3) environmental quality and 4) energy usage.

unnamed, would integrate traffic information collected by loop detectors buried in the road surface and by video tracking cameras. If approved and funded, the experiment could begin as early as 1992. It would be operational 36 months.

Another example of a multistate support consortium is HELP (HEavy vehicle License Plate). Tests are being conducted to determine whether heavy-duty trucks operating along a major truck corridor are able to use transponders to communicate "on the fly" with state regulatory and law-enforcement officials, thereby eliminating delays caused by manual verification of regulatory compliance. The information transmitted replaces the manual verification of certain mandatory truck documents and weighs the truck as it crosses state borders. The project site is along Interstate 10 from the New Mexico-Texas state line, west through New Mexico, Arizona and California to the Los Angeles area, then north along I-5 north through California, Oregon and Washington to the Canadian border. There are 28 toll-collection points.

The Highway Users Federation for Safety and Mobility (HUFSAM), a Washington, D.C., lobbying group, has drawn up a $1-billion, 10-year action plan called Mobility 2000. To start with, HUFSAM wants computerized traffic monitoring and management systems and emergency-vehicle priority at intersections in the U.S. within 20 years. It also wants an international agreement on how cars will "talk" to highways and on which radio frequencies to reserve for the dialogue. By strong consensus, industry experts view both Europe and Japan as being far ahead of the U.S., not in development of technology but where it counts - in real- world application.

Most of the European IVHS programs are subsets of EUREKA, a $5-billion R&D endeavor aimed at improving Europe's industrial competitiveness. Under the EUREKA banner, the principal IVHS cooperative effort is PROMETHEUS, a seven- year, $800-million undertaking begun in 1986. It involves European automakers and the governments of 19 countries. The idea is to create concepts and find practical solutions toward making vehicles safer, more economical to operate, and more environment-friendly. If successful, PROMETHEUS also will make traffic management far more efficient. The end objective is to develop a totally integrated highway transportation system throughout Europe. Indeed, safety is a key element; the target is to reduce European traffic casualties by half by 2000.

Other related European R&D programs:

- **EUROPOLIS** - A $150-million, seven-year project to design automated systems for the next century and to develop technologies toward automating driver functions
- **CARMINAT** - A four-year project to develop in-vehicle electronic navigation and communications systems
- **ARTIS** - AN $8.5-million, five-year project with the objective of providing pretrip information on traffic conditions to tourists
- **ERTIS** - A $2.7-million, three-year project to develop a common road information and communications system for commercial motor carriers across Europe

Another European project with safety a prime objective is DRIVE. This three-year, $132-million undertaking was formally adopted by the European Community in 1988. Funding is half from government, half from industry.

Two IVHS programs not associated with EUREKA are ALI-SCOUT and AUTOGUIDE. The former is a route-guidance system developed in West Germany by Bosch/Blaupunkt and Siemens Automotive. It utilizes infrared transmitters and receivers to transfer navigation information between roadside beacons and onboard displays in appropriately equipped vehicles. Earlier versions of the ALI system were tested along a 60-mile stretch of the West German autobahn. The more advanced ALI-SCOUT system has been tested in Munich and West Berlin.

Yet another route-guidance system incorporating infrared transmitters and receivers is AUTOGUIDE, developed in England. A pilot test is in progress in the Westminster section of London and in a corridor between

London and Heathrow Airport. It is expected that roadside beacons will cover all of Greater London and then the entire country within a few years.

In Japan, an experiment in progress, AMTICS, is considered the most advanced of any to date. An integrated traffic information-navigation system displays on dashboard-mounted CD-ROM CRTs current traffic conditions gathered at traffic control and surveillance centers managed by the police in 74 cities. Via teleterminals, traffic control provides continuously updated real-time information on vehicle position and direction, traffic conditions, roadwork and public parking availability. AMTICS may also be used by taxi and trucking companies and other businesses to operate their fleets more efficiently in the field.

The pilot project, begun in 1988 in Tokyo, involves 59 private corporations, among them automakers and electronics firms. The first commercial derivative of AMTICS is scheduled for launch in Tokyo and Osaka in 1990. Expanded application is expected in future years.

A second effort in Japan, RACS (Road Automotive Communication System), was launched in 1986 by the Ministry of Construction in cooperation with 25 private organizations. It consists of roadside communication units, or microwave "beacons," car units and a system center. In addition to navigation information, the system supplies continuously updated advisories on traffic and weather. RACS may also be used to seek out the shortest route to a given destination and to transmit and receive visual information on maps.

Subsequent refinements include installation in the vehicles of a digital road map of the test area, displaying shortest destination routes and possible downstream traffic congestion. The total concept of RACS underwent initial trial in November of 1989, using 15 cars and eight microwave beacons installed along 40 kilometers of the Tokyo-Nagoya and Metropolitan highways.

Smart highways in appreciable volume remain decades away, even in Japan and in Europe. Although the concept seems to hold much promise, by the time smart highways are operational in this country, enough so as to offer significant relief from traffic congestion, many a metropolitan area may well have long since reached virtual gridlock at peak times, if not around the clock.

Interim, partial solutions may, however, be at hand. Already, experiments involving Automatic Vehicle Identification (AVI) have been conducted in several states - New York, New Jersey and California.

AVI consists of three key elements:

1) A vehicle-mounted transponder or "tag"
2) A roadside reader unit with associated antennas
3) A computer system for processing and storage of data

Each AVI vehicle is given a unique ID number which is "read" at a distance via a radio-transmitted signal to a roadside receiver, typically located at or near a toll booth.

If the signal received is determined electronically to be from a vehicle with a valid ID code, said vehicle is permitted to pass through the toll booth unimpeded, that is, without having to stop for a cash transaction. The vehicle owner is sent an itemized bill monthly posting the toll charges, *a la* a credit-card statement.

This AVI concept is no pipedream. At present, AVI systems are functioning on the Dulles Toll Road in Virginia and in Jacksonville, Fla. AVI also has been tried in California on the San Diego-Coronado Bridge.

Peering much farther in the future, perhaps 20 or 30 years from now, we may see what is known as Automatic Vehicle Control (AVC). In theory, AVC helps the driver to perform certain vehicle functions. In its ultimate state, it relieves the driver of some or all control tasks. Dividends? Greater safety, more consistent driver behavior and vastly improved traffic-flow patterns.

There are three levels of AVC:

1) **Basic** - Provides driver useful informa-

tion and warnings transmitted from on-board sensors.

2) **Intermediate** - Assists driver with the control process, as by automatically adjusting the control of system characteristics.

3) **Advanced** - Allows control system to intervene and, as warranted, virtually "usurp" the human-driver function altogether.

Entering the Nineties, we are still largely at Level I but evolving rapidly toward Level II. Currently available AVC technology includes:

- Antilock brake system (ABS) (first commercial application in 1978 [Mercedes Benz])
- Traction control (late 1980s [Toyota])

Currently under development in the AVC realm:

- Variable speed control
- Collision-warning system[1]
- Radar braking (re. "collision-avoidance systems")
- Automatic vehicle-spacing control (maintains constant "headway" or space between vehicles fore and aft)
- Automatic steering control (vehicle guidance)
- Automatic trip routing and scheduling
- Automated highways

What's ahead for electronics suppliers? Opportunities through the end of the decade are seen as largely confined to the list cited immediately above, and most particularly to the first three items - ABS, speed control and traction control. As for ABS specifically, Dataquest projects that whether federally mandated or not, by the end of the decade ABS will be offered on virtually all passenger cars and perhaps light-duty trucks as well. (See "Government Regulations," p. 117) The forces of marketplace competition, if not Congress, will conspire to make it happen.

MAJOR INTERNATIONAL PROGRAMS

PATHFINDER (SMART Corridor)

Where: Los Angeles
Sponsors: Federal Highway Administration (FHWA), California Dept. of Transportation (CalTrans), General Motors.
Purpose: Test feasibility and utility of onboard navigation and external information systems in coping with traffic congestion on 13 miles of Santa Monica Fwy.
Features: Testing 25 Oldsmobiles equipped with Etak Navigators modified to superimpose traffic information on CRT map display. Packet radio data communications system used to communicate between vehicles and traffic control center.
Initiated: Scheduled Spring 1990.

RACS (Road-Automobile Communication System)
Where: Japan
Sponsors: Public Works Research Institute, Highway Industry Development Organization.
Purpose: Dispense traffic and route-guidance information.
Features: Microwave radio beacons provide location information to vehicle, microwave radio links provide road traffic information, microwave communications beacons provide two-way data links for individual on-board messages, paging, facsimile. Dead reckoning combined with map-matching used for navigation between beacons; system requiring 20,000 beacons planned.
Initiated: 1987.

AMTICS (Advanced Mobile Traffic Information and Communication System)
Where: Japan
Sponsor: Japan Traffic Management Technology Assn.
Purpose: Enhanced traffic flow, highway safety.
Features: Car location, traffic and other information (e.g., parking availability, lodging). Traffic information from surveillance centers processed by computer at AMTICS centers, then broadcast to cars over new radio communication 900 MHz cellular-like teleterminal system.
Initiated: 1988.

PROMETHEUS
Where: Western Europe
Sponsors: 14 VMs under EUREKA, a pan-Europe project designed to improve Europe's competitiveness in world markets, and research institutes and electronics mfgs. from 19 nations.
Purpose: Reduce highway fatalities by half by 2000, increase transport efficiency, develop standards and specifications from which private-sector mfgrs. expected to develop commercially marketable products.

1 Consensus of industry professionals surveyed is that collision-warning systems will be available on passenger cars by 1995, and collision- avoidance systems by 2000 if liability issues are resolved. Meanwhile, so-called machine-vision systems that alert the driver when the vehicle nears an obstacle or when another vehicle approaches too rapidly could find their way onto passenger cars in the mid-nineties. [Source: Automotive Electronics Journal, 10/9/89]

Features: Communications networks between vehicles and from vehicle to roadside facilities processed by onboard computer.
Initiated: 1986.

DRIVE (Dedicated Road Infrastructure for Vehicle Safety in Europe)
Where: Western Europe
Sponsor: European Community
Features: Coordinated with PROMETHEUS, concentrates on roadside infrastructure and smart communications systems for vehicles. **Initiated**: 1986.

SELECTED OTHER PROGRAMS

ARI (Automatic Radio Information)
Where: West Germany, Switzerland, Austria, Luxembourg.
Sponsors: Above-named countries.
Features: Official traffic broadcasts picked up on car radios equipped with ARI decoders. Regional sideband FM broadcasts transmitted along with 57 kHZ identification frequency so car radio can automatically switch to monitor each announcement live.
Initiated: 1986.

ALI-SCOUT
Where: West Berlin
Sponsors: Bosch, Siemens.
Features: Computer-based vehicle-guidance system that evaluates traffic congestion and flow. Provides driver with recommendations for best route(s) to use to avoid worst traffic. Tests in progress.
Initiated: n/a

AUTOGUIDE
Where: Great Britain
Sponsors: n/a
Purpose: Improve traffic flow, especially through heavily congested intersections. Tests under way in London. Uses same equipment as ALI-SCOUT above.

Initiated: n/a