Vehicle Technology Trends in Electronics for the North American Market; Opportunities for the Taiwanese Automotive Industry

by

CENTER FOR AUTOMOTIVE RESEARCH

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The statements, findings, and conclusions herein are those of the authors and do not necessarily reflect the views of the project sponsor.

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Introduction

The purpose of this study is to conduct a preliminary investigation into the future business potential for automotive electronics, particularly for general Taiwanese companies. Although many Taiwanese companies are targeting China as a growth opportunity, our preliminary investigation was based on North America with the understanding that a more targeted investigation for China could be a future investigation. We recognized that the North American perspective would provide significant input, even to the Chinese market, because many of the auto companies and supplier's practices and projections are easy to generalize from since they are global.

Our approach was to take a broad, unstructured survey of industry expert opinions and readily available literature in order to grasp a qualitative perspective on the market potential and barriers for suppliers. We interviewed executives from OEMs and tier-1 suppliers to solicit their opinions about market growth, supplier relationships, technology development, and supply chain. The core information in this study came from industry interviews. There were a few areas of discrepancy, but overall there is a strong consensus about automotive electronics:

- The growth potential is enormous and represents the single most important area of innovation in the automotive industry today.

- The supply chain has well-established expert tier-1 companies with deep knowledge in a narrow range of technologies. Developing complementary technologies is highly desired and there appears to be a strong interest for companies to partner in co-development opportunities

- The high value added areas of the market will involve technology development, software and user applications, and systems integration.

- The established tier-1 companies and the auto companies voice loud warnings over uninitiated firms (i.e., electronic firms without specific automotive experience) entering the automotive supply chain without understanding expectations for research and development relationships, product development cycles, product performance requirements and validation, and financial requirements. None of these factors are a specific problem; however, together they are a significant and sometimes uniquely a big challenge for automotive suppliers.

- No one that was interviewed was aware of Taiwan's ambitions to transition from a recognized quality electronic hardware and technology provider to a more complex automotive technologies and intelligent car systems provider.

This report has three principal sections. Section 2 references specific growth opportunities for automotive electronics. Section 3 summarizes the industry interviews. Each interview started with a questionnaire (see appendix); however, the interviewee was encouraged to diverge on related topics of his interest. Section 4 incorporates interview results with CAR references to discuss supplier performance requirements for an electronics systems supplier. Section 5 is CAR's conclusions and suggestions to consider for next steps.

Active Safety

Safety Systems

Safety systems are in great demand from North American consumers. The three features they desire most in cars including side airbags, stability control, and backup assist, are all safety technologies. Furthermore, seven of the top ten most desired features are safety technologies[1].

North American consumers' demand for safety systems has both positive and negative implications for suppliers. Consumers demand safety systems to such a high a degree that in many cases they believe they should be standard equipment on the cars they buy. That means that they expect the price of safety technologies to be included in the standard price of the vehicle and are not willing to pay extra for them.

Active safety is the most significant emerging trend among safety technologies. Several active safety technologies, such as Electronic Stability Control (ESC), have been in use for several years and have proven their safety benefits. ESC has been shown to reduce 59 percent of Sport Utility Vehicle (SUV) and 34 percent of passenger car crashes[2]. Side impact airbags also have an established reputation for improving occupant safety during collisions. ESC will be required in all vehicles sold in the U.S. by 2012[3] and side airbags will be required on all U.S. sold vehicles by 2010[4].

Regulation by the U.S. government is expected to be the dominant factor driving the implementation of safety technology in the United States. The United States is known for being perhaps the most litigious country in the world. Because direct government regulation is used less than in most comparable countries, American consumers and businesses have engaged in a large amount of litigation to address areas where regulations are not specific or applicable. This element of doing business in the United States makes it very risky for the introduction of certain new technologies, particularly those relating to sensitive areas such as safety. For this reason, government regulation is expected to drive the implementation of safety technologies, as firms are hesitant to deploy active safety technologies to so litigious a customer base.

Active safety technology is considered the most risky for deployment in the highly litigious U.S. market. This is particularly the case with technologies that may, when detecting danger, take direct control of the vehicle. The potential for accidents occurring while the vehicle has taken control away from the driver poses a significant litigation risk. For this reason, active safety technologies in the United States may be limited to functioning as a warning to alert the driver of impending danger, but never taking away control in an effort to avoid the danger. The question of who is responsible when active safety technology fails is also a source of risk. The automaker that produced the vehicle, the supplier of components involved, as well as suppliers of software and programming, may all be exposed to litigation risk. Determining who is responsible for a malfunction presents one of the challenges of adopting active safety technologies.

[1] J.D. Power and Associates, 2006 U.S. Automotive Emerging Technologies Study
[2] NHTSA, Federal Motor Vehicle Safety Standards; Electronic Stability Control Systems
[3] Automotive News, September 25, 2006
[4] Automakers' voluntary agreement, Insurance Institute for Highway Safety (IIHS), October 5, 2006

Chart 1. Major Safety Systems Implementation (Model Year)

Chart 1 illustrates the anticipated timing of major safety systems implementation in the U.S. market. As previously stated, both ESC and side airbags have been available for over a decade[5] and will in the near future be mandated by the U.S. government for all vehicles sold. Apart from these two technologies, no introductions of major safety technologies are expected until 2008. During the brief period between 2008 and 2011, however, a significant proliferation of safety technology introductions is expected. Parking assist[6], lane departure warning, driver monitoring, and night vision are all expected to be launched in mainstream vehicles in 2008[7]. Infrared blind spot detection and Active Cruise Control (ACC)[8] are expected to be launched in 2009. Brake by wire technology is expected to be launched in 2011[9].

The functionality of blind spot detection systems is to prevent two types of accidents: lane change collisions and backover injuries. Major technologies of blind spot detection are:

Radar

- Good at range and velocity.
- Most popular among OEM products.
- Provides wider sensing angle.
- Valeo, Delphi, Siemens VDO, Hella.

Infrared

- Lowest cost, easy to install.
- Often used for aftermarket products.

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[5] Mercedes was the first model to install ESC in MY 1995. Volvo was the first model to install side airbags in MY 1995
[6] Toyota News Releases, April 12, 2006
[7] Delphi Press Releases, October 4, 2006
[8] Automotive Engineering International, November 2005
[9] Automotive News, October 30, 2006

Camera

- Good at identifying the shape of the object, as well as the width and angle to an object.
- Mostly for parking assistant/backup use.

Sonar (millimeter-wave radar, or lidar) - for both front and rear detection.

Cost is critical for market penetration and implementation. According to the J.D. Power and Associates 2006 US Automotive Emerging Technologies Study, blind spot detection ranks fifth among features most desired by consumers. It dropped to 13th place, however, when the market price of $500 was revealed.

The predicted wave of rapid introduction of safety technologies will bring numerous opportunities for not only the suppliers of those technologies, but also for the firms that will supply the components, sensors, and control modules these technologies will use extensively. The established reputation of Taiwanese firms as providers of world-class electronics should serve these firms well if they seek to apply their expertise to the electronics needs of safety suppliers.

Safety systems have a medium length adoption period, meaning that they typically need ten to twelve years after introduction to achieve significant levels of market penetration. ESC, for example, took more than ten years to achieve a 30% implementation rate[10]. Government regulation, such as the upcoming requirement mandating ESC in all U.S.-sold vehicles, can significantly speed up implementation of safety systems.

While the litigious nature of the U.S. market is a challenge for the introduction of safety technologies, the United States offers significant demand for safety technologies. In addition to the popularity of safety systems with U.S. consumers, the United States also needs to continue working to make its roads safer. In 2004, there were 6 million vehicle crashes in the United States, 42 thousand deaths, 3 million injuries, and a $230 billion economic loss due to vehicle crashes[11]. Rollover crashes, for example, are the most dangerous. While rollover crashes account for only 2 percent of vehicle crashes in the United States, they cause about 40 percent of accident deaths[12]. The proven track record of ESC in reducing rollover crashes has resulted in the U.S. government requiring it on all vehicles sold after the 2012 model year. These regulations are implemented by the National Highway Traffic Safety Administration (NHTSA).

NHTSA's mission is to save lives, prevent injuries and reduce economic costs due to road traffic crashes, through education, research, safety standards and enforcement activity. NHTSA sets the transportation safety agenda in the United States. In addition to conducting research related to improving transportation safety in the United States, NHTSA is responsible for implementing safety regulations. It is expected to be the chief determinant of safety technology implementation in the United States. Where the use of active safety technologies is mandated, the litigation risk faced by automakers and suppliers who produce the technology is reduced.

NHTSA currently has two initiatives underway that will drive the implementation of active safety technology in the United States. SAVE-IT is the Safe Vehicle using Adaptive Interface Technology program. IVBSS is a program addressing Integrated Vehicle-Based Safety Systems.

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[10] Ward's Auto, September 14, 2006
[11] NHTSA, Traffic Safety Facts, 2004 Data
[12] General Motors Rollover Crash Backgrounder, October 2006

The two programs differ in several ways, including the paths they take to improving safety. SAVE-IT is more heavily focused on single vehicle crashes while IVBSS seeks to reduce crashes involving multiple vehicles. The programs also differ in their approach. SAVE-IT seeks to find ways to help the driver manage the workload of focusing on multiple tasks simultaneously. The goal is to identify when the driver is distracted, fatigued, or not focusing on the road and use adaptive interfaces to help address the situation. IVBSS, however, seeks to use technology onboard the vehicle to reduce collisions caused by rear end crashes, road departure, and unsafe lane changes.

According to NHTSA, the development of SAVE-IT will spur ongoing industry efforts and create the basis for possible industry standards needed to achieve widespread application of a common adaptive interface. SAVE-IT is likely to result in changes to the vehicle interior, layout of electronics interfaces, and common usability from vehicle to vehicle. This will improve safety through reducing driver distraction and making collision and lane departure warning systems more effective.

Infotainment

Infotainment is much less controversial product area than safety. It holds the potential to be a good match for the expertise of Taiwanese firms. Unlike safety, consumers have demonstrated willingness to pay a premium for infotainment products.

Infotainment products have a short lifecycle which resembles that of consumer electronics more closely than it does the relatively long lifecycle of automobiles. This lifecycles results in consumers replacing external infotainment products more often than they replace their vehicles, giving producers of infotainment products potential for more frequent sales. The infotainment market is crowded with producers who have established brand names and reputations.

Chart 2. Major Infotainment Product Implementation (Model Year)

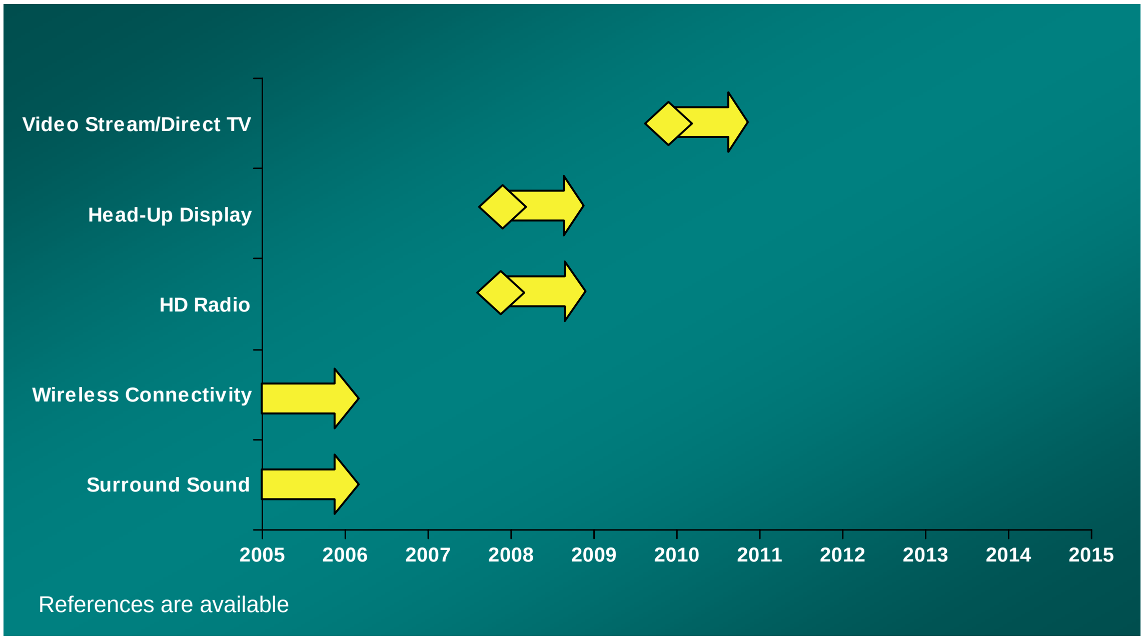

Chart 2 illustrates the anticipated implementation of major infotainment products. While wireless connectivity, particularly through widespread application of Bluetooth technology, is already in use in current vehicles. Surround sound has also already been installed in vehicles through cooperation between automakers and established surround sound equipment producers such as THX and Panasonic. While earlier versions of head-up displays have been available in the marketplace for a number of years, the first application of a new generation of these devices is anticipated in 2008[13]. Future head-up displays will address the brightness and resolution challenges of current systems while also being capable of displaying much more complex images, such as instrumentation, on the vehicle's windshield. While high definition radio has recently become available as an aftermarket product, it is not expected to see wide-scale original equipment application in mainstream vehicles until the 2008 model year[14]. The streaming of customized or on-demand content to vehicles is expected to appear in 2010[15]. The challenge automakers and suppliers face in providing this capability is not the technology necessary to display content. Rather, finding the necessary bandwidth or accomplishing sufficient compression to stream the content to the vehicle is the main obstacle.

Powertrain

Hybrid systems are the only technology-intensive alternative fuel application currently in wide application. While E85 vehicles may be considered as alternative fuel products, their low use of technology excludes them from consideration in the same high-tech category as hybrid and fuel cell vehicles.

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[13] Sanderson , John; Siemens VDO Automotive, *Autoelectronics*, May 1, 2005
[14] Delphi Press Releases, October 4, 2006
[15] Supplier Interviews

Hybrid vehicles have been most successful in the North American market. The different driving tendencies and the availability of low cost clean diesel fuel have resulted in hybrids being less popular among Asian and European consumers. North America accounts for 70% of global hybrid sales[16]. North American hybrid sales increased 35%[17] through the first seven months of 2006 compared to the same period in 2005.

Chart 3. U.S. Monthly and Cumulative Hybrid Sales 2004 Through Q1, 2006

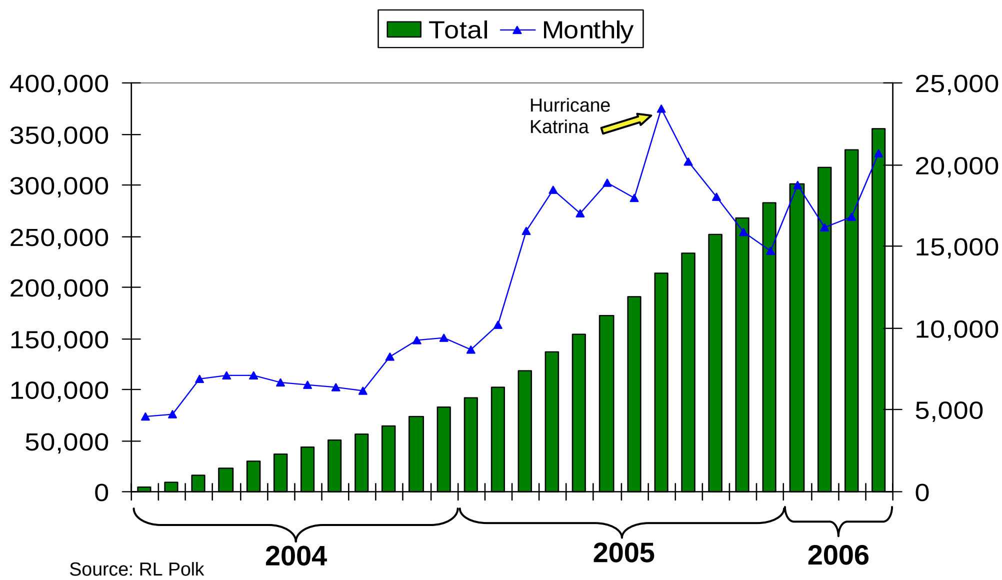

Chart 3 illustrates monthly and cumulative hybrid sales in the U.S. from 2004 through Q1, 2006. While growth of hybrid sales was initially constrained by a lack of supply to meet U.S. demand, introductions of new vehicles allowed U.S. hybrid sales to rise to a peak of nearly 25,000 units in August, 2005. Near the end of that month, Hurricane Katrina struck near the main base of U.S. fuel refining capacity, resulting in a dramatic increase in fuel prices. The sharp drop in hybrid sales during the months following this event is counterintuitive. One may expect that the high fuel prices that followed Hurricane Katrina would have been the perfect environment to increase hybrid sales. The sharp decrease in hybrid sales during that time is a strong indicator that consumers do not buy these vehicles primarily for the fuel savings they offer. Many hybrids appear to be purchased for their environmentally friendly and tech-savvy image. At current fuel prices, most buyers of hybrid vehicles will not realize a cost savings large enough to offset the premium paid for a hybrid vehicle over the cost of a conventionally-powered one. This uncertain economic benefit makes future hybrid sales difficult to forecast. A recent slackening of demand for hybrid vehicles suggests that current sales volumes can be expected to continue until new hybrid vehicles offering lower cost and greater fuel-efficiency reach the market.

[16] Automotive News, October 11, 2006
[17] Automotive News, October 2, 2006

Chart 4. Alternative Powertrain Technology Implementation (Model Year)

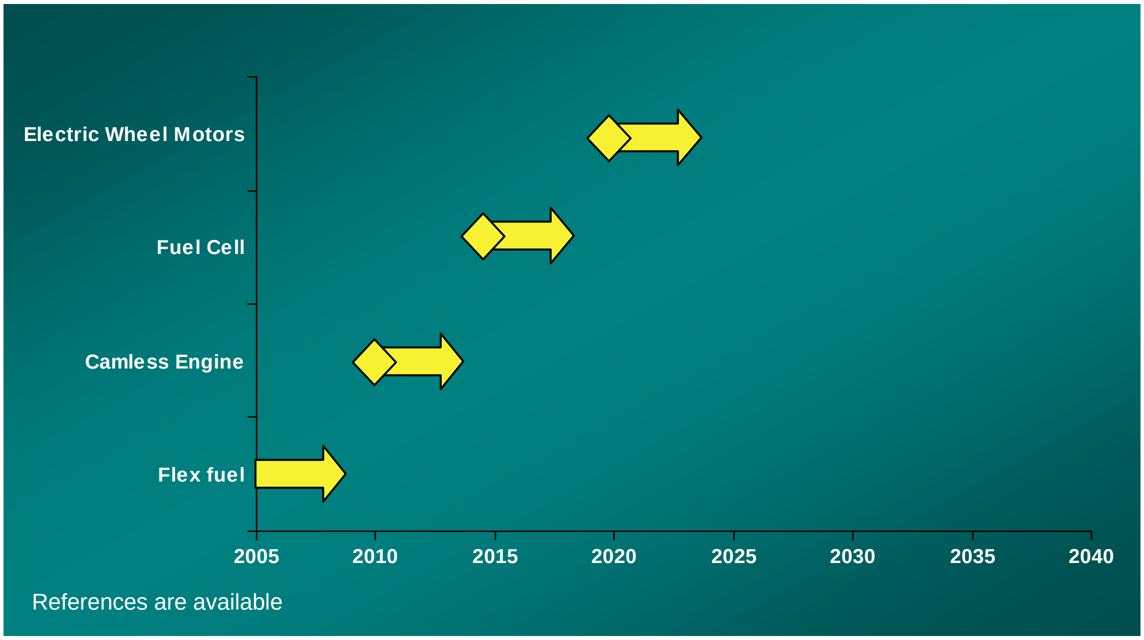

Chart 4 illustrates the anticipated implementation of alternative powertrain technologies in mainstream vehicles. As previously stated hybrid vehicles are already available. Flex fuel vehicles, capable of running either on gasoline or E85 (a blend of 85 percent ethanol and 15 percent gasoline), are also already on the market and widely available.

Camless engine technology, also known as electronic valve actuation, is expected to reach mainstream vehicles in 2010[18]. Camless engines are more efficient than conventional powertrains because they do not use a mechanical means of opening and closing the intake and exhaust valves. Instead, they use either magnetic or electric actuators to control the valves, which eliminates the need for less efficient mechanical components. Camless engines also allow for more precise control of the valves, which allows more optimal engine operation and reduced fuel consumption and emissions.

While vehicles running on fuel cells have seen limited deployment in trial applications around the world, they are not expected to be available in mainstream vehicles until 2015[19]. Fuel cell vehicles run on electricity generated by a fuel cell stack. They require hydrogen to produce the chemical reaction which generates electricity and produces no emissions or by-products other than water. Fuel cell vehicles make extensive use of electronics and may present an opportunity for the sourcing of hardware components from Taiwanese firms.

[18] 10 technologies that could improve the car of tomorrow, *Automotive News*, October 30, 2006
[19] USCAR-FreedomCAR Fuel Partnership plan

Purely electric vehicles are not expected as a mainstream offering until 2020[20]. While sophisticated and efficient electric engines are currently available, the introduction of these vehicles is constrained by the lack of necessary battery technologies. Currently available batteries do not offer the cost, power, and efficiency performance necessary for them to serve as a mainstream vehicle's sole power source. Likewise, battery technology is a limiter of the efficiency achieved by hybrid vehicles. Should a breakthrough in battery technology appear during the coming years, it would have the potential to drastically improve the business case for hybrid vehicles and to speed the introduction of battery-powered electric vehicles.

Table 1. The Cost of Hybridization

Parallel-series	Component	Integrated Starter Generator
$1,800-$2,200	Battery (NiMH)	$1,500-$1,800
$600-$680	Inverter (power conditioning)	$500-$550
$850-$900	Power Control Unit	$600-$800
$500-$600	Electric Motor	$700-$800
$350-$500	Generator	Not applicable
$50-$100	Transaxle/power conversion*	Not applicable
$4,150-$4,890	Total Target Cost	$3,300-$3,950
*Increase over replaced transaxle Source: CAR/Argonne		

Table 1 illustrates the estimated cost of hybrid vehicle powertrain components for the two main types of hybrid vehicles. Parallel and series hybrid vehicles are "true" hybrids, meaning that they can be driven using either electric power, engine power, or a combination of both. Integrated Starter Generator (ISG) hybrid vehicles, or "mild" hybrids, are less expensive but offer smaller efficiency improvements as they are not capable of running on electric power alone. Parallel and series hybrids are estimated to require between about $4,000 and $5,000 in powertrain components. ISG hybrids are estimated to require between about $3,300 and $4,000 in powertrain components, or about $1,000 less. The high cost of hybrid powertrains presents a substantial opportunity for Taiwanese suppliers to supply components for these systems.

[20] Siemens VDO press releases, August 8, 2006

Powertrain technologies have the longest lifecycle of any component used in vehicles. They are typically costly and time-consuming to develop. Once deployed in vehicles, they may last several lifecycles of the vehicles in which they are installed before being significantly updated. The cost and complexity of powertrain technologies makes them challenging to develop. While the powertrain domain, particularly hybrid electric vehicles, presents a potential opportunity for Taiwanese suppliers, it will be difficult to enter this market. Cooperation with established powertrain suppliers may be the strategy most likely to succeed in this area.

Telematics

Telematics technologies are the first step towards deploying a true Intelligent Transportation System (ITS). By enabling communication between the vehicle and the road system (Vehicle Infrastructure Integration, or VII) and between vehicles (Vehicle to Vehicle, or V2V), telematics promises to benefit both the driver and society as a whole by easing traffic congestion and improving traffic system efficiency.

Chart 5. Telematics Implementation (Model Year)

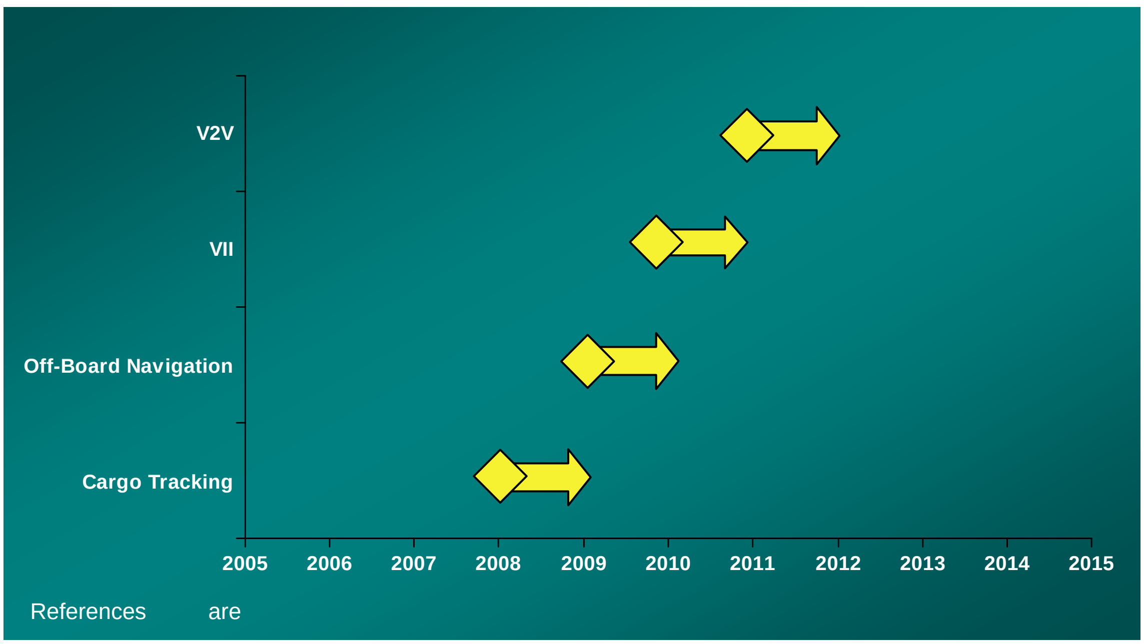

Chart 5 illustrates the anticipated adoption of various telematics technologies in mainstream vehicles. While cargo tracking is already in limited deployment among heavy cargo haulers, it is expected to see mainstream production levels around 2008[21]. Off-board navigation, in which navigation and traffic congestion data is sent to the vehicle from roadside sources, is expected to appear about a year later. In 2010, the first examples of Vehicle Infrastructure Integration (VII) are expected to be deployed[22]. A year later, in 2011, the first examples of Vehicle to Vehicle (V2V) communication are anticipated[23]. Each of these telematics systems is then

[21] Delphi displays at SAE Convergence 2006
[22] National VII Coalition plans
[23] 10 technologies that could improve the car of tomorrow, *Automotive News*, October 30, 2006

expected to continue increasing its market penetration, with the potential for universal adoption being ultimately mandated by government authorities.

Telematics technologies are extremely challenging to deploy as they require close cooperation between automakers, suppliers, government, and local officials. Two main consortia have been formed to address this problem. The Crash Avoidance Metrics Partnership (CAMP) is a consortium of automakers that includes Ford, GM, Toyota, DaimlerChrysler, and Toyota. Within camp, the Vehicle Safety Communications (VSC) group addresses V2V telematics solutions related to safety. The National VII Coalition seeks to develop standards for the implementation of VII technology. It is a cooperative effort among all the stakeholders necessary to implement telematics technology, including the United States Department of Transportation (U.S. DOT), ten state DOTs, automakers such as BMW, DaimlerChrysler, Ford, GM, Toyota, Honda, Nissan, and Volkswagen, as well as the American Association of State Highway and Transportation Officials (AASHTO).

Automotive telematics is currently estimated to be a $9 billion industry and is expected to grow to about $40 billion during the next ten years. As is the case with telematics, this domain appears to have many symmetries with existing capabilities of the Taiwanese consumer electronics industry. Through cooperation with consortia that seek to speed development and deployment of telematics technology, Taiwanese firms stand to benefit from the coming growth of this segment.

Although telematics products are just beginning to enter the market, they do provide significant value to customers. Telematics products such as GM's OnStar service provide improvements in safety. Although this benefit is not as clear as that of side airbags or ESC, telematics does provide certain level of life-saving functionalities, including emergency notification, stolen vehicle location assistance, remote door lock/unlock, and accident assist. Other information and services include travel arrangement, reservation, traffic and weather reports. The relatively low renewal rate of OnStar customers, however, can be interpreted as a sign that many consumers demand more.

Telematics navigation products have enjoyed popularity with consumers and are beginning to migrate to less expensive vehicle segments despite being relatively expensive. The chief benefit of these benefits includes turn-by-turn navigation that is integrated into the vehicle's audio system, as well as local information such as restaurants and points of interest for tourism. Information on traffic congestion and suggested routes to avoid it is beginning to be made available in North America after having been available in many European and Asian countries for several years.

In the future, it is possible that OEMs will take on the costs currently covered by subscription fees paid by vehicle owners. Greater interaction with customers is expected to be a trend. Likewise, real-time information on vehicles will be integrated into telematics products.[24]

The business model for the future expansion of telematics may resemble the model for cable television and cable internet: automobiles will be outfitted with some basic level of embedded telematics when built. Software and hardware functionality can be expanded later.

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[24] *Source: Day, John H., Telematics - it can save lives, but can it sell cars? Auto Electronics, July/August 2006.*

ROI is a major economic consideration for both the public and private sector. In the public sector, telematics has to demonstrate a positive benefit – a reduction of the social cost of delays, crashes, and environmental damages. In the private sector, telematics should provide an ability to generate revenues and make profits that meets the expectations of the OEMs and their shareholders.[25]

Industry Interviews

Industry interviews were conducted to gather a sense of the opportunity and challenges anticipated by knowledgeable individuals. Requests for interviews were sent to approximately twenty companies. The companies/individuals that provided information are identified in the acknowledgements near the beginning of this report. Information was collected from fourteen individuals across ten companies. Most individuals were interviewed one-on-one or over the telephone. One individual/company was not specifically interviewed, but provided information from company literature, presentations, and discussions.

The purpose of these interviews was to "get a pulse" on the industry opportunity that relates to automotive electronics and electronic systems. Our hypothesis was:

> ***"Taiwan industry is interested in positioning themselves at a high level in the supply chain for intelligent automotive electronic technologies."***

Questions were asked around four topics: market size/opportunity, technology standards, product development in powertrain, body (sensors) and telematics, and supply chain opportunities and requirements. The interview protocol (see appendix) was sent to most individuals beforehand to acquaint them with the interview topics. The data collection process was not rigorously controlled to compare results across interviewees, but rather allowed to free-flow so as to encourage individuals to express their opinions and thoughts about the subject. Consequently, the results tend to be qualitative and subjective and are not necessary complete. All interviewees responded to some of the questions, but no one responded to every question. Most interviews lasted about two hours. In spite of this approach, there were very few contradictions and a fairly strong consistent message. The results are summarized by each of the four major topics: market, technology standards, product development, and supply chain.

Market - Introduction

Several interviewees responded positively to the growth potential of automotive electronics. No one challenged the projected high growth rate. There was general agreement that 7% to 15% annual growth in automotive electronics is accurate. One individual indicated that 15% is feasible depending on the definition of automotive electronics and what the growth rate is based on (for example, whether or not to include established electronic devices such as radios, powertrain controllers, brake systems, etc. would affect the percentage growth rate).

The adoption rate of automotive electronics, regionally around the world, is guided by different factors. In general, it was pointed out that drivers in Europe, particularly in Germany, are among the world's most demanding for advanced technologies. This will create a technology

[25] *Source: ITS Orange Book—Smart Highways, Issue 1, 2005*

pull in this region. In Asia, particularly in Japan, the homogeneity of their culture, which is also evident in their automotive businesses, results in generally better integrated technologies. The situation in the U.S. is driven more by cost (and perceived value by the customer), and legislation.

The cost-conscious U.S. market is generally not actively pushing non-safety related technologies into the vehicle. In fact, there are some attempts to “de-content” the vehicles in order to reduce their cost. Auto companies try to maximize vehicle “residual value” after the initial vehicle lease period (3, 4 or 5 years) in order to minimize the monthly lease payment made by the consumer. Adding additional electronic technologies is counter to this effort because their value decreases much faster than the rest of the automobile, resulting in a higher initial cost with little contribution to the residual value. The initial cost of adding a new technology to the vehicle and the customer’s willingness to pay for it will greatly affect market growth in the U.S. Technologies involving vehicle to vehicle communication were cited as one example where the technology is available, but the business case (cost versus benefit) is not there yet. Either a stronger need for the technology needs to be developed, or the cost needs to come down to make it viable.

In the short-term, vehicle infotainment and telecommunications are seen as major growth areas. A survey by the Telematics Research Group indicated that between 2007 and 2011 that both OEM and non-OEM (aftermarket) telematics sales growth will grow over 100% per year. The OEM will focus more on in-the-vehicle communications while the aftermarket will focus more on external vehicle communications. Most see this growth occurring in two parallel paths: one with the auto company (OEM) focusing on integrating these technologies, and one with the electronics companies introducing the technologies.

As with the personal computer, demand for infotainment technologies will be tied closely to the development of applications. Companies that find “killer applications” will be key players. It was emphasized repeatedly that the software (application) development of electronic systems is far more important and financially appealing than the development of hardware, which is more commoditized, competitive, and tied to low operating margins.

The rapid development speed of the electronics industry will move faster than the OEM, so the application of technologies in the car will generally lag the consumer industry. Non-safety related technologies (e.g., radio, PDA, DVD, cell phones, GPS, etc.) will continue to be developed in the consumer market and the OEMs will continue to be pressed to support interfaces of these technologies into their vehicles. (Developing a standard interface is still a problem for the industry.) One example was pointed out where OEMs initially attempted to control the consumer electronics that were introduced in the vehicle and failed in the case of the cell phone. The phone was introduced in high-end vehicles as an expensive option and they became obsolete well before the vehicle did.

Figure 1. Connectivity with consumer electronics into the vehicle's electronic system is a recent development.

Many OEMs are now allowing an interface into the vehicle's electronics (e.g., controller/display in the instrument panel) either through hardwire or Bluetooth connections. Thus far, the communication has been selective and one-way with the vehicle extracting information from the consumer electronic device. The OEM will closely manage the human machine interface (HMI) between the vehicle and the operator. This interface involves vehicle safety and potential liability. Many individuals believe that very little data will ever be shared from the vehicle to a consumer electronic device unless there is a need to support public applications/services or safety needs. The OEMs will likely develop significant firewalls between the vehicle electronic systems and any consumer product that connects to the vehicle. The analogy that the car will become a "computer on wheels" is inaccurate because of the open operating system that exists on a computer will never likely exist on an automobile.

There is a growing trend toward non-OEM accessorizing of the vehicle in multiple areas including electronics. The Scion example allows for a simple product mix at the factory helping to contain costs, while allowing for more extensive accessorizing and personalizing of the vehicle with options available through the dealer network. The generic "vanilla" vehicle platform is shipped with the expectation of adding various plug-and-play options at the dealership (or aftermarket). The aftermarket availability of accessories, especially electronics, has mushroomed in North America with the huge growth of the Specialty Equipment Manufacturers' Association (SEMA, www.sema.org). SEMA products represent hundreds of electronic technologies that, in some instances, are intended to replace ones from the OEM (e.g., radios, powertrain controllers, DVDs, televisions, etc.), or interact with OEM equipment. There are several issues that confront the SEMA companies:

- SEMA involves an eclectic group of companies that are difficult to coordinate.
- Warranty issues when an aftermarket technology affects the vehicle's performance.
- Many companies work in isolation from the OEM even though their technology may interact with OEM devices. The ability of the aftermarket companies to integrate their technologies into improving ***system*** performance is limited.

There may be legal issues involving safety and liability.

Figure 2. The Scion example of combining both OEM and aftermarket customization.

One barrier was identified that could affect the cost/benefit of multiple technologies or applications. The pipeline of getting data into and out of the vehicle was mentioned as a roadblock to numerous applications. Several methods were mentioned that communicate data (cellular, satellite, DSRC, etc.), but all have limited capacity and availability in the U.S. Consequently, applications will be confined to working with smaller amounts of data which will limit their value to the customer. Applications will work more in a batch-oriented data communication mode, and the likelihood of an open internet in the vehicle, via the vehicle's on-board electronic systems, will be unlikely. (Of course, occupants can always have their own non-integrated electronic devices that can surf the web.)

The major growth technologies in North America will likely be associated with safety. This is because of the emphasis that the National Highway Traffic Safety Administration (NHTSA) places on reducing crashes and saving lives associated with vehicle crashes. Although many infotainment technologies will increase with a small lag behind consumer electronics, the safety-related technologies will be adopted at a rate that depends on legislation, which is heavily influenced by NHTSA.

In the U.S., technologies that contribute to safety are seen as the principal growth area. These technologies are valuable over the whole lifespan of the car and carry a high residual value. Drivers are also more willing to pay for safety than they are for infotainment. The critical role that NHTSA has on the adoption rate of safety technologies was repeatedly emphasized in our discussions. Legislation, supported by NHTSA, will largely drive the implementation rate of electronic safety technologies in the U.S. The litigious tendency in the U.S. will delay the introduction and even the testing of viable technologies in some cases until NHTSA supports legislation to develop and adopt certain technologies. One example was mentioned where a technology that proves fallible on rare occasions but results in a significant overall reduction in crashes. The rare false incidences could expose a company to lawsuits capable of bankrupting the company. In other words, a technology that prevented 100 crashes, but inadvertently caused just one crash, can be too risky to introduce. Other countries that are less litigious (e.g., Japan) would more readily adopt the technology because it is better overall for society. Because of this liability, no one interviewed indicated that they ever expected that the control of a vehicle would ever be taken over from the driver (by a computer technology) to help negotiate through a potential crash situation without pressure by NHTSA to force these technologies by introducing legislation.

Three organizations besides NHTSA were mentioned as having interests in automotive electronic technologies. Two interested government agencies are the Department of

Transportation (DOT) and the Department of Energy (DOE). The DOT has interests in traffic management, and the DOE is interested in fuel efficiency. Although these agencies will influence the adoption of automobile electronics, it's likely to be much less so than NHTSA. A third organization with safety interests is the Insurance Institute for Highway Safety (IIHS). IIHS shares many of the same interests as NHTSA for avoiding crashes and minimizing harm to occupants. It was mentioned that while NHTSA has interests that are more societal in nature, IIHS has interests that are more self-serving in reducing the financial costs associated with crashes.

The key areas of growth opportunity will result from technology integration. Individual technologies will continue to grow rapidly, but the biggest benefit will occur from integration of different technologies. This is true for both safety and infotainment applications. No one argued the statement that 80% of vehicle innovation in the near future will be associated with automotive electronics.

Market - Technology Integration

The need and opportunity from integrating multiple electronic systems on the vehicle greatly outweighs the challenge of developing isolated technologies. In the case of alternative fuel vehicles, for example, development of comprehensive energy management and control systems is lagging the development of the powertrain systems themselves. Current electronic systems are poorly integrated and far from optimal. There was skepticism that hybrid vehicles were even economically viable today and they are only being developed because of legislation, which could change on a whim. Consequently, investing resources into developing integrated electronic systems for them is currently risky. Interestingly, no one felt that the availability of the 42 volt electric system in future vehicles would have a significant impact on the introduction of electronic technologies on the vehicle. Forty-two volt systems will be an important step toward introducing more electro-mechanical devices (e.g., servo motors), but the overall importance is minimal.

The challenge for OEMs and electronic systems suppliers to develop comprehensive, integrated technology solutions was uniformly identified as a critical issue. U.S. companies (OEM and suppliers) tend to be functionally organized with different functions possessing deep knowledge in narrow fields (brakes, powertrain, body, etc.), and the expertise to integrate technologies is a barrier to developing integrated solutions. It was pointed out by several individuals that both European and Japanese OEMs are better at integration. For example, the new Lexus is consolidating the number of on-board controllers from 70 to 4 through systems integration, resulting in significant cost and complexity reduction. The new Daimler E-class has 61 controllers. The ability for U.S. companies to consolidate controllers like Lexus was seen as unlikely. One individual from a U.S. company indicated that having many distributed controllers may be an advantage because of distributed processing and a reduced impact from a controller failure, so technology integration may have its limits. One OEM individual pointed out the opportunity to integrate the communication function of the wiring harness (e.g., with fiber optics) and elimination of redundant electrical components (like numerous controllers) could result in a mass savings of nearly 200 pounds. At roughly a $2.00/pound value, this could be worth nearly $400 per vehicle.

Market - General Motors Case Study on Technology Integration

On the application side, GM provided a comprehensive case study on their integrated Rollover Crash Management system. GM's strategy is to provide an active safety system:

1. Before a possible rollover via electronic stability control (ESC).

2. During a rollover event: seatbelt pre-tensioning and deployment of side curtain airbags.

3. After a rollover event: Advanced Automatic Crash Notification (AACN via On-Star), turn off HVAC system to limit possible burning, unlock doors and turn on lighting.

Significant development effort was required to develop electronics on the vehicle, such as:

- Placing electronic sensors on the vehicle to collect data needed to predict a rollover.

- Developing the Rollover Detector – with an algorithm unique to every vehicle able to identify a variety of rollover conditions.

- The Sensoring and Diagnostic Module (SDM) to control the affected systems, such as engine shut-down, airbag deployment, AACN, etc.

- AACN collecting pertinent data and communicating with emergency service and logging accident data for later analysis.

Figure 3. GM's Rollover Crash Management system works before, during and after a rollover incident

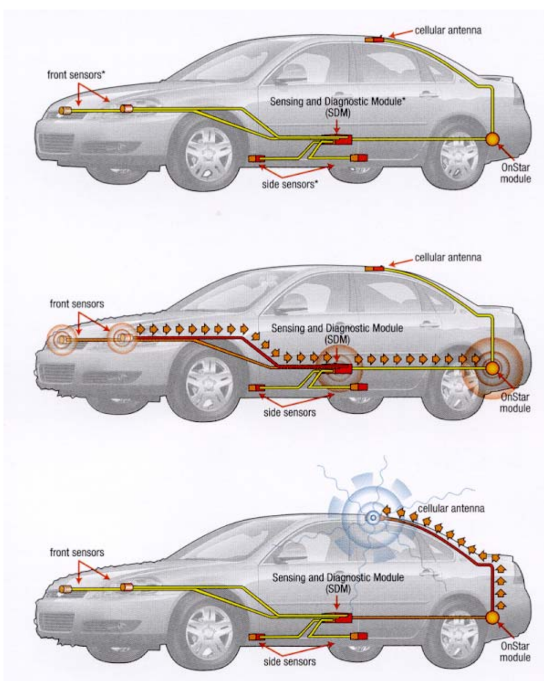
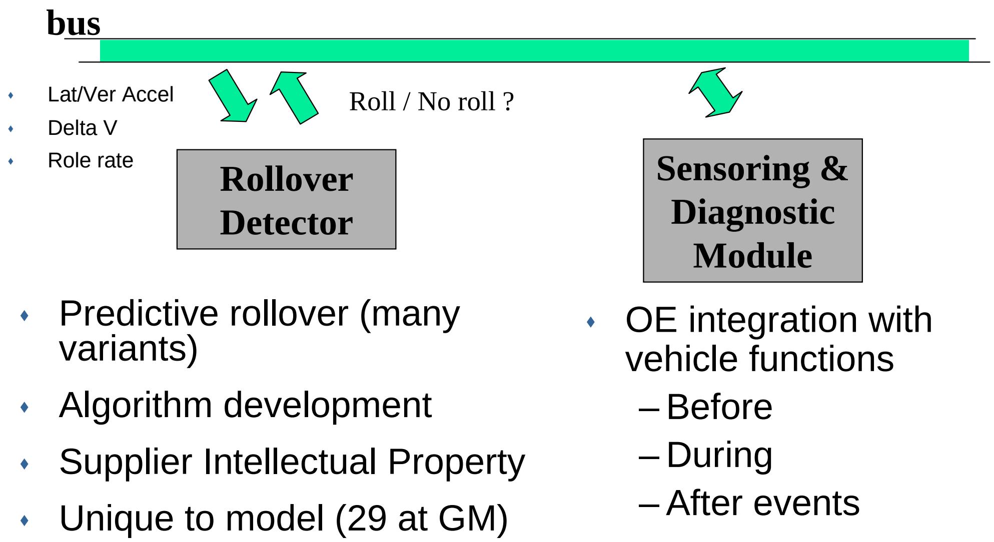


Figure 4. Two principal controllers: one to predict the rollover and one to respond to a rollover.

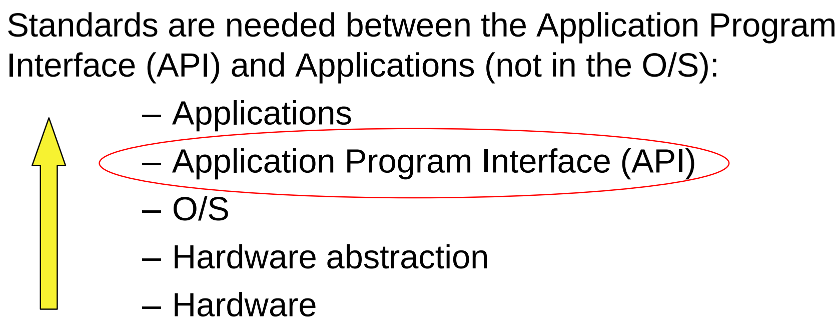


Technology Standards

There were discrepant opinions about the need and impact on electronic technology standards in the U.S. One interviewee felt that development in electronics is moving too rapidly right now and that introducing design and interface standards would be "a drag on innovation." Furthermore, given the priority given to low cost in the U.S., you would likely encounter frequent, significant compromising of the standards by companies attempting to lower their cost or promote their product. One example was mentioned regarding the Bluetooth interface. Although there is a Bluetooth standard, not all Bluetooth communication protocols can easily connect, and special instructions are often needed depending on the device being connected. Standards in other countries, particularly in Europe and Japan are seen as less restrictive and more compatibility with their industry because of the more homogeneous nature of their cultures. The success of AUTOSAR was driven largely by one OEM (BMW), and the likelihood of this occurring in the U.S. was not seen as very likely. There is one exception in the U.S. where a DSRC standard has been developed with the support of NHTSA and the Federal Communications commission. This standard has reserved a frequency band for DSRC communication with a priority given to safety related applications.

Another interviewee disagreed with the negative impact of communication standards in the U.S., and suggested that standards are badly needed. If a standard is properly designed and applied, it can focus innovation on aspects of the technology that are high value-added. This individual suggested that standards are needed for the Application Program Interface, while innovation is applied to applications, and the hardware, hardware abstraction and operating system eventually become a minimal differentiator across technologies.

Figure 5. One proposed standard is needed for the API to focus innovation elsewhere.



Product Development and Supply Chain

There are a few nuances to the traditional product development relationship between an OEM and a tier-1 supplier when it comes to electronic systems. While everyone interviewed supported the notion that the OEM has the need to remain the systems integrator for electronics on the automobile, there was some discrepancy about their ability to do it. The OEMs indicated that controlling technology integration was important because the end product was a strong reflection of the vehicle's "character" and uniqueness that an OEM would want careful control over. However, some tier-1 companies challenged if some OEMs had the technology depth across multiple disciplines to be the integrator. This observation supports the notion that the OEMs will rely heavily on tier-1 relationships for the development of many electronic technologies. One exception to this was powertrain. Powertrain was identified as being so germane to the car's character, that OEMs have traditionally kept more of this product's development within their control. Furthermore, many OEMs try to avoid paying their suppliers for integration and try to incorporate this cost into the product. Even though this is true with software as well, the suppliers see software as the key to providing high value-added products. DaimlerChrysler indicated that 60% of their cost of goods sold (COGS) comes from outside suppliers and they see any change in this strategy for electronics.

This co-dependency between OEMs and tier-1s clearly raises the issue of barriers to entry for tier-2 companies. The prevailing bond between existing tier-1 companies and the OEMs is very strong, which raised the question about how companies from Taiwan could enter this supply chain. On the other hand, no single tier-1 company was proposed as a logical integrator. Two tier-1 companies, Magna (Intier) and JCI, were named as two quality integrators with broad capabilities, but being only two companies raises concern over the lack of competition as an integrator.

One OEM briefly described their model for developing a potential tier-1 partnership. The technology provider needs to develop an application up to a certain point (this is highly ambiguous at best and always subject to change), and then approach the OEM. Together, they develop a performance and cost target and then identify a candidate vehicle program for the technology. The typical program would be a lower-volume model where the new technology gets rolled out with the hope that higher volume models will be warranted in the future. The co-development approach was emphasized as the primary relationship necessary to introduce new products. It was also mentioned by both OEMs and tier-1 companies that it would be expected that whoever developed a proprietary technology (intellectual property, IP) would likely retain rights to the IP. Consequently, this IP could be re-packaged and marketed to other customers. Eventually, cost and performance will be the overriding criteria for supplying mature products.

It became clear that there are many highly respected tier-1 system suppliers that are well established in a narrow range of technology disciplines. Several comments were made that indicated that these companies would wish to stay away from integrating roles with other non-core technologies because of liability concerns. Some respondents believe that there is a need to support the U.S. OEMs technically in this regard. Other comments suggested that since the U.S. companies are set up with functional departments they are not in a position to evaluate integrated products, so tier-1 companies would have difficulty selling highly integrated technology solutions. Again, this observation was not necessarily true for Japanese auto companies, which tend to be more systems oriented.

One compromise was suggested that the OEMs might wish to source “technology chunks” (a collection of two or more systems) to a tier-1 supplier who perhaps integrates their technology with others. OEMs have done this before and may do this with electronics as a way to contract out sub-system integration. Part of this “co-sourcing” strategy may also include directed sourcing so that multiple companies will be identified as the suppliers for pieces of the overall integrated system.

One important observation from all the interviewees was the openness, and in some cases explicit invitation, for other companies in a tier-2 status (including companies from Taiwan) to partner with the current tier-1 companies and with the OEMs. It was recognized that significant technology expertise exists that could be useful to develop new electronic applications. Equally strong comments were made with regard as to why a tier-2 company would aspire to become a tier-1? (Of course, none of our interviews were directed at tier-2 companies.) There are currently strong tier-1 and OEM bonds, and both OEMs and tier-1s are open to partnerships with tier-2 companies.

Generally, the interviewees emphasized the importance of close working relationships between the OEMs, tier-1, and tier-2 companies. Product development tradeoffs are frequent and integration into the vehicle requires close coordination. It was mentioned that product specifications are often inadequate to fully specify product requirements, and the supplier has to understand the environment that their product will operate in beyond what is documented; “you need to know your customer.” A necessary aspect of working closely with your customer also means having the appropriate technical (engineering and product development) and business (sales) staff where necessary. DaimlerChrysler mentioned that their global purchasing office in Stuttgart would be a key office. General Motors has various development centers for certain technologies that would need to be identified.

Product Development Mismatch

The differences in the traditional product development processes for automobiles versus electronics were emphasized repeatedly by the interviewees. The first challenge was the timeline. Automobiles are developed over three years (approximately), before production begins. In electronics the development phase for many technologies (especially consumer electronics that might be used for infotainment and telematics) is often under twelve months. There are also differences in product validation (discussed later) and quality expectations. One specific anecdote was explained by one of the OEM interviewees that involved a Taiwanese company:

- The OEM worked with the Taiwan company on a new electronic application to be introduced in three years.

- The supplier encountered numerous performance changes (engineering change requests), particularly involving performance standards.

- The requirements continued to increase over the development period as prototype products were tried in the evaluation vehicles.

- Eventually, the supplier ran out of financial resources because their financial model was accustomed to receiving revenue for product development within twelve months. After two years of product development, numerous product changes and still speculative future revenue, the supplier dropped out of the partnership.

The vehicle development program (VDP) was another aspect of co-product development that differs significantly between auto companies. Companies in Japan tend to make fewer performance requirements for the supplier. Honda was specifically identified as being one of the "easiest" companies to work with since their design envelop changes the least. Generally, they provided the performance expectations, geometric requirements (space), and connectivity requirements, and kept these items constant for the supplier. Experiences with other OEMs, both in the U.S. and in Europe are less stable, and expect supplier conformance to more dynamic targets.

Supplier Requirements and Gap Analysis

Relationships Between OEMs and Suppliers

Table 2. Working Relationship Index (WRI) 2002 - 2006

Planning Perspectives Survey Results

CAR
CENTER FOR AUTOMOTIVE RESEARCH

OEM	YEAR					2005 - 2006 % Change	2002 – 2006 % Change
	2002	2003	2004	2005	2006		
Toyota	314	334	399	415	407	-1.9	29.6
Honda	292	307	384	375	368	-1.8	26.0
Nissan	225	262	294	298	300	0.6	33.3
Industry Mean	**223**	**234**	**263**	**259**	**266**		
Chrysler	176	180	186	196	218	11.2	23.8
Ford	166	161	163	157	174	10.8	4.8
GM	164	157	150	114	131	14.9	-20.1

Table 1. Overall OEM – Supplier Working Relation Index for 2002 – 2006
The Index ranks OEMs based on 17 criteria across 5 broad areas – Relationship, OEM Communication, OEM Help, OEM Hindrance, and Supplier Profit Opportunity. WRI scores can range from zero to 500, with 500 the best. A ranking of zero to 249 is considered poor; 250-349 is adequate; and 350-500 is considered good to very good.

Source: Planning Perspectives

Table 2 presents results from an annual survey performed by Planning Perspectives. The study grades automakers on how they are judged by their suppliers in maintaining positive relationships. The automakers are assigned a numerical score from 0 to 500, with 500 being the best possible score, indicating very good working relationships with the automaker's suppliers.

Toyota has historically been judged as the best automaker to deal with and achieved the highest score each year. In contrast, General Motors has historically been judged as the automaker with the worst relationships with its suppliers. For 2006, GM received a score of 131 compared to 407 for Toyota. In general, Asian automakers have the reputation as the best to work with while the Big Three traditional automakers have the reputation as difficult to work with. In recent years, as the Big Three have struggled financially, they have put financial pressure on their supply base while simultaneously decreasing their orders. This has contributed to the poor scores they receive in this research and to their reputation in the automotive industry. While Taiwanese suppliers may seek to join the many other suppliers seeking to supply Toyota and Honda, they may face a difficult path as the competition to supply these automakers is significant.

Revenue Acquisition

Automotive suppliers typically begin sourcing relationships with automakers by replying to an OEM's Request for Quotation (RFQ). The automaker sends RFQs to many suppliers it believes capable of producing a given part, compares the responses, and awards the contract to the supplier offering the best combination of price and capability.

CAR's previous research revealed the average automotive supplier surveyed responds to an average of 495 RFQs per year, or about 2 per working day. Only 25% of new business RFQs result in new business for each supplier. The financial implications of both winning and processing RFQs are different for large and small suppliers. CAR's previous research determined that the average cost of replying to a new business RFQ is about $61,000 for large firms compared to $22,400 for small firms. The average new business RFQ was determined to be worth about $55 million of new revenue for large suppliers and about $2.0 million for small.[26]

Suppliers typically have about two weeks to respond to an RFQ. Because they are typically responding to several RFQs simultaneously and certain critical data is often difficult to obtain quickly, the RFQ response process tends to be hurried and filled with incomplete data and assumptions. Should a supplier win the contract for which it is responding, it will typically enter into a relationship with the OEM that may span two years of development followed by five years of production of a given part. Because two weeks of hurrying and guessing may be the basis for a seven year relationship, it is necessary to execute the RFQ response process as well as possible to ensure the financial health of the firm. For Taiwanese suppliers, who are accustomed to the rapid product lifecycles of the electronics industry, it is critical to ensure that this interaction with their potential customers is performed as well as possible. It represents the means by which they will enter the business relationships that will turn them into suppliers of the automotive industry.

Supplier Performance Requirements

The supplier performance expectations for competing in the U.S. market are challenging and fairly well established. On any traditional, non-technologically-based product, i.e., a commodity, there are high standards for delivery and quality, but everything always comes down to cost. The OEM will attempt to place any new product into this classification as quickly as possible, so protecting IP on technologically advanced, unique products is important. Attributes that OEMs look for, particularly in technology-based products, include:

- Adequate product innovation, research, and testing.
- Sufficient R&D resources and financial stability to sustain R&D for several years to last through a VDP.
- Competitive material costs (this is presumably singled out because it removes the material cost fluctuation risk).

[26] Morell, Jonathan, Bernard Swiecki, and David Andrea, Automotive Suppliers and the Revenue Acquisition Process: What's Working and What's Not?, Center for Automotive Research, September 2002.

- The agility to respond to evolving product development demands during development with regards to quality and product performance.

- Best globally landed cost – recognizing all costs (shipping, tariffs, etc.) to get the product to the customer.

- Global sourcing – the ability to provide timely products with minimal supply chain risks.

- Global sourcing so that all components and materials are sourced using "world prices".

Development Process and Product/Process Validation

Many of the interviewees questioned if electronic companies not familiar with working with the auto industry would be able to adjust with respect to the higher level of product performance requirements. Automotive performance requirements are much higher than consumer electronics because all the technologies on the vehicle must work in all driving conditions, including very cold to very warm, under severe, long-term vibration, and for a longer life-cycle. Consumer expectations for automotive technologies is much higher than consumer electronics, and the consequences of a defect are much more expensive, just because of warranty costs if nothing else. One OEM indicated that an infotainment repair under warranty would cost, on the average, ten times the same defect would cost if it was in a consumer product (e.g., radio). Over 50% of warranty repairs result in "no trouble found," after the product is replaced, and in some cases maybe only fails when it is a part of the bigger system on the vehicle. An indirect consequence is that the vehicle owner can become unhappy with the auto company because of a chronic failure, which can contribute to losing a future repeat customer for the OEM. Consequently, the product requirements typically start high and increase over time, and evolve based on integration issues during the VDP. Both the supplier and customer (OEM or tier-1) have made a significant product development investment with an uncertain future product requirement and revenue stream. Both the tier-1 and OEM have to have confidence that any critical suppliers, particularly if they hold IP, will be in the program for the long-term.

A long-term product commitment is also required to service the product. Auto companies provide warranties for three years, and they plan to service their products for a minimum of seven years; a much longer commitment than many electronic companies are accustomed to.

There are varied and dynamic testing procedures depending what is discovered during product development. New technologies typically follow a scale-up regime similar to the following:

- Lab based evaluation.

- Lab-tested, full rollover testing (prototype) – crashing vehicles.

- Component abuse (the "hammer" test).

- Controlled driver tests (prototype scale-up).

- Limited vehicle deployment on higher end, lower volume vehicles for actual user testing.

- Mass production deployment.

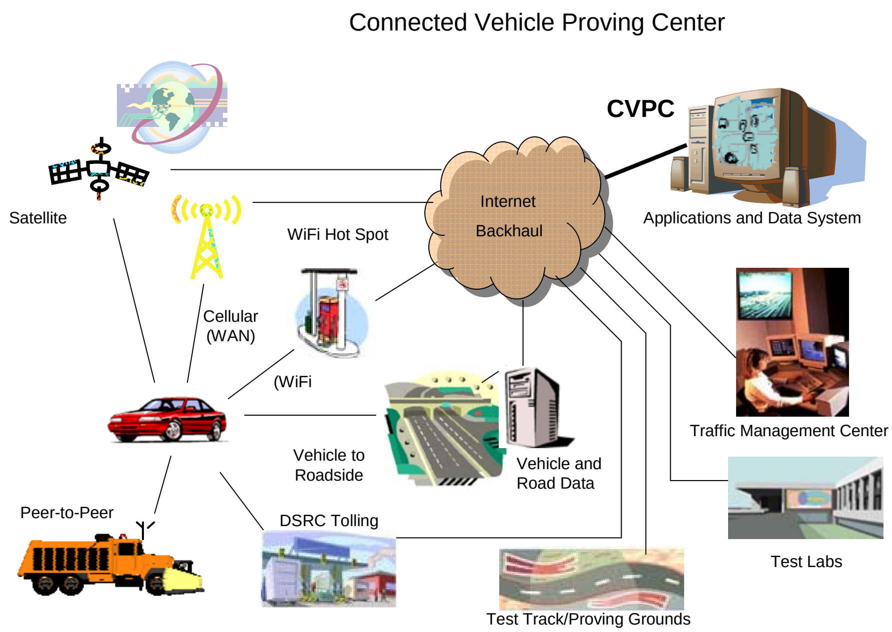
Since the actual product requirements are seldom well established at the start of a VDP, collaborative product development and testing is important. Expensive testing centers are cropping up, and participation in these centers would help develop partnerships and build confidence in product performance.

Figure 6. Results from industry survey regarding desired testing facility attributes.

Test bed open to a range of vehicle infrastructure communication alternatives including DSRC, Wi-Fi, cellular and other alternatives
Continuous support from government agencies at all levels
Test bed outfitted with roadside communications devices to support in-vehicle transceivers and application communication requirements
Prepare a strategic plan for testing and deploying vehicle infrastructure and integration, and related technologies and applications

Delphi indicated that they plan to support the launch of a testing center in Indiana using Indiana University as a management group to offer independent access to the facility. Delphi indicated that they would encourage other companies to participate. The Center for Automotive Research was also recently granted funds to support the launching of a connected vehicle proving center (CVPC) to develop and promote communications to/from the vehicle.

Figure 7. The Connected Vehicle Proving Center (CVPC) Developed at the Center for Automotive Research in Michigan.



- Government awarded funds to CAR, September 2006 to launch CVPC.
- Develop and operate a “one-of-a- kind” proving center as a vehicle communications test bed and evaluation lab.
- Establish Michigan as the national center for Vehicle Infrastructure Integration (VII).
- Partnership with the Connected Vehicle Trade Association and Scott McCormick.
- Advisory board includes Michigan Department of Transportation, Road Commission of Oakland County, General Motors, DaimlerChrysler, Ford, Nissan, VII-C, NAVTEQ, Delphi, Motorola, Cogenia, Dykema Gossett, CAR, University of Michigan Transportation Research Institute, Michigan Economic Development Corporation, Department of Labor and Economic Growth.

Companies wishing to develop relationships in the automotive electronics supplier industry should consider participating at these types of testing centers.

Summary

Conclusions that relate to Taiwan's ambition to better integrate into the supply chain for automotive electronics are:

- Taiwan image (brand) is high quality, competitive cost hardware. The interviewees were consistent with this opinion.

- Taiwan's more ambitious plans to supply electronic systems to tier-1s or directly to OEMs are largely unknown in US.

- There exist several market needs, such as:

    - Technology development (e.g., SEMA model). Develop individual technologies that an integrator (OEM or tier-1) can integrate into a vehicle, or allow the technology to operate independently of other technologies on the vehicle.

    - Development of technology "chunks" (greater than a single technology). Combine one or more technologies into a system (sub-system) as a limited integrated system.

    - Focus on becoming an integrator with a broad capability to integrate many technologies from different suppliers, or with deep knowledge on certain electronic systems. This most aggressive plan offers the greatest investment and risk, and requires careful consideration as this field is already highly competitive.

- Huge unknown manufacturing validation requirements will continue – but will surprise traditional suppliers. Suppliers that wish to provide technologies as original equipment will likely have to understand these requirements better.

- Big difference across Tier-1 and OEM relationships. Pick your customers carefully. The market penetration into the U.S. versus Western Europe versus Japanese versus Chinese all requires different considerations. The nuances of the market you wish to enter needs to be understood along with the companies you will work with.

- It is not known how what kind of a global presence a tier-2 company will need if they are partnered closely with one or more tier-1s. This probably depends on the tier-1 and the technologies being provided and the OEM customers.

Specific suggestions for next steps:

1. Define how far up the value stream the Taiwan suppliers really wish to swim. A very specific strategy is needed rather than a general one. You need to identify viable technologies and tier-1 companies that are either your competitor or your partner. From an industry perspective, you may wish to assess the specific company ambitions in Taiwan (perhaps via a survey). You may wish to develop a "technology roadmap" that outlines a technology growth strategy; potentially moving up the value chain in conjunction with partnerships. The growth would be slower than trying to jump into a tier-1 position, but would have lower risk.

2. Consider pursuing partnerships and networking meetings with tier-1 companies or even tier-2 companies that may have historical relationships from which you can benefit. One surprise in this study was the eagerness of every interviewee to seek technology development partners. We suggest that you test this opportunity. You should prepare a message that you wish to market as you network.

3. Collaboration with current suppliers to the automotive industry may be the most direct route for Taiwanese firms to begin supplying the North American automotive industry. The greatest concentration of these suppliers is located in Michigan. Whether through partnerships, joint ventures, or acquisitions, cooperation with existing automotive suppliers merits careful consideration. Automakers often prefer to work with firms who have experience in the unique business environment of the automotive industry. This is particularly true for complex products such as safety and powertrain technologies. Existing suppliers may have relationships with OEM purchasing staff that would prove useful to Taiwanese firms in entering the automotive industry, as well as experience in dealing with its unique challenges.

4. The "Taiwan Message" needs to get out. More visibility is needed from a business perspective (and less so from a technology perspective). Hence, a presence at a conference like CAR's Management Briefing Seminars, or similar activities in China, Japan and/or Europe where management and the media are present. Developing a press release and make announcements to gain visibility.

5. Explore possible participation or associations with various testing centers. CAR's CVPC and Delphi's proposed center in Indiana are two local possibilities.

6. Once a business strategy begins to take shape, you may wish to develop more targeted seminars for your industry on how to work with the auto industry. You should include topics such as:

   a. The RFP process (responding to requests for proposals).
   b. IP in the auto industry
   c. Product and process validation
   d. Financial considerations (financing throughout the entire product development process)
   e. Etc.

The Center for Automotive Research can provide assistance with any of the suggestions.

Strategic Considerations

Many Taiwanese electronic suppliers aspire to higher levels in the supply chain for automotive customers. Higher levels in the supply chain are associated with higher levels of products and services than tier-2 and 3 suppliers. When higher up the supply chain, revenue becomes more associated with knowledge and innovation than with component suppliers even though the knowledge-based revenue remains closely linked to providing products. In many cases, the tier-1 supplier is seen as an integrator of many products; some of which are provided by other, lower-tier suppliers. Characteristics of a tier-1 supplier include, for example:

- Deep engineering knowledge to complement their customers.
- Research and development; often with numerous patents and extensive product development and product and process validation experience.
- Extensive tier-2 supply chain relationships.
- Systems integrators.
- Deep financial resources to support long-term development efforts and to absorb financial risk.
- Global presence with sales, engineering, and manufacturing networks in the proximity of the customer base.
- Historical track record in the automotive supply chain; often developed through a limited number (sometimes one) of OEM relationships that have demonstrated long-term viability and commitment to the OEM partnership.

This short list briefly describes a tier-1 supplier, and much more can be written about each of these points (this could be a subsequent project). The comments from the industry interviews pointed out several important observations that Taiwan needs to consider if Taiwanese companies wish to move toward a tier-1 status. Some of these points were made explicitly and others were implied:

- The intention to move up the supply chain was news and not broadly communicated.
- Taiwan is recognized as a technology provider and probably more closely fits a traditional tier-2 supplier.
- The global tier-1 electronic systems market is competitive and well established with highly competent companies; so the entry into this field is formidable.
- By and large, the experience base of Taiwanese suppliers would not, as of yet, suggest that they can compete as a tier-1 technology systems provider.

One caveat in these observations is that they were made predominately by current tier-1 company executives, and these established companies probably do not wish to see additional competition. OEMs did indicate that they would welcome new entrants from Taiwan, but then again, they would like to see continued increases in competition.

The following suggestions are provided in response to the specific questions provided by ARTC ("Added-on Content & Questions/Solutions") about strategies for Taiwanese strategies.

1. With respect to entering the global market, Taiwan is currently somewhat isolated. The notion that a Taiwan company that is presently a tier-2 supplier will quickly become a global tier-1 supplier is ambitious. Two viable paths are:

    a. "Climb" up the tier ladder (there are progressive steps to becoming a fully recognized tier-1 global electronics system supplier). There are multiple paths to climb, and some are listed below (see number 2).

    b. Accelerate the growth by entering the PRC (China) as aggressively as possible, in a tier-1 status (which appears to be going on now). This is a unique opportunity for Taiwan companies, both with opportunities and risks, and a long-term growth plan (particularly growth beyond PRC) should probably be evaluated. (This could be a subsequent project.)

2. There are multiple paths for climbing up the ladder to a tier-1, and they should be probably pursued simultaneously. These include:

    a. **Joint Ventures** – Every company that we interviewed expressed interest in finding joint venture partners to share R&D costs and to improve each others chances for success. Potentially, a survey of specific research and strategic product development thrusts could be conducted, by company, to contrast with Taiwan interests and capabilities. A strategy (depending on the candidate partnership areas) could possibly be drawn that is likely to lead up the supply chain for the Taiwan companies depending on the technology, its future and the specific company partnership arrangement. (This could be a subsequent project.)

    b. **SEMA** – The SEMA organization has grown steadily in size and has continued to gain the respect and recognition as an association of credible suppliers. Many Taiwanese companies already participate in SEMA, and are competitive in this market segment. SEMA doesn't only present opportunity to supply components, but as it grows, particularly with tier-1 and OEM participation, there is the opportunity for assertive companies to grow as well. SEMA products are becoming more technical, and in many cases, higher volume than the traditional niche aftermarket add-ons in the past. The technology at SEMA is continues to grow with the respect of tier-1 and OEM companies. As the technology and volumes scale up, there is more opportunity for providing engineering, systems integration and manufacturing resources. Continued participation at SEMA, along with a view of identifying new downstream opportunities for product development and production would support the interests of Taiwan companies.

    c. **Test Centers** – As electronic systems test centers become more prevalent, participation at them will support collaborative efforts and developing new partnerships. Three such centers were mentioned in this report (GM rollover laboratory, Delphi center in Indiana, and CAR's Connected Vehicle Proving Center). We recommend identifying all these centers worldwide (that exist today and proposed ones), and selectively choosing the ones of interest to Taiwan.

d. **Direct OEM Investigation** – Both Ford and GM indicated an interest in collaborating with suppliers that wanted to jointly develop certain technologies. One company indicated that they could potentially target a future program for certain technologies, and this could help set the timeline for a joint development effort. The critical issue here is what technologies are of interest, what Taiwanese companies fit this need, and is there an adequate business case for the joint effort to come together? (Evaluating this option could be a subsequent project.)

e. **Focus on Strategic Technology Development** – One significant area of opportunity for the intelligent vehicle relates to the integration of technologies. This area was seen as a barrier to introducing new technologies, offered the greatest opportunity for benefits, and includes both hardware and software. Except for the complexity of the topic, becoming an automotive electronics systems integrator would be a powerful position in the industry. Focusing higher-end technologies on the integration of lower-end technologies, the on-board controller for example, could effectively position a company at or near the tier-1 supplier level. Another approach could be to develop a deep knowledge base of several inter-related technologies that together make up related system components, or a sub-system. This could include, for example, engine control systems, braking systems, anti-crash (or rollover) systems, etc. This collection of participating companies could form its own supply chain of tier-1 and 2 companies. A technical evaluation of possibilities may be warranted on this topic. (Evaluating this option could be a subsequent project. CAR would have to collaborate with appropriate technical personnel.)

One interesting observation from the study was identifying some of the unique characteristics of the intelligent vehicle systems in different geographical regions. For example, North America's focus on cost, Europe on technology, and Asia (particularly Japan) on systems integration. Of course these are generalizations, but nevertheless important considerations for working with OEMs in these regions. Depending on Taiwan's strengths, perhaps they are better suited to work in one region over another? It will be interesting to see how PRC unfolds, but given the international climate there, perhaps some combination of these three attributes will result. Interviews with OEMs and tier-1 companies with a presence or interest in PRC would be helpful to Taiwan for positioning itself there. (Evaluating this option could be a subsequent project.)

The model of the Korean automotive industry is not a promising one for Taiwanese suppliers attempting to enter the automotive industry. Korean automakers rely upon a supply base of well-established firms. In many cases, Korean automakers have an ownership stake in their major suppliers. In this sense, the Korean automotive industry's structure resembles that of the Japanese automakers and their suppliers. North American and European suppliers have found it very difficult to begin supplying to Japanese automakers. Because the Japanese supply base has a structure similar to that of the Korean supply base, potential Taiwanese suppliers seeking to supply these OEMs may find it similarly difficult. If this subject continues to be of significant interest, it is possible to include it in future research performed by CAR.

Appendix 1. CAR Research Initiative on Electronic Systems Supply for the Intelligent Car

Confidential draft - not for circulation

Background

CAR has been actively supporting the advancement of intelligent transportation systems and related technologies that make up the ***intelligent car*** (IC). Two related CAR activities include the ***Connected Vehicle Proving Center*** (CVPC) and the ***Taiwan Intelligent Car Supplier Project***. Working in partnership with state departments (Transportation and Economic Development), academia, and the Connected Vehicle Trade Association, CAR recently received an award from the state to support the creation of a virtual "CVPC" in Michigan to encourage the development of vehicle communications. CAR is also working with organizations in Taiwan (e.g., Automotive Research and Testing Center and the Industrial Technology Research Institute) to help identify technology development projections, supplier business opportunities, and supplier capability gaps; particularly with Taiwanese suppliers.

We summarize the IC technologies in three systems: powertrain, body (includes safety systems), and telematics. Generally, the integration of these three systems comes together at a node referred to as the on-board unit (OBU).

Purpose

The purpose of our requested interview with your company is to seek informal and unofficial (not necessarily company policy or positions) opinions regarding the development of electronic technologies and systems that support the IC. Results and company name can be anonymous if requested. The objective is to identify "best guesses" as to how the IC technologies will develop and how best to structure the supply chain to meet this development, particularly in North America.

Outline of Questions:

1. Market
    - Do you generally agree with the projected growth that IC technologies will result in about 7.5% compounded growth in auto content over the next several years?
    - Is legislation (e.g., crash worthiness/avoidance, CAFÉ, etc.) a critical variable impacting the development of IC technologies?
    - How do you see IC technology growth relative to the following:
        i. Body (& safety)
        ii. Powertrain
        iii. Telematics – on-board applications
        iv. Telematics – external applications
        v. Other
    - Do electric vehicles (and hybrids) demand significant electronic system developments?
    - Do you expect to see continued movement toward integrating third-party electronic systems (e.g., Apple ipod) into on-board systems, thus allowing broad market participation? If so, would you then expect to see standard electronic interfaces (e.g., USB-like linkages)?

- Is the 42V car a critical variable impacting the intelligent car?

2. Standards
   - How critical is the creation of system standards for these technologies?
   - Do you support the development of international standards for electronic system interfaces to facilitate the global development of these technologies?
   - Is government intervention required to institute appropriate standards?
   - METI (Japan) is attempting to select a common on-board operating system including firmware to control on-board electronics. Managing safety concerns and reliability are principal drivers. Freely open code (publicly available) to the industry is important. Should other countries follow this direction and/or consider the Japanese standard?

3. Product Development – please provide your response regarding each point for powertrain, body, and telematics (please answer for those domains in which your expertise is strongest)
   - What aspects of IC technologies are seen as high valued added (hardware, firmware, operating systems, applications, integrated systems)?
   - What is more critical: hardware or software development capabilities?
   - What are necessary characteristics/capabilities or resources for companies to research and develop IC technologies?
   - Please describe your company's priorities or efforts in developing electronic systems for powertrain, body, telematics, and OBU. Which of these are you relying on the outside for development that might be purchased?
   - What systems (sub-systems) would you be likely to seek from suppliers that integrate into the IC?
   - Can you describe how a supplier of ITS technologies validates its performance and inter-operability with other technologies? What would an "ideal" test/validation center look like?
   - Is a small automotive market (Taiwan has low-vehicle production) adequate to validate IC technologies?

4. Supply Chain – please provide your response regarding each point for powertrain, body, and telematics (please answer for those domains in which your expertise is strongest)
   - Who (companies or tiers) will be the integrator of the components of IC components:
     i. Components (chips/sensors) and software, and
     ii. Sub-systems, and
     iii. Systems , and
     iv. Integrated systems (powertrain, body, telematics, OBU)
   - Who (countries or companies) do you see as the most competitive developers of IC electronic systems?
   - What capabilities are needed for successful suppliers of:
     i. Electronic components?
     ii. Electronic systems?

     (research, software development, collaborative development, agility, systems integration, other?)

   - Do you have any opinions about the technical capabilities that the Taiwan industry has in regards to supporting these development steps?

- What other countries or companies other than resources in Taiwan do you see as viable partners in development and supply?

Final Questions (if time permits)

1. What are you company's future plans for introducing electronic systems that support:
    a. Powertrain
    b. Chassis
    c. Body/safety
    d. Telematics applications

2. What are your company's intentions with outsourcing any of these technologies? What are you looking for in the capabilities of suppliers of these technologies? Would this strategy differ in other countries (e.g., North America vs. Asia)?

3. How important are:
    a. Low cost?
    b. Advanced technology (cutting edge, first to market)
    c. Quality & product validation

4. Do you see companies in Taiwan as having any competitive strengths or weaknesses in their ability to supply these technologies?

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