SDR Market Study, Task 6
The Telematics Market

Prepared for
The SDR Forum

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July 2007

About the Author

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He is currently developing a series of Software Defined Radio (SDR) market and technology studies for the SDR Forum. The completed reports are listed below. He is author of market research reports entitled Wireless Infrastructure: Technology and Markets that have been published by Forward Concepts. He served as principle investigator on a DARPA SUO project to develop advanced software radio architectures for military and commercial waveforms. He is co-author of "Communication Mediums for Intelligent Transportation Systems" (TRB/National Academy Press), which is a multi-media/multi-medium communication system design guide.

Completed SDR Forum Market Study and Technical Reports:

1. SDR Market Study, Task 1: Market Segmentation and Sizing, 2005
2. SDR Market Study, Task 2: Cellular Terminals and Infrastructure, 2005
3. SDR Market Study, Task 3: WiFi, WiMAX and Beyond 3G / 4G, 2006
4. SDR Market Study, Task 4: The US Public Safety Market, 2006
5. SDR Technology Study, 2006
6. SDR Market Study, Task 5: Cognitive Radio Market, 2007
7. SDR Market Study, Task 6: The Telematics Market, 2007 (This study)

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1 Executive Summary

This report, entitled “The Telematics Market”, provides a comprehensive look at initiatives by the automotive industry and government transportation organizations to utilize computer and communications technology to enhance the public’s automobile travel experiences. The highways of the world are becoming increasingly used, leading to increased congestion. Adding new roads and highways to relieve overcrowding is becoming a less attractive option and alternate approaches are needed. Telematics offers solutions by applying and integrating geolocation, communications, and information technologies into vehicle architecture and highway and road infrastructure. The promise of telematics is convenience, safety, and increased highway capacity without new construction.

A key trend in the automotive industry is the evolution to a more international market. Traditionally, the market has been dominated by the high tier, mature economies such as the United States, Western Europe, Japan, and Korea. Figure 1-1 shows vehicles per 1000 population for the world and its regions. North America, dominated by the US has had for many years by far the highest vehicle registrations and yearly new vehicle sales. However, over the next 5 years emerging economies, especially in Asia, are anticipated to create a very high percentage of Year-over-Year (YoY) growth. China and India are especially attracting significant industry interest.

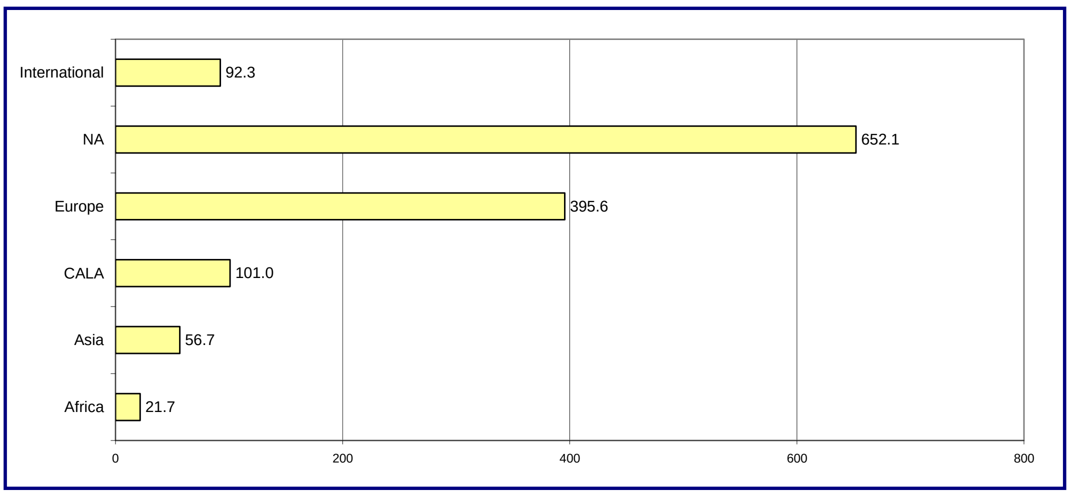

Figure 1-1 Vehicles in 2006 per 1000 Population by Region
(International = World, NA = North America, CALA = Central and Latin America)

In the past, US automotive manufacturers dominated international vehicle production and sales, supported by a strong domestic market. However, for the first time in the first quarter of 2007, Toyota headquartered in Japan, surpassed General Motors (GM) in market share of the international automobile and light vehicles sales. This was significantly impacted by the recent surge in gas prices, resulting in increased demand for more fuel efficient smaller passenger cars.

GM’s OnStar is the recognized leading Telematics service provider, with services focused largely in US and Canadian markets. GM has indicated that all of the 2008 model year vehicles it sells in these markets will have OnStar devices as standard equipment. GM provides free OnStar service for one year for purchasers of OnStar equipped vehicles.

Internationally, the focus of Telematics markets and governments has differed. In the US and North America the concern has been on safety and security. In Europe the emphasis has been navigation and traffic information to address traffic congestion. In Asia, especially region leader Japan, the interest has been navigation and infotainment (information and entertainment). Nowhere, to date, have revenue producing Telematics services achieved significant commercial success. However, traffic information services, often free and sometimes with companion revenue services have been popular in some areas. An example is the Traffic Message Channel using FM sub-carriers service that has achieved wide spread deployment in Europe. On-board navigation units with map data bases and display are achieving popularity as an extra cost vehicle option in all markets.

Another Telematics initiative is Ford’s “Sync” optional factory-installed communication and entertainment system that will be available in the fall of 2007. Ford collaborated with Microsoft and will use Microsoft software. Sync will provide drivers hands-free voice-activated control over their mobile phones and digital music players (e.g. iPod) via USB or Bluetooth interfaces. Initially, Sync will be available on various Ford, Lincoln, and Mercury models in North America. It conveniently connects drivers’ phones and music players with their vehicle’s in-car microphone and sound system. Using “brought-in” devices offers interesting new and enhanced Telematic service opportunities, in more cost effective scenarios, as opposed to the historical preference for built-in devices.

Automobiles employ ECUs (Electronic Control Units) to more effectively and cost efficiently implement features for a variety of traditional mechanical, hydraulic, and electrical/electronic functions. A modern automobile typically has 20 to 80 ECUs. An emerging trend is to consolidate to fewer, more powerful ECUs and enhance functionality with inter-unit communication via vehicle buses. FlexRay[1] is an emerging international automotive bus standard for this purpose.

Many automotive industry initiatives, collectively referred to as Intelligent Transportation Systems (ITS), are synergistic with Software Defined Radio. One is the AUTOSAR[2] (AUTomotive Open System ARchitecture) initiative that targets open and standardized automotive software architecture. AUTOSAR is being jointly developed by automobile manufacturers, suppliers and tool developers. Another program is Vehicle Infrastructure Integration[3] (VII). which involves collaboration between the automotive industry and Governmental transportation organizations. The goal is to provide enhanced transportation information to the traveling public. A key component of VII is Digital Short Range Communication (DSRC). DSRC equipment and standards will provide Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I or sometimes V2R for road) communication. DSRC is an enhancement of the popular 802.11 WLAN standards to accommodate transportation applications and emerging licensed spectrum.

[1] See FlexRay Consortium, www.flexray.com. Also see Table 3-7.
[2] AUTOSAR.org
[3] its.dot.gov/vii

Many feel that Telematics has historically not achieved anticipated successes. However, the need for improved safety and security, improved travel information and navigation, coupled with synergies with the emerging "Any Where", "Any Time", and "Any Service" telecommunication initiatives appear poised to help enable and create a more favorable environment for Telematic successes.

2 Introduction and Conclusions

This report, entitled "The Telematics Market", provides a comprehensive look at a market that has been promoted for many years by the automotive industry, but has had lackluster commercial success. Current indications are that Telematics is likely to turn the corner and more significant success may be forthcoming. This report will discuss these trends and the rational and reasons for this optimism.

We draw our introductory definition of Telematics from the Wikipedia web site[4] which indicates that Telematics is defined in a number of ways that include:

1. The integrated use of telecommunications and informatics, also known as ICT (Information and Communications Technology). It is the science of sending, receiving, manipulating, and storing information via telecommunication devices.
2. The term has been applied specifically to the use of Global Positioning System (GPS) technology integrated with computers and mobile communications technology.
3. Most narrowly, the term has evolved to refer to the use of such systems within road vehicles, in which case the term vehicle Telematics may be used.

Our focus in this report will be on the third definition dealing with automotive application. Thus, Telematics applies communications, informatics (or information processing), computers and GPS to provide convenience and an enhanced experience for vehicle drivers, passengers, and the traveling public in general.

This report is organized as follows:

1. Executive Summary
2. Introduction and Conclusions
3. Automotive / Telematics Driving Forces and Issues
4. The Telematics Market

The conclusions of this Telematics study are:

- International vehicle registration trends indicate that the world will achieve 1 billion vehicles on roads by the end of 2010. The United States / North America, and to a somewhat lesser

[4] http://en.wikipedia.org/wiki/Telematics

extent by Europe (especially Western Europe); Japan, and Korea have dominated historical numbers. Increasingly, emerging markets such as China and India are experiencing growth.

- In the past, vehicle sales have been dominated by the more mature markets. The US is the leading country in terms of vehicle registrations and sales. However, for the balance of this decade, over 70% of global sales growth is anticipated to be in Asia (e.g., China, India).
- GM's OnStar is the recognized leading International Telematics service provider, although services are focused largely in GM's US and Canadian markets. In 2005, GM indicated that for the 2008 model year all vehicles produced for its US and Canadian markets would be OnStar equipped. GM provides free OnStar service for one year for purchasers of OnStar equipped vehicles and indicates that approximately 50% renew thereafter. Ford and ATX also offer telematics services.
- International Telematics services have experienced business model problems with subscribers apparently not finding sufficient value to warrant monthly service fees. Europe and Asia historically have offered free traffic information services, but not pervasively successful fee-based subscription services. An example of these (often) free services is European-centric Traffic Message Channel (TMC) Service that provides weather and traffic information.
- Internationally, Telematics markets and governments focuses have been:
  - -North American / US: safety and security,
  - -European: navigation and traffic information
  - -Asian: navigation and infotainment.
- Since 1978, automobiles have increasingly employed ECUs (Electronic Control Units or embedded microprocessor) to enhance features for a variety of mechanical, hydraulic, and electrical/electronic functions. Increasingly these ECUs are communicating with each other via communication buses in the automobile. FlexRay is an emerging international automotive bus standard.
- Various ITS initiatives including Vehicle Infrastructure Integration (VII) should provide enhanced information and communication capabilities to support enhanced capabilities. Digital Short Range Communication (DSRC) equipment and standards are an important component of VII to provide Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I or sometimes V2R for road).
- With the wide availability of commercial 3G /4G cellular, WiFi, WiMAX, and similar technologies and services, the future for Telematics appears much brighter. They provide an opportunity for enhanced built-in and brought-in devices (e.g. cell phones and navigation systems), as well as beamed in services.
- The automotive industry's AUTOSAR (AUTomotive Open System ARchitecture) initiative has software goals and initiatives that are synergistic with SDR initiatives. AUTOSAR is an open and standardized automotive software architecture, jointly developed by automobile manufacturers, suppliers and tool developers. AUTOSAR targets re-use of hardware and software components between different vehicle platforms, OEMs, and suppliers.
- As future automobile designs take a system-of-systems view of all of on-board wireless functionality, the benefits of Software Defined Radio are likely to become increasingly valuable.

3 Automotive / Telematics Driving Forces and Issues

Among the trends influencing both the automotive and telecommunication industries is the emergence of increased international market opportunities. Figure 3-1 depicts year-end 2006 vehicles per 1000 population for the world, regions, and important countries.

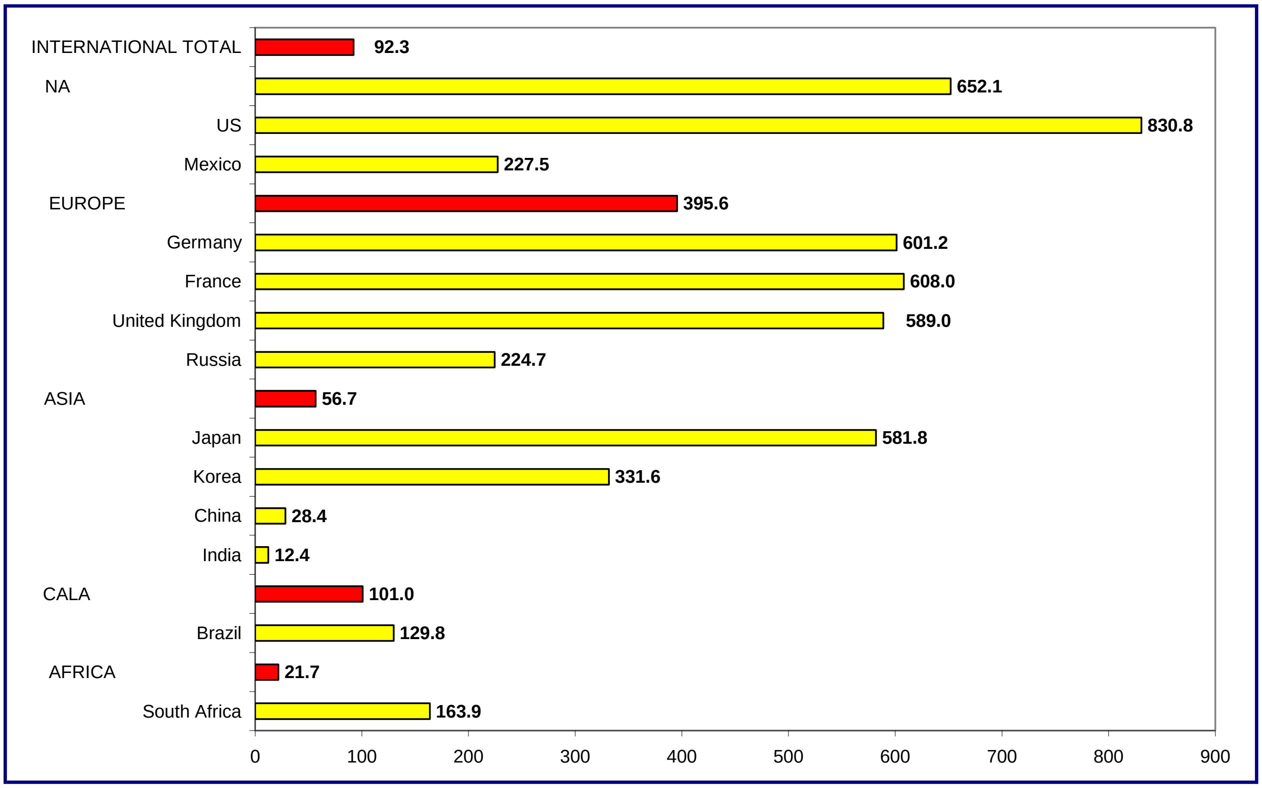

Figure 3-1 2006 Vehicles per 1000 Population by Region and Select Countries
(International = World)
(Source: Wards Automotive and Author Research)

For many years the United States has dominated the automotive market in registered vehicles per 1000 population as indicated in Figure 3-1. It has also led in total registered vehicles deployed on roads (Table 4-2), and in yearly sales (Figure 3-2). Currently, China and other emerging markets are growing while the more mature US and European markets are essentially flat. The US has also been the top international country in yearly automotive sales. For many years, supported by strong domestic sales, the top US automotive manufacturers were also the top international automotive manufacturers.

US automotive manufacturers have had a significant disadvantage in recent years due to high costs of health, retirement, and other benefits for current employees and retirees due to strong labor union representation, longer historical operations, and a large number of retirees. Additionally, the US manufacturers have evolved their sales to include a high percentage of light trucks , Sports Utility Vehicles (SUV), minivans, and similar vehicles that have been popular and generally offer higher margins. However, these vehicles typically have poorer miles per gallon than smaller passenger cars. With the recent trend in the increase price of gas and with many potential buyers now desiring more fuel efficient cars, US manufacturers are not well positioned to address these market requirements. Also, the greatest growth opportunities are overseas.

In recent years, Toyota, headquartered in Japan, has consistently increased market share and for the first time in the first Quarter of 2007 surpassed General Motors (GM) in terms of international automobile and light vehicles sales. The reported international numbers[5] for the first quarter of 2007 are as follows:

- GM 2.26 Million Vehicles, 3% Increase
- Toyota 2.35 Million Vehicles, 9% Increase

Toyota has significant manufacturing and sales in the US and, in fact, has moved into the top three in sales as the data in Table 3-1 indicates.

Rank	Make	2006	2005
1	General Motors	24.6%	26.2%
2	Ford	17.5%	18.6%
3	Toyota	15.4%	13.3%
4	DaimlerChrysler	14.4%	14.9%
5	Honda	9.1%	8.6%
	Total Japan Nameplate	34.8%	32.2%
	Total Korea Nameplate	4.5%	4.3%
	Total Europe Nameplate	6.9%	6.5%

Table 3-1 US Vehicle Unit Sales Market Share (Units) by Manufacturer (2005 and 2006)
(Source: WSJ Web Site, 1/3/2007 based on Autodata data)

The legacy top tier economies, including the United States, Germany, France, the UK, Japan, and Korea, are experiencing flat year-to-year growth in vehicle sales. Automotive growth opportunities are in the countries that have low values of vehicles per 1000 population as shown in Figure 3-1. Countries receiving interest and focus from auto manufacturers are high population countries, including Brazil (Pop: 188M, #6), Russia (Pop: 142M, #9), India (Pop: 1,112M, #2), and China (Pop: 1,314M, #1), sometimes referred to as the BRIC countries. In recent years as presented in Figure 3-2 growth has been accelerating in emerging markets. Many are forecasting that China will overtake the USA as the world's largest automotive market in the 2010-15 timeframe.

[5] "Toyota: A Carmaker Wired to Win", Business Week, April 24, 2007

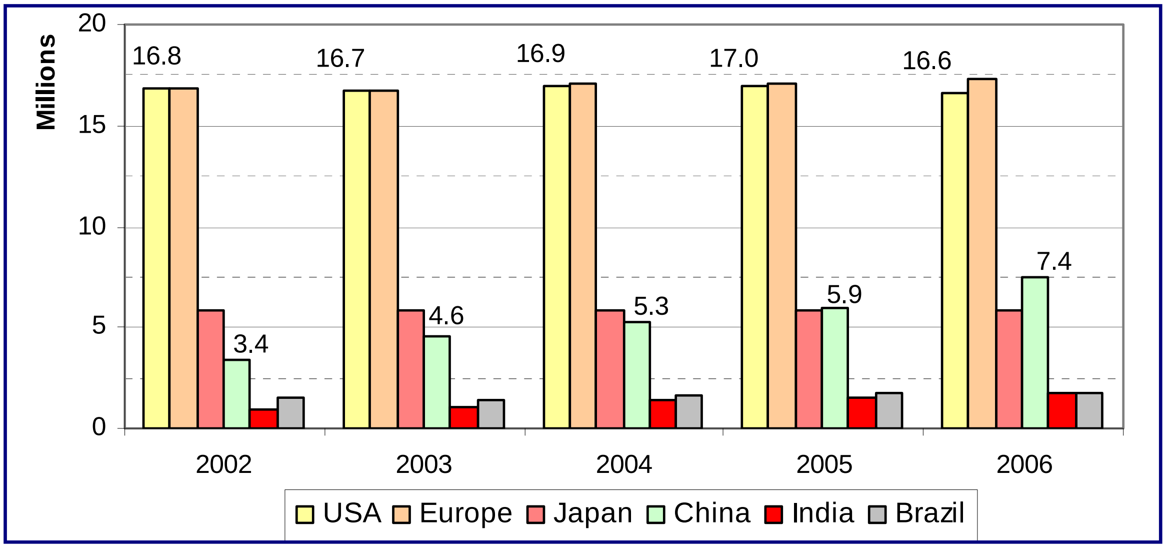

Figure 3-2 Key World Automobile Market Sales
(Source: Toyota in the World 2007, May 2007 and author research)

3.1. General Motor's view of the International Automotive Market

Indication of the interest of the auto industry in emerging economies was presented in a recent speech[6] by Rick Wagoner, General Motors Chairman and CEO, in Delhi, India. He said:

> 2006 was the industry's fifth consecutive year of record global sales... 67.5 million units... up more than 30 percent in the last 10 years alone. In 2007, we forecast yet another industry-sales record of about 70 million units... and continued growth of about 3 percent a year over the next five years. … In fact, over the next 10 years, emerging markets within the Asia Pacific region alone are predicted to account for nearly 70 percent of global automotive sales growth. Three of the top five, and eight of the top 15, fastest growing auto markets over the next decade are expected to be in Asia Pacific... including, of course, right here in India …

Mr. Wagoner indicates that for GM "to succeed globally, we must succeed in the world's emerging economies." In the speech he indicated that China is anticipated to be the number one growth market and India the second. His speech's closing comments were:

> We at GM for sure don't have all the answers, and we don't always get it right... but we have learned from our experience over our almost 100-year history operating around the globe.
>
> - Today, I've talked about four lessons that we've learned over the years:
>   - One size does not fit all - tailor your activities to the local market;
>   - "Get local" in as many aspects of your business as fast as you can;

6 "The Emerging Role of Emerging Markets in the Auto Industry", Rick Wagoner, General Motors Chairman and CEO, Delhi, India, April 17, 2007, transcript available at www.gm.com

- Offer products that are focused specifically on local customer needs, wants, and desires;
- And learn from the new, leaner, more cost efficient models frequently found in developing countries, with India as a great example here.

- Considered broadly, I suspect these lessons apply to companies of all stripes looking to make it on a global basis in markets beyond their own.

He further states that the “easiest and most efficient way to operate is to design and build one model, and then “push it” into many markets around the world.” This conflicts with the requirement that success in local markets requires car suppliers to offer cars and trucks “that are focused specifically on local customer needs, wants, and desires.” Thus automotive OEMs face challenges of balancing common model efficiencies to achieve lower costs for international markets versus local customer “wants, needs, and desires” Thus, we conclude that increasingly emerging “one size does not fit all” international requirements appear very synergistic for common platforms and software concepts, SDR, and Telematics initiatives.

3.2. Telematics Services

GM’s OnStar Telematics service is widely recognized as the international leader in terms of subscribers and an overview is provided here to illustrate services and success. Figure 3-3 provides a picture of the OnStar control panel which is located on the rear view mirror and has few simple buttons for ease of use and minimum driver distractions. The figure also has a picture of one of GM’s models that provides OnStar as standard equipment. GM offers OnStar service free for one year on equipped new vehicles. Reportedly, approximately 50% renew after the first year. In late 2005, GM announced that it would make OnStar equipment standard on all its retail 2008 model year vehicles sold in the US and Canada by the end of 2007. OnStar reports that it achieved close to 5 Million subscribers at yearend 2006. OnStar originally initiated service in 1996 and is now offering its 8th generation of equipment.

Buick Lucerne

OnStar Control Panel
- Handsfree Button (Cellphone Service)
- OnStar Service
- Emergency Request Button

Figure 3-3 OnStar Telematics Control Panel
(Source: GM and OnStar Web Sites)

The services offered by OnStar are indicated in Table 3-2. OnStar offers two service plans.[7] The basic plan is the Safe & Sound which costs $16.95 per month and includes the services in Table 3-2 without an asterisk (*). The Safe and Sound plan is provide free for one year on purchases of GM's OnStar equipped vehicles in the US. The more expansive plan is its Directions & Connections, $34.95 per month that includes all the services in the table. Hands-free calling via cellular is available on a pre-paid basis, either with OnStar or with Verizon Wireless. Verizon Wireless customers have some options to use OnStar hands-free calling via their plans.

OnStar Vehicle Diagnostics	Roadside Assistance
OnStar Turn-by-Turn Navigation*	Accident Assist
Automatic Notification of Air Bag Deployment	Remote Horn and Lights
Emergency Services	Virtual Advisor
Crisis Assist	Driving Directions*
Stolen Vehicle Location Assistance	Ride Assist*
Remote Door Unlock	Information/ Convenience Services*
Access to Hands-Free Calling	

Table 3-2 OnStar Services (* Premium Service, Directions & Connections)
(Source: www.OnStar.com, June 2006)

OnStar is based on two communication technologies. It uses the Global Positioning System (GPS) for location information and it uses cellular technology for two-way communication. In the United States OnStar has a working relationship with Verizon Wireless (VZW) for providing two-way communication with vehicles. Thus, OnStar service is available in area where Verizon has coverage, as shown in Figure 3-4. When OnStar commenced service in 1996, the most pervasive service coverage was with the legacy analog service and OnStar used that protocol. In the intervening years, digital service has become pervasive and OnStar is transitioning to Verizon's digital CDMA cellular technologies. In the 2002 timeframe, the US FCC issued orders authorizing US cellular operators to cease analog operations after a five year transition period. The effective date is February 18, 2008 (FCC Analog Sunset). Verizon has announced that it will cease to offer analog service after this date and OnStar will cease to offer service based on analog cellular service. The coverage map below depicts OnStar's digital (i.e. Verizon's digital CDMA cellular technology) coverage.

OnStar has working relationships to provide service in the US to vehicles of other manufactures that include Acura, Audi, Isuzu, Subaru, and Volkswagen.

[7] www.OnStar.com, June 2007

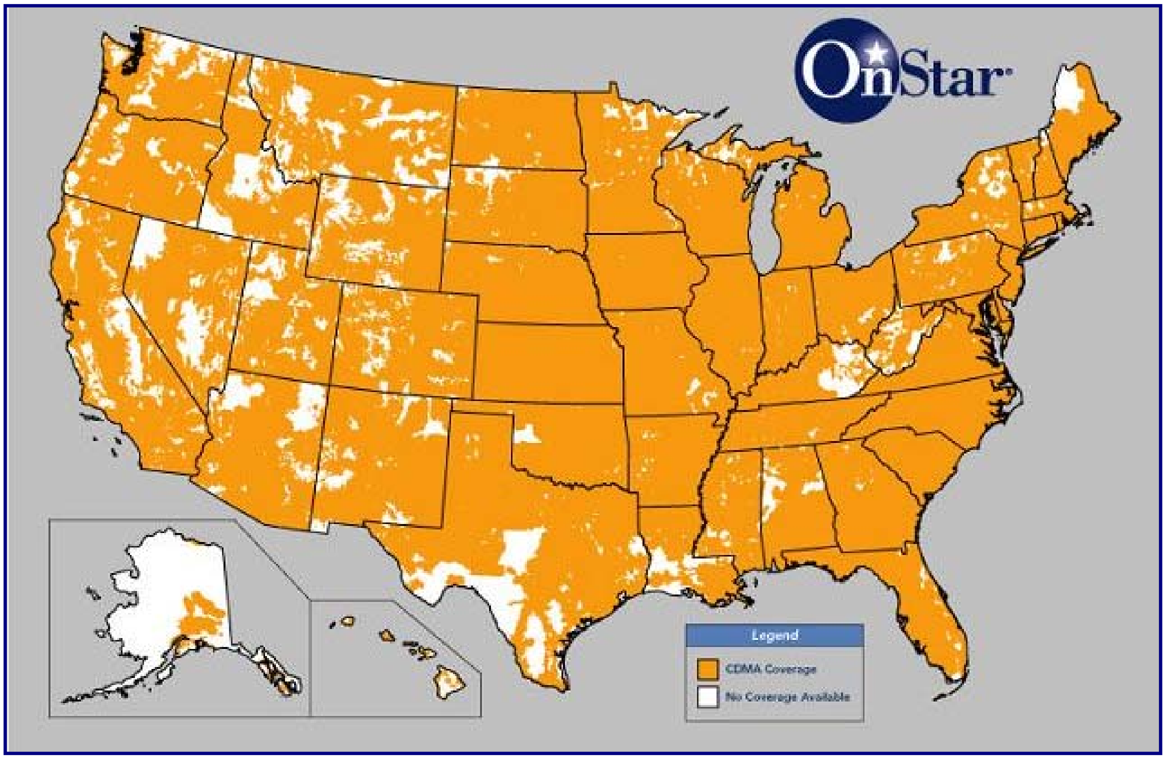

Figure 3-4 OnStar Digital US Coverage Map
(Source: www.OnStar.com, June 1, 2007)

The ATX Group located in Irving, Texas, claims to be the leading independent and second largest Telematics service provider. ATX states that it is partners with the brands listed Table 3-1 to help develop and offer Telematics services and technologies in Europe and North America.

Brand	Country
BMW—Canada	Canada
BMW, Europe	Germany, United Kingdom, Italy
BMW—North America	United States
Maybach	United States, Canada
Mercedes-Benz—USA	United States
Mercedes-Benz—Canada	Canada
Rolls-Royce	United States, Canada

Table 3-3 ATX Telematic's Brand Partners
(Source: www.atxg.com, March 2007)

On March 9, 2007 in Geneva at "The Fully Networked Car Exhibition and Workshop," Steve Millstein, President and CEO of ATX Group, in a presentation[8] predicted that

> A new generation of data-centric services gradually emerging today in the international Telematics market eventually will transform the traditional Telematics business model away from annual service subscriptions for primarily emergency-related, location-based services. The core benefit of future Telematics services will likely be virtual connectivity with the vehicle, enabling Telematics to become standard on every vehicle.
>
> What we've long considered as the basic tenets of the Telematics business will change, essentially becoming ancillary, added-value benefits to a new core of services that leverage the fact the car is simply a node on an information network. … These new services will be data-centric and will integrate vRM (vehicle relationship management), driver interactive vehicle applications (DIVA), voice-activated Web access into the vehicle, information about the environment in which the vehicle is operating as well as real-time, diagnostics information about the vehicle's operation and performance.
>
> The gradual transformation of Telematics operations from call-center environments into data management centers has begun, driving the expansion of current Telematics programs in both North America and Europe and providing new incentive for additional automobile manufacturers and other players -- new to Telematics -- to enter the market.
>
> T3, or third generation, Telematics services will transform every vehicle into a voice browser, a data router, and a node on a wireless communications network … The result will be continual, real-time access to valuable information about the vehicle and its performance, its environment, and its connectivity to the owner and driver.

Four specific areas were cited where Telematics is in the process of expanding beyond its traditional core of subscription and location-based emergency, security and navigation services. These are 1) web access, 2) Driver Interactive Vehicle Applications (DIVA), 3) remote diagnosis of road environment (e.g., temperature, air quality, precipitation, traffic flow), and 4) remote diagnosis of vehicle performance. The latter includes retrieving data from the vehicle "to better manage aftermarket parts and service, warranty and maintenance, leasing and financing, and to assist in the process of insurance claims."

Millstein cited two key developments in North America:

> … BMW's decision to incorporate the four-year cost of its Assist Telematics service, provided by ATX, into the MSRP of its vehicles and General Motors' decision to make its telematics service standard on every one of its vehicles. As a result, other Japanese and American automobile manufacturers are working on Telematics deployment plans in North America.

[8] Press release at www.atxg.com, ATX Identifies Three Pillars of T3 Third Generation Telematics, 9 March 2007

We contacted Dr. P. K. Prasad, who leads Fords Infotronics Research and Advance Engineering Group, and served as co-Guest Editor of a February 2007 special IEEE Proceedings issue on advanced automotive technologies (see section 3.4). He provided information on the Proceedings issue, Ford's Telematic initiatives, and general Telematics perspectives. He also offered insights on the various generations of Telematics as presented in Table 3-4. He indicated that Ford was the first to deploy Telematic services with its Rescu with ATX in the 1996 timeframe, but that it was largely unsuccessful due to business model problems. Drivers did not value the service sufficiently to pay subscription and renewal fees.

Telematics Generation	Timeframe	Typical Services
Telematics 1 (or T1)	1996-2000	Roadside Assistance Emergency Assistance
Telematics 2 (or T2)	2000-2005	Location Services Maintenance Services
Telematics 3 (or T3)	2005-future	Combination of Built-in and Brought-in

Table 3-4 Telematics Generations and Typical Services
(Source: Interview, Dr. P. K. Prasad, Leader, Ford's Infotronics Research and Advance Engineering Group, May 2005)

Ford will initiate a new Telematics service, "Sync"[9] in the fall of 2007 in collaboration with Microsoft, based on Microsoft auto software. Sync will be an optional factory-installed built-in car communication and entertainment system that will provide drivers hands-free voice-activated control over their mobile phones and digital music players (e.g. iPod) via USB or Bluetooth interfaces. Initially, Sync will be available on various Ford, Lincoln, and Mercury models in North America. "Sync automatically connects drivers' phones and music players with their vehicle's in-car microphone and sound system." Its "Smart Voice Recognition" system will allow drivers to operate their portable digital music players and Bluetooth-enabled mobile phones with simple voice commands. The automobile display will be capable of displaying cell phone features such as caller ID, call waiting, conference calling, caller log, contact list, signal strength, and battery charge. Sync claims on its web site that Ford will be the first and only automotive company in North America to offer this product.

Dr. Prasad was very enthusiastic on emerging Telematic potentials for enhanced user experiences and value. The broader user communication experience is being increasingly defined by emerging 3G and beyond 3G[10] services that envision personalized digital content and information anytime, anywhere, via any media. This experience should be extended to the automobile, where many users spend considerable time. They would like to have this information available in the automobile, adopted to their mobile abilities and requirements, and supplemented with supportive automotive travel-centric information and communication facilities such as navigation and emergency services. Dr. Prasad discussed the "Built-In, Brought-In, and Beamed-In" concepts depicted in Figure 3-5. Historically, automotive customers have preferred high quality, built-in devices rather than after-market installations. However, emerging 3G services and digital music devices appear poised to change preferences and service opportunities. Ford's Sync Telematics service is an example.

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[9] http://www.syncmyride.com
[10] SDR Market Study, Task 3: WiFi, WiMAX and Beyond 3G / 4G, Jim Gunn, prepared for SDRF, 2006

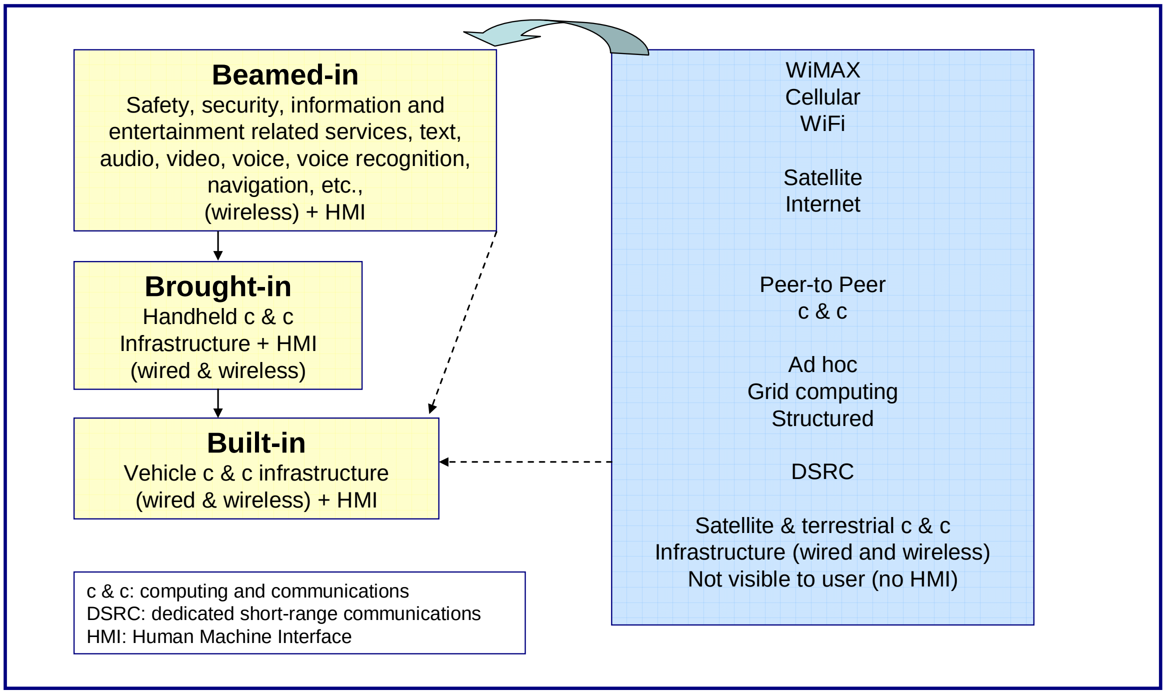

Figure 3-5 Emerging Automotive Built-in, Brought-in, and Beamed-in era
(Source: K. V. Prasad Paper[11]) (c & c = computing and communications)

Built-in devices include radios, Compact Disk/Tape players, and navigation systems. Automobile consumers have preferred these devices as they were designed with driver utility as a goal and of higher quality. Brought-in devices include cellphones, music devices (e.g. iPod), PDAs, and portable navigation devices (e.g. GPS). Beamed-in services include cellular voice service, traffic information service, and concierge services delivered via built-in or brought-in devices. Brought-in devices offer the attractive potential for wireless subscribers to obtain the same services in their vehicles as they do outside, reducing the need for multiple subscriptions. The life of an automobile is typically 15-17 years with a typical 2-4 year/50,000 mile warranty adding to the cost of built-in automotive equipment. For example, a factory-installed GPS navigation system typically costs $2000,[12] while a portable navigation system costs $500-$750, and has an estimated use-life of 3-5 years.

Built-in equipment must also withstand industrial temperature ranges typically from -40°C to 85°C while consumer products normally are specified for the commercial temperature range of 0°C to 70°C. Thus, consumer brought-in equipment has a lower unit cost, and can be updated to the latest state-of-the-art technology and feature sets more frequently.

[11] "Shaping the Future of the Automotive User Experience" Design-for-Experience & the Last-Inch Problem", K. V. Prasad, Ford Motor Company, Proceedings of Convergence 2006 Conference, Oct 2006
[12] Interview with K. V. Prasad, Ford Motor Company, May 2007

From our review of historical information and data, we conclude that Telematics is still a work-in-progress and that successful business models have not been realized to date, with the modest exceptions of OnStar and ATX. As we discussed, Ford initiated its Rescu Telematics service for Lincoln models in the US in the mid 1990's timeframe in partnership with ATX and failed to achieve success. The modest successes of OnStar and the comments of ATX provide indications that Telematic successes may be forthcoming. As integration progresses to include more navigation services, infotainment services (e.g. satellite radio and back seat TV), traffic information and ITS travel guidance services, cellular, and web access, we are optimistic on the potential of Telematics to provide successful business models in the future. We also anticipate significant consumer and commercial fleet opportunities to emerge. While market data does not yet support such conclusions, the potential appears to be very real and possible.

3.3. European-centric Telematic Initiatives

While we did not find indications of significant current successful OnStar-like Telematics service deployments outside the US, a Telematic-like service that does appear to have significant international deployment is Traffic Message Channel (TMC) service. TMC appears most widely deployed and popular in Europe. The TMC unit is typically an in-car navigation system that decodes the received traffic information and presents it to the user on the navigation system display in the appropriate language.

TMC[13] is a specific application of the FM Radio Data System (RDS) (i.e. sub-carriers) and is used for broadcasting real-time traffic and weather information. Transmitted messages are received and decoded by a TMC-equipped car radios or navigation systems, and delivered to the driver in a variety of ways. The most common TMC service is a navigation system that can offer dynamic route guidance that provides alerts to the driver of a problem on a planned route and calculates an alternative route to avoid incident and congestion.

TMC benefits for users include:

- Filtered information only for the immediate route
- Updated traffic information, delivered in real time
- Current knowledge of accidents, roadwork and traffic jams
- Information in user's own language
- High-quality digital transmission
- Europe-wide compatibility of receivers
- Free or low-cost services across Europe

A global standard has been has been adopted by traffic data gatherers, information service providers, broadcasters and vehicle/receiver manufacturers. TMC information is received via FM radio sub-carrier signals. Standardized location database (typically on the navigation system map

[13] www.tmcforum.com, June 2006

CD-ROM or DVD) contains a country-specific set of location codes for the strategic European road network.

Data related to traffic flows, incidents, and weather are gathered from traffic monitoring systems, emergency services, and motorist calls, and collated at a central traffic information center. They are then passed to the TMC traffic information service provider, who generates TMC messages in the ALERT-C coding protocol. The service provider sends coded messages to the appropriate FM radio broadcaster for transmission as an RDS signal within normal FM radio transmissions. The TMC data are received by the vehicle radio, and decoded. This reconstructs the original message, using a database of event and location codes, presented to the driver as a visual or spoken message. It takes typically about 30 seconds from the first report of a traffic incident to the traffic information centre until the same information is available in the vehicle. The user can select the language used to present the traffic information. The user can also opt to filter messages, so that only those concerning the immediate route are selected. New delivery channels are emerging that could carry TMC services, including digital audio broadcasting (DAB), mobile Internet, paging and GSM/GPRS mobile phone networks.

To deliver a TMC service, all of the elements of the chain must be in place. This includes creating a national database of TMC locations, ensuring that TMC receivers are available in the marketplace, and building the links to sources of real-time traffic information. Delivery also requires setting up a service center to validate, integrate and encode the traffic data, furnishing the data to broadcasters, and finally, transmitting the TMC messages. Despite this complexity, the number of TMC services is growing rapidly to serve the expanding base of TMC-equipped vehicles.

TMC Services are well established across Europe. Free services form a network covering nearly all of Europe. Each service is transmitted by a national, regional or local broadcaster, and by agreement, national and international service providers broadcast cross-border messages for long-distance/international drivers. Some countries have both free and commercial services, and some have only commercial services. Some European services supply alerts of incidents, traffic congestion and bad weather. According to the TMC Forum web site[14] (June 2007) TMC message services are also available in North America, will launch imminently in Australia, have been demonstrated in China and are under development for a number of other countries, making TMC a truly global technology.

TMC systems do not currently typically have two way communications with infrastructure or service providers, but are stand-alone navigation boxes with GPS and one-way FM sub-carrier decoding capabilities. Most motorists have non-integrated communication capabilities via cell phones or other brought-in devices. Thus, TMC concepts appear to offer features and capabilities to facilitate and enhance more encompassing Telematics service suites. In a telecom with James Burgess, of the TMC Forum in Belgium, he indicated that an increasing number of vehicles in Europe of all cost ranges are delivered equipped with navigation systems and TMC capabilities.

[14] tmcforum.com

A European program that provides succinctly articulated goals for emerging Telematic-centric programs is the eSafety Support[15] initiatives of the European Commission (EC). While the specific of this initiative focus is on European requirements, the general concepts are applicable internationally.

The eSafety Support program[15] was initiated by the EC along with industry stakeholders in 2002. The participating community has evolved to include the European Commission, member states, road and safety authorities, the automotive industry, telecommunications companies, service providers, user organizations, insurance writers, technology providers, research organizations, and road operators. The program was initiated to address the unacceptably high number of deaths and injuries on European roads. The established goal by the EC was to reduce by half the number of road deaths by 2010 through development and deployment of Intelligent Vehicle Systems. In a year end 2006 report, eSafety Support indicated that road safety has gradually increased in the EU-15 Member States, a trend likely to continue in the future. It indicated that the reduction in the number of fatalities was 3% in 2001-2002 and 7% in 2002-2003. However, in 8 of the 10 recently added EU member states, "road fatality and accident figures are still rising due to inadequate road networks, lack of enforcement, and poorly maintained vehicle fleets. At the same time, the cost of injuries and material damage caused by road accidents remains extremely high, a total of €50 billion per year for accidents with fatalities and €40.5 billion per year for accidents with severe injuries. These issues, when compounded, call for drastic road safety measures."

eSafety has concluded that more than 90% of all accidents in Europe involve human error, usually a mismatch between driver skill and situation complexity. Thus, a goal is to assist the driver by decreasing his workload, detecting dangers, and providing support in hazardous situations. The program has developed priorities for both vehicle-based systems and infrastructure-related systems. Discussion of these priority systems was presented in a late 2006 eSafety brochure[15] that is presented in Table 3-5.

[15] www.esafetysupport.org

EC eSafety Priority vehicle-based systems: • Electronic Stability Control - Helps to stabilize the vehicle and prevent skidding when cornering through active brake intervention on one or more wheels and intelligent engine torque management. • Blind spot monitoring - Either provides better vision into the blind spot area or uses warning signals to alert the driver to obstacles in this area. • Adaptive headlights - Ensures optimum illumination of the lane in bends, directing the headlight into the bend as soon as the vehicle begins cornering. • Obstacle and Collision Warning - Detects obstacles and gives warnings when collision is imminent. • Lane departure warning - Gives an acoustic, visual or haptic warning to the driver in order to avoid leaving the lane unintentionally. **EC eSafety Priority infrastructure-related systems:** • eCall - When an accident occurs, the eCall device will establish a 112 emergency call to the nearest emergency rescue centre giving the precise location of the incident. The call can either be triggered automatically when the car senses a major impact, or manually by pushing a button. • Extended environmental information - The in-vehicle equipment detects the location of the car and other potentially safety-related information from the vehicle's sensors and systems for instance in the field of visibility, weather or friction, and sends the information to a central system or to other vehicles. • Real-time traffic and travel information - By warning drivers of congestion, incidents, adverse weather and road conditions and allowing them to find alternative routes or otherwise change their travel plans, traffic information services improve traffic flow and help drivers avoid potentially hazardous situations. • Dynamic traffic management - The systems are used to increase the safety and flow of traffic in cases of disturbance caused by incidents, congestion and adverse weather by controlling and informing traffic via Variable Message Signs and possibly via in-vehicle devices. • Local danger warnings - The systems warn drivers either via roadside Variable Message Signs or in-vehicle devices of local safety problems caused by incidents, congestion, adverse weather, pedestrians, animals, obstacles, etc. • Speed alert - The system alerts the driver with audio, visual and/or haptic feedback when the speed exceeds the locally valid legal speed limit.

Table 3-5 EC eSafety Priority vehicle-related and infrastructure-related systems
(Source: www.eSafetysupport.com, 2006 Brochure, May 2007)

The eSafety 2006 brochure contained several informative additional discussions of various eSafety systems and initiatives that are presented in Table 3-6.

Real-time traffic and travel information for 80% of all European Journeys by 2010 By 2010, the Real-Time Traffic and Travel Information (RTTI) Working Group wants 80% of the trips made in Europe to be covered by state-of-the-art real-time traffic and weather information services. By enabling drivers to anticipate disruptions and delays and thereby avoid them, real-time traffic and travel information could help reduce both accidents and congestion.
Safe Integration of nomadic devices The in-vehicle use of mobile phones, personal digital assistants and other portable devices is increasing rapidly. These technologies could be important tools in improving road safety. However, their safety benefits may be significantly reduced or cancelled out altogether if they are not well designed controlled and installed. In 2005, the Human Machine Interaction (HMI) Working Group published detailed recommendations on how this can best be achieved. On the basis of this report the Commission will issue a new version of the European Statement of Principles (ESoP) on HMI.
Improving road safety with digital maps Digital maps can include updated safety information. This information may complement vehicle speed and position sensors such as lasers and video cameras, which have limited range, to extend the driver horizon at least 500 to 1000 meters ahead. In this way, drivers can be alerted to what is coming after the next road curve or intersection. To encourage such use of digital maps in vehicle safety applications, the Digital Maps Working Group has proposed a cooperation model for the public and private sector to produce, maintain, certify and distribute *e*Safety attributes for digital map databases.

Table 3-6 EC eSafety supplemental discussion on systems and initiatives
(Source: eSafety 2006 Brochure, May 2007)

In late 2005 the EC in a Commission-Industry initiative established an action plan to add eCall capabilities to all new cars in Europe by 2009. In a press release in December 2006, it was reported that indications are that some member states have been slow planning and deploying eCall. The Commission issued a Communication on November 23, 2006 entitled "Bringing eCall back on track – Action Plan", presenting items essential to supporting eCall initiatives. Industry plans to push back its deployment schedule until 2010, while the Commission indicated that it would be providing assistance to facilitate eCall deployments.

3.4. Emerging In-Vehicle Information and Communication Technologies

The February 2007 Proceedings of the IEEE was a Special Issue on "Advance Automotive Technologies" that included papers addressing information and communication technologies. Of particular interest were the first three papers.[16,17, 18] This issue provided information, supporting references, and leads contributing to the following discussions.

A key continuing trend in the automotive industry that started in 1976[12] has been the addition of electronic control units (ECUs or microprocessors) and software to more effectively and cost-efficiently implement many vehicle functions. An ECU is an embedded component in a vehicle that implements and/or controls various electrical, electronic, mechanical, hydraulic, or

[16] "Scanning Advanced Automobile Technologies" Edited by H. Gharavi, K. V. Prasad, and P. A. Ioannou; Proceeding of the IEEE, Vol 97#2, pp328, Feb. 2007
[17] "Control, Computing, and Communication: Technologies for the Twenty-First Century Model T" By Jeffery Cook, Ilya V. Kolmanovsky, David McNara, Edward C. Nelson, and K. V. Prasad; Proceeding of the IEEE, Vol 97#2, pp334, Feb. 2007
[18] "Engineering Automotive Software" by Manfred Broy, Ingolf Kruger, Alexander Pretschner, and Christian Salzmann; Proceeding of the IEEE, Vol 97#2, pp356, Feb. 2007

combinations thereof, functions in a vehicle. Figure 3-6 illustrates a common classification of these functions. They include powertrain control, body electronics, safety functions, infotainment, driver assistance, chassis, in-vehicle networking, man-machine interface, telephone control, door control, seat control, and climate control. Prior to 1976 microcontroller availability, these functions were typically implemented as standalone, often bulky, mechanical, hydraulic, or electrical functions, with specified interfaces to other vehicle functions to facilitate sub-function/system manufacture and vehicle mass assembly. ECUs have been increasingly designed in over the years to lower costs, improve performance, and add functionality. ECU's have historically been added on a standalone function-by-function basis. A modern automobile might have 20 to as many as 80 ECUs that provide intended functionality on an independent basis with minimal communication and interoperation.

Current trends are to:

- Replace the current 20 to 80 ECUs in an automobile with a reduced number by integrating functions using more powerful 16-bit or 32-bit microcontrollers replacing 8-bit or 16-bit versions.
- Maintain a few key functions, such as powertrain control and braking, on dedicated ECUs, and integrate other functions on fewer more powerful microprocessors.
- Add in-vehicle networks for functionality enhancements via improved communications. Proprietary automotive networks, buses, and protocols are being replaced by those based on emerging automobile industry standards.
- Provide system (sometimes referred to as "System-of-Systems") automotive functionality for enhanced driver experiences including enhanced beamed-in features and services using both built-in and brought-in devices.

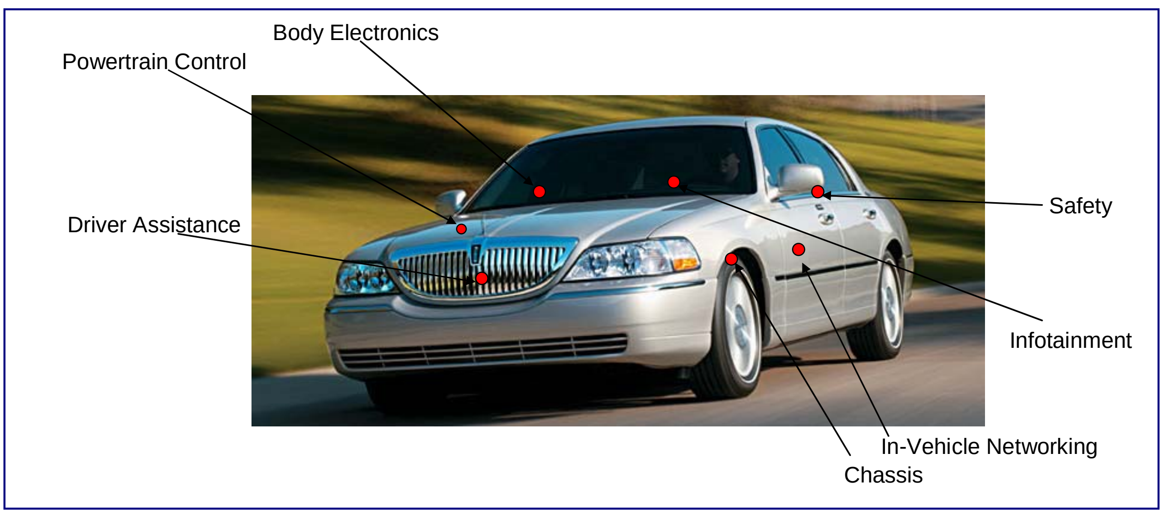

Figure 3-6 Key Automotive Electronic Functions
(Source: Picture: Ford Web Site, labeling: Freescale Automotive Web Site, June 2007)

Managing the increasing complexity of increasing numbers of ECUs in a vehicle has become a key challenge for automotive manufacturers. Unanticipated functional interactions have become an increasing problem with growing automotive software content. The value of electronics and software in automobiles is becoming a significant part of vehicle cost. The February 2007 IEEE

Proceedings special issue on Advanced Automotive Technologies[18] provides additional insight into the increasing value of electronics and software in automotive applications indicating that the international value in 2002 was €127 Billion and is expected to grow to €316 Billion in 2015, with software being approaching 38%. Other key emerging technologies to support these emerging intelligent vehicle opportunities are a variety of sensors and actuators to support various functions such as vision recognition for such tasks as lane tracking, emission control, etc. The emerging more stringent emission standards and fuel economy (e.g. Corporate Average Fuel Economy, or CAFÉ, regulations in the US) are increasingly enabled by (and not achievable without) ECUs (including DSPs), software, and appropriate sensors and actuators.

Historically, as ECUs were added to vehicles, automotive manufacturers implemented proprietary communication busses to interconnect sensors, actuators, ECUs, and vehicle subsystems. In general they used point-to-point wires for dedicated functions. More recently there has been a trend to create and use automotive standard busses that serve broader uses.

These standards include:
- Local Interconnect Network (LIN)
- Controller Area Network (CAN)
- Media-Orientated Systems Transport (MOST)
- FlexRay
- IEEE 1934 Firewire (IDB-1394)
- Bluetooth for wireless

An overview of these standards is provided in Table 3-7. The LIN and the CAN busses have been the recent dominant deployments.

	Embedded Control				X- By-Wire		Mobile Media		Wireless
	LIN	Single-wire CAN	Low speed CAN (CAB-B)	High Speed CAN (CAN-C)	FlexRay	Byteflight	MOST	IDB-1394	Bluetooth
Medium access control	Master / slave	Contention	Contention	Contention	Time triggered	Master / slave	Master / Slave	Contention	Master / slave
Bus speed	20 kbps	33 kbps	125 kbps	500 kbps to 1 Mbps	Two 10 Mbps channels	10 Mbps	25 Mbps	98 Mbps to 393 Mbps	1 Mbps
Physical layer	Single wire, 12 V	Single wire, 5 V	Twisted pair, 5 V	Twisted pair, 5 V	Twisted pair	2-wire, 3-wire or fiber optics	Fiber optics	Unshielded twisted pair	Wireless
Cost	Low	Low / medium	Medium	Low / medium	High	High	High	High	High
Application	Sensors/ actuators (e.g., window lifters, door modules)	Comfort / convenience	Comfort / Convenience	Powertrain & comfort/ convenience	Safety / chassis	Safety	Streaming data	Streaming data	Voice communica tion
Affiliation Support	LIN Consortium	GMLAN	CAN in automation	CAN in automation	FlexRay Consortium	BMW	MOST Cooperation	1394 Trade Association	Bluetooth SIG

Table 3-7 In-Vehicle Data Busses

(Source: adopted with permission from insert entitled "2008 In-Vehicle Buses" Wall Chart, Auto Electronics Magazine, May / June 2007, www.autoelectronics.com/2008-in-vehicle-data-buses.pdf)

The FlexRay standard is an emerging standard targeting emerging higher performance automotive networking requirements and especially the emerging drive-by-wire (or "x-by-wire") initiatives. In the Auto Electronics Magazine in the May / June 2007 issue an article indicated that the first FlexRay application to enter production was an "option called AdaptiveDrive on BMW's x5 sport activity vehicle." The following is information from the FlexRay Consortium web site[19] on the basics of FlexRay and Consortium initiatives:

> In recent years there has been a significant increase in the amount of electronics that have been introduced into the car, and this trend is expected to continue as car manufacturers introduce further advances in safety, reliability and comfort.
>
> The introduction of advanced control systems combining multiple sensors, actuators and electronic control units are beginning to place demands on the communication technology that were not previously addressed by existing communication protocols.
>
> Additional requirements for future in-car control applications include the combination of higher data rates, deterministic behavior and the support of fault tolerance. Flexibility in both bandwidth and system extension will also be key attributes as the need for increased functionality and on-board diagnostics also increase.
>
> Availability, reliability and data bandwidth are the key for targeted applications in Powertrain, Chassis and Body control, and these must also be supported within the automotive environment which presents some unique challenges.
>
> The core member companies of the FlexRay Consortium (BMW, Bosch, DaimlerChrysler, Freescale, GM, NXP Semiconductors and Volkswagen) have been working together in developing the requirements for an advanced communication system for future automotive applications. These seven companies have brought together their respective areas of expertise to define a communication system that is targeted to support the needs of future in-car control applications.
>
> FlexRay is a communication system that will support the needs of future in-car control applications. At the core of the FlexRay system is the FlexRay communications protocol. The protocol provides flexibility and determinism by combining a scalable static and dynamic message transmission, incorporating the advantages of familiar synchronous and asynchronous protocols. The protocol also supports:
>
> - Fault-tolerant clock synchronization via a global time base
> - Collision-free bus access
> - Guaranteed message latency
> - Message oriented addressing via identifiers
> - Scalable system fault-tolerance via the support of either single or dual channels

[19] www.flexray.com

A physical layer incorporating an independent Bus Guardian provides further support for error containment. The FlexRay system is targeted to support a data rate of 10Mbit/sec with increased flexibility for easy system extension and the dynamic use of bandwidth. The 10Mbit/sec data rate is available on two channels, giving a gross data rate of up to 20Mbit/sec.

In support of FlexRay, an array of development tools for design, measurement and simulation of the communication system is available on the market.

FlexRay is targeted at meeting the needs of present and future in-car control applications and the aim is to establish FlexRay as the de facto standard in the automotive industry.

The FlexRay Consortium indicates that its focus during 2006-08 timeframe will be the following main tasks:

- Ensure conformance of FlexRay devices
- Encourage commercial exploitation of the FlexRay system
- Extend the technical specifications to cover additional specific application domains

The automotive industry has software goals and initiatives that are very synergistic with SDR initiatives in the AUTOSAR (AUTomotive Open System ARchitecture) development partnership[20]. AUTOSAR is an open and standardized automotive software architecture, jointly developed by automobile manufacturers, suppliers and tool developers. The proposed AUTOSAR software architecture is presented in Figure 3-7. The fundamental benefits that AUTOSAR targets include:

- Enable innovative electronic systems that further improve performance, safety and environmental friendliness
- Enable a strong global partnership that creates one common standard: "Cooperate on standards, compete on implementation"
- Provides a key enabling technology to manage the growing electrical/electronic (E/E) complexity. It aims to be prepared for the upcoming technologies and to improve cost-efficiency without making any compromise with respect to quality
- Facilitate the exchange and update of software and hardware over the service life of the vehicle

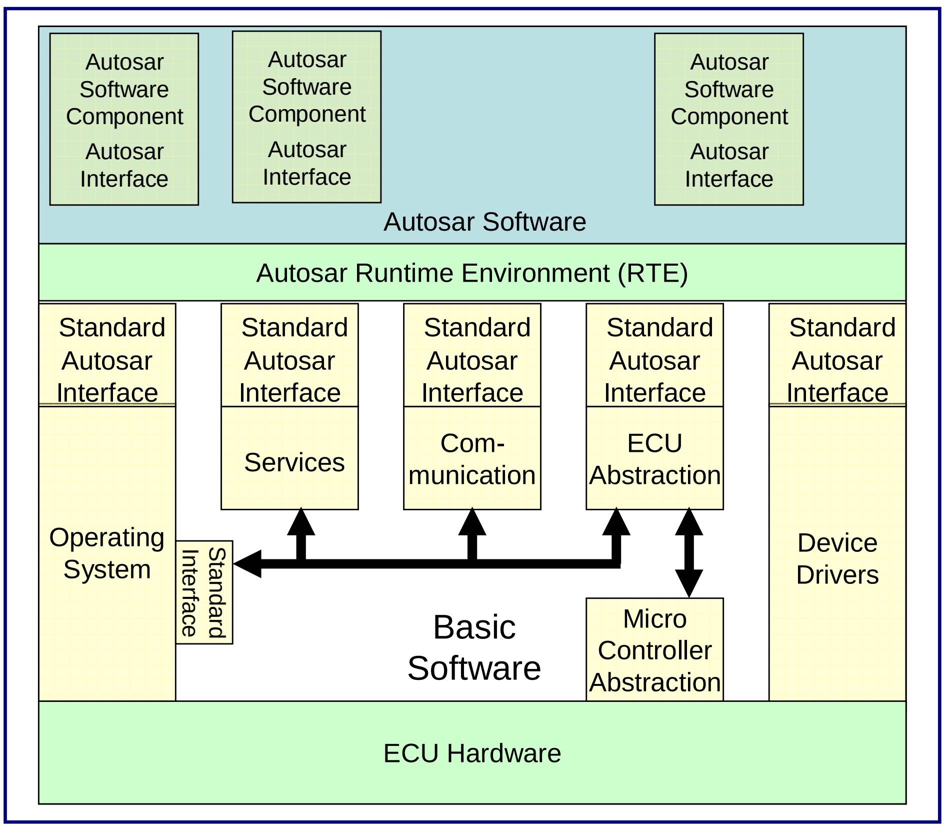

Figure 3-7 Proposed AUTOSAR Software Architecture
(Source: recreated from www.autosar.org, May 2007)

The AUTOSAR initiatives[20] are driven by the advent of innovative vehicle applications and contemporary automotive E/E architecture that has reached a level of complexity that requires a

[20] www.autosar.org, 6/2007

technological breakthrough in order to manage it satisfactorily and fulfill the the full extent of passenger and legal requirements. This need is particularly acute for high-end, luxury vehicle manufacturers and their leading Tier 1 suppliers who are faced with often conflicting requirements resulting from:

- Legal enforcement - key items include environmental impact and safety requirements
- Passenger convenience and service requirements from the comfort and entertainment functional domains.
- Driver assistance and dynamic drive aspects - key items include detection and suppression of critical dynamic vehicle states and navigation in high density traffic surroundings.

AUTOSAR was founded in 2003 by leading OEMs and Tier 1 suppliers. AUTOSAR has evolved to now include a large number of OEMs and Tier 1 suppliers plus automotive, semiconductor, electronics, hardware companies and software companies. The goals that motivated the founding of the AUTOSAR partnership include:

- Implementation and standardization of basic system functions as an OEM wide "Standard Core" solution
- Scalability to different vehicle and platform variants
- Transferability of functions throughout network
- Integration of functional modules from multiple suppliers
- Consideration of availability and safety requirements
- Redundancy activation
- Maintainability throughout the whole "Product Life Cycle"
- Increased use of "Commercial off the shelf hardware"
- Software updates and upgrades over vehicle lifetime

AUTOSAR[21] targets re-use of hardware and software components between different vehicle platforms, OEMs, and suppliers. This is achieved by defining a methodology that supports a distributed, function-driven development process. It standardizes the software architecture of deployments and defines compatible software interfaces at the application level. Not unlike SDR initiatives, AUTOSAR uses abstraction to separate software from hardware and targets decentralized networks. The benefits include:

- Management of E/E complexity associated with growth in functional scope.
- Flexibility for product modification, upgrade, and update.
- Scalability of solutions within and across product lines
- Improved quality and reliability of E/E systems.

The AUTOSAR standard will serve as a platform upon which future vehicle applications will be implemented and will also serve to minimize the current barriers between functional domains. It will, therefore, be possible to map functions and functional networks to different control nodes in the system, almost independently from the associated hardware. We found the following

[21] "Achievements and exploitation of the AUTOSAR development partnership", Convergence paper, 2006

statements on the AUTOSAR web site concerning modularity and configurability to be particularly interesting and SDR synergistic:

- Definition of a modular software architecture for automotive electronic control units
- Consideration of HW dependent and HW independent SW modules
- Integration of SW modules provided by different suppliers to increase the functional reuse
- Transferability of functional SW-modules within a particular E/E-system at least at the final software linking process
- Resource optimized configuration of the SW infrastructure of each ECU depending on the function deployment
- Scalability of the E/E-system across the entire range of vehicle product lines

3.5. US ITS Initiatives

Intelligent Transportation Systems (ITS) appear on track to be an important synergistic component to enable successful Telematics initiatives. One future-looking international initiative is the U.S. Department of Transportation's ITS[22] program that is:

> …based on the fundamental principles of intelligent vehicles and intelligent infrastructure and the creation of an intelligent transportation system through integration within and between these two components. … Increasingly, the Federal investments will be directed at targets of opportunity -- major initiatives -- that have the potential for significant payoff in improving safety, mobility and productivity. These targets of opportunity will include both the infrastructure and vehicles, but to the greatest extent possible will focus on the integration between vehicles and infrastructure, between modes of transportation, and between jurisdictions.

We have noted in our research that US ITS priority focus appears to be safety, Europe to be traffic information (e.g. TMC), and Japan to be traffic information and infotainment. Longer term international goals encompass all these capabilities.

The US DOT has had ongoing ITS initiatives since Congress enacted

> … The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) to establish a Federal program to research, develop, and operationally test Intelligent Transportation Systems (ITS) and to promote their implementation. The program was designed to facilitate deployment of technology to enhance the efficiency, safety, and convenience of surface transportation, resulting in improved access, saved lives and time, and increased productivity. … The ITS program carries out its goals through research and development, operational testing, technology transfer, training and technical guidance in the areas of

[22] US Department of Transportation ITS web site, www.its.dot.gov

intelligent vehicles, advanced traffic and transit management, commercial vehicle operations, public safety, traveler information, and intermodal freight.

A key initiative has been the ongoing and evolving development of the national ITS architecture that is depicted in the high level block diagram of version 6.0 (June 2006 release with many 2007 updates) in Figure 3-8. As the figure depicts the architecture includes 22 subsystems (rectangles) that grouped into four classes that include centers, travelers, vehicles and field. The architecture includes four general communication links (ovals) that provide information exchange between subsystems. These communication links include fixed point-to-point links that are generally wireline links such as fiber. Wide area wireless is generally fixed to mobile and includes both private and public (e.g. cellular) links. Key emerging requirements are for vehicle-to-vehicle (V2V) links and for vehicle-to-infrastructure (V2I) (dedicated short range communication or DSRC).

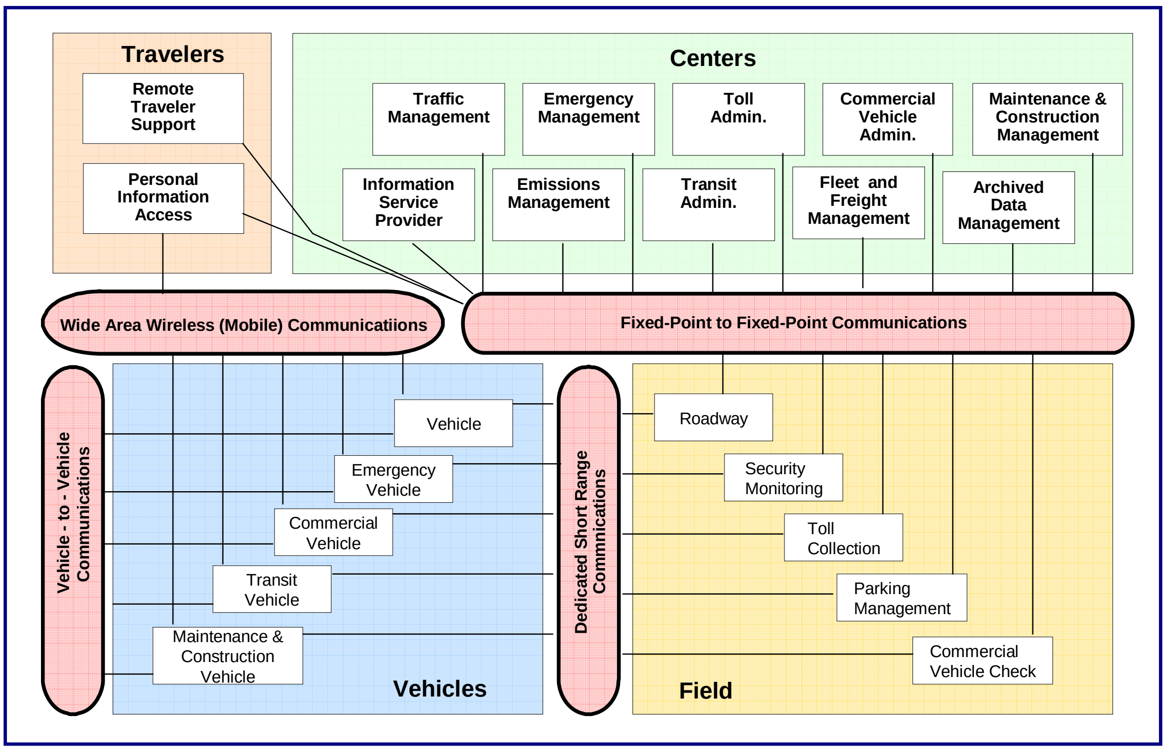

Figure 3-8 US DOT ITS Architecture
(Source: Source: http://www.iteris.com/itsarch, June 2007)

In 2004 DOT's ITS Management Council[22] reorganized the functions of the ITS program to focus on nine particular high pay-off areas that include:

- Vehicle Infrastructure Integration (VII)
- Next Generation 9-1-1
- Cooperative Intersection Collision Avoidance Systems
- Integrated Vehicle Based Safety Systems
- Integrated Corridor Management Systems

- Clarus (named for a Greek oracle) is an integrated surface transportation weather observing, forecasting, and data management, and warning system
- Emergency Transportation Operations
- Mobility Services for All Americans
- Electronic Freight Management

All the above initiatives involve communications and/or computer technologies. Of particular interest for SDR is the Vehicle Infrastructure Integration (VII) initiative. A key motivation for VII is that about 21,000 of the 43,000 deaths that occur each year on U.S. highways result from vehicles leaving the road or traveling unsafely through intersections. To save lives and prevent injuries on roadways, communication between vehicles and between vehicles and the roadside are needed. The advanced wireless communication technologies that are envisioned to enable VII initiatives include the Dedicated Short Range Communications (DSRC) standards that are enhancements to the IEEE 802.11 WLAN standards. The application opportunities envisioned for VII are presented in Figure 3-9.

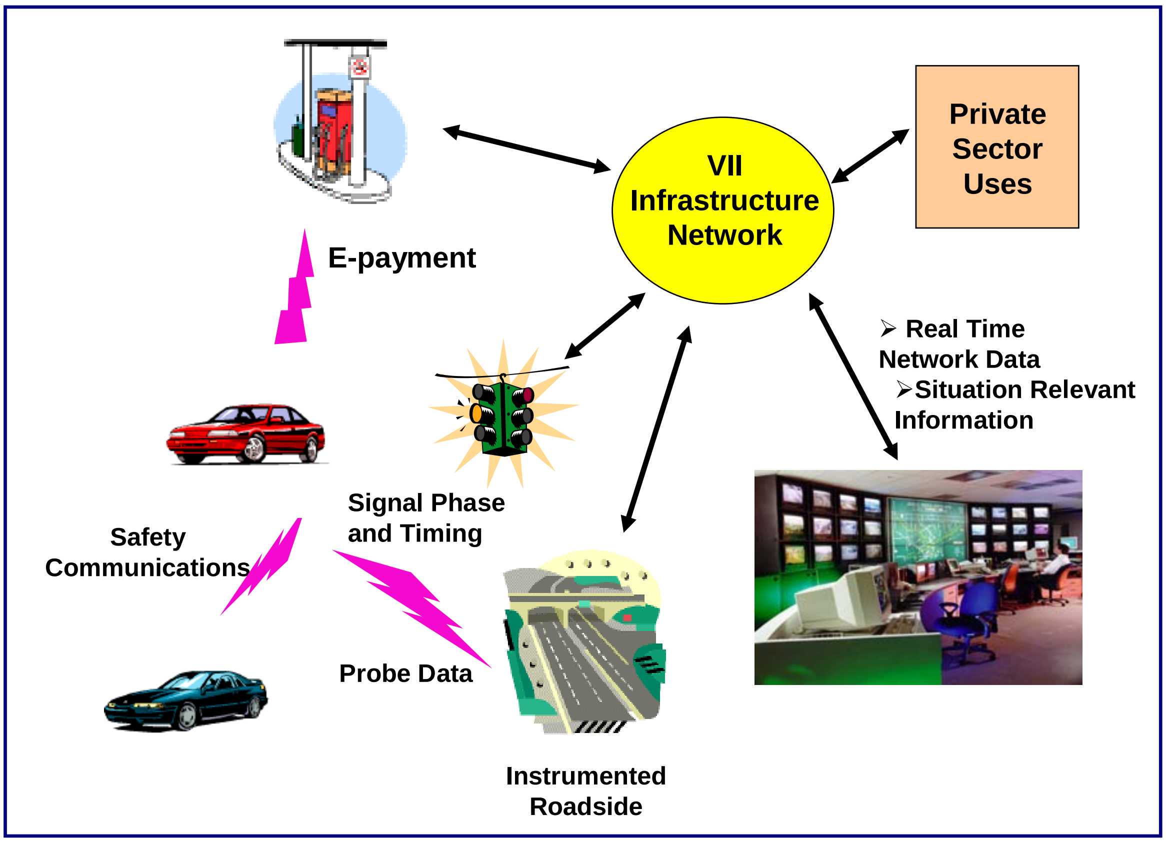

Figure 3-9 Vehicle Infrastructure Integration (VII) Application Opportunities
(Source: Mike Schagrin, VII Applications Manager, ITS JPO, USDOT Presentation, ITS America Annual Meeting, June 2007)

The DSRC standards for VII are based on the IEEE 802.11 family and will include the pending IEEE 802.11p standard referred to as Wireless Access in the Vehicular Environment (WAVE). The standard defines enhancements to 802.11 required to support Intelligent Transportation Systems (ITS) applications. These enhancements include data exchange between high-speed vehicles and between the vehicles and the roadside infrastructure in the licensed ITS band of 5.9

GHz (5.85-5.925 GHz). A companion family of standards, the IEEE 1609 (Also referred to as (WAVE), define higher layer standards on which IEEE 802.11p is based. The 802.11p Task Group schedule indicates that the formal standard is to be published in April 2009. The ultimate vision is a nationwide network that enables communications between vehicles and roadside access points or other vehicles. IEEE 802.11p will eventually replace the current family of ASTM[23] E2213 standards. The key standards for DSRC are summarized in Table 3-8.

ASTM E2158-01, Standard Specification for Dedicated Short Range Communication (DSRC) Physical Layer using Microwave in the 902-928 MHz Band
ASTM E2213-03, Standard Specification for Telecommunications and Information Exchange Between Roadside and Vehicle Systems - 5 GHz Band Dedicated Short Range Communications (DSRC) Medium Access Control (MAC) and Physical Layer (PHY) Specifications
IEEE 802.11p, Wireless Access in the Vehicular Environment (WAVE), Scheduled for April 2009 publishing, will replace current ASTM E2213 standards
IEEE 1609.1-2006, Standard for Wireless Access in Vehicular Environments (WAVE) - Resource Manager
IEEE 1609.2-2006, Standard for Wireless Access in Vehicular Environments (WAVE) - Security Services for Applications and Management Messages
IEEE P1609.3, Standard for Wireless Access in Vehicular Environments (WAVE) - Networking Services
IEEE 1609.4-2006, Standard for Wireless Access in Vehicular Environments (WAVE) - Multi-Channel Operation

Table 3-8 DSRC Standards
(Source: ASTM and IEEE)

The DSRC system contains RoadSide Units (RSUs) and vehicle On-board Units (OBSs). The RSUs connect to a land-based infrastructure with ITS application interface. While the OBUs are integrated into a vehicle's internal network and will support embedded vehicular applications. The operating parameters of DSRC include:

- DSRC will operate in the 5.9 GHz (5.850-5.925) band, which is divided into seven 10 MHz channels (one control and six services).
- Vehicle speeds up to 120 mph
- Communication range up to 1000 meters for special vehicles; nominal is 300 meters
- System Latency < 50 ms
- Data rate default is 6 Mbps; up to 27 Mbps
- Half duplex operation

The 5.9GHZ DSRC standards enhance the 802.11 standards for licensed operations and to include the special operating parameters and requirements for VII applications such as latency, high availability, and security.

[23] ASTM – American Society for Testing and Materials

In 1998, the President signed into law the Transportation Equity Act for the 21st Century ("TEA-21")[24] which directed the FCC to consider, in consultation with the Department of Transportation (DOT), the spectrum needs “for the operation of intelligent transportation systems, including spectrum for the dedicated short-range vehicle-to-wayside wireless standard,” DSRC. TEA-21 also directed DOT to promote, through the National Architecture, interoperability among ITS technologies implemented throughout the United States. In October 1999, the FCC allocated the 5.9 GHz band for DSRC-based ITS applications and adopted basic technical rules for DSRC operations. In February 2004, The FCC issued the Report & Order “03-324A1” defining the initial service and licensing rules for DSRC. The FCC licenses DSRC RSUs, which are fixed communication units along the roadside, under subpart M (Intelligent Transportation Radio Service) of Part 90 of the Commission’s rules. Licensees are required to register RSUs by site and segment(s). OBUs are in-vehicle communications units and operate under new subpart L of Part 95.

Governmental entities will be authorized a geographic-area license based on that entity’s legal jurisdictional area of operations. Non-governmental entities, will be licensed based on each applicant’s area-of-operation, i.e., by county, state, multi-state, or nationwide. Frequency coordination will not be necessary. Those applicants who are approved will each be granted a non-exclusive license for the geographic-area requested. Operation may not begin until licensees register RSU sites, channels, and other relevant data in the Universal Licensing System (ULS). RSUs at locations within 75 kilometers of Government radar sites are also subject to NTIA[25] coordination. Operation may not begin until NTIA approval is received.

[24] www.fcc.gov
[25] National Telecommunications and Information Administration

4 The Telematics Market

As discussed in Section 3, the automotive market is rapidly trending to become an international market. Historically, the United States has been the world's dominant automotive market in terms of both vehicles on the road (i.e., vehicle registrations) and in terms of yearly automotive sales. However, automotive trends in mature markets are saturating and sales growth is slow to even flat in some mature markets. The most growth in upcoming years will be in emerging markets such as the BRIC countries (Brazil, Russia, India, and China). China and India, especially, are attracting special interest from virtually all automotive OEMs and suppliers.

The number of registered automobiles, based on current trends, appears on track to internationally reach 1 billion registrations by year end 2010 as depicted in Figure 4-1. The figure plots passenger cars and vehicles (i.e. light vehicles and light trucks).

Table 4-1 provides data on automobile registrations from 2000 to 2010 by region for North America, the Caribbean and Latin America (CALA), Asia, and Europe (including Africa). The number of automotive registrations by region for 2006 is presented in Figure 4-2.

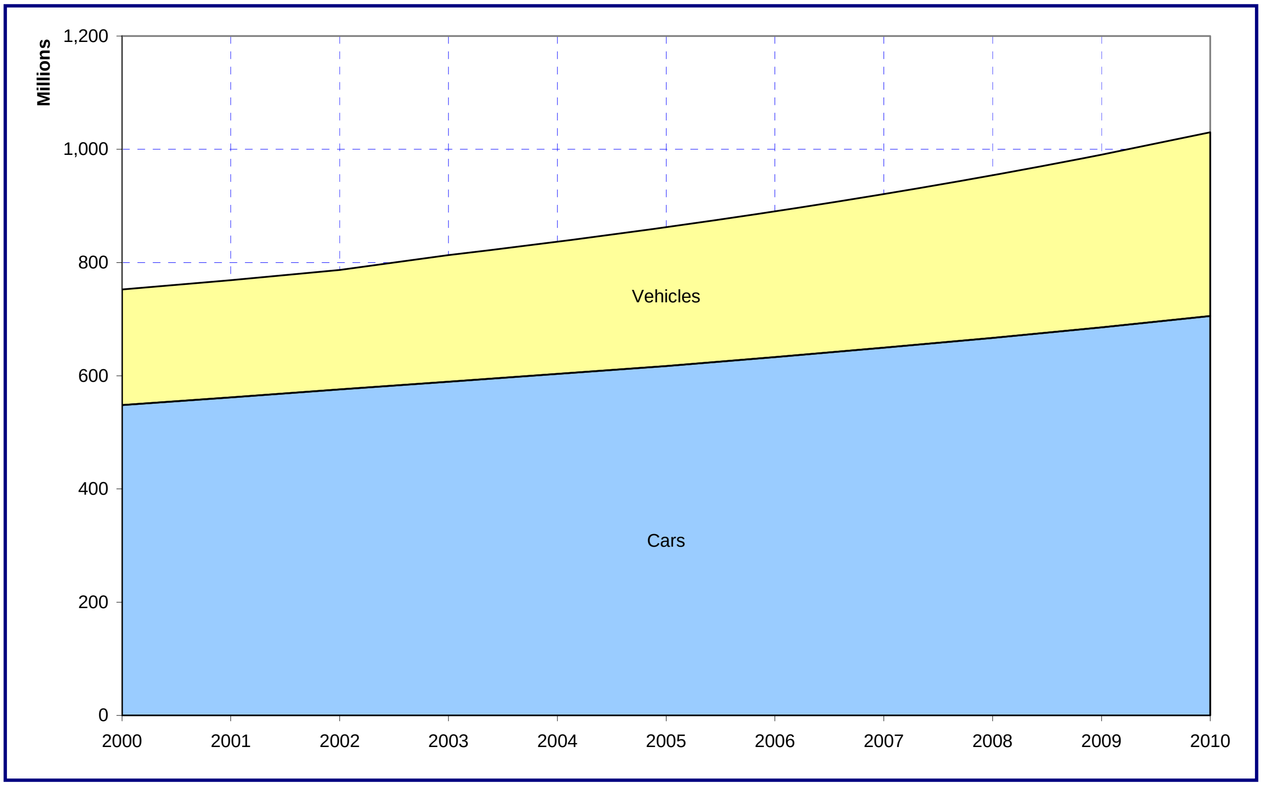

Figure 4-1 International Automobile Registrations
(Source: Table 4-1)

Total Auto Registrations	2000	2001	2002	2003	2004	2005	2006	2007E	2008E	2009E	2010E
NA	246,520,968	252,250,726	258,178,231	264,403,931	271,506,800	279,112,609	286,533,859	294,265,524	302,322,987	310,722,458	319,481,031
CALA	38,921,427	39,998,195	41,125,920	41,560,877	43,231,840	44,600,288	45,854,404	47,153,072	48,497,955	49,890,774	51,333,322
EUR	295,599,173	283,293,281	290,168,636	296,230,120	301,691,265	309,023,880	316,060,271	323,360,901	330,938,754	338,807,964	346,983,996
Asia	171,481,543	174,990,754	179,457,096	192,567,444	201,725,770	210,184,947	222,179,373	235,893,553	251,624,771	269,728,254	290,628,731
Total	752,523,111	768,681,146	786,623,306	813,000,354	837,022,825	862,419,914	890,509,319	920,956,817	954,090,193	990,297,247	1,030,037,576

Table 4-1 International Vehicles on the Road by Region
(Source: Ward's Automotive Group, 2006 data, and Author Research)

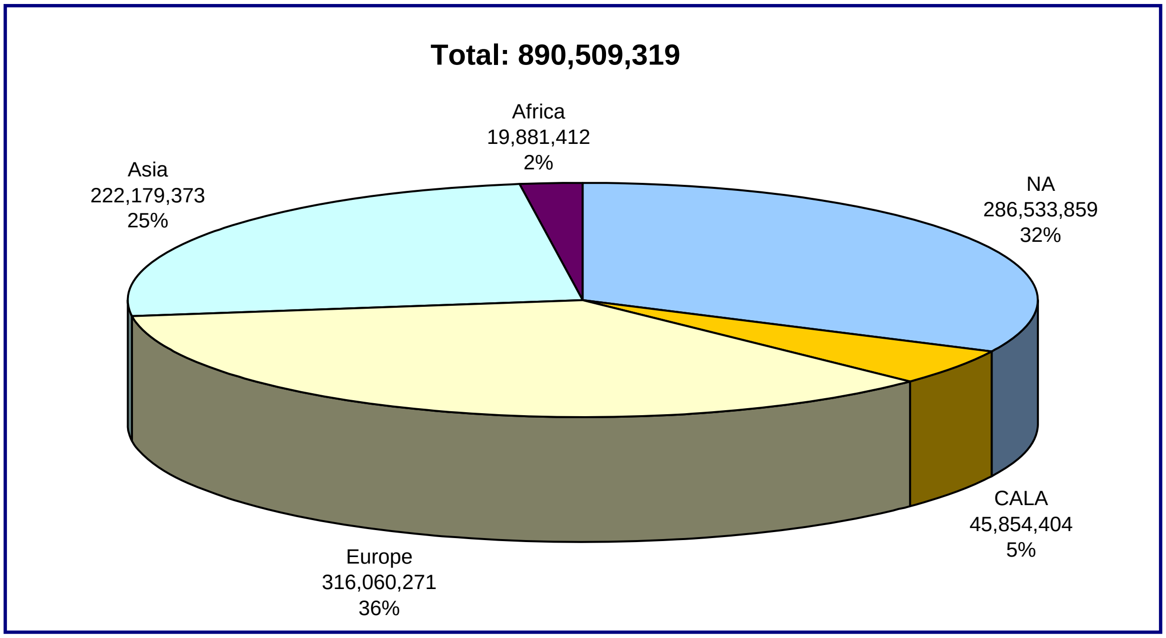

Figure 4-2 2006 World Automotive Registration by Regions
(NA = North America, CALA = Central and Latin America)
(Source: Table 4-1)

The number of automobile registrations for the top 25 countries is presented in Table 4-2.

Rank	Country	2006	% Int. Total
1	US	243,452,098	27.3%
2	Japan	74,087,238	8.3%
3	Germany	49,555,160	5.6%
4	Italy	39,640,770	4.5%
5	Peoples Republic of China	36,934,823	4.1%
6	France	36,736,164	4.1%
7	United Kingdom	35,499,805	4.0%
8	Russia	32,301,605	3.6%
9	Spain	25,926,776	2.9%
10	Brazil	23,894,110	2.7%
11	Mexico	23,879,709	2.7%
12	Canada	19,202,052	2.2%
13	Poland	16,164,709	1.8%
14	South Korea	16,113,440	1.8%
15	Australia	13,895,822	1.6%
16	India	13,231,161	1.5%
17	Turkey	9,149,128	1.0%
18	Thailand	8,954,265	1.0%
19	Netherlands	8,419,204	0.9%
20	Malaysia	8,395,418	0.9%
21	Ukraine	7,369,634	0.8%
22	Indonesia	7,143,016	0.8%
23	Argentina	7,094,889	0.8%
24	South Africa	7,000,095	0.8%
25	Taiwan	6,924,507	0.8%
	Total Top 25	770,967,604	86.6%
	International Total	890,509,319	100.0%

Table 4-2 Top 25 International Automobile Registrations by Country
(Source: Wards Automotive Group, 2006, and Author Research)

As the table illustrates, the US dominates international vehicle registrations and has for many years. In the upcoming years, it is anticipated that many international economies will experience substantial growth in registrations. The most significant growth is anticipated in Asia and includes China and India, both with populations over 1 billion. Many anticipate that China may overtake the US in vehicle sales in the 2010 – 2015 timeframe, and eventually in registrations.

New automotive vehicle sales by region are presented in Table 4-3 for 2000 to 2010. Figure 4-3 presents the percentage of international sales by region from 2000 to 2010. As the table and figure indicate Asia sales are forecast to exceed North American sales (NA) beginning 2007 and to exceed European (including Africa) sales beginning in 2009.

New Vehicle Sales, Units											
(000)	2000	2001	2002	2003	2004	2005	2006	2007E	2008E	2009E	2010E
NA	20,455	20,250	20,118	19,821	20,279	20,546	20,191	20,245	20,553	20,632	20,906
CALA	4,297	4,009	3,673	3,570	4,605	5,242	6,076	6,911	7,356	7,509	7,888
EUR	20,054	19,705	19,172	19,468	20,778	21,079	21,763	21,921	22,211	22,677	23,051
Asia	12,491	13,101	14,373	15,720	17,160	18,287	19,485	20,734	21,995	23,532	24,735
Total	57,297	57,065	57,336	58,579	62,822	65,154	67,515	69,811	72,114	74,350	76,580
Historical From GM annual reports, other AN Reps.; Forecasts are Author Estimates											
New Vehicle Sales, % Total											
NA	35.7%	35.5%	35.1%	33.8%	32.3%	31.5%	29.9%	29.0%	28.5%	27.8%	27.3%
CALA	7.5%	7.0%	6.4%	6.1%	7.3%	8.0%	9.0%	9.9%	10.2%	10.1%	10.3%
EUR	35.0%	34.5%	33.4%	33.2%	33.1%	32.4%	32.2%	31.4%	30.8%	30.5%	30.1%
Asia	21.8%	23.0%	25.1%	26.8%	27.3%	28.1%	28.9%	29.7%	30.5%	31.7%	32.3%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.00%	100.0%
% YOY Growth											
NA	2.1%	-1.0%	-0.7%	-1.5%	2.3%	1.3%	-1.7%	0.3%	1.5%	0.4%	1.3%
CALA	0.5%	-6.7%	-8.4%	-2.8%	29.0%	13.8%	15.9%	13.7%	6.4%	2.1%	5.0%
EUR	2.6%	-1.7%	-2.7%	1.5%	6.7%	1.4%	3.2%	0.7%	1.3%	2.1%	1.6%
Asia	7.1%	4.9%	9.7%	9.4%	9.2%	6.6%	6.6%	6.4%	6.1%	7.0%	5.1%
Total	3.2%	-0.4%	0.5%	2.2%	7.2%	3.7%	3.6%	3.4%	3.3%	3.1%	3.0%

Table 4-3 2006 International Automotive Sales
(Source: GM Annual Reports and Author Research, June 2007)

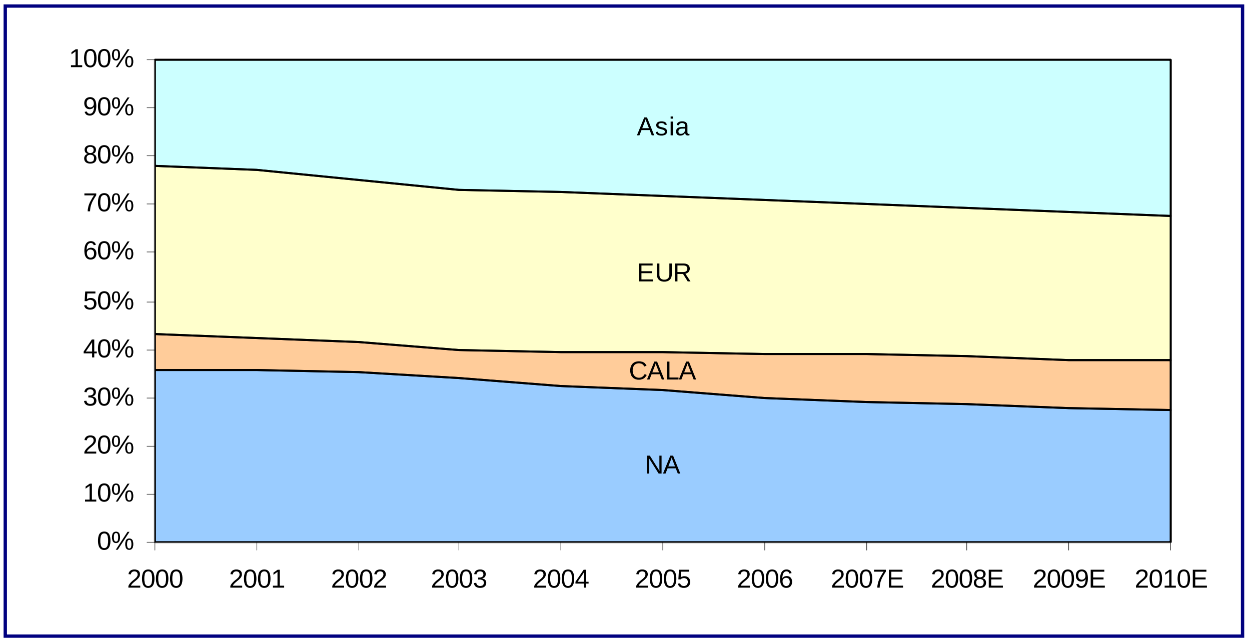

Figure 4-3 International Automotive Vehicle Sales percentage by Region, 2000 – 2010
(Source: Table 4-3)

Table 4-4 provides a breakout of international production by type of vehicle for 2000 – 2010. Figure 4-4 graphically presents the 2006 breakout by type.

Vehicle Production by Type	2000	2001	2002	2003	2004	2005	2006	2007E	2008E	2009E	2010E
Passenger Cars	42,307,434	41,378,845	42,553,171	43,418,901	45,021,993	46,660,492	47,624,059	48,618,072	49,642,462	50,697,222	51,782,414
Light Commercial Vehicles	14,797,611	13,749,124	13,099,694	14,360,785	16,163,477	16,950,107	17,431,678	17,930,821	18,447,834	18,983,045	19,536,810
Heavy Trucks	1,133,664	1,033,563	2,800,095	2,486,428	2,578,699	2,511,310	2,946,823	3,458,614	4,060,078	4,766,964	5,597,791
Bus & Coaches	153,663	163,736	387,339	333,173	401,086	343,499	403,801	474,793	558,373	656,780	772,651
Total	58,392,372	56,325,267	58,840,299	60,599,287	64,165,255	66,465,408	68,406,361	70,482,300	72,708,747	75,104,011	77,689,665
% of Yearly Total	2000	2001	2002	2003	2004	2005	2006	2007E	2008E	2009E	2010E
Passenger Cars	72.5%	73.5%	72.3%	71.6%	70.2%	70.2%	69.6%	69.0%	68.3%	67.5%	66.7%
Light Commercial Vehicles	25.3%	24.4%	22.3%	23.7%	25.2%	25.5%	25.5%	25.4%	25.4%	25.3%	25.1%
Heavy Trucks	1.9%	1.8%	4.8%	4.1%	4.0%	3.8%	4.3%	4.9%	5.6%	6.3%	7.2%
Bus & Coaches	0.3%	0.3%	0.7%	0.5%	0.6%	0.5%	0.6%	0.7%	0.8%	0.9%	1.0%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 4-4 International Automotive Vehicle Production by Type, 2000 – 2010
(Source: International Organization of Motor Vehicle Manufacturers, June 2007 and author forecasts)

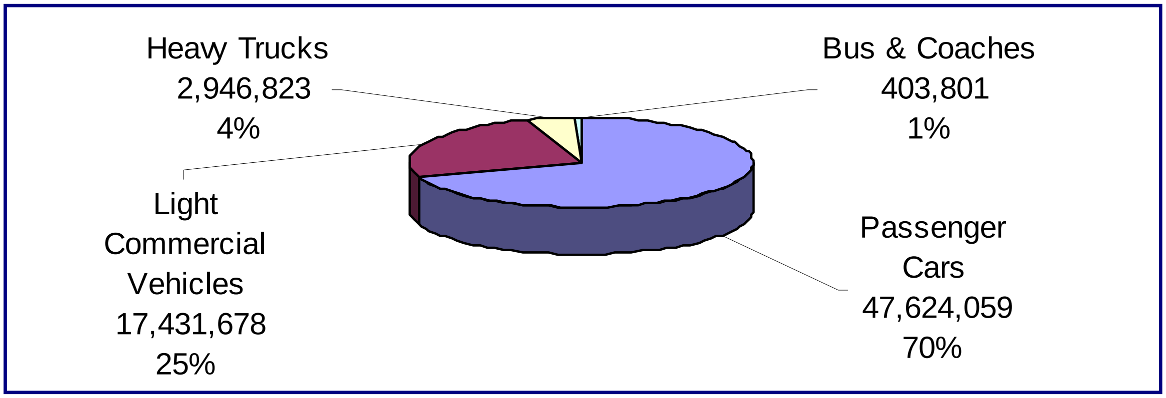

Figure 4-4 2006 Vehicle Production by Type
(Source: Table 4-4)

Automobile production and sales in individual countries are usually not the same. Countries such as Japan and South Korea are net exporter of vehicles. Other countries such as the US are net importers of vehicles. However, the international number for production and sales, while not the same, tend to track reasonably closely as may be observed by comparing Table 4-5 presenting production by region with Table 4-3 presenting sales by region. Figure 4-5 presents the percentage of production by region for 2000 to 2010. As would be expected Asia, with Japan and Korea and generally lower cost labor in other Asian countries, leads the world in automobile production.

Vehicle Production by Region	2000	2001	2002	2003	2004	2005	2006	2007E	2008E	2009E	2010E
North America	17,697,020	15,798,439	16,724,047	16,243,280	16,278,082	16,318,783	15,881,796	16,040,614	16,201,020	16,363,030	16,526,660
CALA	2,086,867	2,115,246	2,005,956	2,037,032	2,669,223	2,989,892	3,189,180	3,422,760	3,673,447	3,942,495	4,231,248
Europe	20,519,264	20,436,818	20,184,455	20,396,219	21,257,367	21,336,527	21,881,238	22,131,124	22,388,992	22,655,507	22,931,402
Asia	18,071,011	17,954,422	19,925,841	21,986,694	24,291,548	25,905,845	28,260,541	29,532,265	30,861,217	32,249,972	33,701,221
Total	58,374,162	56,304,925	58,840,299	60,663,225	64,496,220	66,551,047	69,212,755	71,126,763	73,124,676	75,211,004	77,390,531
% of Total	2000	2001	2002	2003	2004	2005	2006	2007E	2008E	2009E	2010E
North America	30.3%	28.1%	28.4%	26.8%	25.2%	24.5%	22.9%	22.6%	22.2%	21.8%	21.4%
CALA	3.6%	3.8%	3.4%	3.4%	4.1%	4.5%	4.6%	4.8%	5.0%	5.2%	5.5%
EUR	35.2%	36.3%	34.3%	33.6%	33.0%	32.1%	31.6%	31.1%	30.6%	30.1%	29.6%
Asia	31.0%	31.9%	33.9%	36.2%	37.7%	38.9%	40.8%	41.5%	42.2%	42.9%	43.5%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 4-5 Automotive Vehicle Productions by Region, 2000 - 2010
(Source: International Organization of Motor Vehicle Manufacturers, June 2007 and author Forecasts)

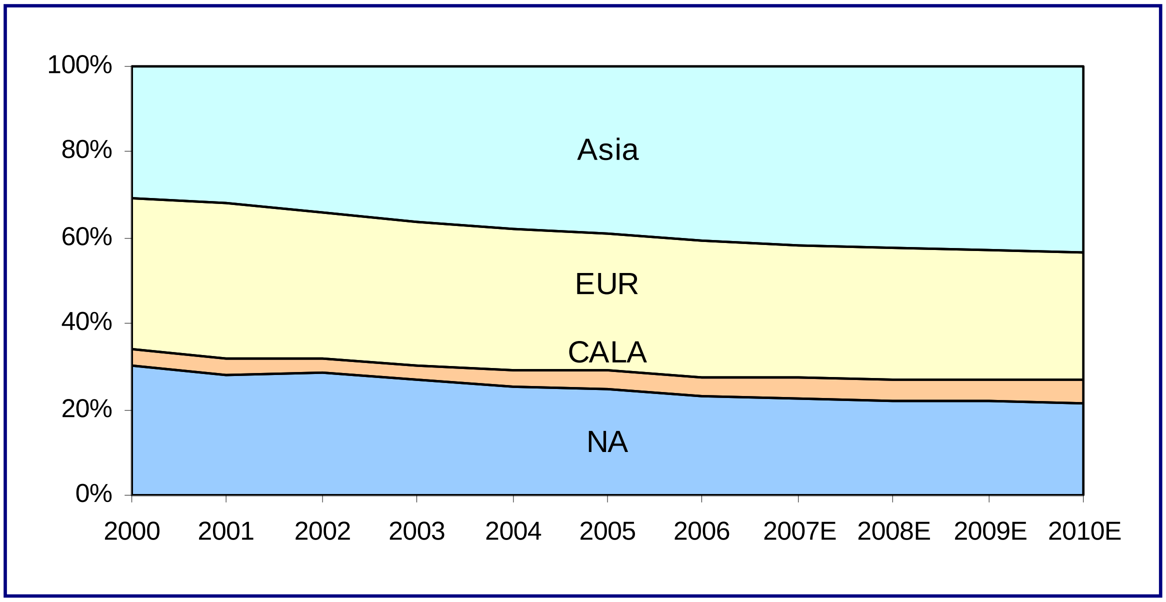

Figure 4-5 Percentage Automotive Vehicle Production by Region, 2000 – 2010
(Source: OICA and author Forecasts, June 2007)

	Company	Total	Passenger Cars	Light Commerical Vehicles	Light Commerical Vehicles	Heavy Vehicles
1	General Motors	8,926,160	5,708,038	3,156,888	43,838	17,396
2	Toyota	8,036,010	6,800,228	1,049,345	122,569	63,868
3	Ford	6,268,193	3,800,633	2,386,296	81,264	
4	Volkswagen Group	5,684,603	5,429,896	219,537	29,175	5,995
5	Honda	3,669,514	3,549,787	119,727		
6	PSA	3,356,859	2,961,437	395,422		
7	Nissan	3,223,372	2,512,519	570,136	134,874	5,843
8	Chrysler	2,544,590	710,291	1,834,299		
9	Renault	2,492,470	2,085,837	406,633		
10	Hyundai	2,462,677	2,231,313	966	145,120	85,278
11	Fiat	2,317,652	1,753,673	450,544	89,071	24,364
12	Suzuki	2,297,277	2,004,310	292,967		
13	DaimlerChrysler	2,044,633	1,275,152	378,278	340,296	50,807
14	Mazda	1,396,412	1,169,640	223,995	2,777	
15	Kia	1,381,123	1,181,877	197,060		2,186
	Total Top 15	56,101,545	43,174,631	11,682,093	988,984	255,737
	Total	68,340,304	51,953,234	13,187,688	2,850,233	349,149

Table 4-6 Top 15 World Automotive Production by Manufacturer, 2006
(Source: International Organization of Motor Vehicle Manufacturers, July 2007)

In our first study entitled “SDR Market Study: Market Segmentation and Sizing” it was concluded that the US, with OnStar the leading international Telematics service provider, was the leader in international Telematics. We excluded stand-alone GPS-based navigation systems as being insufficient to be considered Telematics as these only had GPS receivers and map data bases, but with no communications to support a core suite of Telematics services as per the Telematics definition in Section 2 of this report. Our opinions remain unchanged at this time; however, we have elected to include these stand-alone navigation units in our current Telematics market estimates and forecasts for the following reasons:

- Navigation units with maps, display, and GPS location capabilities are core to a suite of Telematics location based services (LBS). These stand-alone navigation units appear on-track over time to be integrated with more pervasive Telematics features and capabilities including communications. An integrated navigation unit with a map data base and display and with an integrated OnStar-like unit (see Figure 3-3) with two-way communication capability provides a significantly enhanced user experience.
- Stand-alone navigation units are achieving substantially increasing penetrations in passenger car sales, trending from early penetration in essentially only large/luxury cars, to mid size cars, and even increasingly in smaller cars.
- Stand-alone built-in and brought-in navigation units are becoming increasing popular for both automotive and non-automotive use.
- While the business case for Telematics still does not appear to have captured pervasive subscriptions and renewals, automobile manufactures are observing that Telematics services provide enhanced on-going customer relationship management benefits and that offering it at little, or no, charge supports gains in automobile maintenance revenues and eventually increased repeat sales at replacement time.
- Many governments around the world are very concerned with increasing traffic and congestion and needs to improve safety and reduce accidents and fatalities. Many free Telematics services may be offered and/or funded by governments as part of ITS initiatives to support goals to address these concerns.
- The business model for Telematics services is still a work-in-progress. The Telematics and navigation equipment required to support such services are increasingly being deployed in vehicles. Successful business models will undoubtedly emerge.

Thus, we provide market estimates for both navigation and Telematics equipment. Historically, the navigation units have been primarily standalone units with displays and map data bases. The map data bases have traditionally been updated by replacement of CDs or DVDs. The Telematics equipment is illustrated by OnStar control unit depicted in Figure 3-3. As discussed in section 3, GM has indicated that it intends to equip all of its US and Canadian market automobiles with Telematics units as standard equipment on model year 2008 vehicles and offer customers OnStar service at no cost for one year after vehicle purchase. After one year, customers must sign up for an OnStar service plan at the then current rate. Stand-alone navigation units are typically an option and customers may elect to purchase or not. We envision continuing markets for both stand-alone navigation units and Telematics units. An emerging market will be units providing feature sets of legacy stand-alone units plus enhanced integrated Telematics services such as Location Base Services (LBS), concierge, traffic alerting services, and navigation.

Table 4-7 presents Telematics equipment market estimates and forecasts for 2000 to 2010. Table 4-8 presents navigation equipments estimates and forecast 2000 to 2010. These tables present both units and penetration of automobiles sold. The data estimates and forecasts in these tables are for in-dash Original Equipment Manufacturer (OEM) units.

Telematics Penetration: Cars Sold											
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
NA	0.61%	1.14%	3.22%	7.32%	12.08%	17.40%	22.83%	28.25%	31.24%	34.95%	38.31%
CALA	0.00%	0.00%	0.05%	0.28%	0.26%	0.46%	0.82%	1.09%	1.70%	1.66%	1.58%
EUR	0.07%	0.18%	0.39%	0.77%	0.73%	1.42%	2.44%	3.88%	4.63%	4.53%	4.46%
Asia	0.04%	0.08%	0.14%	0.19%	0.24%	0.38%	0.46%	0.80%	0.91%	0.85%	0.81%
Total	0.25%	0.50%	1.30%	2.80%	2.8%	2.8%	2.8%	2.8%	2.8%	2.8%	10.8%
Telematics: New Vehicles Equipped Units (000)											
NA	125	230	648	1,450	2,450	3,575	4,610	5,720	6,420	7,210	8,010
CALA	0	0	2	10	12	24	50	75	125	125	125
EUR	15	35	75	150	152	300	531	850	1028	1028	1028
Asia	5	10	20	30	41	69	90	166	200	200	200
Total	145	285	745	1,640	1,759	1,824	1,890	1,955	2,019	2,082	8,271

Table 4-7 Telematics Equipment Market Units and Penetration Estimates and Forecasts
(Source: Company reports and author estimates and forecasts)

Navigation Penetration: Cars Sold											
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
NA	0.98%	1.48%	1.99%	3.03%	4.44%	5.96%	7.55%	8.94%	10.07%	11.10%	11.62%
CALA	0.02%	0.06%	0.14%	0.28%	0.34%	0.47%	0.51%	0.53%	0.57%	0.64%	0.70%
EUR	3.49%	5.58%	6.26%	7.70%	9.14%	9.96%	10.11%	10.54%	10.90%	11.69%	10.76%
Asia	6.32%	7.37%	7.48%	8.78%	9.73%	10.53%	10.32%	11.09%	11.14%	11.37%	11.26%
Total	2.95%	4.15%	4.67%	5.96%	7.14%	8.10%	8.54%	9.25%	9.68%	10.31%	10.12%
Navigation: New Vehicles Equipped Units (000)											
NA	200	300	400	600	900	1,225	1,525	1,810	2,070	2,290	2,430
CALA	1	2.5	5	10	15.5	24.4	31.1	36.7	41.8	47.8	55.5
EUR	700	1100	1200	1500	1900	2100	2200	2310	2420	2650	2480
Asia	790	965	1075	1380	1670	1925	2010	2300	2450	2675	2785
Total	1,691	2,368	2,680	3,490	4,486	5,274	5,766	6,457	6,982	7,663	7,751

Table 4-8 Navigation Equipment Market Units and Penetration Estimates, 2000 – 2010
(Source: Navteq, company reports, and author estimates and forecasts)

Table 4-9 presents the total international navigation and Telematics equipment revenue estimates and forecasts for 2000 to 2010. These estimates and forecasts are based on consistent inputs that typical costs of OEM in-dash navigation units are approximately $2000 and that of in-dash Telematics units are approximately $400. Figure 4-6 graphically presents the total equipment revenue estimates and forecasts for 2000 to 2010.

Total Navigation and Telematics Equipment Market											
$ B	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
NA	$ 650,000	$ 1,060,000	$ 2,096,000	$ 4,100,000	$ 6,700,000	$ 9,600,000	$ 12,270,000	$ 15,060,000	$ 16,980,000	$ 19,000,000	$ 20,880,000
CALA	$ 2,000	$ 5,000	$ 14,000	$ 40,000	$ 55,000	$ 96,800	$ 162,200	$ 223,400	$ 333,600	$ 345,600	$ 361,000
EUR	$ 1,430,000	$ 2,270,000	$ 2,550,000	$ 3,300,000	$ 4,104,000	$ 4,800,000	$ 5,462,000	$ 6,320,000	$ 6,896,000	$ 7,356,000	$ 7,016,000
Asia	$ 1,590,000	$ 1,950,000	$ 2,190,000	$ 2,820,000	$ 3,422,000	$ 3,988,000	$ 4,200,000	$ 4,932,000	$ 5,300,000	$ 5,750,000	$ 5,970,000
Total	$ 3,672,000	$ 5,285,000	$ 6,850,000	$ 10,260,000	$ 14,281,000	$ 18,484,800	$ 22,094,200	$ 26,535,400	$ 29,509,600	$ 32,451,600	$ 34,227,000

Table 4-9 Total Navigation and Telematics Equipment Market Revenue Estimates, 2000-2010
(Source: Author Estimates)

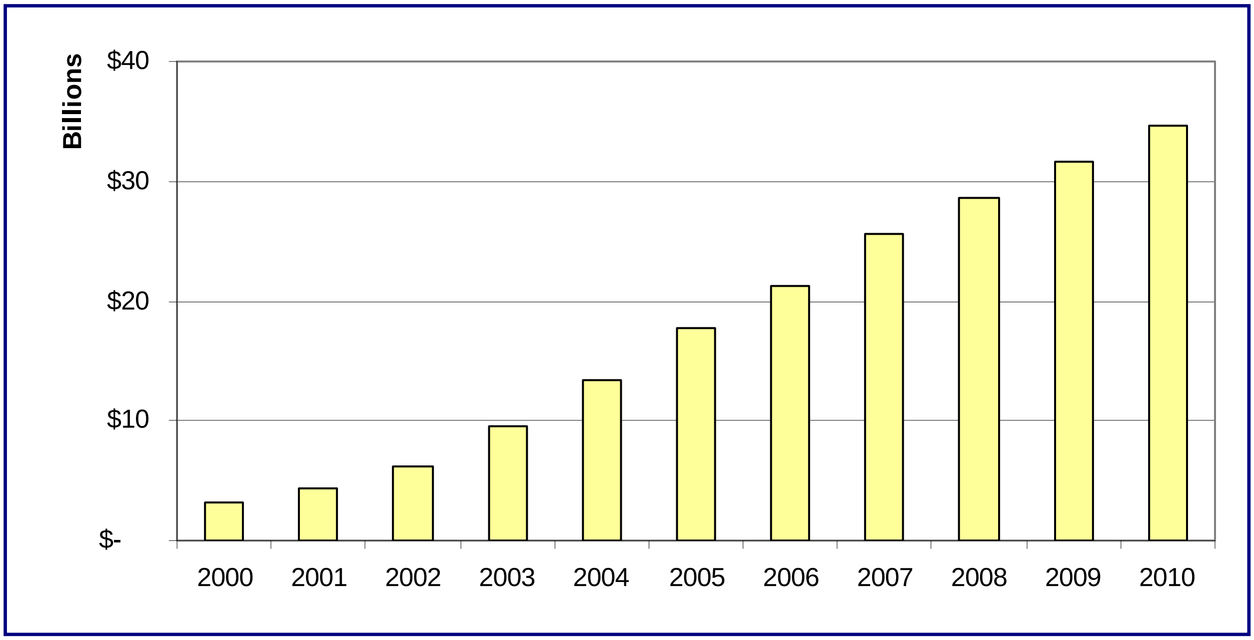

Figure 4-6 Total Telematics Equipment Revenue Estimates and Forecasts
(Source: Table 4-9)

In reviewing international information, a consistent conclusion has been that the North American / US Telematics markets and governments have been focused on safety and security, the European Telematics markets and governments have been focused on navigation and traffic information (see TMC service discussion in section 3), and that the Asian Telematics markets and governments[26] have been focused on navigation and infotainment. Although market data is not yet conclusive, indications are that international markets are evolving to similar sets of features and services that include safety, security, navigation, traffic information and management, and infotainment, providing similar capabilities in all regions.

We continue to conclude that Telematics services (e.g. OnStar, ATX) are dominated by the US and North America. However, the penetration of navigation units often with integrated traffic information features seems clearly more pervasive in comparatively more congested Europe and Asia, and especially in Japan. While these services often require other equipment such as RDS-capable FM receivers and satellite receivers for Telematics data transmission (usually one way), the purchase decision for this other equipment appears typically motivated by non-Telematics applications. Thus, we do not include units and revenues associated with such equipment in our above Telematics market estimates and forecasts, although in many cases they are essential to enable some Telematic functions and would significantly increase European and Asian market estimates and forecasts if included. It appears that on-board units will include integrated Telematics functionality including navigation and communications, and will provide core functionality in future automobiles.

There are numerous other wireless functions available for automobiles, including geolocation, traffic conditions, door locks, garage door openers, and ignition control. Others, such as anti-

[26] currently dominated by Japan, but in rapid evolution in Korea, Taiwan, China, plus others

collision radar and car-to-car data exchange, are under consideration.[27] As future automobile designs take a system-of-systems view of all the built-in and brought-in on-board wireless functionality the benefits of Software Defined Radio are likely to become increasingly valuable.

[27] US Department of Transportation ITS web site, www.its.dot.gov

5 Acronyms

2G	2^{nd} Generation
2.5G	Between 2^{nd} and 3^{rd} Generation
3G	3^{rd} Generation
4G	4^{th} Generation
AM	Amplitude Modulation
ARPU	Average Revenue per Unit (or user)
AUTOSAR	AUTomotive Open System ARchitecture
BRIC	Brazil, Russia, India, & China
BS	Base Station
BWA	Broadband Wireless Access
C & C	Computing and Communications
CALA	Caribbean and Latin America
CAN	(Automotive) Controller Area Network Bus
CAPEX	Capital Expense
CFR	Code of Federal Regulations (US)
CMRS	Commercial Mobile Radio Service (US)
COMSOC	IEEE Communications Society
CR	Cognitive Radio
DAB	Digital Audio Broadcasting (Eureka 147)
DIVA	Driver Interactive Vehicle Application
DOT	Department of Transportation
DSP	Digital signal Processor
DSRC	Digital Short Range Communications (802.11p)
DVB	Digital Video Broadcasting
DVB-H	Digital Video Broadcast – Handheld – T Terrestrial
DWTS	Digital Wideband Transmission System
EC	European Commission
ECU	Electronic Control Units
EHF	Extremely High Frequency
EMC	IEEE Electromagnetic Compatibility Society
ETSI	European Telecommunication Standards Institute
EU	European Union
FCC	Federal Communication Commission (US)
FlexRay	Communication System for Advance Automotive Control
FM	Frequency Modulation
GHz	Giga (10^9) Hertz
GM	General Motors
GPS	Global Positioning System
GSM	Global System for Mobile Communication
GSMA	GSM Association
HF	High Frequency
HMI	Human Machine Interface
HSPA	High Speed Packet Access

IF	Intermediate Frequency
IP	Integrated Project (e2r)
IP	Intellectual Property
IP	Internet Protocol
ISDB-T	Integrated Services Digital Broadcasting – Terrestrial
ISTEA	Intermodal Surface Transportation Efficiency Act
ITS	Intelligent Transportation Systems
ITU	International Telecommunication Union
kHz	kilo (10^3) Hertz
LAN	Local Area Network
LBS	Location Based Service
LF	Low Frequency
LIN	(Automotive) Local Interconnect Network Bus
LMR	Land Mobile Radio
LTE	Long Term Evolution
MAN	Metro Area Network
MANETs	Mobile Adhoc Networks
MHAL	Modem Hardware Abstraction Layer
MHZ	Mega (10^6) Hertz
MOST	(Automotive) Media-Orientated System Transport Bus
MSRP	Manufacturer's Suggested Retail Price
NA	North America
Net Adds	Net Additions (Subscribers)
NPRM	Notice of Proposed Rule Making
NTIA	National Telecommunications and Information Administration (US)
OBU	On-board Units (DSRC)
OEM	Original Equipment Manufacturer
OET	Office of Engineering and Technology (FCC)
Ofcom	Office of Communication (UK)
OFDM	Orthogonal Frequency Division Multiplexing
OPEX	Operating Expenses
PDA	Personal Digital Assistant
PAN	Personal Area Network
PAR	Project Authorization Request (IEEE)
PDN	Portable Navigation Device
PHY	Physical Layer (OSI Layer 1)
PLMRS	Private Land Mobile Radio Service
PSK	Phase Shift Key
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
R&O	Report and Order (FCC)
RAT	Radio Access Technology
RDS	Radio Data System
RF	Radio Frequency
RSU	Road Side Units (DSRC)
RTTI	Real-Time Traffic and Travel Information

SCA	Software Communication Architecture
SDR	Software Defined Radio
SHF	Super High Frequency
SIG	Special Interest Group
SMS	Short Message System
SNR	Signal to Noise Ratio
SUV	Sports Utility Vehicles
TCB	Telecommunication Certification Body
TDMA	Time Division Multiple Access
T-DMB	Terrestrial Digital Multimedia Broadcast
TEA	Transportation Equity Act for the 21st Century (US)
TETRA	Terrestrial Trunked Radio
TIA	Telecommunication Industry Association
TMC	Traffic Message Channel
TPC	Transmit Power Control
UHF	Ultra High Frequency
ULS	(US) Universal Licensing System
UMA	Unlicensed Mobile Access
UMTS	Universal Mobile Telecommunication System
UWB	Ultra Wideband
V2I	Vehicle to Infrastructure Communications
V2R	Vehicle to Road (or V2I) Communications
V2V	Vehicle to Vehicle Communication
VHF	Very High Frequency
VII	Vehicle Infrastructure Integration
VLF	Very Low Frequency
WAN	Wide Area Network
WAVE	Wireless Access in the Vehicle Environment, IEEE 802.11p
WCDMA	Wideband Code Division Multiple Access
WG	Working Group
WiFi	WLAN brand (Wireless Fidelity)
WiMAX	Worldwide Interoperability for Microwave Access
WIS	Wireless Internet Service
WLAN	Wireless Local Area Network
WMTS	Wireless Medical Telemetry Service
WNW	Wideband Networking Waveform
XML	eXtensible Markup Language