Latest Trends In Automotive Electronic Systems - Highway Meets Off-Highway?

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ABSTRACT

The rapid development of electronic systems in automotive vehicles has been driven for decades by constantly growing requirements of legislation for environmental protection, as well as rising demands of the end-user to improve fuel economy, safety, driving comfort and driving excitement. The manufacturers of mobile work machines also see themselves increasingly confronted with these requirements. Can Robert Bosch GmbH use the technical experiences from automobiles also in this area to efficiently develop high-quality electronic systems, which are future-oriented and be able to flexibly adapt the systems to different platforms?

The number of calibration parameters for example in an engine management system has risen within the last 20 years from a few hundred to over 7000. Therefore, the engineering effort for software and their calibration has increased dramatically. In the meantime for manufacturers of vehicles with low volumes, the engineering costs are comparable with the actual cost for the system components. Therefore, the future challenge will be the re-use of software functions engineered by manufacturers and suppliers for different vehicles and systems. In the automotive industry this attempt is being undertaken by different companies under the name AUTOSAR. Additionally, the software development is done in compliance to standards like CMMI or SPICE which ensure a consistent, high quality product. The exchange of information between control units makes the interaction of the systems much more complex and asks for more efficient, faster data communication systems by new standards, such as the bus system FlexRay. When electronic devices are viewed with a holistic approach, a large potential is evident for manufactures and their end-user.

Keywords: AUTOSAR, CMMI, electronic systems, network bus systems, quality, software, SPICE

1. INTRODUCTION

The automobile, a product in a marketplace with a fast technological development, is influenced by different technology drivers. The company Robert Bosch GmbH, as a recognized supplier and technical expert in this segment, asks itself the question whether there are similar boundary conditions in other high technology markets with similar mechanisms. Can Bosch learn from experiences in other industries and use synergies while sharing technical knowledge?

2. DRIVERS FOR DEVELOPMENTS IN THE AUTOMOTIVE INDUSTRY

The electronic systems in motor vehicles have evolved rapidly during the last 25 years, and according to forecasts their proportion of vehicle value will further increase in the next decades.

This development was driven from the beginning by three factors, which were also used very early as an advertising slogan by Bosch for their products: Safe, clean, and economical. Figure 1 show these and more technology drivers for automotive systems.

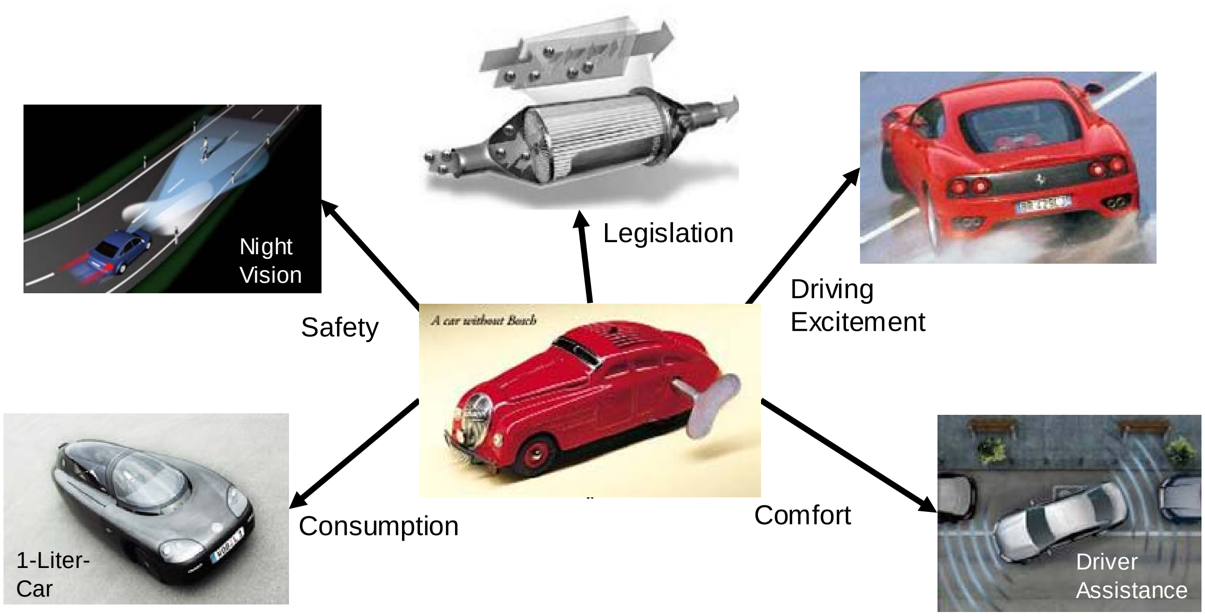

Figure 1. Technology drivers for automotive systems.

Safe: The rising consumer demand for safety has led to the fact that airbag, antilock braking systems and electronic stability controls are offered in almost all vehicles in production, at least as an option (Bosch, 1998). While the current systems offer passive safety, the future systems actively work to avoid dangerous situations for the driver and those around him or her (Seekirchner et al., 2006). Current innovative systems on the market are predictive safety systems like Brake Assist, Collision Warning and Emergency Braking.

Clean: The society and respectively the legislators are challenging the automotive engineers since the seventies with continuously rising requirements for low exhaust emissions. The legal requirements, created and driven by US legislation (EPA, CARB), have reached a high standard also in Europe and in emerging market countries like China. Based on this pressure the reduction of tailpipe emissions, particulate emissions, and the avoidance of other harmful materials has reached a very good state today and therefore, has contributed to the rising quality of life - specifically in densely populated areas.

Economical: The lower fuel consumption in modern automobiles is primarily a consequence of the lower tailpipe emissions, avoidance of parasitic engine losses and by the use of lighter materials. The next step is to operate the engine in more efficient areas and also to recuperate brake energy as shown in the hybrid vehicles. Certainly, the direct comparison of today's automobiles with the ones from 15 years ago does not always show a reduction of the absolute fuel consumption, but in the sum of its properties (safety, emissions, comfort, driving excitement) the automobile has become more efficient overall. This view opens two other factors you can see as relevant drivers of the development in the automotive industry.

Comfort: The electric operation of windows, seats, mirrors, etc. has been taken for granted in our day. Nearly all customers are opting for air conditioning with a new vehicle purchase. Low interior noise and vibration levels inside the vehicle guarantee relaxing driving conditions over long distances. The vehicle content with electrical motors and electronic devices will continuously increase and new innovations will emerge into smaller vehicle model lines.

Driving excitement: The car is not a simple transportation device any more. The customer identifies himself much more with the brand and the image. Providing driving excitement to the customer has become an important unique selling point for the manufacturer - most automotive advertising slogans want to meet this customer demand. The low sales figures of vehicles that followed the demands of politics and environment groups show that vehicles developed uncompromisingly to the economic market did not reflect the real customer demand. However, the current and future automotive development tries to merge the contrary points of economical and driving excitement closer together. The sales figures of current vehicles with turbo diesel engines, or supercharged gasoline engines designed for downsizing (small engines with high specific power performance) support the development trend. In the chassis area systems can be seen like active suspension and wheel individual torque distribution to improve the agility of the vehicles.

3. DRIVERS IN OFF-HIGHWAY APPLICATIONS FROM AN OUTSIDER POINT OF VIEW

The technology drivers of the automotive industry are well known to a supplier in this area. However, other markets and other products have other drivers, so an automotive supplier can only look onto the recent developments on the Off-Highway market as an amateur. How far apart from each other are these industries? Customers of Off-Highway equipment most likely want to have high industrial safety, low running cost, reduced operator fatigue and operator satisfaction. Certainly, these are other words, but actually serve the same basic needs.

From the point of view of an automotive supplier the world of the Off-Highway market is surprisingly complex and the portion of electronics in the modern machines is fairly high. Several control units are communicating with each other and their handling needs quite an amount of software which will rise further in the future. The high diversity of model types with low quantities challenges engineering to deliver a solution with restrained cost targets. Additionally high reliability and life-time durability are to be considered.

In the automobile business there are also products which are not comparable with high volume series production. The manufacturers of these products often use “off the shelf” hardware and software components which are customized from engineering service providers like Bosch Engineering GmbH. Projects with a yearly production volume from less than 10 to several thousand are standard in this case. Here we can observe very similar challenges arise as in the Off-Highway development.

4. HISTORY AND EVOLUTION OF ELECTRONIC SYSTEMS IN AUTOMOBILES

A review in the technical development allows good forecasts for the future and provides data to compare the parallel subjects (Bosch, 2005). Today, the technical development of vehicle systems is influenced clearly by increasing system complexity. Figure 2 and 3 represent the technical developments in the engine management system area from the first mechanical fuel injection in 1952 up to electronic direct gasoline injection DI-Motronic in 2000 with the most important milestones (Bosch, 2003).

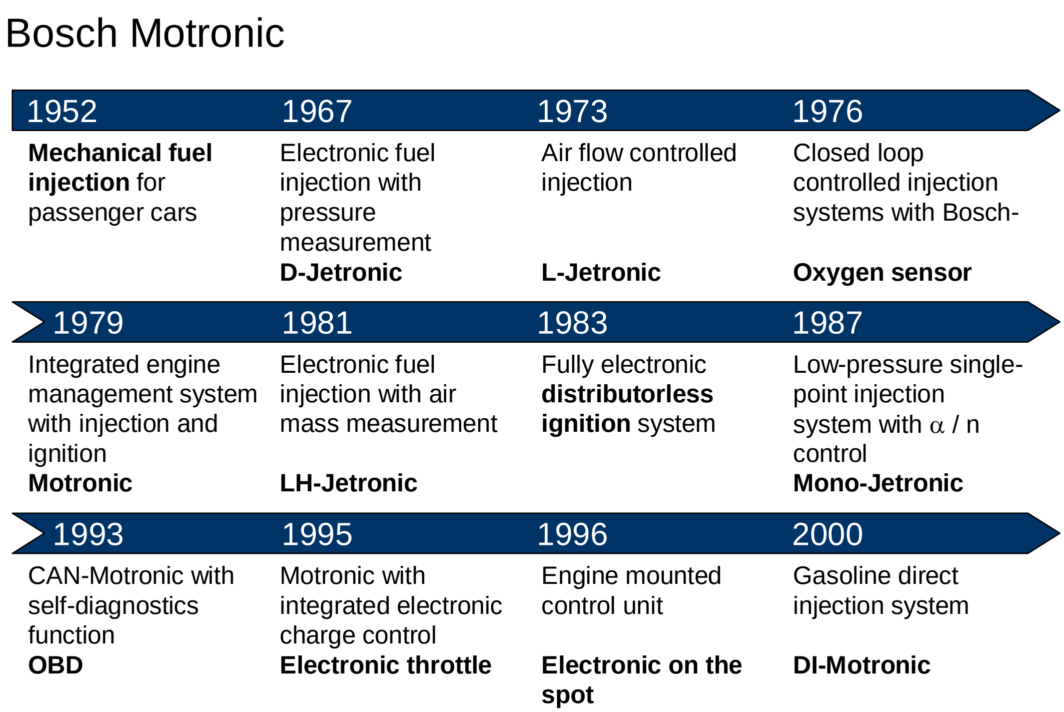

Figure 2. History of Bosch engine management systems.

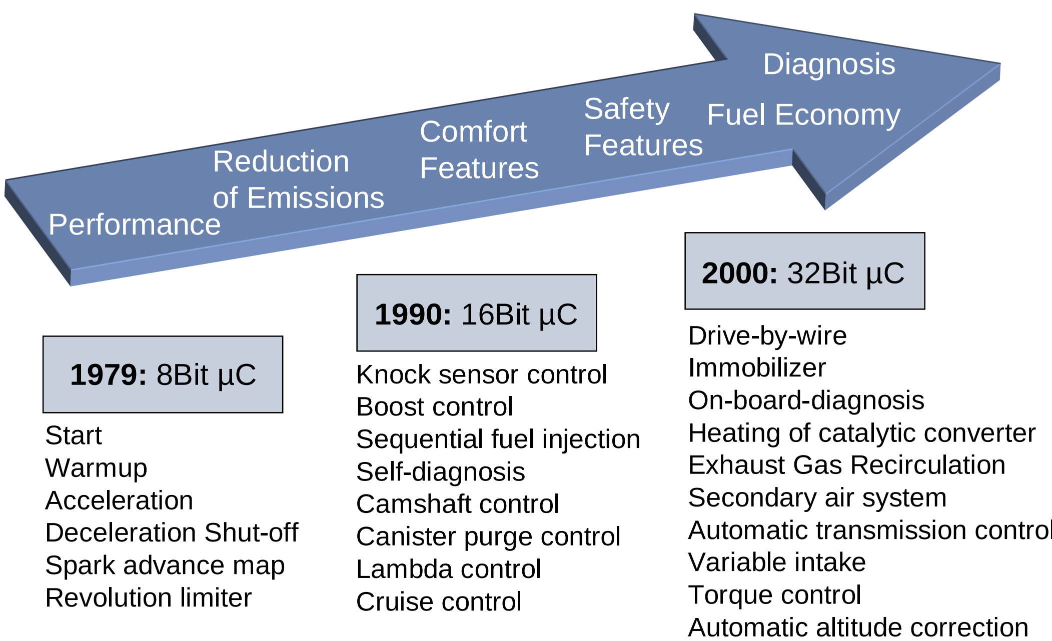

Figure 3. Historical milestones of microprocessors in automotive systems.

The engine management system software is designed for variable use in different engine configurations (Markus et al., 2006). Calibration of the software is performed with changing parameters that influence the activities in the functions. In the early nineties, a single engineer was able to calibrate the data of the whole engine management system. In the meantime the functional complexity has risen so high that a full engine calibration of a vehicle variant is executed by about half a dozen specialists each of them responsible for a self-contained subsystem. The number of labels to be calibrated has increased during this time from less than hundred to over 7000. Figure 4 shows the increased system complexity represented by examples of different variables like CPU speed, memory and number of lines of code.

		< 1990	1995	2005
Hardware	Processor	8 Bit	C196, 16 Bit	TriCore, 32 Bit
	Frequency	4 MHz	20 MHz	80-150 MHz
	Flash	10-100 kB	0,25–0,5 MB	1-6 MB
	Sensors	10	17	25
	Actuators	14	22	31
Software	Lines of Code	20,000	44,000	690,000
	Features	1,800	3,100	5,200
Calibration	Calibration Parameters	1,000	1,800	7,200

Figure 4. Evolution of system complexity in the power train.

5. CONTRARY TENDENCIES OF HARDWARE AND SOFTWARE COST

The primary focus of production applications in the past was clearly on the system component cost. In the meantime this has turned around and an increasing amount of the development budget is now allotted to software and calibration cost. The cost of control units, as well as the sensors and actuators have dropped by optimized design, cheaper subcomponents and more efficient production. The development expenses for production software and the calibration of more complex systems shows a rising trend.

This situation leads to a differentiated view and budget planning of automotive manufacturers with different quantities (fig. 5). A large-volume manufacturer with a platform of several 100.000 pieces per year has its focus clearly on the cost of the components. Certainly, the software and calibration cost also have an influence, but big saving potentials can be reached with small reduction of component prices. However, a manufacturer with quantities smaller then 1000 yearly has another attempt. The one-time effort for the software and calibration has a stronger effect on its cost per vehicle, than the components themselves. While it makes sense for a high volume manufacturer to invest several months of manpower in the production of software and calibration to save a sensor, it makes sense for a small volume manufacturer to add a sensor in his system if he can keep the software smaller and simpler.

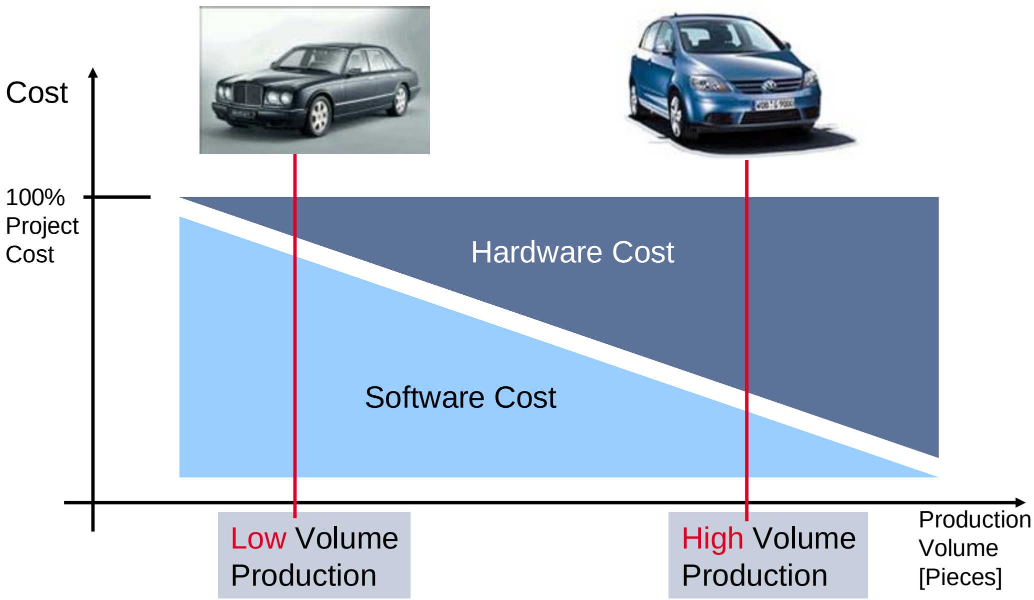

Figure 5. High volume vs. low volume project cost.

The challenge of a small volume manufacturer is the re-use and adaptation of proven high volume functions. This can still give him a unique selling point on the market accompanied with short development times, but with the same quality targets. This allows him a balanced relation of hardware cost to engineering cost.

6. MARKET OVERVIEW AND SHIFT OF ENGINEERING MARKET CONDITIONS

Based on the increased development efforts, the supplier market is changing. Studies of independent institutes confirm the aforementioned trends:

- The diversity of vehicle types rises and more niche vehicles are offered.
- The vehicle and engine families decrease, the number of the derivatives increases.
- The complexity and functionalities of the electronic system controllers increases.
- The importance of the driving comfort and driving performance increases.

The external engineering services have increased since the mid-90s, while the OEM's concentrate the resources on their core competence of functional characteristics which can be directly experienced by the end user. This is particularly apparent in the new growing markets like China, for example. The classic component suppliers play a central role in these markets. They offer their system know-how to the market of the engineering services.

Some representative numbers are shown in figure 6. The market volume of engine engineering for spark-ignition engines and diesel engines world-wide will rise within 5 years from EUR 10,100 million in 2003 by 4.3% annually to EUR 12,500 million. Approximately 2/3 of the volume is still performed within the OEM’s and about 15% are performed by Tier 1 suppliers and engineering service providers.

It is shown that Europe will remain the strongest region for engineering with over 50%. However, the segments in the emerging countries will rise disproportionately.

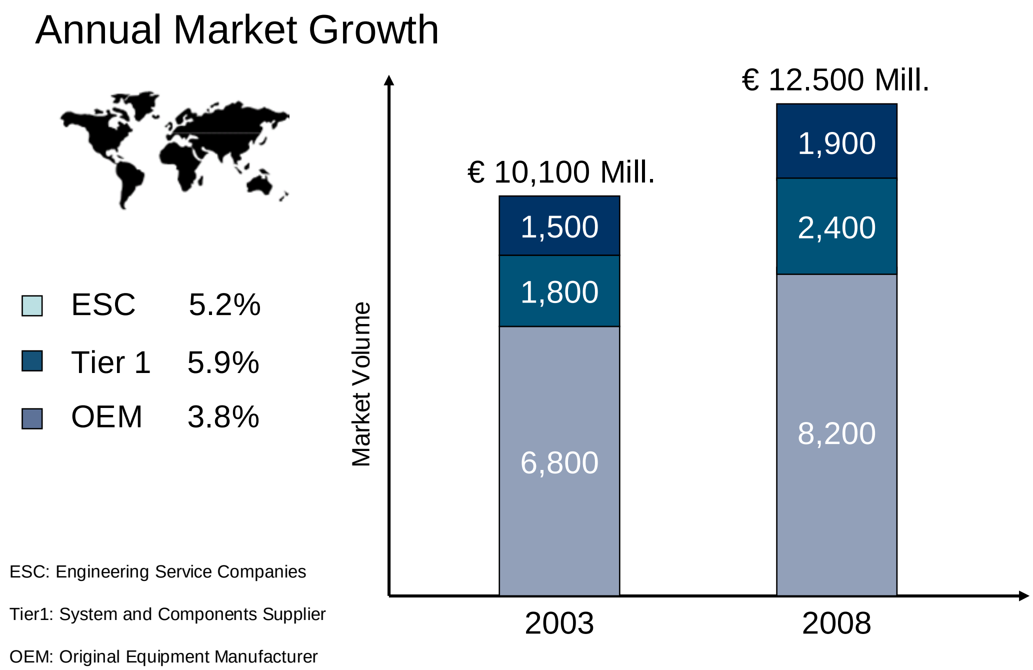

Figure 6. Worldwide market volume for engine engineering.

7. CONSEQUENCES OF SQUEEZED DEVELOPMENT TIMING AND LESSONS LEARNED

The challenge from the engineering viewpoint will be the shortened development time for much more complex systems in order to stay ahead of competition. The result from the networking of different systems is unforeseen defects which are discovered at a late development stage due to late system availability. The root cause analysis and trouble-shooting prove to be very difficult due to poor repeatability of errors in the overall system. High service cost and a negative influence on customer satisfaction are the consequence. The electric and electronics malfunctions are on the top of the list in the vehicle breakdown statistics of ADAC, the largest German Automobile Association (ADAC, 2006).

Therefore, different lessons have been learned and several consequences were drawn by the automotive industry:

- Downsizing of the functions. Even if the number of the functions will increase further, not every imaginable functional variation will be offered to the end user. Only those functions directly perceived and used from the customer will bring an added value.
- More simulation in the early phase of engineering. The software and hardware can be tested with designed system models. Even if system modules are still not available in the early stage of development, the interaction between the systems can be tested.

- The number of tests will be greatly increased, and to keep the cost within budget, the tests have to be executed automatically. The frequency of test runs can be raised with a high degree of automation. This will also improve the repeatability of testing.
- Quality processes and development models (for example, CMMI and Spice) help to structure the development so it is predictable and reproducible. Another target of these process models is the unwanted requirement creep, underestimated development resources, as well as the typical increase of change requests right before start of production.

The software structures are designed in a way that re-use of software parts is made easier. With strictly defined and documented interfaces it will be simpler to tie software modules from different vendors together (fig. 7).

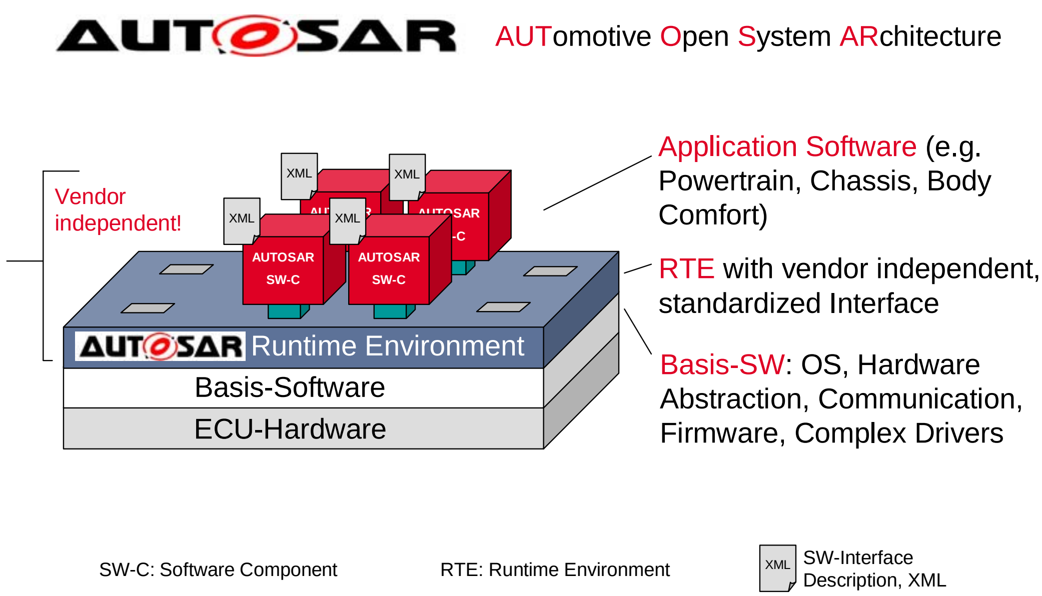

Figure 7. Next generation automotive software platform (AUTOSAR, 2006).

With an integrated consideration of the electronic systems, a big potential presents itself to the use of the manufacturers and their end-users.

8. CONCLUSION

Electronic system developments in the automotive world are driven by the major factors safety, environment, fuel consumption, comfort, and driving excitement (Aral, 2005).

The electronic value inside the vehicle and system complexity has drastically grown during the last 20 years due to the

- high number of controllers and their networking inside one vehicle,
- high amount of functionalities and lines of code inside the software, and
- requirements concerning hardware memory capacity and speed.

For some small volume manufacturers the software engineering effort to develop an electronic system is already higher then the electronic hardware cost over the lifetime of a vehicle production. It will be a challenge also for the large-volume manufacturers to meet future customer demands while keeping the engineering effort to a reasonable amount. Nevertheless, the need for electronic engineering will continue to grow worldwide.

An integrated consideration of electronic system development will open big potentials to help the manufacturers creating products with unique selling points for their customers.

With the viewpoint of an automotive-professional, certain aspects of the automotive world are also found in the environment of the Off-Highway developments.

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