AUTOFORE

WP340 – Future Developments and their Implications in Diagnostic Technology for Vehicles

WP350 – Future Infrastructure Developments and Capabilities of Off-board Diagnostics and Remote Sensing

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1 Summary

Today’s automobile industry is exposed to strong changes, which can be attributed to different influencing factors. Changed consumer behaviour is responsible for the major part of these new requirements. Next to comfort functions, the increased demands for vehicle safety became important purchase factors for the customer. This trend and also legal regulations for environmental protection lead to the development of new vehicle systems with a higher complexity and therefore with an increase of efforts for the development of the vehicle. On the other hand, the competitive pressure requires a reduction of development costs and time, which can have an influence on the quality and reliability of the products.

In order to react to these external influences development tasks are being outsourced to system, component and engineering supplier. The influencing factors for outsourcing are shown in Fig. 1-1. Cost and complexity reduction are here of main interest for the development for future vehicles and vehicle systems.

![Fig. 1-1: Influence factors for outsourcing in future development [1]](image)

In order to be able to ensure the system integrity for the operation of electrical and/or electronic systems, the manufacturers seize for the application of different on-board mechanisms for fault detection and localisation. Furthermore, fault management strategies, partially based on component redundancies, and self-diagnostic mechanisms have been documented in detail in the present report. Despite the mentioned efforts, recent breakdown statistics show that the complexity of electronic vehicle systems is still a challenge and leads to increased reliability problems.

The consideration of new requirements through adapted homologation regulations will be an OEM independent mechanism for the specification of system integrity with a direct influence on road safety.
Here, an extension of the lever by the legislator will play a particular role for the future definition of safety requirements, the possibility and necessity of technical inspection and maintenance of vehicle systems. For this scenario, however, the legislator has in future to anticipate technological developments in order for being able to define safety requirements for type approval and homologation before new systems are developed.

Due to technological changes also the requirements and the possibilities for the technical inspection will change. Telematic systems enable the possibilities on long-term range to implement permanent compliance testing and conformity checks for safety-relevant systems with self-diagnostic capabilities. The mid-term future will and has to offer the time efficient possibility to check electronically controlled systems through the application of off-board diagnostic tools with a standard interface like e.g. the CARB connector during the PTI.

For the detection of creeping system degradation, especially for mechanic components, modifications or manipulations of components, the visual inspection and/or efficiency testing by inspection authorities within PTI cannot be replaced by automatic self-diagnostic functions in future. Similar to vehicle homologation also here an adaptation of directive 96/96/EC to consider the changed conditions are to be taken forward, also for ensuring reproducible inspection procedures basing on best practice recommendations on an European level. In order to lead to a successful realisation the extensions have to be defined in close cooperation with the OEM, legal authorities and technical inspection organizations. As basis for the definition of requirements and the necessary diagnostic depth for the practical application of an inspection of electronically controlled systems e.g. the results of the EU-funded IDELSY project can be exploited. For the evaluation of the necessary diagnostic depth the diagnostic pyramid (Fig. 1-2) can be consulted.
The actual situation of a technical inspection of electronically controlled safety-relevant systems covers a visual inspection, check of the MIL and in case of concerns also a function test through a drive test of the corresponding system. For brake systems efficiency tests are carried out. Until now, only for the OBD-inspection of exhaust related components off-board diagnostic tools are being applied using the standardised CARB connector. Therefore, today not the whole for PTI possible diagnostic depth is exploited yet, lastly because of the fact that the goal of the vehicle inspection is only to assess whether a vehicle is operating properly and safe.

For a vehicle repair and maintenance necessarily all levels of the diagnostic pyramid have to be applied as the further tasks of fault localisation and elimination are scope of the work. Regarding the growing requirements concerning the function integrity within technical inspection investigations in a deeper diagnostic depth will be necessary. In future even an access to system-internal test routines within PTI could be necessary for the assessment of vehicle systems. It is also obvious that operative work like flashing and coding of ECUs will not become part of the scope of future PTI.

The fulfilment of the mentioned challenges presupposes however the access to necessary data for inspection authorities. Therefore, the clear necessity of a technical PTI-database is given, which requires a change of the perception of OEMs towards testing authorities. Through the advanced examination of vehicles in the field, inspection organizations in future can play a central role as service provider for the OEM for an efficient quality improvement and monitoring. The requirements for such a PTI-database on a European level, including business cases and privacy objectives will be part of WP360, as a database would extend the possibilities for PTI significantly.
2 Introduction

During the last decades an increasing trend to the use of electronically controlled systems in vehicles can be observed. Especially in the area of the emission regulation and reduction, which was intensified by the legislation, we owe our success to the first electronic engine management and monitoring systems. Also in other areas, e.g. security, comfort or infotainment this trend can clearly be observed. Additionally, a lower number of accidents and road casualties, although the traffic volume in this period constantly increased, has been achieved by the introduction of different vehicle safety systems (discussed in WP320). Beside the mentioned advantages, these new systems also carry certain disadvantages, e.g. the complexity of the systems and thus a certain fault liability. In order to make the complexity of the systems controllable and to ensure their functionality, different diagnostic mechanisms are required, which have to be considered already in the development and used over all phases of the vehicle life cycle.

As a goal of this work package, diagnostic mechanisms for different phases of the vehicle life cycle will be documented and their contribution to the road safety shall be evaluated. In addition, today's and future developments in the vehicle diagnostics in order to improve both the system integrity and the development quality, are to be dealt with. In particular there are numerous standardisations and new technologies to be considered. Furthermore, different applications of telematics in the vehicle are to be presented and to be evaluated regarding their use for the off board diagnostics and their role for the road worthiness enforcement.
3 Vehicle Diagnostics - Definition und Categorisation over the Product Cycle

"The procedure of finding error causes is called diagnostics. Thereby it is to be detected, what the reason for the error is (error cause), how the error becomes apparent (error symptom), what it’s effects are (error effect), what part is actually defective (error location) and how the error can be eliminated (error remedy)\(^1\). This could be a diagnostic definition out of the view of a skilled workshop worker.

However, vehicle diagnostics is no longer only one part of the daily work in the workshop. Meanwhile the simple workshop diagnostics developed to a diagnostic process, which has to be applied over all phases of the product development and product life cycle. In an early stage the processes serve for the avoidance of any system errors and to guarantee the system integrity, while diagnostic mechanisms find their employment at a later time of a vehicle life for error detection and classification.

The diagnostic process begins already with the specification of new functions (Fig. 3-1, left side). For this purpose, relevant diagnostic tasks in the later utilization of the vehicle, in order to fulfil legal directives or product safety, are considered. The result of these examinations is a requirements specification, which must cover requirements to diagnostics in all phases of the product cycle.

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\(^1\) Definition of the term „diagnostics“ (Source: "Diagnosearbeit im Kfz-Handwerk als Mensch-Maschine-Problem")

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After the specification phase the defined functions are developed. Due to the high complexity of today’s systems and a high cross-linking degree of functions, the diagnostic process can no longer be regarded separately from the development process but goes as well through each phase of the development process. Beside the definitions and drafts it covers numerous test phases, in which diagnosis (e.g. in form of HiL/SiL- (Hardware/Software-in-the-loop) testing) as proven tools are used since a long time. Beside the manufacturer, usually suppliers and service providers are also to be involved in this development process.

In return, the high complexity and increasing safety relevance of today’s systems require very complex and elaborated testing methods for the type approval of the product, which must correspond to the requirements defined by the legislator. This fact makes it necessary and indispensable that the process of homologation, which is approached at the end of the development, is started as early as possible and runs in parallel to the development process.

After a successful homologation the developed system can be produced. At this point, hardware and software modules are linked and tested by on- and/or off-board mechanisms. In the off-board diagnosis during the production process, also called EOL (End-Of-Line diagnostics), predominantly external devices and tools are used, which on the one hand follow the basic principle of the devices used in the aftersales range, but on the other hand are optimised for fast production flows.

The on- and off-board diagnostic mechanisms which are used in a vehicle are provided for different requirements in the aftersales range and must ensure under all circumstances a safe vehicle operation.

On-board diagnostics covers all mechanisms which are implemented and running permanently in vehicles. These mechanisms monitor safety-relevant systems in the car and in future submit defects to a workshop or an inspection body. Furthermore, they guarantee the safe operation of the vehicle. For the detection of system faults different online diagnostic mechanisms are necessary. For the monitoring of signals, which are used e.g. control variables, a signal plausibilisation is applied as a detection mechanism for sensor faults. An error management is implemented, which decides on the further operation of the system based on hard- and software concepts. Further aspects, which will win relevance in the future are the driver dialogue, self-diagnostic functions and beyond that an intelligent connection to the environment, e.g. in order to inform a workshop just-in-time about an upcoming maintenance or repair.

With the help of future standardized communication interfaces to the vehicle (e.g. CARB connector with supported protocols), external diagnostic tools can access on-board mechanisms for the purpose of an off-board diagnostics. By reading out the error memory, actual values and control values, they can contribute to a safe error recognition and fault location. Due to the high cross-linking degree of today’s systems the process of fault location does not present itself always that simply. Thus it requires different auxiliary systems, which can help to locate a fault on the basis of existing error symptoms.
Furthermore, one could implement a complete workshop manual in a computer-aided diagnostic system (also called expert system), so that a skilled worker is supported during the whole process of fault locating and removal. This means, such systems are intended to be predominantly for the workshop employment. For the PTI (periodic technical inspection) of vehicle systems the requirements to the diagnostic depth can be less sophisticated, although the demands will see a clear increase in future. For these purposes, diagnostic tools which can determine a faulty or error free operation (in some cases this can be on-board mechanisms existing in the vehicle), are sufficient.

As a result, we obtain certain diagnostic requirements and tasks for each of the described phases, which apparently differ in principle. However the cross-linking of the diagnostic knowledge from the different subranges is compellingly necessary in order to be able to exhaust the entire diagnostic potential. In each phase different mechanisms are used, which are described in the following.
4 Diagnostic Mechanisms during Product Development

Since automobiles exist, man has always been striving to improve it’s technology. In the last decades, the automobile developed from a simple means of transport to a scientific laboratory. So what drives us again and again to install new systems in cars, although their complexity and therefore developing costs grow continuously?

On the one hand it is the high state of knowledge which science and technology have reached – each day there are new scientific insights in the most diverse areas, which are realised in new technologies. This constant increase of technical possibilities allows us to replace technologies already existing in current applications by new, improved ones. On the other hand there are certain social requirements, according to new functions. During the last years, a clear trend towards systems, which offer beside already available driving-dynamic systems such as ABS and ESP more security, comfort and environment-friendliness can be noticed.

However, this technological development carries some challenges. On the one hand the manufacturers are exposed to a very high competition pressure, which becomes apparent through generally shortened development times. On the other hand the constantly growing complexity of today’s vehicle systems requires a significantly increased developing effort. Often, these challenges express themselves in a worsened reliability of the vehicles, which lead to a worse performance in the breakdown statistics. Another reference to the worsened reliability can be seen in the rising number of callback actions over the last ten years, which are initiated either by the manufacturer or arranged by official intervention. As one can see in Fig. 4-1, these numbers increased constantly from 1992 to 2004. With the high number of safety-relevant systems available on the market today, it must be ensured, that a system’s function is not affected by a high failure rate.

![Number of vehicle callbacks in Germany from 1992 to 2004](image)

Fig. 4-1: Number of vehicle callbacks in Germany from 1992 to 2004 (Source: KBA – Kraftfahrtbundesamt, Germany 2005)
In order to avoid that, a well structured development process is required. Recently, there have been several approaches to this topic, which are similar in their objective, but different in their method.

In the development of complex systems, the V-model plays nowadays a very large role (Fig. 4-2). The V-model represents a guidance path over the whole development process and is a standard method in many industry branches. Apart from the product specification it consists of draft-, programming- and test-phases and finishes with the acceptance test and/or the homologation of the appropriate system.

Fig. 4-2: V-model for the development process

The fundamental advantages of the v-model can be seen in the verification and validation of the partial products, which makes it possible, that the appropriate subsystems are examined separately for the fulfilments of the demands made towards them. Thus, some test scenarios can already be examined in a rather early stage of the development process. There, the verification serves as an examination of the correlation between a final software product and its pre-agreed specification, whereas the validation serves for the examination of its suitability and its value concerning the targeted application. Apart from a cost reduction, also a higher product quality is reached via a systematic debugging.

4.1 Diagnostic Mechanisms during Product Specification

The specification phase represents the first step of a development process. In this phase the demands made towards a product are defined and summarized. The groups which take part in the specification of a new function are shown in Fig. 4-3. Each of these groups makes own demands against the product, which are documented in a to-be-defined requirement specification. Finally, the provided work statement represents the optimum compromise of all these requirements.
Customized requirements take a crucial influence on the emergence of a new product. Thereby, on the one hand functional requirements which define the actual function of the later product are concerned. On the other hand there are criteria like e.g. the quality, the maintenance, the state-of-the-art or certain manufacturer-specific characteristics of the appropriate product. The interfaces to the manufacturer can be seen in the customer marketing and service. The marketing experts forecast the customer and market desires. The prognoses given by the experts rely on the results of different market studies and analyses. This service is the only one with a direct contact to the final customer, which accordingly implicates own customer-specific requirements. These are directed in particular towards maintenance and repairability of the product. The fulfilment of the customer-specific requirements promotes primarily the customer satisfaction, in which the success of the later product is justified.

Beside the customer-specific also manufacturer-specific requirements play a large role. These can refer both to the development and production of the product as to the enterprise strategy. Concerning the development it is very important to precisely define demands on SW- and HW-components and their development process, in order to be able to ensure a high quality of the development. These can be very different demands, which consider other aspects (interfaces, material, operating conditions etc.) apart from the fulfilment of the appropriate function. The requirements of production require a high assembly quality on the one hand, on the other side however fast production flows with a high degree of reproductibility. By company-strategic requirements demands are meant, which concern e.g. the firm image. In this connection especially the unique selling points of a manufacturer are to be men-
tioned. They take a manufacturer or a brand off from the remaining mass and thus contribute to the image.

In addition, the requirements already specified must be examined for the fulfilment of legal regulations. These contribute primarily to the safe function of the product and represent a further step in the debugging process. The requirements of safety-relevant electronics, defined by the legislation, concern predominately product security, product liability and type approval, covered by homologation regulations like e.g. directive 70/156/EC. Additionally, there are requirements, which are directed towards the feasibility of a technical inspection during the usage of the product. Thus the guideline 96/96/EG defines a periodic exhaust investigation for vehicles with spark ignition engine, catalyst and regulated mixture preparation as well as for vehicles with compression ignition engine.

For the accreditation of new systems in a vehicle, the legal situation currently provides a requirement catalogue. For brake systems e.g. the minimum requirements for the European homologation are defined in the guideline ECE-R13, for steering systems in the guideline ECE-R79. Recently, those guidelines were recently extended concerning the implementation of by-wire systems. A fundamental regulation draft for new, complex electronic systems was submitted to the European commission by the German Federal Ministry of Transport. The legal requirements on European level for the examination of these systems were so far regulated in the appendices of the ECE standards:

- The fail-safeness of complex electronic systems must be guaranteed,
- The possibility for auditing the appropriate measures must be made available to a technical inspection body.

For auditing, a system analysis shall not be provided under the criteria of the availability but instead regarding the hazard potential in case of failure of a construction unit or a subfunction.

![Legal requirements of safety-relevant electronic systems](image-url)
Additionally, there are standards for safety-relevant electronic systems like the safety standard IEC 61508 (as a generic basis standard for functional safety), or the machine guideline DIN EN 954 for safety-relevant electronic systems, which contains the requirements of safety relevant parts of machines and controls in its general organization guiding principles.

To simplify the application of appropriate standards, FAKRA released a standardized design template as an application standard for the automobile industry, based on the IEC 61508.

The general requirements of the safety of the described systems can be summarized for the automobile as follows:

- **Primary / Electric safety:** e.g. protection against touching live parts at voltages 60+ V

- **Functional safety:**
  - Error tolerance of the hardware (suitable structure to avoid coincidental hardware errors),
  - Few errors within the software (error reduction during the development),
  - References to security in technical information (e.g. references in the driver manual)

- **Environmental compatibility:**
  - Electromagnetic compatibility (noise immunity, emitted interference),
  - Climatic capacitance (Operation at extreme temperatures)
  - Mechanical capacitance (Operation under oscillations and vibrations during normal operation)

- **Resistance against special environmental influences:**
  - Salt-test
  - Dust-test

- **Product-related quality assurance in production, test field and product care**

The goal of the specification phase is a requirement specification document, which unites all demands made against the later product. In this work statement, the functionality of the system, its purpose and boundary conditions of the most diverse kind are outlined. Thus they form the basis for communication between the different groups of developers within the OEM and the supplier. A precise, complete
and between all project partners agreeable description of the requirements is an inevitable condition for a structured and successful development.

In this connection some challenges, which concern particularly the specification phase are to be mentioned. So e.g. a clear increase of complex electronic systems in vehicles can be registered during the last years. For this development, the risen customer-specific and legal requirements are responsible, which must be considered with the specification of a product. An example for the development of the requirements of an engine ECU is depicted in Fig. 4-5.

![Fig. 4-5: Development of the requirement specification for an engine ECU (Source Volkswagen, 2005)](image)

However, in order to be able to consider all resulting demands, certain tools are required, which clearly define the work during the specification phase, so that both the coordination and communication between the different groups can be improved.

### 4.2 Diagnostic Mechanisms during Product Development

Originally, the procedure of finding error causes was called vehicle diagnostics and was mainly linked with applications for vehicle service and maintenance. With the increasing safety relevance of the systems used in the vehicle, it is evident to eliminate all possible error causes already during the development stage of the systems in order to be able to ensure their integrity and robustness. This task is getting more and more difficult due to a growing system complexity and degree of system cross-
linking. That was mainly the reason for the fact that diagnostics recently found its introduction in the vehicle development and production.

Fig. 4-6 shows like diagnostics increasingly has been shifted from the workshop to vehicle development. The goal of these efforts is to design an error free product and to already identify possible errors during the development phase. That contributes primarily to the fact that the diagnostic online mechanisms in the vehicle, implemented during the development, are able to identify and locate arising system errors immediately during vehicle operation.

In case of faults the workshop has then only to replace the appropriate component which has been identified by self diagnostic mechanisms. Apart from the attempt to handle the system complexity the employment of diagnostics in the development serves at the same time as reduction of development times and concomitantly development costs.

Fig. 4-6: Development of vehicle diagnostics from workshop to development

An aspect, which contributed to this development, is the increasing application of electrical and electronic vehicle systems, which enabled a new level of development. On the other side these developments are also combined with a clearly risen complexity and difficult-to-understandness of new systems themselves. Meanwhile it is usual that a vehicle system is provided with an electronic control unit and that all procedures are controlled by software modules. That has the consequence that not only mechanical components (on the hardware side) need increased development work, but also the the corresponding software modules. In consequence, the software development process runs through the same organisational stations as for mechanical components. Due to the high portion and increased
requirements for electronic systems more efforts must be headed for software development and testing, than for the mechanical components.

In order to satisfy these new and more complex development tasks, it requires sophisticated tools, which are already applied successfully as well in the vehicle industry as also in other industry branches. Under these, in particular methods FMEA (Failure Mode & Effects Analysis), CBR (Case Based Reasoning), FMM (Failure Mode Modeling), AD (Anomaly Detection) and risk assessment analysis are to be mentioned. These system and risk assessments are consolidated elements of the quality management and can today be considered as state-of-the-art. Central diagnostic mechanism for the detection and analysis of risks during the product emergence is the FMEA for the evaluation of the product itself or for the evaluation of the production process.

The basic principle of the FMEA analysis were already used since a longer period. The differences consist in the proceeding and its documentation. Today the developers are supported by computer-operated tools, which take over both the processing and the documentation of the information.

The FMEA has to be seen only as one part of the quality management and as interface to other methods which are applied during the complete product development process and the later product application. During the advancement of the FMEA-method, elements from other methods like QFD (Quality Function Deployment) and FTA (Fault Tree Analysis) have been integrated. The advantages of the FMEA are a consistent proceeding, a defined documentation and an international acknowledgment.

Fig. 4-7: Diagnostic methods for the product development
The different types of the FMEA are the system-, the construction- and the process-FMEA and are applied in the different phases of the product development process (Fig. 4-7).

With the **System-FMEA** the concept for a product or a component is examined regarding the function and the customer demands. Here in particular lacks of concept are to be discovered and evaluated.

The **Construction-FMEA** serves for the investigation of details and/or functional parts regarding the structural design and helps to detect conceptual errors.

Finally the **Process-FMEA** is used to examine processes, subprocesses or work procedures regarding the ability to ensure reproducible results in the production.

For the user of the FMEA finally the following advantages result:

- Comprehensible documentation of the ideas and the work for all parties participating in the development process
- Test sequence for product release
- Reusable documentation (e.g. for development, production and distribution)
- Documentation and description of interfaces

In addition, the FMEA can be used both preventively and correctively. In the first case the application takes place at the earliest possible time and accompanying to the development. In the second case it is accomplished for identified problems in order to optimize the product or its production process. Diagnostic mechanisms like the FMEA serve to avoid conceptional errors during the product development and represent a central lever for the cost effective stabilization of the reliability of future vehicles.

Next to the presented mechanisms an extended product testing also plays a key role to ensure the system or component robustness and reliability. During the traditional testing procedure of E/E-vehicle systems the software modules are examined on possible errors (module test). Afterwards the integration test is executed, where the interaction and the specified compatibility of hard- and software modules is examined. Due to the high complexity of today's vehicle systems the traditional development is replaced increasingly by model-based development, which increases the efficiency of the test phase in a favourably manner.

"In-the-loop-test” methods represent the current status in the vehicle development. In the first step a simulation model of the system or a component is developed and examined (model in the loop). The next integration step covers the test of the software component (software in the loop), which can automatically be generated from the model or can also be handprogrammed. If this test is successful,
the integration into the controller and the examination of the component test bench or of the interlaced hardware in the loop test bench (HiL) can be carried out.

![Hardware-in-the-loop test bench](image)

Fig. 4-8: Hardware-in-the-loop test bench

From the above described methods, the following diagnostic tasks can be derived for this stage in vehicle development:

- Testing of the hardware compatibility (e.g. control of actuators or check of analogue and digital inputs)
- Transfer of calibration data (e.g. characteristics, limit values and configuration data)
- Examination of the software (e.g. internal test routines, error code setting and resetting conditions, reaction to country-specific settings)
- Flash data transfer for software update
- Measurement data transfer during testing.

In future, the development of the model-based approach will play a decisive role for the development and conversion of diagnostic mechanisms. The actually applied knowledge-based approach, which relies on the cause-effect-relationship, will recently push the border due to the high system complexity. A remedy can be created by a model-based diagnosis, which applies a model as basis for diagnostic applications.
During the development, necessary and system-relevant diagnostic tasks, which have to be accomplished in the later phases of the vehicle life cycle, have to be defined and implemented. As diagnostic mechanisms applied for production as also for vehicle service and maintenance become more complex, it is necessary that different diagnostic mechanisms are considered in an early stage of development.

Up to now, the requirements for an employment of vehicle diagnostics was strongly dependend on the corresponding OEM and its philosophy. Since the introduction of OBD (on board diagnostics) regulations for exhaust relevant systems, diagnostics including its technical implementation depends primarily on legal defaults. This development opens the possibility for an extension of the current OBD testing for the inspection of safety-relevant systems.

Extensive standardisations of different hard and software modules as well as development tools and methods represent a further suitable instrument for the future extension of diagnostic and inspection procedures. Thus a standardisation of hard and software components contributes to a decrease of the developing costs and time and help to stabilise the reliability of new systems.

Several working groups consisting of different car manufacturers and suppliers are concerned with this task. Among these e.g. different working groups like HIS (manufacturer initiative for standard software modules), AUTOSAR (Automotive Open System Architecture) and Automotive Spice) have been fathered. HIS deals with standard software modules for vehicle networks, standardised testing of software, software tools and programming of ECUs. The intention of the AUTOSAR consortium is, to make a manufacturer-comprehensive re-use of software possible. In order to accomplish this target, AUTOSAR is recently setting up a specification for integration methods of function-oriented software modules and also for the entire base software and an abstraction layer with standardised interfaces. A well-established example for software automotive standards is represented with the operating system OSEK (Open systems and their interfaces for electronics in the vehicle). It permits simplified communication within and between controllers of different manufacturers or suppliers and can in future lead to extensive simplifications for the software implementation accompanied with high cost savings. A further example in this context is the standardisation of communication protocols in the last years (e.g. KWP 2000 on K-line, ISO 14230 and on CAN, ISO 15765), in which particular standardisation committees such as ASAM (Association for Standardization of Automation and Measuring systems), SAE (Society of Automotive Engineers) and ISO (International Standard Organisation) are involved.

A further approach using standardized database models for data exchange, is taken forward by the ASAM (Association for Standardization of Automation and Measuring Systems) consortium. Therefore, ASAM recently presented the standardized ASAM-MCD database as supplement to standard interfaces like e.g. via CAN, ISO 9141, SAE J1850 or J1708 The goal of this approach is to simplify the exchangeability of data between different bodies like OEMs, suppliers and inspection organisa-
tions which are involved during a vehicle life cycle. For these purposes ASAM applies a standardized SGML format.

Except the data exchange within the development mentioned before, it requires further communication and/or diagnosis interfaces, which reach from the production to the vehicle service. In future, the information flow from the vehicle service in repairshops back to the development is very important for the development of updates or new diagnostic systems. This flow will supply new cognitions concerning error emergence and can be considered in further developments.

4.3 Homologation of Vehicle Systems

The process of type approval after the operative conclusion of the development is called homologation. Basically, this process cannot be separated from the product development process. Legal regulations for a homologation are essentially concerning vehicle safety (passive and active), the environment (emissions, consumption, noise, materials) and vehicle-specific characteristics like engine performance, theft safety devices etc. The general goals for a product homologation are to approve:

- Regulation conform development for the defined market
- Documentation
- Organization and execution of the necessary testing by technical inspection bodies
- Completion of official licensing procedures
- Conformity of production during the production phase
- Documentation of supplement permission (regulatory changement procedure)

The groups involved in the homologation process, beside the manufacturer and suppliers, are the legislator and NGOs (non governmental organisation) and technical inspection authorities. Due to the increasing complexity of the systems in future vehicles, the necessity for a cooperation between manufacturer, inspection authorities and the legislator, already starting in the beginning of the development process, becomes essential.

As the homologation process presupposes a consistent testing method in order to ensure a safe vehicle operation, these new methods for type approval must be accordingly adapted to the technical development. The homologation is the main phase in the whole product cycle, where the legislator can affect the development process and concomitantly also the product. Due to the rapid development of mechatronic safety systems in the vehicle, it is necessarily required that the legislator is able to adapt homologation regulations actively. Therefore the legislator must be able to anticipate on short- and
medium-term developments and directions on the vehicle sector, in order to be able to react with legal regulations before a new technology is up to be introduced on the market.

Another challenge regarding the homologation process forms the partially different homologation regulations of the different markets (Fig. 4-9). These differences are to be ascribed on the one hand to different needs and on the other hand to different priorities. Although a partial acknowledgment of different markets has been achieved, the world-wide permission of the same product is often still not possible.

![World-wide homologation requirements](image)

**4.4 Diagnostic Mechanisms in Vehicle Production**

The first employment of off-board diagnostics in the vehicle takes already place during the assembly of the vehicle during its production. During the so called end-of-line (EOL) diagnostics subsystems are assembled and laced into operation. Their operability is examined on different test benches. With static tests electrical connections are checked, ECUs are coded and programmed (if this has not been carried already out in a preassembly at the supplier’s site), on dynamometers dynamic tests for the examination and adjustment of chassis geometry or the engine management, including the exhaust behavior of the vehicle are accomplished.
Abb. 4-1: Diagnostic applications in the vehicle assembly (EOL)

The typical diagnostic tasks in production consist in:

- Assembly test
- Identification of the component and determination of the current configuration
- Reset and check of the error codes (delete the error codes occurred during the assembly and determination of still existing errors)
- Parametrisation on vehicle-specific characteristics (e.g. country-specific attitudes, adjustment on vehicle configuration and customers requests, anti theft device training)
- Function test in the sheeted condition (interaction test with other controllers in the existing vehicle configuration)
- Flash programming
- Documentation

The diagnostic tasks which can be accomplished in the production process are similar to those for vehicle service and maintenance. Therefore allied communication interfaces and tools can be applied. The difference consists in the fact that usually diagnostic tools for the production process are shaped for very short cycle times, which is achieved by a high degree of automation. An automated documentation of all process steps is then also easily possible.
5 Diagnostic Mechanisms for Vehicle Monitoring, Service and Inspection

While diagnostic mechanisms mentioned before are used for the avoidance of biased errors in the development process, the off- and the on-board diagnostics serve to ensure the system integrity and thus a safe function during work. The center of attention can only be the detection of system or component faults and a fault strategy but not a system-related avoidance of errors.

5.1 On-board Diagnostics

With the term on-board diagnostics all procedures during the vehicle operation which are started by on-vehicle diagnostic mechanisms in order to ensure a safe function of the systems is meant. For a successful diagnosis it is important to recognize occurring faults. For this purpose different hard- and software mechanisms and methods are intended which are used dependent on the system structure and field in the vehicle. After a successful identification and localization of a system fault, its impact must be rated regarding vehicle safety. This is important, as an on-board fault management mechanism has then to decide whether the system is totally or partially deactivated. For the operation in case of system faults, there are different concepts which will be described in the following. These concepts include different types for the fault management and also an adequate dialog to the driver in order to inform the driver about the fault and to give clear instructions.

5.1.1 Fault Detection

The defects occurring in vehicle systems can reach from defects in hardware modules (sensors, actuators, ECUs) to software errors. In most cases, hardware defects are caused through thermal and/or mechanical overstressing and ageing. As software faults generally do not age, such errors are caused either by programming errors or incompatibilities. Software errors can occur e.g. through errors during data transfer or processing of not defined cases. In order to ensure a precise and an efficient error detection, there are different mechanisms and concepts, which are specified below.

Important for the perfect function of many vehicle systems are sensors, which have to measure physical sizes as input value for the control of the corresponding system. Therefore, sensors have to work properly also and especially in critical vehicle states, in order to ensure a correct operation of the vehicle. To verify the quality of sensor signals, an evaluation on the plausibility of the measured input values is necessarily required. Several already existing concepts for the assessment of the quality of sensor data, basing on hardware and software mechanisms, will be introduced and described in this WP report.

Under these concepts the single signal, the redundancy based and the model based plausibilization are to be mentioned. Each individual mechanism is able to examine the appropriate signal for errors and plausibility, but usually only supply a limited evaluation for sensor data plausibility. A combination of these concepts, arranged in a closed-loop, makes a high-dynamic and precise error recognition with
maximum error tolerance possible. This three stage sensor data plausibilization concept, consisting of
the single concepts specified before are depicted in Fig. 5-1. During a cycle of these plausibilization
chain the plausibility evaluations of the individual stages are summed. Additionally the concept has a
parameterised feedback (Block4).

![Three stage sensor data plausibilization concept](image)

**Fig. 5-1:** Three stage sensor data plausibilization concept

Block 1 represents thereby the single signal plausibilization. The single signal plausibilization checks
each signal regarding limiting threshold values, gradients and can also analyse a signal noise character-
istics for a plausibility assessment in case of suitable signals. Errors with this method can only be
recognized if they already occurred. The second block describes the redundancy-based plausibilization
method, which is based on a comparison of signals of at least two sensors. With a simple redundancy
(with two sensors) thereby, it cannot be differentiated in case of deviations, which of the sensors is the
incorrect one. The last block is the model-based signal plausibilization. Basing on physical models
and/or an analytic context, a corresponding signal for the comparison with the measured value can be
computed. This procedure presupposes the presence and the correctness of the values used in the
model. So e.g. for the computation of the vehicle yaw rate the so-called “one trace vehicle model” can
be applied (Fig. 5-2). Therefore, the constant vehicle-specific "characteristic speed", the steering
wheel angle and the vehicle speed are necessary, which must be acquired by additional sensors.
Besides the monitoring of sensor data through signal plausibilization mechanisms the monitoring of actuators is also possible but more problematic. A redundant application of actuators like in avionics is due to high prices, additional weight and space requirement in the vehicle in most cases impossible. Usual on-line monitoring of actuators is based on the measurement of current, resistance, voltage, temperature and other physical sizes, which must be seized with additional sensors. Usually this procedure does not permit a sophisticated differentiation between component and powernet errors.

Next to the corresponding application, the software also provides a framework for the identification and an adequate handling of system defects. These software functions are called self-diagnostics applications and cover faults of sensors, actuators and also of the signal processing within the frame of the corresponding technical possibilities. Further software methods to check the operation are so-called Watch Dogs, First Error Data Capture and checksum calculations.

System self checks represent an efficient method to discover software failures. In comparison with the signal plausibilization which permits a permanent signal control during operation, self tests usually are accomplished at the beginning of each trip.

As already described for the signal plausibilization, redundancies can basically be applied to achieve a high system integrity. In particular this method is already implemented for the application in control units of safety-relevant vehicle systems. Thereby, software and hardware, can be laid out redundantly. In the example of the BMW active front steering (Fig. 5-3) two different 32bit microprocessors of different types are monitoring the function.

The application software for the computation of critical processes is implemented in a divers manner. The term "divers" designates, that for the development of the two software variants another appendage and even other development teams were selected, in order to exclude concept-based errors during the software development.

\[ \dot{\psi} = \delta \cdot \frac{v}{l \cdot (1 + \frac{v^2}{v_{char}})} \]

- \( \dot{\psi} \): Yaw Rate
- \( \delta \): Steering Angle
- \( v_{char} \): Characteristic Speed
- \( v \): Vehicle Speed
The detection of a creeping system degradation of mechanic components represents an even bigger challenge for self-diagnostics. In particular, the usual mechanisms for signal plausibilization permit only a differentiation between defined boundary values. Therefore, a gray area between the value of the specific component tolerances is existing, in which the weight of the fault impact concerning system functionality cannot be exactly evaluated. This leads to the fact that a creeping system degradation usually can be detected only when a defined fault or malfunction appears. This interrelation between the weight of the fault impact and its detectability is depicted in Fig. 5-4.

Fig. 5-4: Interrelation between the weight of the fault impact and its detectability
The bad detectability of creeping system degradation can lead to complete function losses and thus represents, for safety-relevant applications, a grave safety endangerment. In order to avoid such cases, visual checks of safety-relevant components within the PTI will not be evitable in future.

5.1.2 Fault Management

If a fault is detected successfully, a failure management has to decide in dependence of the impact of the corresponding malfunction how and if the operation of system can be kept up. Then the corresponding system has to be transferred into a so-called fail-safe mode. To the most well-known fault management strategies the following are belonging:

- Fail Fast (complete system loss, as soon as the redundancies are exhausted)
- Fail Soft (system loss, if no intact components is existing)
- Fail Operational (a critical loss does not lead to an immediate loss of)
- Fail Safe (a critical loss transfers the system into a safer condition with a possible loss of entire functionality)
- Fail Silent (after one or several failures the component behaves passively by switching off and therefore doesn’t affect other components in a possible wrong form)

The last three methods are usually applied for safety-relevant systems. An example for a "Fail Silent" concept is shown in Fig. 5-5 for the BMW active front steering. During a total system shut down the steering falls back to a completely mechanical level.
5.1.3 Driver Dialog

A central interface device to the end-user and thus also decisive for the acceptance is the dialog with the driver and/or passenger. By the application of new technologies like e.g. head-up displays more ergonomic and safer transferring of information will be possible in future. In current vehicles indicating instruments are often overloaded, not in all cases self-describing and from manufacturer to manufacturer also defined differently. With the further increase of the vehicle systems the driver’s view on the indication instruments could grow to the in Fig. 5-6 depicted instrument.
Fig. 5-7 shows the possible combinations for the indication of the brake system status. Here it becomes clear that an interpretation of already 3 indicator lights can lead to misunderstandings - a clear instruction for the driver in the case of a defect is not clearly derivable.

![Table showing possible brake system status combinations](image)

For the future, several challenges for a clear organization of the driver dialogue result from these examples. The future concepts primarily have to supply clear information and a clear instruction regarding the current system status, in order to be able to achieve a high customer acceptance.

A normative directive for a uniform, OEM-independent and non-distractive display of contents and information will be of advantage for the acceptance and the delivery of vehicle information and therefore also an objective for roadworthiness enforcement through on-board diagnostics.

### 5.2 Off-board Diagnostics

Off-board diagnostics plays a major role for the service in workshops and for vehicle monitoring (Fig. 5-8). Both for authorized and for free workshops the spirit of service is in the foreground, which is directed predominantly towards the repair of vehicle systems. For technical inspection organizations, the possibility to verify the proper function of vehicle systems is of crucial importance. Contrary to authorized workshops, free workshops and technical inspection organizations are currently dependent on the use of OEM independent systems. Due to extended requirements, the future of off-board diagnostics saves some changes, which will affect both the service and vehicle monitoring. Especially in the repair sector, the use of special devices and tools, which require an appropriate training of skilled worker, became inevitable. Also for off-board examinations of a system through technical inspection organizations, special tools and procedures, which correspond to the state-of-the-art, are required. However, in this area, another diagnostic depth than in the service sector is required.
Fig. 5-8: Off-board diagnostics during vehicle operation

5.2.1 Off-board Diagnostics for Vehicle Service

Diagnostics within the service sector conduces primarily to fault detection and localization. These are the most important conditions for a successful fault elimination process. Despite their same goals, free workshops and authorized workshops have to cope with different challenges. While the service of an authorized workshop is limited to one manufacturer, free workshops have the possibility to support several brands. Hence in each case different needs and strategies result, which will be dealt with in the following.

Authorized workshops

As previously mentioned, the rising complexity of today's vehicle systems also affects the workshop service. Especially the skilled workers often seem to be overtaxed with the new tasks placed against them. In order to adapt the work in the workshop to the new needs, it primarily requires new tools and measures, which ensure an effective repair and thus a stable customer satisfaction.

Particularly, repair tools have massively developed within the last years. The first diagnostic tools were simple measuring instruments (e.g. current probes), which were used dependent on the decision of a technician. Those tools supplied only a limited result regarding fault detection and localization. It was still the technician’s own decision to interpret the results and to initiate proper steps for fault elimination. Due to the high complexity and the numerous electronic components in current vehicles system it is nowadays hardly possible for a skilled worker to determine an error cause from the given error symptoms with conventional diagnosis units. Currently, the devices used in workshops are mostly computer-aided diagnostic systems, which are able to locate the defective part either directly by reading out the error memory or indirectly by performing a guided error tracing tour. Additionally, a part description or a repair introduction can be requested after a successful error detection.
These so-called expert systems increase the degree of automation and thus the speed and efficiency of a workshop. In response however they cause a reduction of the diagnostic authority of the skilled workers.

The reasons for this development of the diagnostic tools are primarily to be seen in the changed requirements in the service range, which require on their part appropriate diagnostic tasks. The diagnostic extent which is attainable with current devices and their usage by skilled workers in a workshop, shows Fig. 5-9. One can clearly see, that diagnostic tools are differently often used for different tasks in the workshop service.

![Fig. 5-9: Application of computer-aided diagnostic tools through a skilled worker](image)

A change of the diagnostic tasks in a workshop demands in response a change of the educational course contents and course measures for a skilled worker. Many manufacturers offer numerous programmes for further education, which are intended to introduce the skilled worker particularly into handling diagnostic tools and coping with different diagnostic tasks.

Despite the efforts already mentioned, sometimes a direct interference of the manufacturer into the repair process in a workshop can not be excluded. Due to the frequent application of software, the development of updates both for vehicle systems but also for off-board diagnostics tools is required. On the other hand, repairs of electronically controlled systems have partially become so complex that the workshops need a direct support through the manufacturer’s own service engineers. Since the introduction of the VW Phaeton, VOLKSWAGEN offers e.g. manufacturer-supported repairs for this model. This service covers automatic guidance and coordination of each workshop stopover through the technical service centre (TSC) as well as a complete service documentation of each vehicle. Addi-
tionally, a remote control or a visual investigation of a vehicle connected in the workshop is possible. For this purpose, an off-board diagnostic unit attached to the Phaeton (VAS 5051) is remote controlled through an expert workstation in the national TSC by a TSC specialist, in order to download the necessary diagnostic data directly from the vehicle. VOLKSWAGEN intends to transfer this concept to other models in the future.

**Free workshops and technical inspection**

Contrary to authorized workshops, additional problems occur for technical inspection authorities and for free workshops. The reason for these problems can be seen in the poor availability of necessary information. Basically, test organizations do not need the same diagnostic depth which is necessary for the recovery of errors in a workshop, nevertheless, legal directives do currently not cover all requirements to be able to examine all systems used in current vehicles. An improvement regarding the availability of manufacturer-specific information was achieved through the group exemption regulation (GER) 1400/2002, whose principal purpose is the stabilization of the competition for the benefit of the consumer. Thereby, the GER refers to the ranges selling and repair of vehicles including the pertinent spare part market. The GER mainly specifies a free access to all technical information, which is needed for maintenance, repair, diagnostics and training courses. The free workshops must not be disadvantaged compared with authorized workshops both temporally and concerning the price. Also for test organs the GER facilitates the availability of relevant information for a vehicle examination.

Although the availability of information was improved by the introduction of the GER, the free workshops still have to face certain problems, which obstruct the competition in the repair sector. On the one hand, the effective access to the information portals provided by the OEMs is often blocked by high or non-transparent prices. On the other hand, sometimes even the kind of information distribution, which can strongly vary from manufacturer to manufacturer, represents a challenge. Apart from the conventional distribution methods via books or electronic data carriers (CD, DVD), many manufacturers are nowadays offering an internet-based access to their technical information. In order to standardize the appearance of such Internet portals and thus to facilitate the search for appropriate information, several manufacturers initiated a project under the umbrella of the OASIS organization (Organization for the Advancement of Structured Information Standard). For exhaust-relevant repair information, a standardized electronic format is already specified by the guideline 98/69/EC (E-OBD).

Apart from the poor availability of information, free workshops have to face problems with manufacturer-specific diagnostic tools. Since these tools usually only cover current models of one manufacturer, they do not really offer a solution for a free workshop due to the high acquisition and maintenance costs. Instead, universally applicable offboard diagnostic tools (see Fig. 5-10) represent an efficient possibility for free workshops to perform brand-spanning repairs. However, these devices show brand-dependent differences within the availability of vehicle-specific information. The reason for
these differences is to be seen in the already mentioned manufacturer-dependent differences concerning the availability of manufacturer-specific information.

Additionally, a study published by DEKRA (Germany) points out the clear differences in the function range and the demands on different brand-spanning diagnostic tools. The study examined the diagnostic extent of eight different tools concerning several electronic systems (engine electronics, brake system, airbag, transmission control, lighting etc.) during operation on several vehicles from different manufacturers. It turned out, that the diagnostic depth of exhaust-relevant systems was quite identical with all examined devices. This is primarily based on the standardisation and legal regulation of the access to exhaust-relevant data in the engine control unit via an OBD interface (CARB (California Air Recorce Board) plug). Supplementary to the exhaust-relevant data, many manufacturers nowadays also offer access to other controllers (airbag, transmission, ABS, ESP). However, the DEKRA investigations pointed out, that the diagnostic extent attainable over the OBD interface can vary from manufacturer to manufacturer. This is a great challenge particularly for free workshops and breakdown services, since many of the OEM specific extensions and services are not subject to the generally accepted standards and thus usually remain exclusively available for authorized workshops.

![Universally applicable diagnostic tools](image)

*Fig. 5-10: Universally applicable diagnostic tools*

Fig. 5-11 shows the schematic structure of a computer-aided diagnostic system. As a basis, usually a PC platform with a Microsoft Windows operating system is provided, which offers interfaces for different software modules and hardware components. The installed equipment depends on the diagnostic tasks, which the final system is intended for. A diagnostic chip allows a communication with vehicle control units by the use of different transport protocols. For the operation of the device interfaces for the connection of a mouse, keyboard, screen etc. are provided. In addition, the systems usually offers possibilities for measuring different physical (e.g. current, voltage, resistance) and chemical values (e.g. exhaust gas). The different network cards serve for outward communication (e.g. to the manufacturer’s service centre). From the service centre, updates or general repair information can be requested.
Future requirements for off-board diagnostics

Nowadays, a skilled technician in a repair workshop or an technical inspection shop is dependent on diagnostic tools for repairs and monitoring of electronically controlled systems and their components. The interface to the vehicle and the diagnostic depth, which are reached with these tools, should be specified during the above described vehicle development phase. Unfortunately, the requirement definition for workshop diagnostics often takes place after the specification of a new system, when vehicles operating these systems are already on the market. These are the substantial reasons for the fact that in the past the diagnostic requirement for workshop service and technical inspection mostly could not be completely fulfilled for new vehicles. In order to at least partly meet this problem, a closer cooperation between service, which represents a direct connection to the customer, technical inspection authorities, ensuring an independent assessment of the vehicle in order to provide safe vehicle operation, and the OEM is required.

In addition, this process in future has to get a higher significance already in the development process and should start as early as possible. This problem is reflected e.g. by the fact that many of new vehicles coming onto the market cannot be repaired in case of defects at electronic systems within the first months. Even authorized workshops can offer only reduced service, because off-board diagnostic tools are still not available.
A further step to more efficient technical inspection and workshop diagnostics of electronically controlled systems is a technical documentation of the systems and of possible errors, in a central database. The requirements for such a database for technical vehicle inspection will be contents of WP360. On one hand, free workshops and inspection authorities could so be able to access necessary data more easily. On the other hand this procedure also could facilitates the data exchange between workshops / inspection authorities and the development departments of the OEM, which can consider the gathered information regarding possible faults for the development of new systems or updates.

In order to be able to detect and to repair occurring defects with off-board diagnostic tools, the framework of requirements also defines the interfaces on a physical and on a protocol layer. Since these interfaces have to be applied not only by authorised workshops, but in the future also by free workshops and by technical inspection organizations for the execution of the PTI (Periodic Technical Inspection), a trend towards a standardization of interface can be noticed. The introduction of OBD exhaust emission regulations (described in WP330) was the first step - a consequent extension of OBD regulations (with a standardized interface) for vehicle safety systems could facilitate the future development of off-board diagnostic tools for technical inspection.

Fig. 5-12 shows a customer-oriented approach for off- and on-board diagnostics for service and technical inspection. Next to the driver dialogue, where the driver is provided with vehicle information and instructions, in case of a vehicle malfunction, a call center in order to register the fault and necessary boundary information (position, vehicle information) is contacted by the driver or automatically through the vehicle itself. These information are then forwarded to a service workshop or/and an technical inspection authority, which releases further steps e.g. the order of necessary parts or the vehicle rescue. Technologies for transmitting the described information can be e.g. GSM or GPS connections, however these transmission technology play only a subordinated role and can simply be replaced by the topicality corresponding transmission technologies.

Apart from the use for the customer service, the employment of such a system can also make the permanent monitoring and compliance testing of vehicle conformity for technical inspection organizations possible. Finally, the customer advantage of this approach would be refelcted in an improved road safety.
5.2.2 Off-board Diagnostics for Vehicle Inspection

One of the most important goals of vehicle monitoring is to identify a faulty vehicle and to assess its condition regarding the road safety endangerment. Among the conventional proceedings (e.g. visual check, efficiency tests) the off-board diagnosis became an unavoidable part for inspection organizations to examine the vehicle condition regarding the safety of electronically controlled systems.

The tools for the identification of a system malfunction within the PTI are similar to those for vehicle service and repair. The inspection organizations are dependent even more on manufacturer-independent devices and tools than workshops, but as the requirements regarding the amount of technical information is clearly lower, the future feasibility seems to be possible. In this context the already mentioned GER (group exemption regulation) represents a first possibility to provide manufacturer-specific information for the monitoring and inspection of vehicle systems.

Until now the off-board diagnosis e.g. within the German PTI was limited on examination of exhaust-relevant components (exhaust investigation). Therefore, the visual inspection of the MIL (malfunction indicator lamp), a scan of the error memory and of readiness codes have been executed. For 2006 a new approach for the inspection of safety-relevant vehicle electronics is planned in Germany – a legal regulation has not been implemented yet.

For this approach the eight main electronic systems are examined:
• ABS - anti lock braking system (incl. EBS)
• EPS - electronic power steering
• Electronically controlled headlights/lights
• Seat belts and restraint systems
• Airbags
• Dynamic rollover-protection
• Speed limiter
• Driving dynamic systems with interference to the brake (e.g. ESP).

In this approach the usual visual inspection and efficiency testing is extended by a check of the system assembly, check of error codes, direct measurement of physical sizes and read out of non-manipulatable informations via the CARB-connector. Suitable tools to execute these tasks have to be employed with various models of different manufacturers and have to offer support e.g. in form of a guided test including vehicle specific information for the inspection technician.

The German approach is driven by the FSD GmbH, which is implementing the described inspection plattform in cooperation with different OEM. The intention of the approach is to create an easy method to assess vehicle systems, which meets the requirements within the range of technical inspection. This tool must be easily applicable and must permit a fast execution of the PTI.

A further approach for the inspection of electronically controlled systems has been called into live in the IDELSY-project (Initiative for Diagnosis of Electronic Systems in Motor Vehicles for PTI). In the beginning of IDELSY preliminary investigations concerning diagnostic tools were accomplished on approx. 500 different vehicles with different manufacturer-independent off-board diagnostic scan tools. The intention was to select a reference tool with the most promising possibilities in order to be able to apply it for later project phases. In the next step test procedures for the most important safety-relevant systems in the vehicle (Airbags, ABS, ESP etc.) were defined basing on experiences from the preliminary investigations. In addition, field tests are being carried out on 1000 to 2500 vehicles. This project phase will be terminated until the end of 2005 and shall determine the feasability of the test procedures under real-world conditions.

Next to the PTI, conformity checks and compliance testing of vehicles by inspection authorities like mentioned in chapter 4.2.1 will get into the focus. The development of telematics will show the enabling technologies. Therefore, actual approaches and trends are documented and assessed in the docu-
ment ‘Appendix WP350_Telematics’ which is joint to this report. An overview of future developments of telematic functions has been given in WP320.
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