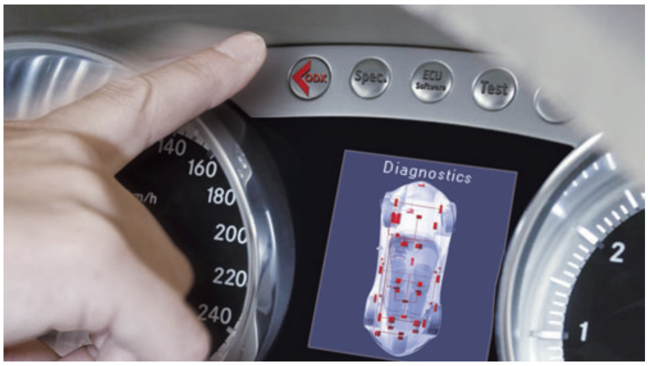
Vehicle Diagnostics – The whole Story

Efficiency gains by standardization and the use of tool-supported processes in diagnostic development

The development and introduction of new diagnostic concepts and diagnostic solutions offer significant potential to automotive OEMs and suppliers for realizing efficiency gains and quality improvement. Growing complexity in automotive electronics can only be mastered – technically and economically – by use of nonproprietary standards such as ODX, close cooperation and powerful tools. This article offers an overview of topics relevant to the past, present and future of automotive diagnostics as presented and discussed in October 2006 before an audience of 350 participants at the Vector Congress in Stuttgart.



20 years of automotive networking and diagnostics

The fast growth of electronic functions in vehicles during the second half of the 1980s at first led to many insular solutions that prevented comprehensive concepts from taking hold in the area of electrical/electronic architectures. At the beginning of the 1990s a consolidation phase began that was marked by development of electrical/electronic structures and associated networking topology from a comprehensive perspective. This meant that electrical/electronic content and its networking could claim an undisputed position in the vehicle. The recognition that many functions could only be implemented sensibly with the help of electronics also prevailed. So the image of electronics transformed from being a necessary evil to being a key to new, interesting and innovative functions. The three bus nodes in commercial vehicles in 1989 have become more than 70 today in similarly equipped vehicles; see Figure 1. The underlying software amounts to about 10 million lines of programming code.

This trend has not been without consequences for diagnostics either. Twenty years ago the diagnostic capability of a function was not even considered until shortly before production startup. Today basic diagnostic functions usually exist as early as in the B-Sample. Handling of diagnostics has improved significantly. In the times of flash codes the process required that users tediously count the number of flashes and convert them to error codes based on printed-out tables. Today testers output instructions in clear text.
In the past it was possible to do without tool support entirely. Today powerful diagnostic tools are an everyday reality. It is possible to create the diagnostic specification, generate ECU-specific code and parameterize the diagnostic tester utilizing the "single source principle". A precondition is that specification of diagnostics must be shifted to the beginning of the development process (Frontloading); see Figure 2. The ODX format also enables cross-OEM exchange of diagnostic data.

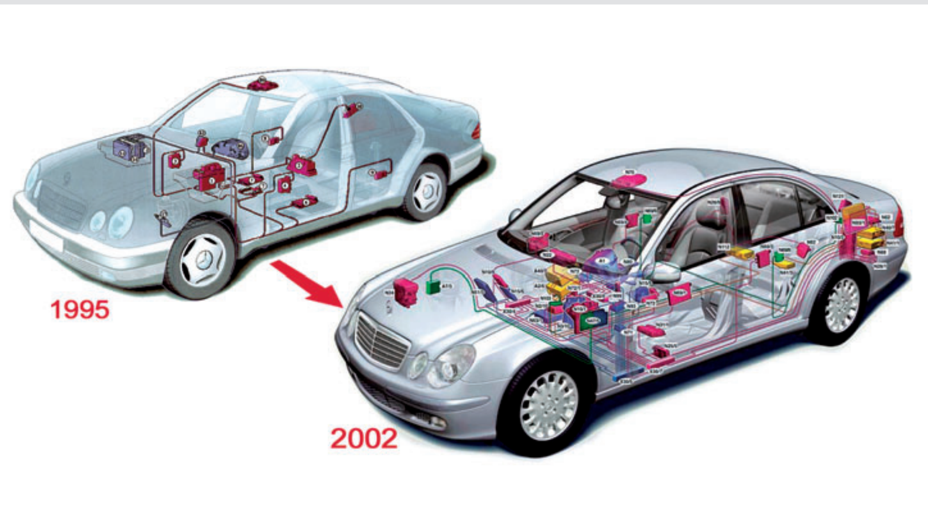


Figure 1: Development of electronic networking based on the example of the E-Class model series W210 (1995) and W211 (2002).

From proprietary diagnostic tool to standard tool chain

The developing trend of diagnostic tools is similar to the trend of electronics in the vehicle. Back in 1990 automotive OEMs created their own tools in-house. Specialists in different departments customized their tools precisely to their requirements and specific applications. This produced individual in-house solutions within each OEM and even for different process steps.

About 1995 automotive OEMs came around to a new way of thinking, i.e. that they wanted to once again focus more on their core business. Accordingly, tool development was outsourced to external service providers. Initially, these outsourcers produced special in-house solutions as well, but they succeeded in reducing the differences between tools and standardizing existing solutions within certain limits. This trend continued until open, nonproprietary diagnostic tools became available on the market in the year 2000. For users, the route of product licenses is noticeably more cost-effective than assuming responsibility for developing and maintaining proprietary tools in-house. Moreover, there are shared benefits due to synergistic effects of the combined experience of other market participants. In 2005 the tools began to support general standards. Contemporary tools offer standardized interfaces that can be seamlessly integrated into existing tool chains.

Old and new standards for diagnostics

Standards currently in the spotlight include the diagnostic data model per ISO 22901-1 ODX (Open Diagnostic Data Exchange, ASAM MCD-2D), the hardware interface per ISO 22900-2 (D-PDU API) and the interface between the runtime system and the test application per ISO 22900-3 (ASAM MCD-3D, D-Server API). Each of the programming interfaces mentioned are available to the user as software libraries. Also worthy of mention are the diagnostic-relevant standards per SAE J2534 and in the context of AUTOSAR standardization AUTOSAR WP4.2.2.1.4 (DCM, DEM). Furthermore, the UDS diagnostic protocol per ISO 14229-1 (Unified Diagnostic Services on CAN) will gradually replace older protocols such as the K-Line per ISO 9141-2 and “KWP2000” as well as “KWP2000 on CAN”; see Figure 3.

Characteristics of modern diagnostic solutions

The development of comprehensive, homogeneous diagnostic solutions is a challenge. It requires studies and efforts on many different levels, in order to satisfy all requirements under one roof. On the one hand, this involves rationally creating powerful diagnostic systems and on the other hand developing a user-friendly approach. It is only possible to realize these two goals with a universal, complete and practical diagnostic tool chain. Solutions must be specified, implemented and documented for both the overall vehicle diagnostic system and diagnostics for specific ECUs. Furthermore, consistent management and distribution of diagnostic data must be assured. That is because the applications of diagnostic solutions range from the development process with its many different areas of focus, to quality assurance in production and finally diagnostics in the service garage.

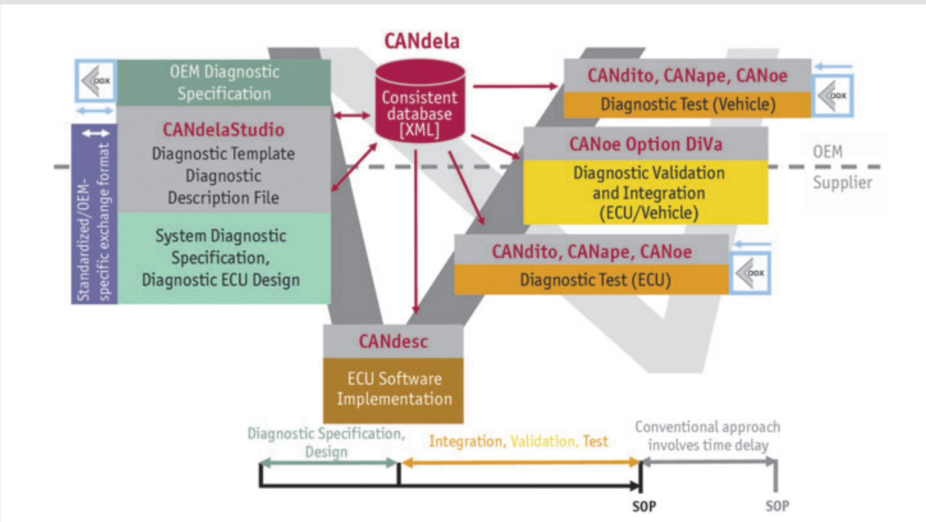


Figure 2:
Diagnostic tool chain based on single-source principle utilizing standardized exchange formats.

The above-named standards serve as a foundation and building blocks for implementation of such comprehensive diagnostic systems. They benefit individual market participants without restraining natural competition. Besides achieving cost reduction, standardization brings the user additional advantages such as interchangeability of products, components and data. It can be expected that even more standards will be created in the future, which in turn will affect the tools used.

Practical capabilities are trump

In introducing modern diagnostic tools, focus on the needs of users is of fundamental importance for their acceptance. The user should not be confronted with the full complexity of the standards. Rather it makes sense to present a diagnostically-driven perspective of the data to the user. Special knowledge of the underlying data format should not be necessary. It is also important to optimize typical recurring work steps by guiding the user in performing the necessary tasks correctly, consistently and with time savings. In particular this includes avoiding redundant processes and wherever possible reusing already existing data material.

Flexibility in handling customer-specific features

In all of the efforts to achieve uniformity and standardization in creating powerful tools, it is important not to lose sight of flexibility. Current diagnostic standards offer a certain degree of latitude that can be exploited to address supplemental requirements not covered by the standard. These include customer-specific features and conventions or special wishes not supported by the majority of the standardization committee. For suppliers, for example, it is crucial that they be capable of handling projects for different automotive OEMs with one and the same diagnostic tool. And to accomplish a gentle migration from the existing solution to the standardized diagnostic system, special temporary measures are often necessary during a transition time. In the introductory phase for new standards it is important to support multiple parallel versions in a consistent way.

Openness for progress and innovation

Even if standardization and innovation seem to be two irreconcilable goals at first glance, automotive electronics is characterized by continual development. Progress is one of the most important key performance indicators for automotive OEMs and suppliers. Therefore expandability of currently used tool chains is always in demand, so that innovations and functionalities of future standards can be utilized or tested in advance.

Enough ideas and tasks still remain to ensure that in the future automotive electronics, networking and diagnostics will continue to improve on the achievements of the last 20 years and adapt them to new requirements. It must be assumed that the pace of innovation will accelerate even more, and even closer collaboration will be necessary between automotive OEMs, suppliers and tool producers. This also pertains to a common approach in dealings with legislative bodies.

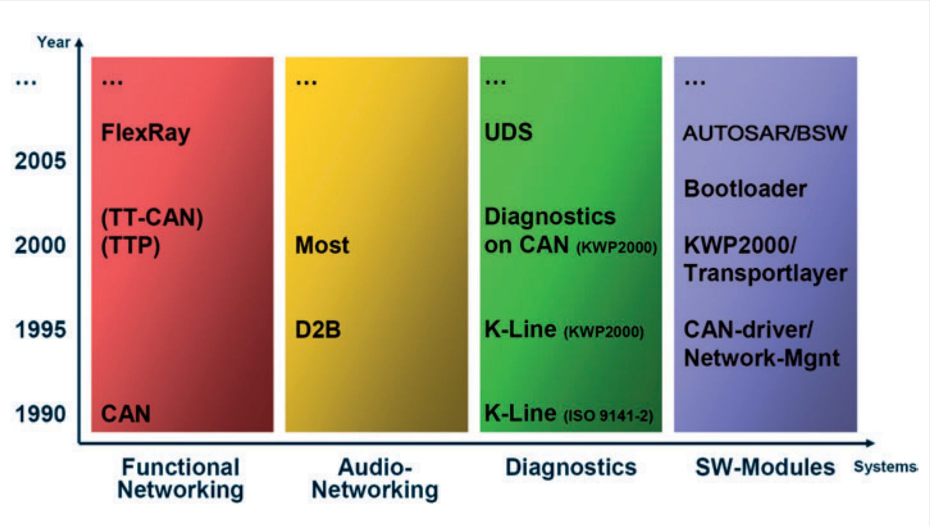


Figure 3:
The most important applied networking and diagnostic technologies over the past 15 years.

Universal and automatic tool chain

Similarly, there is much future potential for diagnostics, now that it has succeeded in quasi evolving from a "minor appendage to functions" to a "function in its own right". This signifies the step from simultaneous development to integrated development, which results in even closer cooperation between diagnostic and functional developers. For the diagnostic system a model-based approach also came to fruition, which applies knowledge acquired from FMEA (Failure Mode and Effects Analysis) for example. Tools like DaVinci and CANdelaStudio from the Vector Informatik company, IQ-FMEA and Matlab/Simulink enable diagnostic design strategies utilizing a universal and automated tool chain, from modeling tool to authoring system.

Diagnostic developments at DaimlerChrysler

DaimlerChrysler AG and Vector Informatik GmbH have expanded their close cooperation over the past several years, including in the area of diagnostic tools. Easy and convenient use of tools and description of all diagnostically-relevant data in a uniform format are important principles of their joint projects. Data and diagnostic functions are only formally specified once in the solutions, which are based on the "single-source principle". Therefore they are universally available to all project participants and suppliers in machine-readable XML description files; see Figure 2.

In CANdela (CAN diagnostic environment for lean applications) Vector Informatik structured its diagnostic product line-up with sufficient flexibility so that OEM-specific export formats could be integrated. DIOGENES, the DaimlerChrysler-specific description data format, is also automatically generated and is then processed by the uniform diagnostic runtime system. The requirements and experiences of other cooperation partners such as OPEL/GM and agricultural machine producer CLAAS have had significant influences on the CANdela approach too. In the meantime Vector has also been working together with companies such as Fiat, Ford and numerous automotive suppliers worldwide.

Handling special project-specific features with templates

In formal diagnostic description templates, or just templates, are important services for taking into consideration specific requirements of the manufacturer, project and vehicle model. Fully specifying diagnostics at a very early time prevents most misunderstandings, errors and iterative optimization loops in the diagnostic development process. The use of CANdela is firmly established in the development process at DaimlerChrysler. ECU suppliers not only develop the diagnostic functions in the ECU; they also supply the associated formal descriptions. Often standard software components are used to implement diagnostics in the ECU. The diagnostic component CANdesc (CAN diagnostic embedded software component) can be automatically generated from the CANdela data; see Figure 2. This gives ECU and vehicle producers a way to achieve uniform implementation of the diagnostic protocol across all products.

ODX exchange format and UDS diagnostic protocol

The international standard ODX (Open Diagnostic Data Exchange) serves as the standard for exchanging data and nearly all diagnos-

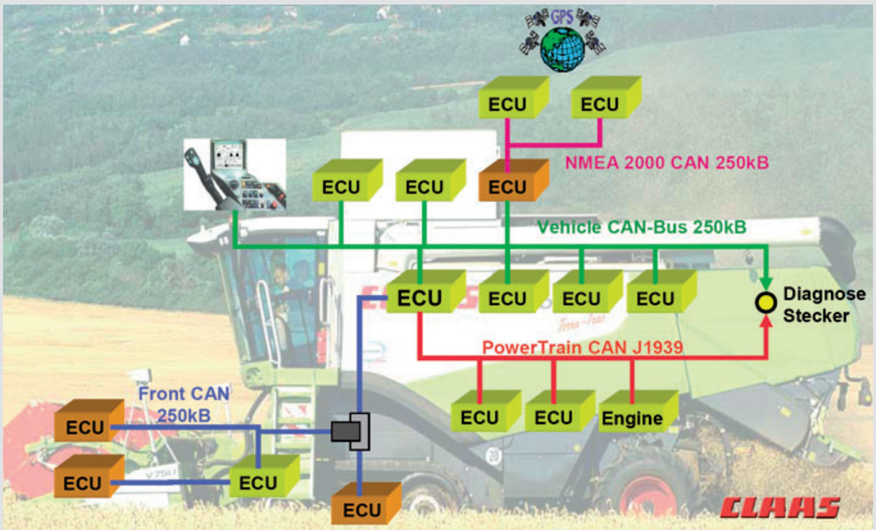


Figure 4:
Complex bus networking in the LEXION combine harvester.

tic information between individual tools, as well as between automotive OEMs and suppliers. It is being developed within the ASAM standardization body (Association for Standardization of Automation and Measuring Systems) and is expected to be released as ISO standard 22901-1 in 2007. DaimlerChrysler plans to replace its own DIOGENES format by ODX on future projects.
The CANdela approach handles import and export of ODX data and enables a smooth transition from proprietary formats to the standardized exchange format for suppliers. Moreover, the Vector Tools CANoe, CANape, CANdito and CANdelaStudio support the new UDS diagnostic protocol (ISO 14229), which DaimlerChrysler is introducing in all of its corporate divisions on each successive model change beginning with the current C-Class where it will replace the previous KWP2000 protocol. DaimlerChrysler is relying on the standard ODX-F format for describing the flash data too. This is done with the flash data management tool CANdelaFlash from the CANdela product line.

Automating tests at harvesting machine producer CLAAS

At Europe's leading producer of harvesting machines, CLAAS, efficient development of diagnostic systems plays a key role. In a combine harvester there are up to four highly complex bus systems optimized for agricultural tasks; see Figure 4.

The challenges facing the agricultural vehicle diagnostic system are enormous: 350 connectors with 3,000 electrical contacts, 3,000 m of copper lines, up to 25 ECUs or CAN nodes and numerous opto-electronic machine guards, potentiometers, valves, servo-drives and speed sensors must all operate properly and work together.

In its diagnostic development process CLAAS runs through the V-Model with the CANdela tool chain. CANdelaStudio is used to create the specification of diagnostic functionality consistently. The captured data are used directly to generate the ECU-specific diagnostic software component with CANdesc. To parameterize the tester CLAAS utilizes ODX data exported by CANdelaStudio, Figure 5.
For a half year now CLAAS has also been using CANoe Option DiVa (Diagnostic Integration and Validation Assistant). DiVa makes it possible to automatically generate and execute reproducible test cases for implementation and integration of the diagnostic protocol. Serving as requirements are internal CLAAS test specifications and the diagnostic database. Suitably configured, DiVa permits test scenarios of varying depth and intensity, e.g. comprehensive tests or just tests of specific services. The program outputs detailed HTML test reports for error analysis purposes. In the future, automated testing with CANoe Option DiVa will be used for all CLAAS ECUs.

Joint diagnostic project by DaimlerChrysler and Volkswagen

A joint project pointing the way to the future and simultaneously serving as a test case for new diagnostic standards and exchange formats was the joint development of the new transporter generation "Sprinter" and "Crafter" by DaimlerChrysler AG and Volkswagen AG. The project executed under the name "Phoenix" started in the year 2003 and reached its interim conclusion in mid-2006. Technically, the Sprinter and Crafter vehicles are for the most part identical and will be produced in various body configurations, weight classes and equipment variants at DaimlerChrysler plants in Lud-

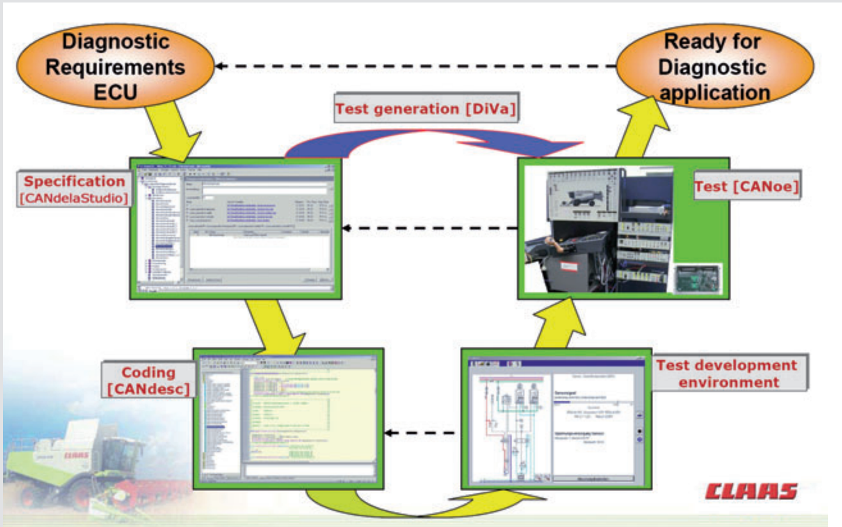


Figure 5:
Diagnostic development at CLAAS by the V-Model using the CANdela tool chain.

wigsfelde and Düsseldorf. Besides differences in body design, other key differences lie in each vehicle's brand-specific powertrain.

The initial idea for a diagnostic concept was to "translate", so to speak, the Sprinter diagnostic data from DaimlerChrysler to VW via a central ECU in the Crafter. This would have made it possible to omit adaptation to the VW service tester, since to a certain extent it speaks a different language due to incompatible diagnostic philosophies. However, this strategy was rejected in favor of modifying the service tester and exchanging diagnostic data by ODX. Stated in somewhat simplified form, an ODX converter now processes the ODX diagnostic data generated by CANdela and uses them to prepare the ODX data for VW, Figure 6. Existing components of the VW service tester are not replaced, rather they are supplemented by other functions needed for a migration.

ODX: Trials passed successfully

In this first joint diagnostic project the participating automotive OEMs were able to acquire valuable experience, even though they were confronted with difficult constraints. It was necessary to deal with fundamentally different diagnostic philosophies involving different languages for coding, parameterization and control. Furthermore, all components contained in the diagnostic development process, such as export to ODX and the ODX standard, were still just in the development stage. Numerous internal departments and external suppliers were involved, there was as yet no practical experience with the new ODX standard, and a tight schedule had to be maintained. In the Phoenix project the performance of the ODX standard was put to the test in a challenging large project and it passed successfully.

Future visions: Where does the road lead?

With relentless progress in standardization many things are simplified, and it is possible to come to grips with new challenges. As ever, natural competition will generate a great deal of dynamism in future development. Of course, it is impossible to predict exactly what effects this will have on vehicle electronics and diagnostic systems of the future. However it can be stated with certainty that the significance of Internet technologies will continue to grow, as is also the case in many other technological areas. For example, "Diagnostics-over-IP" is conceivable. Initial studies with Ethernet and TCP/IP are already underway in conjunction with FlexRay gateways. If vehicles take on the position and functionality of a HTTP server from an information technology perspective, general identification via IP addresses might make sense, for example, and this would make Vehicle Identification Numbers superfluous. Standardization will continue to advance in test modules and test procedures, and re-use in development, production and the service garage will become commonplace. Similarly, error messages in clear text will become available on PCs and Web Browsers. Prerequisites

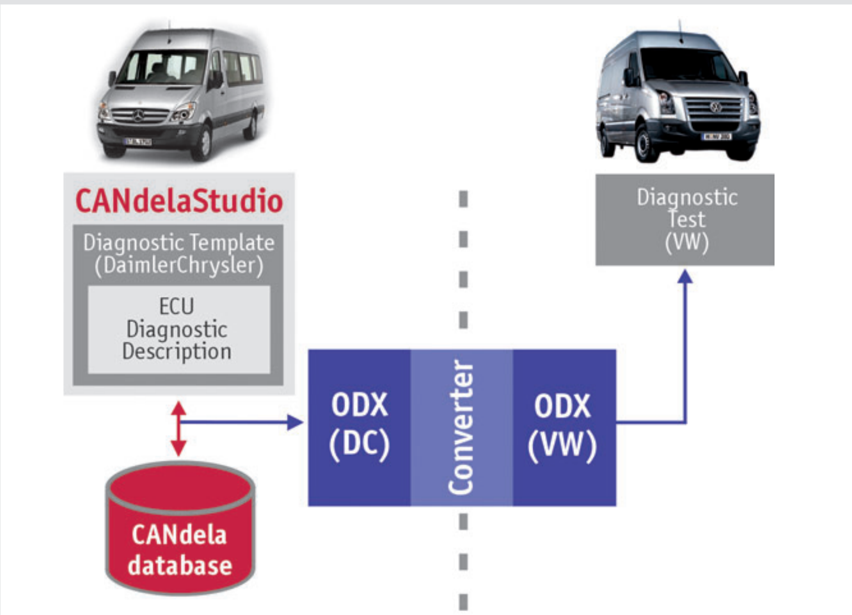


Figure 6:
Cross-OEM exchange of diagnostic data between DaimlerChrysler and VW based on ODX.

for this are diagnostic design concepts with universal and automatic tool chains that can generate diagnostic data for all components, from the modeling tool to the authoring system. Vector will help to drive sustained development of these innovative concepts.

Literature:

[1] Kühner, T.: "20 years of vehicle networking and diagnostics – What do we anticipate in the future?", Vector Congress 2006

[2] Schlingmann, N.: "Specification – Coding – Test: Development of diagnostic software", Vector Congress 2006

[3] Johanson, D.: "Introducing ODX diagnostics in a OEM joint venture project", Vector Congress 2006

[4] Rätz, C.: "What is the market demand for diagnostic solutions?", Vector Congress 2006

[5] Stimmler, S. and Rätz, C.: "On a solid basis – Efficient development of diagnostic functions in the automobile", Automotive Electronics 2/2005

Helmut Frank
(Graduate Engineer)is a Business Development Manager at Vector Informatik responsible for the Diagnostics product line.

Uwe Schmidts
(Graduate Engineer) is a Marketing Coordinator at Vector Informatik whose responsibilities include the Diagnostics product line.