Media Release

October, 2006

AUTOSAR – Enabling Technology for Advanced Automotive Electronics

The **AUTOSAR** (**AUT**omotive **O**pen **S**ystem **AR**chitecture) initiative aims to develop and standardize (in sense of a de-facto standard) an open software architecture for automotive electronic control units (ECUs). This architecture is being developed by a partnership of automotive manufacturers, suppliers and tool vendors.
The partnership is focused on managing the growing complexity in the development of automotive electric/electronic (E/E) architecture, with the aim of both enabling new technologies and improving development efficiency – without making compromises on quality. AUTOSAR will develop a set of specifications describing software architecture components and defining their interfaces.

1 Introduction

These days there may be up to 70 ECUs in a car, responsible for controlling major functions of the vehicle. Ever more demanding requirements on safety, environmental protection and comfort/convenience over recent years have resulted in a sharp increase in the number of electronic systems to be found in vehicles. Increasingly stringent legal requirements on exhaust emissions and safety have also fed the trend, as have the numerous infotainment and driver assistance systems, whose functioning relies on the simultaneous interaction of a variety of different sensors, actuators and control units. However, the pace of development and the increasing integration of functions and control units is creating a problem for vehicle manufacturers in that the interaction and dependency between different signals in the vehicle are becoming more and more complex.
The growing complexity of vehicle electrical and electronic systems is presenting developers with ever-increasing challenges throughout the development process, from formal description through to system testing. At the same time new functions are increasing the cost and complexity of producing and maintaining hardware and software.

Furthermore nowadays car manufacturers and tier 1 suppliers rely on individual basic software standards which have to be maintained and integrated individually. The derived maintenance and integration efforts have potential for improvement: Harmonization of these local standards and the provision of a common base for automotive software development must be a goal for the automotive community. So even for the development of cars with a persistent feature set and constant complexity the efforts for software development and integration can be reduced in providing common and well maintained community solutions.

In the light of this, leading automotive manufacturers and suppliers launched the AUTOSAR initiative in 2003. The aim is to develop common automotive software standards for ECUs and to prepare for future challenges in modern automotive software development. The “Core Partners” in AUTOSAR are BMW Group, Bosch, Continental, DaimlerChrysler, Ford, Opel, PSA Peugeot Citroen, Siemens VDO Automotive, Toyota and Volkswagen, while more than 100 other companies have now joined the development partnership as “Premium” or “Associated Members”.

The AUTOSAR initiative is based on the following principles:

- AUTOSAR is an enabling technology for the development of new E/E systems that will provide enhanced safety, performance and environmental friendliness.
- AUTOSAR is a global partnership which is working to develop a common standard in accordance with the motto: “Cooperate on standards, compete on implementation”
- AUTOSAR will manage the growing complexity of automotive E/E development. The aim of the standard is to enable new technologies and to improve cost-efficiency – without making compromises on quality.
- AUTOSAR facilitates the replacement and updating of software and hardware across the vehicle lifecycle.

2 AUTOSAR - The Idea

The AUTOSAR specifications are a de facto standard facilitating the use of independent software components. Such components can be used in vehicles of different manufacturers and in electronic components of different suppliers and can span multiple (electronic) product generations.
The AUTOSAR approach is based on the definition and specification of a layered software architecture. The runtime environment (RTE) and the basic

software (BSW) provide developers with a clearly defined and standardised infrastructure for developing the application software (application layer). This allows applications to be developed independently of the actual electronic hardware used.

Switching from proprietary software to a standardised software architecture offers cost and capacity benefits for everyone involved in modern automotive electronics development.

Important objectives include:

- easy integration and transferability of functions
- flexible maintenance
- scalable functionality
- high standard of system reliability
- software independence of hardware

Automotive manufacturers

- reduce maintenance and integration efforts for today's software development,
- can focus on achieving competitive differentiation of the defined/developed software,
- can provide functions which are compatible across platforms,
- can cater for a large number of versions and equipment features.
- The conformance process is standardised and
- manufacturer innovations can be incorporated at a later point in time of the development process.

Suppliers

- can partition development activities,
- can contain the proliferation of manufacturer-specific versions,
- can enhance the efficiency of function-specific development,
- can establish new business models and
- can prepare themselves for the growth in software-relevant functions.

Tool providers

- benefit from standardised development interfaces,
- can more easily incorporate tools of third-party suppliers into their integrated tool chain or integrate their own tools into existing chains.
- Additionally, a complete process from design through to code generation can be supported.

New market entrants

- The formulated standards remove barriers for new companies entering the market.
- New business models can be developed.

The common standard covers the basic software, the runtime environment – the communication interface for all software components of an ECU – and the interfaces with the concrete application. The standard also defines the required layers and interfaces with controllers and peripheral hardware. Other important objectives of the initiative are the definition of a standardised development methodology, and maintenance and release management.

3 Technical Concept

In developing the AUTOSAR specifications, the partners' objective is to make use of proven software development components wherever possible, rather than reinventing everything from scratch. The initiative aims not for a smallest common denominator approach but for the "maximum common denominator" which will help all partners to undertake future development projects more efficiently.

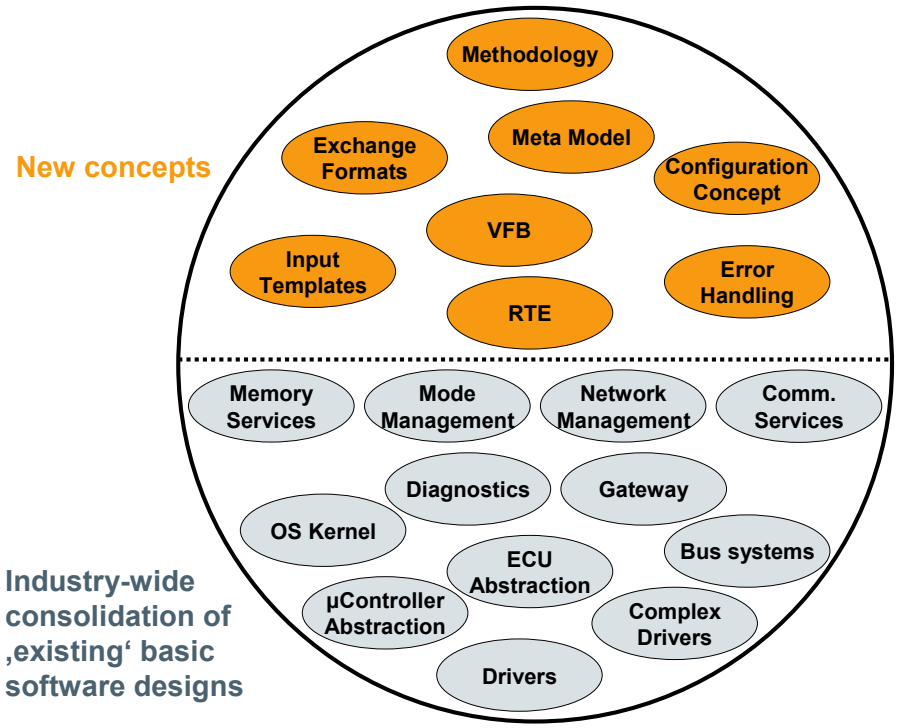

Figure 1: Concepts and designs

The lower part of figure 1 shows proven software design components which have been adopted in AUTOSAR largely unchanged. The upper segment shows concepts which had to be newly created for AUTOSAR.

These include the pivotal concept of the Virtual Functional Bus (VFB). This virtual bus decouples the applications from the infrastructure. It communicates via dedicated ports, i.e. the communication interfaces of the application software must be mapped to these ports. The VFB handles communication both within the individual ECU and between ECUs. From the application point of view, no detailed knowledge of lower-level technologies or dependencies is required. This supports hardware-independent development and use of the application software.

The runtime environment implements the Virtual Functional Bus on any ECU. The RTE is scalable and is created statically for the applications of the particular ECU, thus allowing resources to be conserved.

The modularity aspect of AUTOSAR allows easy partitioning and transfer of functions between automotive manufacturers and suppliers. It also allows easy transfer of functions across different platforms of the same vehicle manufacturer or between control units within the same vehicle. The standardised, structured approach also facilitates modular application software design, creation of reliable, reusable standard software and updating of vehicle software throughout the entire vehicle lifecycle.

The following areas of automotive electronics development have been addressed by AUTOSAR so far: power train, chassis, body and convenience electronics. The fact that AUTOSAR also comprises a diagnostics concept will facilitate servicing of vehicles in the field, with diagnostic interfaces now providing access to all the relevant data.

4 AUTOSAR Architecture

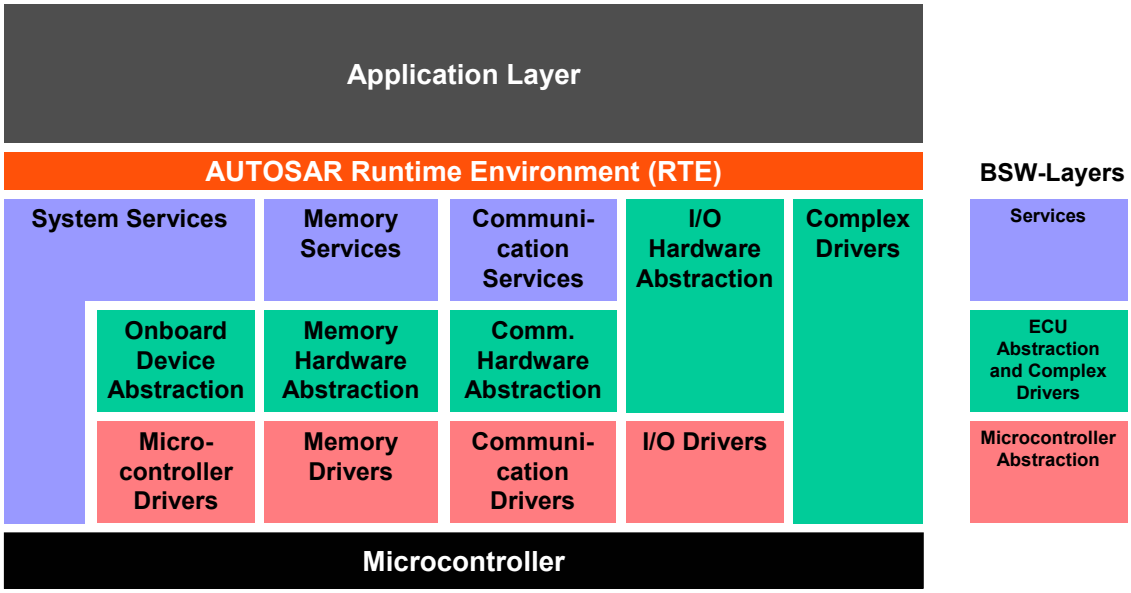

Figure 2: Software architecture layers

The AUTOSAR architecture maintains a clear separation between application software, RTE, standard (basic) software and the hardware layer on which it is implemented.
The application software is divided into software components. It operates in an environment where interfaces with the rest of the control unit and the vehicle are clearly defined. The basic architecture concept is that the hardware is abstracted in layers.
The lowest software layer is the microcontroller abstraction layer (red). Here all functions and peripherals of the microcontroller are abstracted, so that the higher layers are independent of the microcontroller. The microcontroller abstraction layer comprises microcontroller drivers, memory drivers, communication drivers and I/O drivers. Also on this layer, missing features are emulated by appropriate software.

The next layer is the ECU abstraction layer (green). The purpose of this layer is to abstract all basic components of the ECU. It also contains the drivers for external peripherals.

The third layer is the services layer (blue). This layer is largely independent of the hardware and its function is to provide background services of various kinds such as network services, memory services, bus communication services and operating system services.

The next layer above this is the runtime environment (RTE, orange). This layer abstracts the application software from the basic software and organises the data and information traffic between them. All software above the RTE consists of hardware-independent components. Its defined transfer interfaces allow application software to be developed without specific knowledge of what hardware will later be used. Also, existing software components can be transferred freely.
A further feature of the software architecture are the complex drivers. These control complex sensors and actuators which are subject to special timing constraints. They connect these components directly to the microcontroller. Such drivers are required for example by injection-timing or valve-timing systems.

5 Methodology

In addition to defining architecture and interfaces, AUTOSAR also includes a development methodology description based on a metamodel containing precise description concepts for a complete AUTOSAR system. This description contains XML templates for all components of the system. The metamodel also defines operations for template processing and thus forms the basis of the development methodology.
The development methodology starts with a software component description, an ECU resource description and a system constraint description, from which the system configuration generator then produces a complete system configuration description and translates it into an ECU configuration description. Various generators then create the RTE and basic software code (including operating system). This structured methodology allows developers to identify missing hardware features, contradictory application component interfaces and any required configuration changes at an early stage.

Tool suppliers already provide wide-ranging support in all phases of the product creation process. Here too the conceptual framework of AUTOSAR has benefits for the developers: for any application during the development process a specific tool can be used; at the same time, however, the system offers the user an integrated development chain from model design through to code generation and testing. It is also easier to integrate tools from different tool providers, thanks to the defined interfaces.

The development methodology also offers advantages for the development of application components. Hardware independence and the standardised communication interfaces facilitate the simulation and generation of test

scenarios. In this way software components can be tested more frequently and yet at the same time at less cost – particularly in the early phases of development. Software component manufacturers can already adopt the AUTOSAR development methodology today, irrespective of their clients' specifications, and thus free up resources for developing new software.

6 Maintenance and Release Management

Continuous maintenance of this standard is vital if developers are to be able to incorporate future developments, new bus standards or other innovations into the AUTOSAR specifications on an ongoing basis both during the initial definition and validation phase and during later real operation. A change control board is responsible for release management. If specifications need to be changed, the change management team checks the requests for changes and takes all necessary actions to change or supplement the specifications.

7 AUTOSAR Partnership

Any company can become a member of the AUTOSAR partnership. Membership is a precondition for using the specifications for commercial purposes. AUTOSAR comprises 10 "Core Partners", who are steering the project and have organizational and administrative responsibility and control. To others the partnership offers "Premium Member", "Development Member", "Associate Member" and "Attendee" status.

Within the core the Steering Committee is responsible for admitting new members and for press and contractual matters. It is also responsible for all non-technical matters.
One step above the Steering Committee is the Executive Board, which defines the strategy and objectives of the partnership.
The Project Leader Team is responsible for technical matters. It coordinates the technical working groups, which provide reports to the Project Leader Team. All teams meet on a regular basis.

Work on the AUTOSAR specifications is divided into a number of work packages (WP) which, if necessary, are divided into sub-packages. Besides the Core Partners the Premium Members and Development Members do actively contribute to the work in the work packages.
WP1 is responsible for the software architecture and methodology concept, WP2 for system generation and system description format and content, and

WP4 for ECU configuration and basic software. WP5 is responsible for test and integration processes and WP10 defines the interfaces for selected application functions. WP20, finally, is responsible for conformance tests, version control and maintenance processes.

8 Status of Specifications

The implementation of the theoretical concepts developed by AUTOSAR into concrete specifications is based on a detailed plan. Figure 3 shows the schedule to the end of 2006. Whenever a specification has been completed, this is followed by a validation phase and, if necessary, by additions and corrections.

Release 1.0 of the AUTOSAR specifications related primarily to parts of the basic software below RTE level. This was followed by a “proof of concept”: 14 companies implemented 33 different basic software modules in 55 implementations. An independent company integrated all 55 implementations on two different hardware platforms (16 and 32 bit). A specially appointed working group was responsible for overseeing integration. The findings from this phase then resulted in further refinements being made to the specifications.

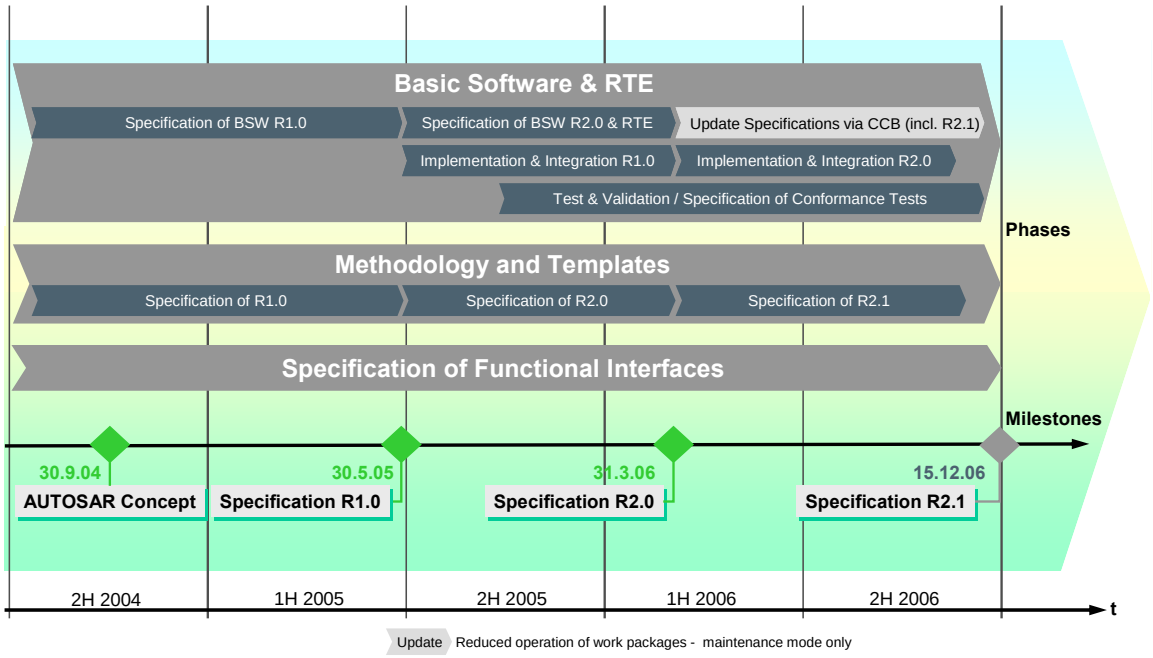

Figure 3: Top-level schedule

Next, the partnership focused its attention on further BSW components, on RTE implementation and on implementation of the AUTOSAR configuration concept. In May this year, Release 2.0 was approved. 40 out of 46 work

packages have been completed and have already been defined in the specifications. Release 2.0 is now also publicly available for free downloading for information purposes. The modules of Release 2.0 have been implemented and are currently integrated on two different hardware platforms (validator 2). The results from these tests, together with any missing architecture elements, will be incorporated in Release 2.1, which will be completed by the end of the year. The first AUTOSAR products are expected to be incorporated in production vehicles starting in 2008.

9 Next Steps

The automotive industry will not be able to implement the de facto standards overnight. Rather, the vehicle manufacturers will develop suitable modules in AUTOSAR-compliant form on an incremental basis. The development partners' existing software modules will be adapted to the AUTOSAR specifications and transformed into standard-compliant components on a project-by-project basis.
Finally, tests by accredited conformance test agencies will establish compliance with the AUTOSAR specifications for each individual module and each system component. The specifications will also be applied to purchased modules, which will have guaranteed interfaces and defined parameter transfers. Ultimately, therefore, all AUTOSAR partners will be able to rest assured that hardware and software components can be developed, tested and implemented independently of other components.

10 Phase II

At the end of 2006 the AUTOSAR project will finish phase I. The crucial role that AUTOSAR has been taken in the automotive industry is the main motivation for continuing the project with phase II for another three years, 2007-2009.
The activities in phase II basically can be distinguished in a) the exploitation and maintenance of the outcome of phase I and b) the further development of the standard.

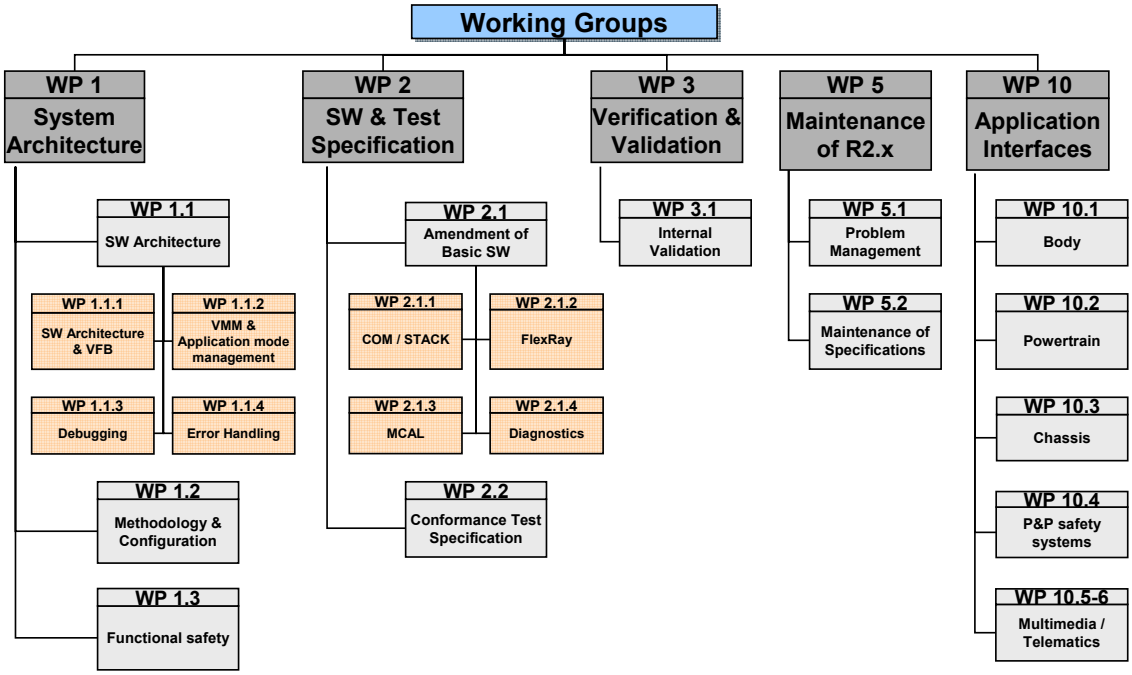

Figure 4: Phase II work package structure

Figure 4 shows the work package structure of AUTOSAR phase II. Regarding exploitation and maintenance there is already established a release process for future releases and a change management for further improvements of the standard. Moreover the defined conformance test process has to be established. This is a very important aspect for production application of AUTOSAR. It affects the BSW modules (e.g. AUTOSAR OS, communication manager, RTE), and the compatibility between application software components and RTE.

Besides these activities the further development and amendment of the standard shall be driven. This will incorporate the experiences from the validation at the end of phase I and generally consider feedback from all AUTOSAR stakeholders. And also additional safety features shall be in focus of phase II.

Last but not least the AUTOSAR interfaces of many application software functions (e.g. central locking, power train control, adaptive cruise control, etc.) will be standardized in phase II. As a prerequisite the AUTOSAR partnership works on an appropriate decomposition for such functionalities. For many of them this already has been achieved, but this also will be the task of AUTOSAR work packages in phase II. In particular the work package dealing with pedestrian & passenger safety systems is completely new in phase II. The interface standardization not only means a further

development, it also supports the exploitation, because it will ease the exchange of application software between car manufacturers and suppliers.

11 Conclusion

AUTOSAR is an enabling technology for the development of new vehicle functions that will provide enhanced safety, performance and environmental compatibility. The standard facilitates efficient, high-quality development work in the increasingly complex E/E systems field.
The integrated specifications for methodology and architecture decouple application software from hardware by means of standardised basic software. Based on defined interfaces the standard therefore promotes reusability of developed and proven software components, thereby allowing resources to be devoted to genuine innovation in line with the motto “Cooperate on standards, compete on implementation.”

AUTOSAR (AUTomotive Open System ARchitecture) is a global development partnership of automotive manufacturers, suppliers and companies specialized in electronics, semiconductors and software. Since 2003, they are working together to develop and establish an open and standardized automotive software architecture. By facilitating the exchange and update of software and hardware, AUTOSAR will be an enabling technology to manage the growing electrics/electronics complexity and to improve cost-efficiency without making any compromise with respect to quality. The core partners of AUTOSAR are the BMW Group, Bosch, Continental, DaimlerChrysler, Ford, Opel, PSA Peugeot Citroën, Siemens VDO, Toyota, and Volkswagen. In addition to these companies, the about 50 premium members are playing a significant role in the success of the partnership. AUTOSAR specifications can be used free of charge by any companies that join the AUTOSAR development partnership.

For further information:
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