

AUTOSAR – A Worldwide Standard is on the Road.

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Abstract/Summary

The AUTomotive Open System ARchitecture (AUTOSAR) was founded as a development partnership in 2003 and produced the first set of major specifications by the end of its Phase I in 2006. In Phase II (2007-2009) Releases 3.0 and 3.1 were made available, while AUTOSAR Release 4.0 will follow by the end of 2009.

With Release 2.1 and Release 3.0/3.1 the majority of partners and members started their series roll-out of AUTOSAR. When introducing the AUTOSAR standard in series products dedicated migration scenarios need to be applied. The use-cases for these different migration scenarios will be presented and there will be shown ways of how to further migrate to a fully AUTOSAR compliant solution.

Release 4.0 will be the next big step of AUTOSAR in providing the features that were demanded by the different applications of the domains AUTOSAR is covering. In the following, a top-level overview is provided.

Since the current AUTOSAR development contract ends by the end of 2009, the AUTOSAR Core Partners have set up a new contract for AUTOSAR Phase III lasting from the beginning of 2010 to the end of 2012. The focus of Phase III will be on maintenance, increasing maturity, supporting new hardware mechanisms and further enhancing the existing AUTOSAR system. Details on AUTOSAR Phase III will be given with respect to

- the major changes in the organization of the AUTOSAR Partnership,
- the top level schedule; and
- the planned technical content.

1. Introduction

Since its foundation in 2003, the AUTomotive Open System ARchitecture (AUTOSAR) Development Partnership has provided several releases as a result of its joint development activities. With Release 2.1 at the end of Phase I in 2006, AUTOSAR finalized the first set of major specifications. In Phase II, Release 3.0 and 3.1 introduced dedicated additions and helped to mature the specifications. Release 4.0 will follow by the end of 2009 containing a remarkable number of new and even unique features. Development will continue during AUTOSAR Phase III. In parallel, the existing releases will be maintained.

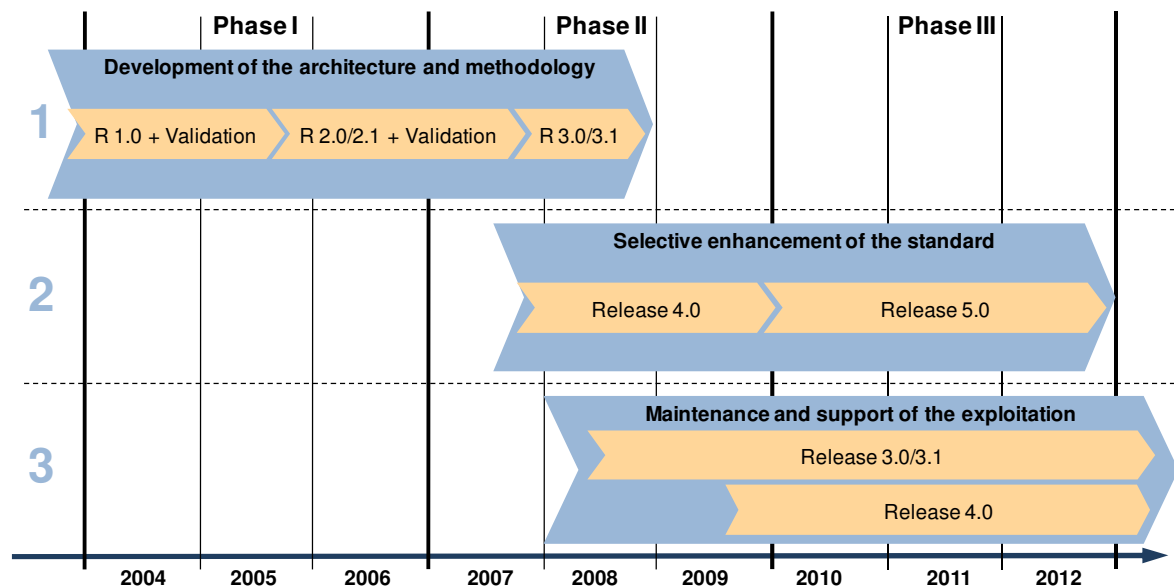


Figure 1: The AUTOSAR Timeline

The objective of AUTOSAR is to establish an open industry standard for the automotive software architecture between suppliers and manufacturers [2].

The standard comprises a set of specifications describing software architecture components and defining their interfaces [3].

The principal aim of the standard is to master the growing complexity of automotive electronic architectures. The need to build a common architecture became stringent for a variety of reasons, among which:

- Defining a common understanding how electronic control units (ECU) cooperate on same functions
- Separating the software from the hardware in order to allow software reuse and smooth evolutions limiting re-development and validation.

Finally AUTOSAR is enabling multiple different functions as for example software modules to be hosted on the same ECU, independently from the supplier of either part.

The ongoing development of AUTOSAR products by the member companies provides a unique feedback loop into the development of the standard itself. This allows fast and pragmatic improvements. The reusability of software has already been experienced in major developments and it has resulted in substantial savings in the overall development costs.

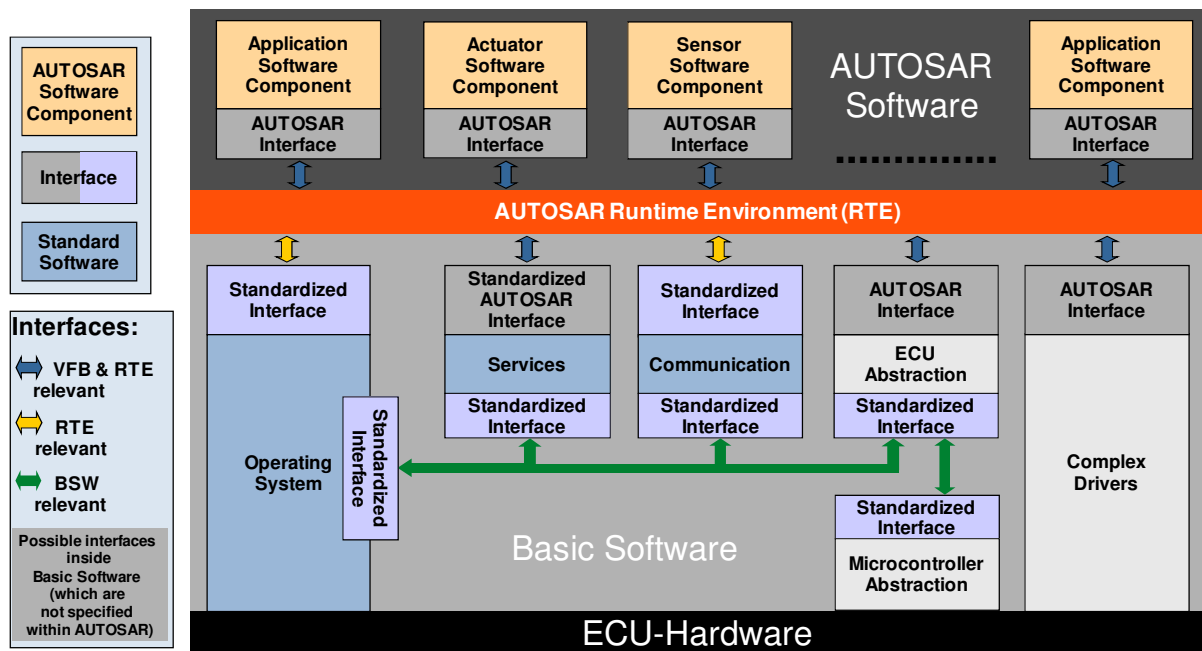


Figure 2: AUTOSAR Software Architecture – Components and Interfaces

2. Current Releases of AUTOSAR

2.1. A Brief Reflection of AUTOSAR Phase I [3], [4]

The main purpose of Phase I was to achieve a complete set of specifications of architecture, methodology and templates.

Release 1.0 of the AUTOSAR specifications related primarily to parts of the basic software below runtime environment (RTE) level. This was followed by a “proof of concept” phase. The findings from this phase then resulted in further refinements being made to the specifications.

Release 2.0 and 2.1 focused on the completion of Basic Software (BSW) components and the RTE. Release 2.1 is a complete set of specifications including the configuration concept. It is an update of Release 2.0 with the outcome from implementation and validation of BSW modules on series like hardware platforms.

Both, Releases 2.0 and 2.1, are in use by several AUTOSAR members for series productions.

2.2. Overview on AUTOSAR Phase II

Three releases had been planned for AUTOSAR Phase II, providing a continuous improvement of the specifications and introducing new concepts.

Release 3.0 was published early 2008 on the AUTOSAR web site [1]. It included a large number of improvements and corrections with respect to the previous releases.

Release 3.1 was dedicated to the incorporation of On-Board-Diagnostics (OBD) II regulations support mechanisms.

At the end of Phase II, Release 4.0 will integrate new features – e.g. related to safety or communication – and conformance test specifications. Release 4.0 will be delivered by the end of 2009 after its validation.

2.3. Achievements of Release 3.0

158 documents are part of Release 3.0, a large part of them being quite stable, 30% with significant improvements, and 10% of these documents were completely new. In total, more than 500 change requests have been processed improving the quality of the standard.

Architecture (BSW and RTE) [6], [7]:

The basic software architecture has reached a high level of maturity. Commercial implementations of the basic software modules based on Release 3.0 as well as 2.1 are available on the market. Major improvements were made on the wake up and start up of ECUs and networks providing both, harmonization of features and reduction of complexity. As an example of evolution of existing modules the approach of abstraction was refined by introducing state managers as an architectural layer for CAN (Controller Area Network), LIN (Local Interconnection Network), and FlexRay (see Figure 3).

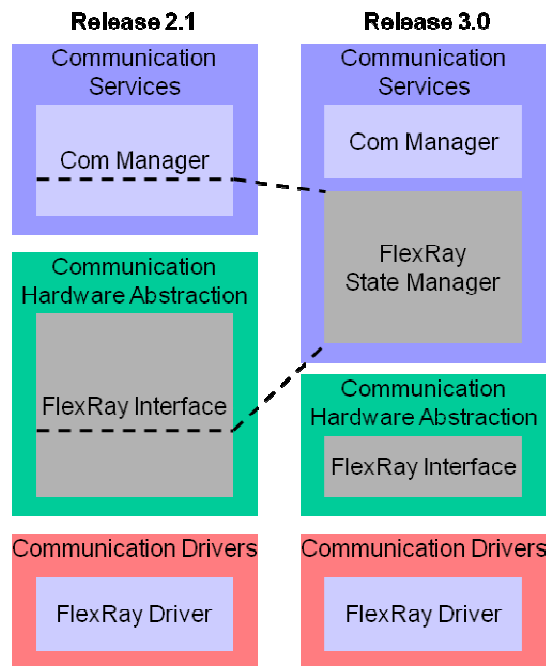


Figure 3: Evolution of the communication stack in Release 3.0, for example FlexRay

Methodology and Templates [8]:

The improvements made on the templates ensure the consistency of the standard. Interfaces, behavior and configuration parameters of the basic software are now included in AUTOSAR models – following the single source principle. This allows a better control of further evolution and the automatic generation of the relevant specification chapters as shown in Figure 4.

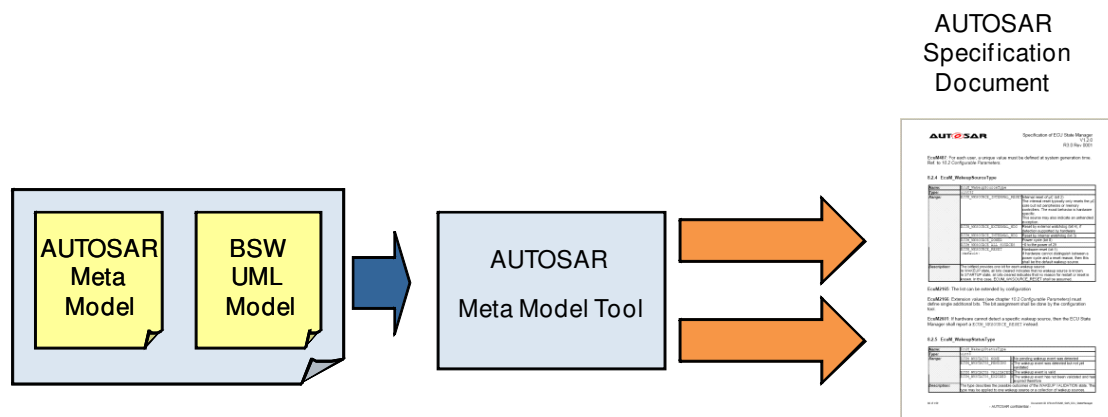


Figure 4: Model based generation of specifications

Furthermore, AUTOSAR has worked out the harmonization between the ASAM FIBEX standard [9] and the AUTOSAR System Template: both meta models are now matching up: FIBEX tools describing topologies, networks and communication can easily be integrated into AUTOSAR methodology and tooling.

Application Interfaces:

In order to cover all vehicle functionalities, AUTOSAR has started working on two new car domains in the area of Application Interfaces during Phase II: Telematics/Multimedia/HMI and Occupants and Pedestrian Safety Systems. Moreover, Powertrain, Chassis, and Body and Comfort interfaces have performed their first steps of integration. Release 3.0 contains both, explanatory documents of each of the latter domains and an integrated table available in XML format specifying the entire set of interfaces.

2.4. Release 3.1

Release 3.1 was a limited extension of Release 3.0, delivered by mid 2008. It was dedicated to the introduction of the OBD features into AUTOSAR basic software modules. All the variants of different OBD regulations (OBDII, European OBD, Japan OBD...) were covered in this release impacting mostly the three basic software modules of the diagnostic services, i.e. Function Inhibition Manager (FIM), Diagnostic Event Manager (DEM), and Diagnostic Communication Manager (DCM).

Release 3.0 and 3.1 are available as download on the AUTOSAR website [1].

3. AUTOSAR Release 4.0

Release 4.0 will introduce new concepts on architecture and methodology. In addition, conformance test specifications for basic software specifications will be provided on module level. Release 4.0 specifications are currently validated in order to reach the final approval state end of 2009.

3.1. Basic Software and RTE

Concepts

The new concepts to be introduced with AUTOSAR Release 4.0 are adding technical and functional improvements and extensions to the following main areas: functional safety, architecture, communication stack, and templates. Some of these concepts are summarized in this chapter.

Functional safety concepts

Functional safety is one of the main objectives [5] as AUTOSAR will support safety related applications and thereby has to consider the upcoming ISO 26262 standard. Exemplarily some of the new safety features are mentioned below:

- The memory partitioning concept will provide a fault containment technique to separate software applications from each other. This concept is allowing safety and non safety applications to be implemented on the same ECU.
- Defensive behavior is a solution that prevents data corruption and wrong service calls on microcontrollers which have no hardware support for memory partitioning.
- Support for dual microcontroller architectures aims on detection of faults in the core microcontroller by a secondary unit.
- Program flow monitoring controls the temporal and logical behavior of applications by checking, at specified points of code execution, if the timing and logical order of execution requirements are met.
- The end-to-end communication protection library is providing a state of the art safety protocol at application level.

Architectural improvements

The multi-core concept will enable AUTOSAR to handle microcontrollers with more than one core and support the migration of one cohesive application to a multi-core microprocessor. One approach will be a single operating system managing all cores of a microcontroller. New services will be added in order to activate tasks or to send events across cores, and to synchronize or protect shared objects.

Harmonizing and completing the local error handling mechanisms, the error handling concept has been designed for reusing the same strategy within different architectural areas (memory stack, communication stack, etc.). It will enable application specific decisions for example allowing specific Software Components (SW-C) to be stopped and restarted.

New concepts of Release 4.0 and existing constraints required a new approach for the vehicle and application mode management concept. The new mode management provides mode dependent control of BSW resources according to different modes' needs, e.g. mode dependent control of communication, and support of arbitrary modes. It increases flexibility and eases future extensions by the abstraction between resources and modes, distribution of application and vehicle wide mode information, and arbitration between contradicting mode

related resource requests, e.g. application request for communication resource and diagnostic request to disable normal communication.

Evolutions of the communication stack

Currently the AUTOSAR LIN stack is supporting LIN 2.0 master functionality. The changes from LIN 2.0 to LIN 2.1 do not affect the protocol but the transport layer, diagnostics and application programming interface (API). A specific configuration parameter will be introduced that allows switching LIN 2.0 specific functionalities on and off.

The AUTOSAR FlexRay stack, currently relying on version 2.1 of the FlexRay specifications [10], will be updated to version 3.0 providing new features like the Time Triggered Master. Some FlexRay features will be implemented directly on hardware, offering ways for high-performance implementations.

Release 3.0 is restricting signals to 8 bytes. This restriction only exists due to the CAN and LIN frames format. The extended AUTOSAR architecture is able to overcome this restriction. Therefore Release 4.0 will implement the support of large data types and dynamic length signals.

3.2. Methodology and Templates

Release 4.0 will improve methodology and templates because of

- harmonization of ECU configuration parameters,
- enhancements on measurements and calibration,
- rework of the ECU Resource Template,
- further alignment with the FIBEX standard.

One main objective of AUTOSAR is to handle the large variability found in vehicles and the scalability to different vehicle and platforms variants. The variant handling concept will provide the ability to support variants in different situations:

- different usage of a given SW-C with conditional or optional interfaces;
- allocation or implementation of this SW-C on different platforms or topologies; and
- adaptation of the system description/generation to different communication matrixes.

Last but not least, the methodology and templates will be enriched with the ability to describe timing requirements.

3.3. Application Interfaces

Release 4.0 will contain a large set of application interfaces standardized by AUTOSAR for all five vehicle domains: Body and Comfort, Powertrain, Chassis, Occupant and Pedestrian Safety and HMI, Telematics and Multimedia.

Efforts have been focused on interface specification of well established applications in order to emphasize software reuse and exchange, which is considered as one of the main requirements of AUTOSAR. The use of AUTOSAR Standardized Application Interfaces is a key factor for the reuse of applications.

The application interfaces table contains a richness of data standardized by experts of all partners and members. These standardized interfaces allow software designers and implementers to use them in case of expanding or reusing SW-Cs independent of a specific HW/ECU.

In general, applications are the competitive edge of an ECU. AUTOSAR is not going to standardize the functional internal behavior of an application (e.g. algorithms, optimization) but the content exchanged between applications. This clarifies the exchange of applications between the automotive community, from OEM to suppliers as well as supplier to supplier and so forth.

3.4. Validation of Basic Software and RTE

To ensure the high quality of Release 4.0 of the AUTOSAR specifications, AUTOSAR started intense validation.

In previous releases the specifications out of one development release were validated on hardware platforms, providing further improvements for the next release.

Release 1.0 was followed by a “proof of concept”, the so called Validator 1. The findings from this validation then resulted in further refinements being made to the specifications of Release 2.0.

The modules of Release 2.0 were implemented and integrated on two different hardware platforms (Validator 2). The results from these tests were incorporated in Release 2.1.

For Release 4.0, AUTOSAR chose another approach: The results of the validation of Release 4.0 will mainly be incorporated into the Release 4.0 or in other words, Release 4.0 will be validated before being released.

This is possible, because Release 4.0 is a partial extension of the existing architecture which is very stable. Implementations of Release 3.0 have been available on the market for more

than a year. AUTOSAR partners and members are already in the exploitation phase with former releases and have made their own experiences. Change requests have continuously been raised resulting into a mature technology.

The approach includes that the validation is split into different bundles. This split allows that

- the validation is done in parallel by different companies,
- a complete Release 4.0 implementation is not required, and
- validation methods other than the implementation on a target can be applied, e.g. functional tests in a PC environment or intensive reviews and requirements tracing.

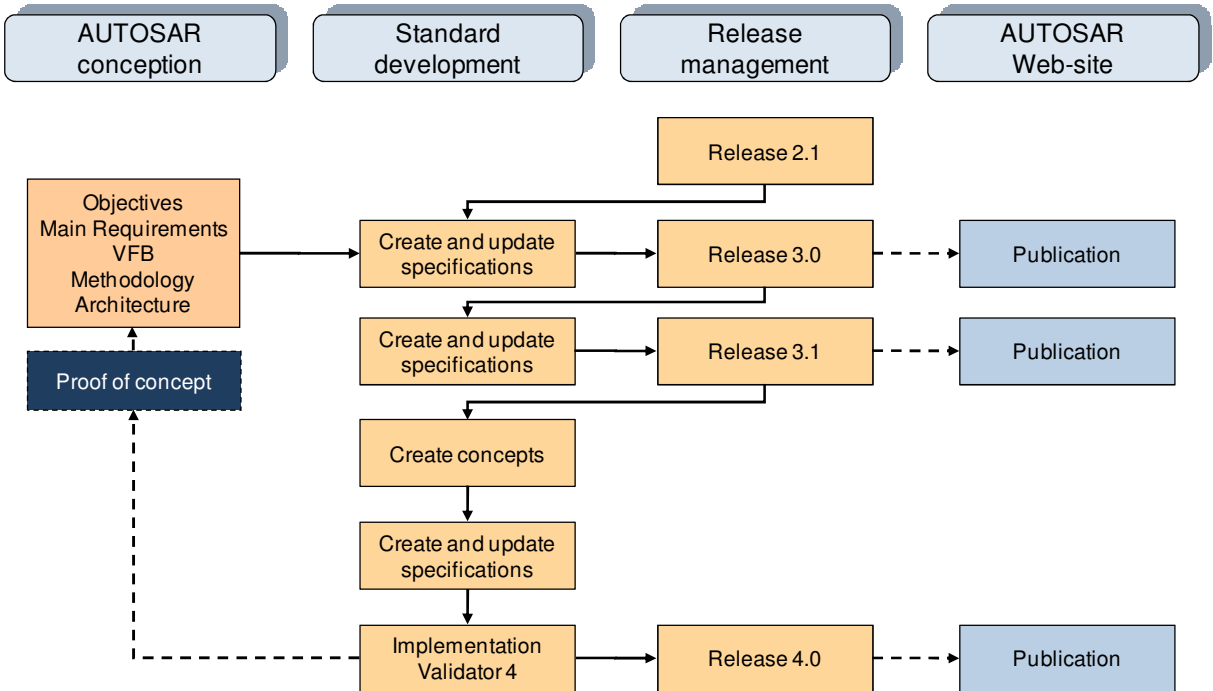


Figure 5: AUTOSAR Phase II development and validation approach

3.5. Validation of Methodology and Templates

A further step to ensure the high quality of Release 4.0 is the validation of Methodology and Templates for the first time. The validation of the Methodology is based on Release 4.0, whereas the validation of the Templates is partly based on Release 3.0 due to tool availability.

The Validation approach is centered on use cases in order to cover typical use cases efficiently. The respective use cases will be validated by different companies.

3.6. AUTOSAR Conformance Testing

AUTOSAR specifications are now used by many companies for building automotive products and bring them on the market. The use of the AUTOSAR trademark implies conformance to AUTOSAR specifications which is a basic condition for interoperability, reuse, portability and scalability of those products. Therefore they have to demonstrate their conformance to the AUTOSAR standard.

In order to ensure that implementations of AUTOSAR basic software modules and run time environment are behaving according to the dedicated software specifications (SWS), conformance test specifications (CTS Specs) are being developed and established by AUTOSAR. The conformance test specifications for the corresponding SWSs will be part of AUTOSAR Release 4.0. The CTS Specs will be used, in a further step, by conformance test agencies in order to check the conformance of basic software implementations against the standard and to deliver the relevant attestation to the product supplier. These CTS Specs are partially specified in TTCN-3 for automated test execution in a conformance test suite and partially in check lists that can be automated by a conformance test agency later on.

4. AUTOSAR Phase III Prospects (2010 – 2012)

4.1. Major Changes in the Organization

AUTOSAR Phase III will focus on maintaining the existing releases and on enhancing existing functionality selectively. Also the market situation will influence the trends and technology specified by AUTOSAR. The Phase III organization will reflect this in the way the work packages are defined.

On the one hand, expert knowledge on the basic software architecture, methodology and templates set-up, and the system approach of the application interfaces has to be ensured over the whole project cycle of Phase III. On the other hand, depending on the market situation and in order to react flexible on scope adaptations, the work package structure needs to be adaptable too.

The AUTOSAR Phase III structure will therefore implement specific work packages taking care of the architecture and system views of the AUTOSAR architecture, the so-called Technical Expert Groups. These groups are a fixed part of the AUTOSAR organization and will be available over the whole time span of AUTOSAR Phase III.

Additionally, work packages that are responsible for developing and maintaining the specific module specifications are going to be established. Their structure is depending on the project scope and can flexibly be adapted, whenever adaptations are necessary. Most of members'

and partners' experts will specify the next release of AUTOSAR in these work packages. The Phase III work package structure will be defined in the 2nd half of 2009.

The division into fixed Technical Expert Groups – to ensure continuity – and a flexible work package structure enables AUTOSAR to breath and will make the organization even more prepared for the upcoming needs.

4.2. Top Level Schedule of AUTOSAR Phase III

After having developed the standard specifying mature software architecture, AUTOSAR will selectively enhance the standard by adding specific concepts. Finally, a maintenance phase starts for the different releases used for series production in order to support the distribution of AUTOSAR into the market. Consequently, AUTOSAR Phase III will center one major release, Release 5.0.

The Release 5.0 concepts are going to be elaborated and approved within a dedicated project phase similar as for Release 4.0. All Core Partners and Premium/Development Members are invited to identify and propose concepts, which should form the set of specific additions. The approved concepts will jointly be worked out in 2010.

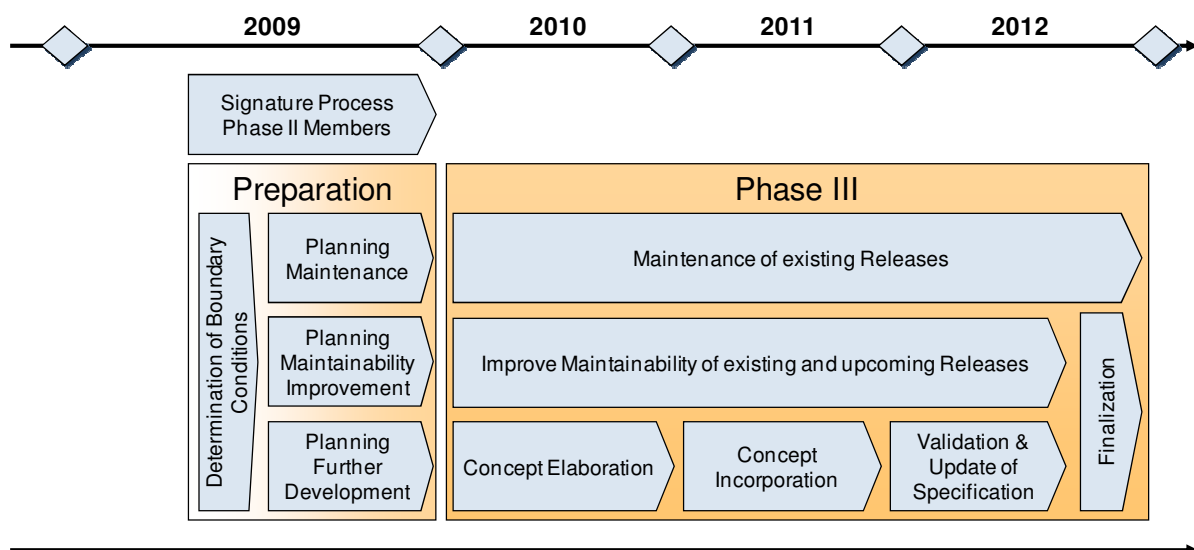


Figure 6: Top level schedule AUTOSAR Phase III

4.3. Planned Technical Content

Maintenance and selective additions to the standard are the main topics for Phase III. The additions will be specified in such a way that it is possible to ensure backward compatibility, wherever feasible, and/or to make reliable compatibility statements.

In general, the additions shall support new technologies and trends, and shall extend existing functions.

The following list shows the overall technical themes of AUTOSAR Phase III. The detailed content will be defined during the concept phase of Release 5.0. Further content may be identified.

Basic Software Architecture and Modules

- New functionality, e.g. additional hardware support, interoperability between AUTOSAR and automotive multimedia applications, etc.
- Extensions to the existing communication mechanism, e.g. adding further capabilities to the Release 4.0 Ethernet functions, facilitating interoperability to internet protocol based networks, adding the interface to MOST and enabling of data streaming.
- Means for efficient energy management at the ECU and BSW module level, e.g. handling of partial networks
- Complete support for multi-core, e.g. use of single-cores of a multi-core
- Improvements to the current support of functional safety, e.g. by hardware resource and test management and evolution of the memory partitioning.
- Improvements and extensions to existing functionality, e.g. diagnostics and specific requirements for the truck domain.

Methodology & Templates

- Additional new functionality based on the existing method and templates e.g. for the support of iterative development.
- Improvements and additions to existing functionality, e.g. variability, distributed development, configuration and Open Diagnostic Data Exchange (ODX).
- Improvements to simplify the interoperability of authoring tools.
- Support of the new functionality defined for the Basic Software.

Application Interfaces

- Specification of application interfaces will be improved and extended to support further applications with a priority set on well established and often used application interfaces.

To ensure quality and maturity of the specifications, major concepts of Release 5.0 will be validated. Also the conformance concept will be followed-up.

5. AUTOSAR Roll-Out

5.1. Current Status for Releases 2.1, 3.0 and 3.1

First cars with AUTOSAR compliant ECUs are already on the road. Currently more and more AUTOSAR compliant products based on Release 3.0/3.1 are released. Complete basic software stacks including microcontroller drivers are on the market. All major ECU suppliers have AUTOSAR on their roadmap and most of them offer already products based on Release 3.0/3.1. Tool solutions covering the essential parts of the standard are helping to implement AUTOSAR easier.

Each company has to follow its own strategy based on the roadmap of its product lines. Since the advantages of AUTOSAR – like the transfer of functions between ECUs, the selection of modules from different suppliers, the usage of off-the-shelf solutions, just to name a few – are so convincing that in the next years we will see a lot of car model launches having AUTOSAR ECUs on board.

OEMs and suppliers are realizing and further developing roadmaps to migrate to AUTOSAR, which proves that AUTOSAR is already a great success.

5.2. Further Plans and Migration Scenarios

The roll-out of AUTOSAR in vehicles does not happen like a big bang. Instead, every car maker is applying various migration scenarios depending on what kind of products are suitable at the developing phase of the specific models. On the other side, product suppliers' offerings depend of course on their internal product plans.

One way to migrate a car's ECU network to AUTOSAR is to focus on one or a few ECU first. These ECUs are also not 100% AUTOSAR at once and will follow an own migration path. Most probably in a first step the RTE is introduced. AUTOSAR applications are on top of the RTE whereas the existing legacy basic software architecture is interfacing the RTE on the hardware side.

In a second step, parts of the AUTOSAR Basic Software are used for dedicated modules, for example the communications stack. These AUTOSAR Basic Software modules typically replace legacy software in the great majority of all ECUs in a car.

Finally, the remaining legacy modules are exchanged and the ECU will be fully AUTOSAR compliant. In parallel, more and more ECUs of the board network are migrated to AUTOSAR in such a way.

Another migration path for a single ECU – suitable when introducing a new hardware platform – is starting with AUTOSAR basic software and RTE, and implementing legacy application software via wrapper code on top.

The development of AUTOSAR compliant ECUs relies on available development tools considering the AUTOSAR methodology and templates. Various development kits are on the market. They cover parts of the development process. To accelerate the development on a complete tool chain, some AUTOSAR members formed the user group Artop [11]. First results are available for tool suppliers.

It is expected that the first fully AUTOSAR compliant ECUs will be based on Release 3.0/3.1 and with AUTOSAR Release 4.0 the majority of ECUs will be fully AUTOSAR compliant. Once AUTOSAR is introduced in series products, backward compatibility of subsequent AUTOSAR Releases is getting more and more important. One reason is to keep the integration costs low. Another important one is to evolve an AUTOSAR compliant network instead of making it completely new, every time a new release is used. Moreover, product plans and strategies of product suppliers can base on a stable software platform, which ensures that efforts and risks will be predictable. Therefore, AUTOSAR Phase III will emphasize on backward compatibility wherever necessary. By that the AUTOSAR organization of Phase III supports the migration of products very close to the market.

AUTOSAR is on the road today. The migration plans of the AUTOSAR Core Partners and Members are proofing that it will become THE Standard for E/E systems in the automotive domain. The AUTOSAR organization is prepared.

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