Conformance Testing for the AUTOSAR Standard

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Abstract: The paper presents why AUTOSAR conformance tests are required, what has been achieved, and how 3 car manufacturers will use conformance tests as part of their vehicle E/E engineering process. Important topics covered are the need for conformance testing when developing a standard, the relationship between conformance and interoperability, the need for interoperability of ECUs in a vehicle, and the need to avoid diverging implementation of a standard.

Keywords: AUTOSAR, conformance testing, automotive software, TTCN-3

1. Introduction

By the second half of 2010, the AUTOSAR consortium (AUTomotive Open System Architecture) will deliver the conformance tests regarding basic software modules of the Release 4.0 revision 2.
Until now, the conformance of AUTOSAR products had been performed by product suppliers themselves based on their own test suites. This procedure is known as a self-declaration of conformance.
With the full availability of the conformance test system (i.e. conformance test specifications, process and Conformance Tests Agencies – CTAs) another step of the acknowledgment of the AUTOSAR standard on the market will be reached as the use of its specifications for selling products will be legally bound to the conformance attestations delivered by CTAs.

2. Background

2.1 The need to have conformance tests with AUTOSAR

AUTOSAR has gained a large popularity worldwide in the automotive industry: products (basic software modules and tool chains) are well established on the market, OEM and Tier 1s are introducing more and more of the standard in series projects and you can already see on the road vehicles that have been developed with AUTOSAR. However, is it sufficient to make use of it for ensuring the continuity of this standard: will it stay useful and used in the future ? Maintaining the integrity of the standard and keeping implementation in the long term conformant to the standard are necessary conditions.

How can we know whether a product meets the requirements of its related specifications? Among checking techniques, testing is in general the main answer to this question. In the scope of standardisation, conformance tests are checking whether various implementations are meeting the requirements of the standard. Regarding AUTOSAR standard, basically one more question arises: what are the needs behind that make conformance testing necessary ?
Interoperability and reuse of products are the main targets when building a standard for open systems. At network level, standardisation (CAN, Lin, Flexray) has been providing interoperability between ECUs for years. This has not been the case regarding software, whose standardisation has been a long term effort.
During the 90s, the OSEK/VDX initiative launched by the European Automotive industry has been a first step towards the standardisation of automotive software architecture: the standard is known now as ISO 17358. Although the operating system (OSEK OS) has been standardised and conformance tests have been established, the communication and network management parts of the standard (OSEK COM and OSEK NM) did not reach a full consensus and let large degrees of freedom for proprietary implementation.
In the early 2000s, several initiatives named AEE/EAST at European level and HIS in Germany have been a continuation of OSEK effort for standardisation. In 2004, at the beginning of AUTOSAR project, automotive electronics had to deal with a large variability of basic software architecture depending on two main topics: the supplier proprietary solutions and the specific requirements of OEMs (some of them defining their own internal standard). Now the situation has been dramatically improved but the lesson learned is that software architecture standardisation is a huge effort and a big investment that needs to be secured on the long run.
We can get an idea of the continuity of a standard on the long term by looking at other industries where the needs for interoperability and reuse are high like in IT systems with UNIX and in the telecom with protocols. UNIX is a good example of a standard where the needs for open systems and efforts for standardisation were contradicted by diverging

interests. Starting in the late sixties, UNIX development is still very popular but has led to a large number of incompatible variants, supported by different vendors on different platforms. The attempts to find a way for conformance (e.g. Posix, IEEE P1003) could not possibly be generalised. Despite this variety which opened the way to alternative solutions (e.g. Windows), the large and worldwide installed base of UNIX stations is ensuring the continuity of this family of standards. The competition between suppliers led to divergences on solutions on the market, the target on interoperability and reuse was not fully achieved. The market constraints happened to be stronger than the initial needs.

On the contrary, in the telecom domain, especially in the protocol area, interoperability is actually a must: networks have to operate worldwide and nobody could imagine that equipment installed on networks from different operators do not operate in accordance to the requirements. Therefore, standards are driven by international bodies (e.g. ETSI) and conformance testing supported by the different stakeholders has been achieved by the means of a common methodology and dedicated standards. The needs for interoperability being a pre-requisite, conformance tests have been established on the long term.

Going back to automotive industry, the basic software is not considered as an area for competition: the real added value is on application side. Suppliers are competing on innovative systems and struggling against the variety of OEM specific requirements on the non-competitive area. The need for a standard on software architecture is agreed among the AUTOSAR partnership as a necessary common investment. AUTOSAR specifications have reached the industrial maturity level: interfaces, features and configurations are now stabilised and the roll-out for series production has been set in motion for a couple of years. The members of the cooperation had agreed on the mutual interest of the standard.

The concern would be if the various implementations of the standard would progressively derive leading again to proprietary solutions: the integrity of the standard will then be endangered. In the worst case the objectives of AUTOSAR regarding standard offers available on the market, interoperability of basic software modules, reuse and transferability of functions throughout the networks would be reappraised. Then the persistency of the standard would be affected and we would come back to the previous situation of a large variability of the various implementations.

Conformance tests specifications which will be delivered by AUTOSAR for Release 4.0 Rev.02 of basic software modules are checking the three main areas of the standard regarding basic software: interfaces, behaviours and configurations; they ensure that the standard has been used properly when implementing the specifications of basic software modules. Mutually agreed by the AUTOSAR community they will preserve the standard continuity.

2.2 Conformance and interoperability testing in the telecom

From the beginning, industrials, service providers and operators in the telecom have identified the need to develop and maintain standards to assure interoperability during the deployment of new equipments. For example, as far back as 1865, the International Telegraph Union (ITU) has been created with the aim to begin the work of standardization. Then it derives into the International Telegraph and Telephone Consultative Committee (CCITT) and ITU is now known as the International Telecommunication Union (ITU-T) since 1993.

The first aim of standardisation is the construction of an efficient and optimised realisation - for all participating parties - of the corresponding underlying technology or process. Being interoperable is one of the major constraints for standards because oppositely the market aims at developing solutions independent from each other.

Conformance testing

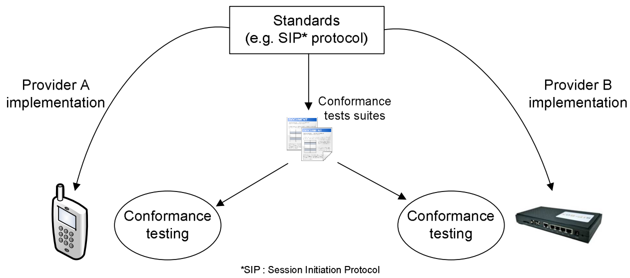

Figure 1: Conformance testing

Conformance testing (see figure 1) measures how accurately a product (e.g. a phone or a core network equipment) implements the correct handling of the standardized protocol. Each product is connected to the conformance test system. The level of conformance achieved helps vendors, providers and users to evaluate how the tested products will behave in the network where they will be integrated with other network devices to provide a network service.

In the case of a complete telecom infrastructure, conformance testing does not address end-to-end functional testing (i.e. the test of functionalities provided by a complete integrated system). Therefore, interoperability issues are to be checked during the integration phase (see V cycle of figure 3).

To develop and maintain the specifications of conformance tests, the International Organisation for Standardization (ISO) and the International Electrotechnical Commission have defined the ISO/IEC 9646 standard "Conformance Testing Methodology and Framework" where TTCN-3 (the language for describing the test cases) comes from.

Interoperability testing

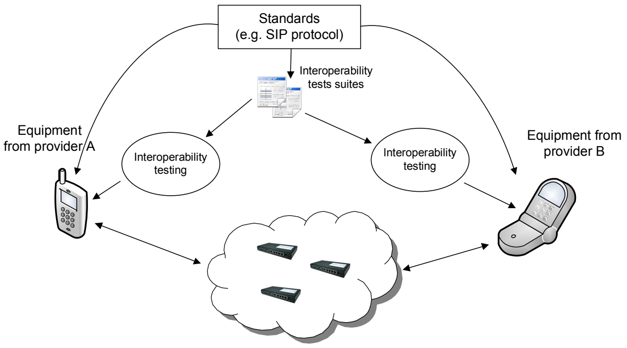

Figure 2: Interoperability testing

Interoperability testing (see figure 2) verifies if two or more products correctly interact to ensure the successful integration of the whole system in order to provide a service (SIP in our example). Interoperability of products is key to maximise the reach and adoption of rich communication services which give telecom providers opportunities to uncover new margins.

It is worth reminding that interoperability testing does not address either the interoperability of not tested devices, or the compliance to standards (two devices can communicate together and be non compliant to any standard), or the test of invalid behaviour. Because interoperability testing activities must be undertaken with the same quality than conformance testing, European Telecommunications Standards Institute (ETSI) is currently developing generic methodologies to address New Generation Networks interoperability testing (e.g. ETSI EG 202 237 Internet Protocol Testing – Generic approach to interoperability testing). Moreover, ETSI organises "Plugtests" manifestation each year (one week interoperability testing in a given area).

Needs for conformance and interoperability testing in the telecom

For service providers, conformance and interoperability testing is necessary to reduce the occurrence of errors during the network integration phase which might have an impact on the timeline of commercial deployment. This results in additional costs and in the loss of market shares due to longer time to market or to customers experiencing poorly tested services.

For equipment manufacturers, conformance and interoperability testing services are useful for marketing purpose. Many service providers will require proof of conformance before accepting a product into their networks. By taking a proactive approach, equipment manufacturers have an opportunity to correct any non-conformance and improve the marketability of their off-the-shelf products. The (obvious) link between conformance and interoperability testing is addressed in the following chapter.

As a conclusion, we can just remind that ITU is implementing a set of measures that will give purchasers of telecom equipment a much clearer vision of the ability of equipment to interoperate with other devices. A key component of the new conformance and interoperability program will be a global database that will log products declaring compliance to ITU standards (ITU-T Recommendations) (source ITU communication Geneva, 3 November, 2009).

2.3 Relationship between Conformance Tests and Interoperability Tests

A well-known process in software development is the "V" model. In principle the V cycle makes you aware that on one hand you have the specification of a technical artefact and its realisation (this is the left path of the "V" model) and on the other hand you have the integration and test of that technical artefact (this is the right path of the "V" model). Here is below an illustration of the main generic objectives of the "V" model. These main generic objectives are equal to those of all process models in software engineering.

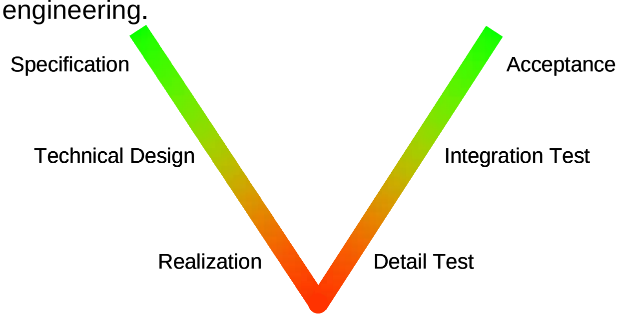

Figure 3: Main generic objectives of the V model

As we – in AUTOSAR – deal with specifications, we also have to think about the testability of the specifications. This means having for each testable item in the specification one or several test case(s) that can evaluate the corresponding expected behaviour.

This is exactly what conformance tests intend to be: these are the dedicated test cases against the specification items. Keeping this in mind, we will now introduce the specific characteristics of engineering processes used in automotive development. Let us have a simplified and abstract look from an OEM point of view at the development cycle using AUTOSAR within E/E engineering departments:

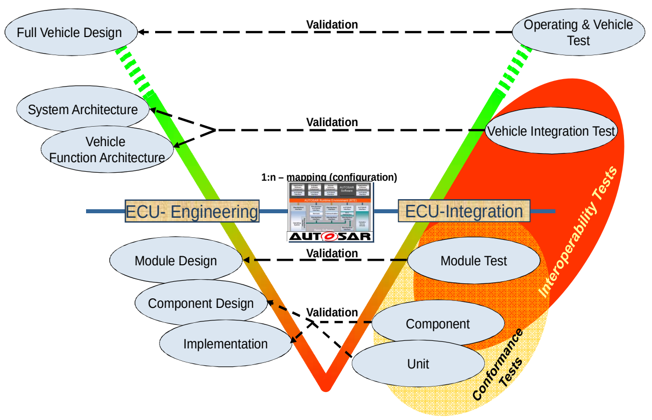

Figure 4: Vehicle Engineering with focus on E/E

We will now go again through the “V” model cycle from the upper left down to the upper right.
Starting with the decision to design a dedicated series model for the market, the subsequent activities (in parallel to the other design and engineering activities) are system design with respect to E/E architecture and vehicle function architecture (in fact both influences each other). Then using the system design and the vehicle function architecture as inputs, the next activity is to configure the generic scalable software architecture of AUTOSAR to produce the corresponding BSW instantiations for the vehicle ECUs. Based on the resulting configured BSW of each specific ECU, the engineering process then steps into the lower part of the “V” model cycle (see in Figure 4 above ECU – Engineering). Next – using the vehicle function architecture as an input – the breakdown into module design is performed followed by the component design of the dedicated applications. The implementation of the components (coupled together to applications and finally collected into modules) will complete the traversing of the left path of the “V” model cycle.
Then we are back on the right path the “V” model cycle through several test and integration steps. First the implementation is tested at unit and component level. The (micro) integration into modules calls for a test at module level. After all modules of an ECU have passed the tests – i.e. meaning that all modules / components are implemented according to the specification - the software integration of the ECU is the next step upward. If the software integration worked out correctly, then the integration of the ECU into the vehicle network is performed. At this step, the correct behaviour of the ECU in the network (i.e. the correct handling of states, data and timing by each ECU) is tested. After the successful integration of ECUs into the vehicle network, the tests of each single vehicle function within the car are performed. Finally the operating and vehicle tests, including winter and summer tests, are performed.

As we have now presented “how we develop” in E/E engineering departments with AUTOSAR, we can come back to the initial question about why conformance and interoperability tests are necessary. Conformance tests are surely relevant at module and component levels since these tests are designed to check the correct behaviour of implementation with respect to specifications. AUTOSAR will provide conformance tests for the AUTOSAR BSW modules. Apart from legal aspects of conformance tests, we expect that AUTOSAR BSW module vendors will perform their module and component tests against the specifications provided by AUTOSAR. Conformance tests are then an essential part of the module and component tests (see Figure 4) and can be considered therefore as *state of the art* software engineering.

We see two main aspects with respect to interoperability:

1. Interoperability of AUTOSAR BSW Modules
2. Interoperability of AUTOSAR ECUs

In AUTOSAR, interoperability of modules has to do obviously with conformance tests because the conformance tests verify that the signature and behaviour of a module are the ones specified, and therefore allow the module to be interoperable with its surrounding modules as defined in AUTOSAR. Of course there are some “gray areas” in the assumption that conformance tests can help granting interoperability of AUTOSAR modules. For example the timing behaviour of modules is not specified at a level detailed enough to ensure that a specific module from one vendor could expect an output from another module (supplied by another vendor) in a time frame matching for both modules. Nevertheless we think that we made a big step towards interoperability of modules with the AUTOSAR specifications and the relevant conformance tests.
Test of interoperability of ECUs is part of the Vehicle Integration Test (see the red area on Figure 4). With respect to the scope of interoperability we clearly focus on the correct behaviour of an ECU within the network. Therefore bus and OEM specific vehicle network layouts and designs are important drivers for achieving this kind of interoperability. Let us have a closer look at it. Correct ECU behaviour on the network is mainly related to the handling of defined states, timing and data on the dedicated buses which is driven by OEM-specific design decisions e.g. the so-called “Communication Matrix”, the ECU layout (i.e. which and how communication relevant hardware is used) and of course the E/E architecture.
Conformance tests can serve as an intermediate step towards the tests of interoperability of ECUs. The rationale for this is that the standard also specifies relevant state, timing and data information

for the communication modules (i.e. CAN, Flexray, LIN and Ethernet modules) that are common to all partners in AUTOSAR. The verification of the correct implementation of these state, data and timing information are of course part of the conformance tests for the communication modules. Currently AUTOSAR provides no further support than the verification mentioned here to achieve interoperability of ECUs at network level.

As said before, we have to keep in mind that the tests of interoperability of ECUs on network level are affected by specific OEM/Supplier design decisions. We think that addressing the issue about how to cope with these design decisions should be in the scope of AUTOSAR partnership in the future. Most of OEM-specific design decisions about the communication matrix, the ECU layout and the E/E architecture) are “configurable” i.e. we can say that the effect of design decisions can be seen in the dedicated AUTOSAR configuration files. With such information available, it should be possible to work out test approaches and methods for interoperability tests at bus level for AUTOSAR ECUs. Probably there will be always OEM/Supplier specific tests within this area. The question is whether the test methods can be generic enough to cope with most interoperability test requirements or if the methods cannot be generic how strong the differences have to be.

However if AUTOSAR ECUs can be tested for interoperability at bus level in the way expected and actually defined by the AUTOSAR configuration process, then to some extent the interoperability testing of ECUs shall grant to ECUs some kind of plug-in capabilities at bus level. This is similar to what we expect at software module level: the interoperability testing of AUTOSAR modules shall grant to modules some kind of plug-in capabilities into AUTOSAR layered architecture.

2.4 Advantages of avoiding diverging implementation of the standard

The purpose of conformance tests is to avoid diverging implementation of the standard. Let us now have a look at the advantages that we can benefit from a stable and non diverging standard. There are several topics to talk about:

- boost of test depth
- distributed development
- extensibility
- reliability
- exchangeability
- IP protection

First one advantage is that modules will be more widely used by multiple development and series projects and therefore surely in a more comprehensive manner. This means a significant boost of the depth of testing of these modules.

Second with respect to the distributed development, there are two areas to consider. On one hand you need to ensure that the distribution of work is possible, i.e. everyone has everything at hand to work on her/his issues locally. On the other hand you need to ensure that the integration of distributed work items (i.e. here the software integration) will result into a working system. AUTOSAR gives you support for both areas thanks to a standardised software architecture (with standardised module signatures), standardised services (with their APIs) and a middleware layer called the RTE.

These various artefacts can be configured to the needs of a specific project. By using pre-configured BSW and RTE customised to his / her project needs, every developer can have at hand the exact set of functionalities he or she needs and get therefore a clear knowledge of the required BSW module interface and behaviour.

Then with respect to software integration, AUTOSAR defines a standard way of implementing and integrating software into an ECU (see Figure 4) This is achieved through the specification of standardised methods, processes and templates (document interchange formats based on XML standard) for building ECU software. Because the build process and its outputs are standardised, tool vendors can develop and provide interoperable tool chains to support the build, integration and deployment of AUTOSAR ECU software.

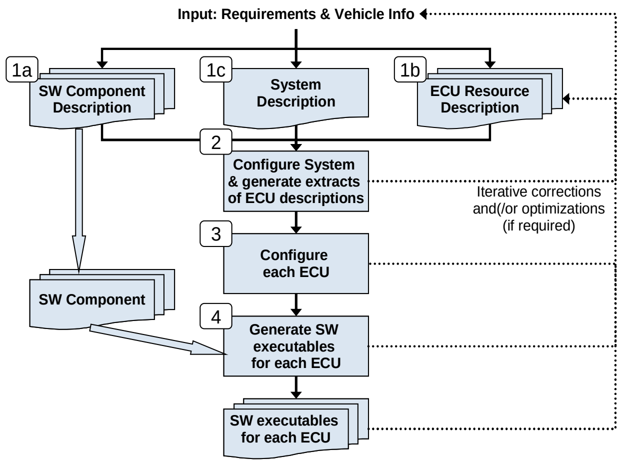

Figure 5: Implementation / Integration Process as defined by AUTOSAR

Extensibility is also a very important technical aspect that is required both by TIERs and OEMs for specific developments. We know that we have often followed a generic approach in AUTOSAR in order to fulfil the needs of all partners. Sometimes however it is important for vendors and (or) OEMs to achieve a competitive differentiation of their products and therefore of the relevant software parts of the products. For those software parts we normally use the (AUTOSAR specified) signature of the affected modules and extend those modules by the specific

needs. The reliability of a non divergent standard is needed for deploying such an approach to extensibility.
For the development of an application it is important that the services and functionalities provided by the underlying stack remain the same whatever implementation of the underlying stack is used. As a consequence of the reliability objective, exchangeability of basic software modules can be achieved. If applications can rely on the basic software services, i.e. if these services demonstrate a non-diverging behaviour at bus level and a non-diverging internal behaviour with respect to application needs, the swap of the underlying basic software stack for a different implementation can be considered. This enables competition on the basic software market. As a conclusion the OEM main interest is not that one unique basic software implementation be used and is rather that all implementation used behave the same way. This can only be achieved if the basic software specifications are unambiguous and mature enough to ensure a high quality of the standard and if conformance tests ensure that implementations do not demonstrate diverging behaviours.
Finally from a legal standpoint, conformance tests aim at ensuring that the intellectual property provided by AUTOSAR partners and members be protected because they prevent the standard from being manipulated.

3. Scope & Methodology

3.1 Purpose & Nature of AUTOSAR Conformance Tests

AUTOSAR conformance tests check whether a variant of a BSW module (the test object) implemented by a product supplier complies with relevant AUTOSAR software specification (SWS). A variant is a single, integrable and testable instantiation of the implementation of a module whose features can vary according to the SWS.
Within AUTOSAR, a software specification defines the complete scope of functionality, interface and configurability of a BSW module. Not all of the functionality, interface and configurability specified in a SWS is mandatory. Optional parts (i.e. any combination of functionality, interface and configurability) are indicated textually within the SWS and formally within the BSW module description (BSWMD) which takes the form of an XML document. Configurable parameters are the mechanism by which functionality and interfaces are declared optional. The BSWMD contains the list of configurable parameters and their ranges. When a Product Supplier creates an implementation of a BSW module (a family of variants) the BSWMD for that implementation specifies the implemented ranges of those parameters. The BSWMD can be considered as some kind of ICS because this is the statement by the PS of what is implemented and what can be tested for conformance. AUTOSAR conformance tests take into account all possible production variants of the modules, i.e. they intend to cover as much as tractable the possible ranges of values of configuration parameters. The BSWMD is used (as an ICS) for adapting the conformance test suite at execution time with an actual implementation.
The AUTOSAR architecture divides into two major sections separated by the Run Time Environment (RTE). Above the RTE are application software components. Below the RTE is the basic software (BSW) which is composed of up to 60 modules. AUTOSAR conformance tests are relevant to these modules and to the RTE.

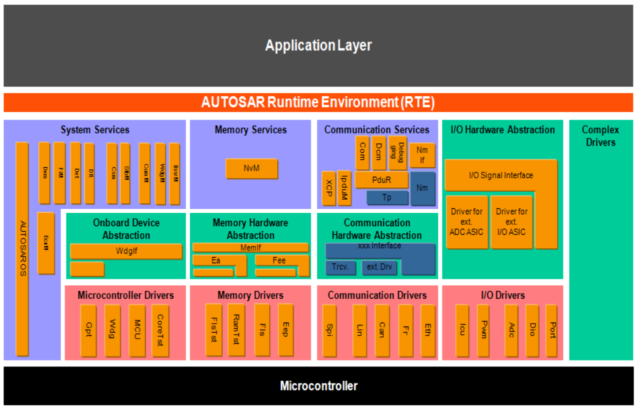

Figure 6: AUTOSAR Layered Architecture (not all modules are shown here)

AUTOSAR conformance tests are subdivided into dynamic tests and static tests. Dynamic tests are functional tests that intend to show the correct functionality of BSW modules in terms of their public input/output behaviour (i.e. as triggered or observed from the module API). They intend to check also whether the module correctly used collaborating modules. Dynamic tests are engineered using a black-box approach and are suited to the checking of test items with reasonable effort.
Static tests intend to check the configurability of modules, i.e. to check that the presence, multiplicity and value range of configuration parameters match what is specified in the SWS and that any interdependency rules are correctly followed. Static tests check also for the presence and content of interface files.
As a summary, AUTOSAR conformance tests intend to detect the following bugs in the module under test:

- invalid configurations and interfaces
- incorrect configurations resulting from correct configuration parameters
- missing functionality
- incorrect output data from correct input data

- incorrect use of the specified operations of collaborating modules

3.2 Process of AUTOSAR Conformance Test Specification

The process for developing AUTOSAR conformance test specification was organised according four work phases:

- analysis phase
- design phase
- implementation phase
- validation phase

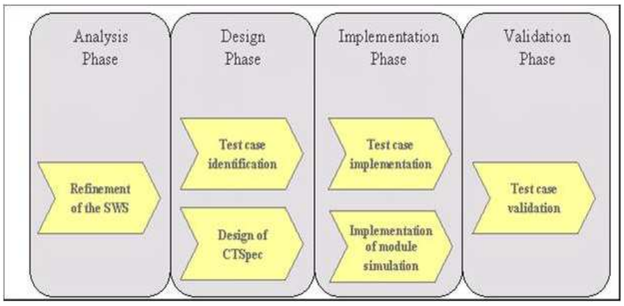

Figure 7: Conformance Test Specification Process

The analysis phase consists in categorizing which software requirements are relevant for conformance testing and how they can be tested, either by static tests or dynamic tests.
The categories relevant for conformance testing are listed below along with the test method:

- Static tests by configuration inspection
  - Definition of Configuration Parameter
  - Requirement on Configuration
- Static tests by source code inspection
  - Provided Header Files for External Use
- Static tests by compile-build process
  - Provided Signature
  - Required Signature
- Dynamic tests (using TTCN-3 scripts)
  - Requirement on Module Behavior

Among the categories *not* relevant for conformance testing, it is worth mentioning the following categories:

- Direct Hardware Access: Such requirements can only be tested with individually designed hardware interfaces. In AUTOSAR conformance test, no hardware-related functionality is to be tested. However the analysis work shows that some of these requirements can be tested in a standardized way and are therefore eligible for conformance tests.
- Non-observable Module Behavior: Each BSW module has 2 modes of operation, the production mode and the development mode. The non-observable module behavior category corresponds to functionalities of a module that are only observable in development mode via the Development Error Tracer (DET) and are therefore not relevant for conformance testing. AUTOSAR conformance tests which follow a black-box testing approach are dedicated to the production mode only.
- Vendor Specific Extensions: These functionalities cannot obviously be standardised and are then not relevant for conformance.

AUTOSAR conformance tests amount to a total number of 6500 test cases, that breaks down into 2500 dynamic test cases and 4000 static test cases.

The design phase consists in identifying the test cases, defining the test strategy for each test case and the rules for generating configuration sets. In addition, the design phase includes the definition of the test system architecture and the specification of test components that simulate the behavior of neighbouring modules.
The implementation phase consists in programming the dynamic test cases in TTCN-3 test language. The resulting test scripts are part of the AUTOSAR standard in order to control the diversity that would result from having test cases implemented by different parties using possibly different testing technologies. For each BSW module, the relevant AUTOSAR conformance tests include a text-based test specification, a set of TTCN-3 scripts specifying the dynamic test cases and the set of configuration parameters used for validating the execution of TTCN-3 scripts.
The validation phase consists in reviewing for each module the test specification and the TTCN-3 code, compiling and linking the TTCN-3 scripts with module simulation APIs and configuration sets and executing the TTCN-3 scripts against simulated modules to validate that the dynamic test cases correctly report ”pass” and ”fail”. The simulation objective is first to emulate a correct module behavior. Then fault-injection is performed in the simulated module in order to check that the conformance tests can detect a misbehavior of the module under test. Validation of dynamic test cases with fault-injection is a key feature of AUTOSAR conformance test development process.

4. CTA Point of View

4.1 AUTOSAR Conformance Test System

AUTOSAR has defined an organisation and relevant processes to attest that products and tools developed from the standard specifications comply with them. AUTOSAR has identified for this purpose so-called Conformance Test Agencies (CTA) which are performing specific tasks of the AUTOSAR Conformance Test Process. These tasks are the execution of conformance tests by means of appropriate test equipment, i.e. Conformance Test

Suite (CTS) and the delivery of an independent attestation of product conformance to the AUTOSAR standard.

AUTOSAR Accreditation Schema

As the owner of the standard, AUTOSAR partnership seeks to secure the capability of an accredited party. The acceptance as an accredited party is based on an impartial assessment by an accreditation body of the party candidate to accreditation based on ISO-17025 guidelines for the accreditation of test laboratories and Guide 65 recommendations for the accreditation of attestation / certification agencies.

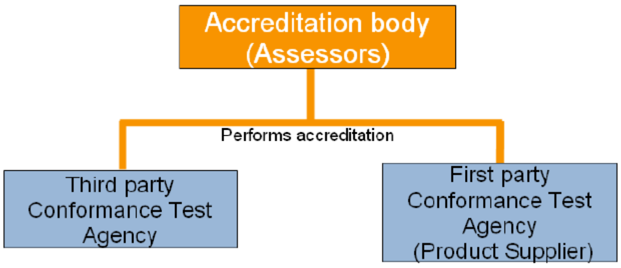

Figure 8: AUTOSAR Accreditation Schema

CTAs can either be independent parties providing a third party attestation of conformance (third party CTA) or product suppliers accredited as CTAs and providing a self-attestation of conformance for their products (first party CTA).

Third party CTA accreditation is based on AUTOSAR Application Rules of both ISO Guide 65 and ISO-17025 whereas first party CTA accreditation is based on Application Rules of ISO-17025 only.

AUTOSAR Attestation Schema

The attestation schema takes into account both types of CTA introduced above. This is presented in the following figure:

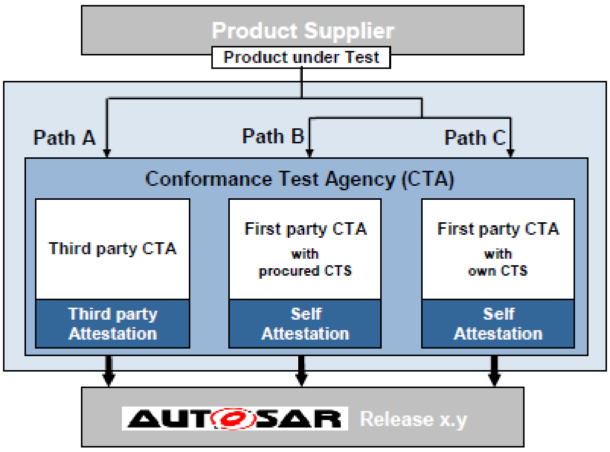

Figure 9: AUTOSAR Attestation Schema

A **Third-Party CTA** performs the following tasks:

- Conformance Test Execution, i.e. CTA has to apply CTS (developed by the CTA itself or externally procured) and provides a test report following its own conformance activities.
- Test Attestation Delivery (**Third party attestation**), i.e. CTA has to prove that the BSW implementation is conformant to AUTOSAR after the analysis of the consistency and completeness of the conformance testing activities and results. This assessment is provided by an entity which is independent of product providers.

A **First Party CTA** performs the following tasks:

- Conformance Test Execution. In the **path B**, the first party CTA procures a CTS from a CTS provider to check its own product for conformance. In **path C**, the CTA directly develops its own CTS.
- Test Attestation Delivery (**First party self attestation**) with a justification based on the results of the tests. This assessment is provided by an entity belonging to the product provider.

4.2 Implementation and use of a conformance test system as a CTA

Conformance test execution

As showed in Part II "Scope, methodology" ([reference]), AUTOSAR provides conformance test specifications including static (non-TTCN-3) test cases and dynamic (TTCN-3) test cases.

A Conformance Test Platform (figure 14) must support and execute both kinds of test cases (as Conformance Test Suites - CTS) and provide a common view of the results collected in a test report.

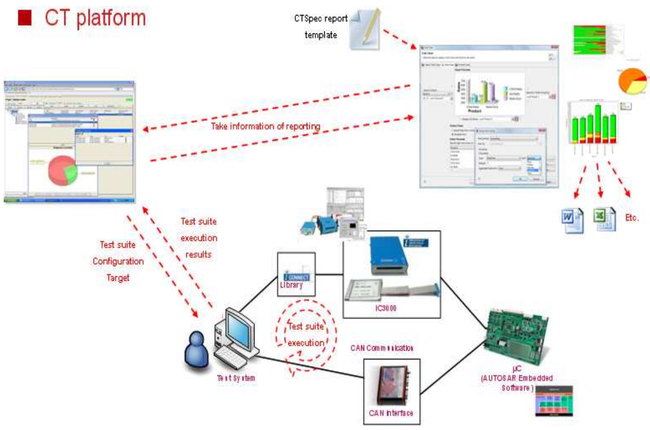

Figure 10: Conformance Test Platform

The product under test is developed and given by a product supplier. The product under test is a software module that can be delivered as object code or source code, with or without an XML description of the product configuration and with or without a related generation tool (for supported configuration sets).

Business models

AUTOSAR Conformance Tests Specification will be delivered in 2010. This is why business models are not yet neither defined nor established. From the description of the AUTOSAR attestation schema above, we can assume that first business models will be the following:

- **Sale of CTS**: a third party CTA (path A) or a first party CTA (path B) might need to procure a CTS to be able to execute the conformance tests and deliver an attestation report. This is similar for example to the business model used for the certification of OSEK/VDX products.
- **Service of attestation**: the objective of a third party CTA is of course to provide an attestation as an independent and accredited entity. This business model is used in the telecom and in the certification of security products like smart cards (based on Information Technology Security Evaluation Criteria - ITSEC and Common Criteria security evaluation standards).

Business models can be influenced by the way the attestation is requested. Due to various possible relationships between an OEM, a Tier1 and software providers, the following different business models might be considered.

Attestation ordered by the OEM: in this case, the targeted hardware platform and the configuration of the whole set of basic software modules is well-known. The hardware platform could be reused to benchmark different basic software. The cost is reduced because the conformance testing platform is set and configured only once and the set of configurations could be less important than the one defined in the CTS. But, the OEM and the CTA must have close relations with tier-ones and software providers to solve conformance problems.

Attestation ordered by a tier-one: as we can see in the telecom, the attestation can be requested by service or product providers. In the AUTOSAR context, it could be the same. The attestation requested by a tier-one can have much value and be cost effective thus favouring the delivery of a complete hardware and basic software solutions as commercial off-the-shelf products (e.g. a COTS product like the standard core platform). In addition, conformance tests could be inserted in the development process and help testing during the implementation and integration phases as well as for non-regression tests.

Attestation ordered by a software provider: similarly to a Tier-one, a basic software provider can request an attestation in order to provide certified COTS.

Point of view of a CTA

The purpose of AUTOSAR conformance testing is to verify that the product under test adheres to the relevant AUTOSAR specifications. AUTOSAR must ensure that the standard will not deviate due to proprietary modifications of specifications and / or implementations. The accreditation of third-party CTAs and the delivery of attestation by “external eyes” will guarantee the maintenance and evolution of a unique version of the standard.

Third-party CTAs will have the following advantages:

Independence: third-party CTAs are totally independent from any OEM, tier-one or software providers. Thus, they have pressure neither on the utilisation of equipment and human resources nor on the delivery of positive results in an attestation. Their business will not be boosted by conformant products.

Impartiality: due to their independence, CTAs will provide objective results for the conformance tests and an impartial attestation. This will be confirmed by the use of a conformance testing platform under CTA control and maintained thanks to different basic software conformance assessments.

Repeatability: this is a requirement of 17025 standard which is verified during the accreditation of a third party CTA. The use of the Conformance Testing Platform for the test and the attestation of BSW from different providers on different hardware platforms but using the same CTS will demonstrate the repeatability of the AUTOSAR Conformance System.

Capitalisation: first, third-party CTAs would have the advantages of using their own platform to test the conformance of different basic software on different hardware platforms. They will be able to build a knowledge base of execution runs and extend their set of CTS. Second, CTAs will build up their expertise on defect detection during the execution runs and will use this feedback to improve their CTS.

Continuous improvement: third-party CTAs will be able to improve continuously their testing platforms and CTS thanks to the capitalisation process. Thus, they will improve their productivity and reduce the cost of conformance tests and attestation deliveries.

Expertise: due to the variety of CTS execution and the continuous improvement of their testing system, CTAs will be able to offer expertise and new services like benchmarking of basic software solutions or fault-injection testing.

5. Achievements & Challenges

5.1 AUTOSAR achievements

The development of a standard is always a challenge for all participating partners as additional effort has to be spent and barriers have to be pulled down for a successful cooperation of competitors. To call it a worldwide standard, a critical mass, i.e. the majority of companies of the industry, is needed to cooperate to the standard. Comprehensive contributions from partners are a precondition for a standard to become successful but are not sufficient to make it real. The achievements and the usability of the standard have to be demonstrated and proven before what is foreseen as a worldwide standard be used as expected and become a real and accepted standard.

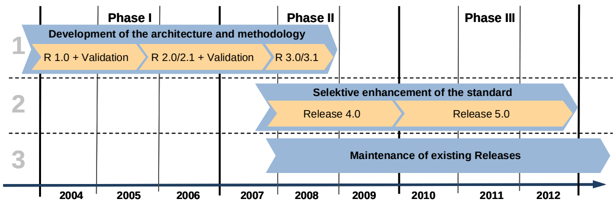

Figure 11: Periods of AUTOSAR Development

AUTOSAR development partnership has paved the way for a worldwide standard thanks to the two following major steps. Within the first period of AUTOSAR the standard has been iteratively developed and has encountered several validation activities. By approving Release 3.0/3.1, AUTOSAR partnership has reached such a maturity of the specifications that products based on this release can be used for series development. Herewith AUTOSAR completed the first major step for getting a standard. The second major step to ensure that a worldwide standard is achieved is to develop means which ensure that all partners and members will adhere to the standard on the long term. The second important step will be made by approving the Release 4.0 Revision 2 in 2010 that includes conformance tests and the test methodology relevant to it. By achieving these steps AUTOSAR will establish the baseline to become a successful worldwide standard.

5.2 Challenges during the migration

The next challenge is to exploit the standard in products. Assuming that a completely new product is developed from scratch, the migration towards a standard seems to be very easy. But for an OEM in most cases there is some legacy to carry over. Therefore the more usual approach is to take advantage of an evolutionary development of a car line towards a new generation. That leads to the necessity for establishing a migration scenario for the introduction of a new standard that will replace an old solution. Therefore an implementation based on the standard might be enhanced by proprietary extensions. Modifications or extensions should be limited as much as possible but are likely on the transition towards a clean standard. In addition a modification of the valid network specifications of an OEM should be considered if they differ from the standard.

5.3 Roll-out scenarios at OEMs

For a dedicated migration scenario of an OEM Conformance Tests can also be considered as an aim on the way to the product exploitation. Each OEM can define its own strategy for using conformance tests of products launched in its car line. The importance and urgency might differ from OEM to OEM. Nevertheless all parties in the business like OEM, Tier 1s, software and tool-vendors should be interested in keeping the standard as clean as possible. When we talk about the roll out scenarios of different OEMs in the following chapters it has to be explained that the voluntary use of Conformance Tests is only with R3.0/R3.1. For R4.0 and beyond the use of Conformance Tests is legally binding. The following sections present the roll-out scenarios at different OEMs.

5.3.1 Daimler roll-out scenario

After several internal discussions where pros and cons for different introduction scenarios were evaluated, Daimler decided to switch to the new technique defined by AUTOSAR. Instead of having a step by step migration Daimler decided to start the introduction of AUTOSAR with a one step approach on FlexRay, CAN and LIN ECUs. This was possible because we aligned the introduction of AUTOSAR with the design of a new E/E Architecture that will first come with the new S Class. Surely the introduction of FlexRay was a main driver for this decision. Daimler has decided to use Release 3.0 / 3.1 for its roll-out scenario.
Due to the fact that this roll-out scenario faced the challenge that no one used this Release before and no official Conformance Tests and no Interoperability Tests were available for these Releases, Daimler decided to go in the short term for a so called “Buy Out” scenario. This means a dedicated supplier was chosen to implement the AUTOSAR BSW Stack and this dedicated AUTOSAR BSW Stack is meant for being used in each ECU. It is worth underlying that with this “Buy Out” BSW Stack Daimler is focusing more or less on the communication relevant parts of the AUTOSAR BSW Stack. This is because Daimler as an OEM have a specific interest and responsibility for the integration of ECUs on the network (refer to Figure 4 above).
As Daimler started to develop this AUTOSAR BSW Stack in cooperation with a supplier in year 2008, Daimler was able to provide several feedbacks to AUTOSAR and helped therefore making the standard even more stable and usable. Today Daimler has the latest revision of Release 3.0 (and Release 3.1) up and running and most of the needs that Daimler brought into the change management

process of AUTOSAR are now available with these revisions and will be used for series production.
But as we said before in this paper, everything cannot be standardised because the specific needs or the competition of partners in the consortium can prevent a common technical solution to be achieved. Daimler tried to solve most of the differences between AUTOSAR partners by means of configuration approaches but this was not always possible. In case where a common solution cannot be found even by using a configuration approach the consortium often decides to provide an interface for a module generic enough to ensure that AUTOSAR partners can extend the module to their specific needs by using the provided interfaces and build their proprietary extensions based on common interfaces. OEM specific extensions on diagnostic modules are a good example of this situation.
As a conclusion to the presentation of Daimler point of view on conformance tests it is necessary to remind two issues mentioned before:

- Since some parts of AUTOSAR BSW Stack are under OEM responsibility, Daimler needs a means of qualifying interoperability at module level.
- Daimler needs also AUTOSAR modules to be extensible while still having interfaces and behaviour defined by AUTOSAR Software Architecture and Module Design specifications.

Both issues are relevant to having a clean, reliable and interoperable standard at module level as said before. Daimler is convinced that conformance tests are a means of answering those two issues. Having legally binding conformance tests with AUTOSAR Release 4 will be a major step into the direction of interoperability at module level. Daimler would then be able to leave the short-term approach of having a "Buy Out" BSW Stack and go for an Open Vendor Policy.
Moreover, Daimler is highly interested in having interoperability tests at ECU level. This will constitute the next step into the direction of interoperability and exchangeability of BSW Stacks and ECUs. This would give us all (not only the OEMs) the largest degrees of freedom for setting up cooperation.

5.3.2 PSA roll-out scenario

AUTOSAR has been introduced by PSA at a very early stage in 2 classes of ECUs: body controllers and engine management systems. Two different approaches have been implemented: bottom-up for body controllers, top-down for engine management systems. They have in common to follow a transition path to AUTOSAR, nevertheless in both cases conformance tests will be very helpful.
Let's start with body controllers for which PSA has been developing its own application and basic software for years:

- it was very hard to synchronize the development of applications with different suppliers having different maturity levels,
- a standard covering both the basic software infrastructure and application interfaces was necessary. As many OEMs, PSA decided therefore to have its own standard based upon OSEK,
- The flexibility and reactivity requested by this cross-cutting platform required that PSA have its own development for applications.

The AUTOSAR Release 2.1 gave us the opportunity to replace the proprietary development for basic software with standard products on the market:

- hardware abstraction modules from silicon vendors,
- the rest of the infrastructure by tier ones.

Of course, due to the transition to AUTOSAR, some modules had to be adapted to PSA network characteristics. This is the bottom-up approach where applications are integrated on a complete AUTOSAR infrastructure. The integration and configuration of the infrastructure made by tier ones have led to intensive testing and iterations. For the upcoming generation of body controllers, the conformance testing will make this integration task easier.
On engine management systems, the business case was completely different as the target was to reuse application software on different suppliers platforms: with this approach a SW-C from a supplier "a" has to be integrated into the platform of the supplier "b". It was therefore not intended by PSA to wait for a complete AUTOSAR platform from all our suppliers. Instead, the supplier platforms have to provide a black box with the AUTOSAR RTE and the services requested by the application modules. This is the top down approach where PSA has taken the opportunity to reuse application software thanks to AUTOSAR.
With this approach, application software, RTE and some basic software services have to be AUTOSAR compliant. Conformance testing, delivered by AUTOSAR with the Release 4.0, will give this evidence for RTE and services. Regarding application software, some tools are currently available on the market in order to check the conformance to AUTOSAR requirements of application software components.
As soon as you want to reuse software or integrate parts from different suppliers, i.e. to benefit from the AUTOSAR standard, conformance testing is a must. It will never prevent from testing at all but either as a pre-requisite or as part of the testing process it will avoid late findings on obvious and also non obvious errors and finally costs and delays.

5.3.3 Volkswagen roll-out scenario

Although Volkswagen has contributed intensively to the standard definition and heavily influenced many ideas and requirements of the standard, some trade-offs had to be made to agree on a common solution. The trade-offs led to incompatibility issues with existing solutions within a car line. In addition the timeline of the car line development was not aligned to AUTOSAR top-level schedule. Consequently Volkswagen has defined a roll-out scenario of the standard which mainly considers the standard but also deviates partially from the standard. To cover such a deviation Volkswagen has enhanced AUTOSAR specifications by additional Volkswagen specific specifications. In order to respect the standard to a greater extent basic internal network specifications have been modified too where possible. Nevertheless some minor deviations of the standards were necessary for Volkswagen to migrate to AUTOSAR. In spite of these deviations the conformance tests played an important role in the definition of the migration scenario.
Volkswagen chose Release 3.1 for rolling out into the volume segment and enhanced it by minor proprietary extensions covered in Volkswagen specifications without preventing standard AUTOSAR implementation from being used. Volkswagen allows thus several implementations in their car lines as long as they are recommended by Volkswagen. Several AUTOSAR stacks enhanced with Volkswagen deviations and extensions are listed and recommended as Volkswagen compatible and proven solutions. This recommendation list will be extended gradually. To ensure a successful integration of the recommended implementations into the volume segment the migration is supported by intensive test and validation activities at the SW vendor and the Tier 1 and Volkswagen. Similar to the test procedures of a whole network, the tests of a particular AUTOSAR implementation is divided into several levels ordered by the degree of integration as depicted in the following figure.

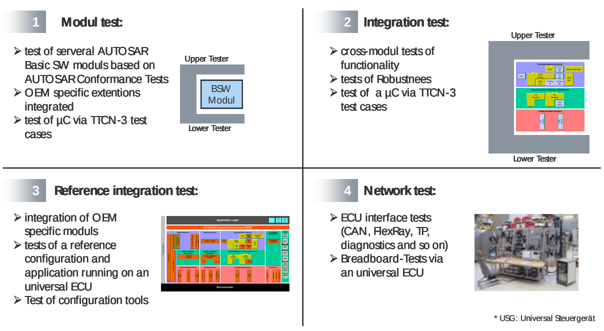

Figure 12: Test levels for AUTOSAR stacks

The level one is based on module test and the second level on first integrated modules. These two levels shall be performed by the SW vendor. The third level contains a first integration of Volkswagen specific extensions including a representative application and is done at Volkswagen site. The final test shall be done at the well known test environment which is used to test and approve ECUs.
Within the first level the SW vendor has to present their test strategies at module level, ensure that they have been passed successfully and that the risk of implementation faults is reduced to a minimum.

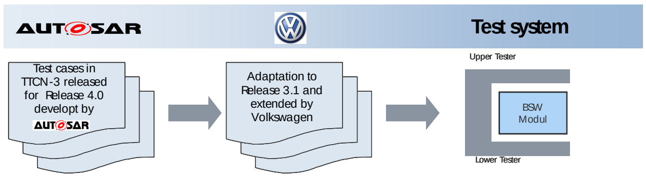

Figure 13: Adaptation of Conformance Tests

To support the launch of AUTOSAR Volkswagen has set up additional acceptance tests based on AUTOSAR Conformance Tests. By adapting the existing TTCN-3 implementations which are available for AUTOSAR Release 4.0 to the required Release 3.1 standardised test cases can be reused easily. Further on test cases covering Volkswagen extensions have been defined. The second, third and fourth test levels of the Basic Software stacks complete the test strategy and enable a successful exploitation of the standard in the volume segment.
The utilisation of AUTOSAR conformance tests as internal acceptance tests combines the advantages of standardized test cases for internal validation purposes and migration to the final conformance test process defined by AUTOSAR. Based on experiences Volkswagen is making by using standardized test cases the applicability of AUTOSAR conformance test process is proven and confidence is reached for the next long-term step of exploitation when Volkswagen requests Release 4.0 in future. Then conformance tests shall be performed according to the process defined by the AUTOSAR development partnership. This shows that conformance tests have already played an important role in the definition of the migration scenario and will still play this role in the future.

6. Conclusion

The AUTOSAR conformance test suite will be available with AUTOSAR Release 4.0 Rev 2 at the end of 2010. This will be a major achievement for AUTOSAR that will enable both OEMs and Tier 1s and software vendors to experience a more seamless traversing of the right hand of the V cycle.

7. References

Information on AUTOSAR conformance tests can be found at www.autosar.org / Release 4.0 / Conformance testing.