Research Planning
Assignment 2

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1 Research project

1.1 Background

The complexity of automotive electronics systems has increased to a level where it becomes very hard to adapt to new technologies in order to fulfill new customer, environment and legal requirements. One reason is that the electronics system constitutes a more and more important part of the functionality and the business around it. The functions that before was managed by stand-alone systems, are today dependent on several inter-connected systems which all contributes to the desired functionality.

One example is the Electronic Stability Control, ESC, also referred as Electronic Stability Program, ESP. It improves security through recognizing unstable driving conditions and takes appropriate actions. To prevent over steering and under steering braking is applied to the vehicle wheels.

ESC (1) consists of several other vehicle systems, Anti-lock Brake System, ABS, a safety system which prevents the wheels from locking up, Electronic Brake force Distribution, EBD, a technology that varies the braking force applied on each wheel, Traction Control System, TCS, a system which regulates the power supplied to the wheels and Active Yaw Control, AYC, a system that uses an active differential to transfer torque to the wheels that have the best grip on the road.

Traditionally each of these systems consists of at least one electronic control unit, ECU, which together with connected sensors and actuators, handles system functionality. Instead, the modern system must be able to cooperate and sometimes between different domains. These interconnections add dependencies in the system, like temporal dependencies or state dependencies of control units.

To deal with the complexity problem an alliance of OEM manufacturers and Tier 1 automotive suppliers have developed an open standard for automotive electronics architecture. The result is AUTOSAR (AUTomotive Open System ARchitecture which fourth release is planned in 2009 (2). AUTOSAR provides a common software infrastructure for automotive systems based on standardized interfaces. Key features are modularity, configurability, standardized interfaces and runtime environment. A layered software platform has been designed to facilitate the achievement of the technical goals modularity, scalability, transferability and reusability of components (2).

The architecture consists of a basic software component which includes infrastructural services such as operating system functionality, vehicle network communication, memory services, diagnostics and ECU state management. The basic software component is built as a layered structure where each layer is abstracted from the lower layers and hence independent of hardware implementations.

Such a revolutionary change as a change the basic software component will affect the quality attributes of the electronics system but probably also cause organizational affects. New tools may be needed for development, production and aftermarket, time-to-market may be shorter, and there might be a possibility to buy software components. All this might lead to new processes and professional roles both in the organization and for suppliers.
1.2 Aim of the research

The system designers must know if the system still meets system quality and other business drivers like customer requirements, regulations, reduced costs and time-to-market, after the change. Thus new system architectures must be analyzed carefully before realization decisions are taken. The aim of my research is to produce tools for the industry that facilitates electronic systems designers in their analyses of organizational impacts. To accomplish this goal and to bring a broader understanding of the involved mechanisms two research questions have been stated:

RQ 1: “What in organizations is affected by a change of basic software?”

RQ 2: “How are organizations affected by a change of basic software?”

1.3 Volvo Case Study

1.3.1 Volvo AB

Volvo (3) is one of the world leading suppliers of commercial transport solutions with products like trucks, busses, construction equipments, drive systems for marine, industrial applications and aircraft engine components. The Volvo group also provides business solutions for their customers. Today the Volvo group has customers in more than 180 countries all over the world, mainly in Europe, Asia and Northern America.

Volvo 3P is responsible for product planning and global vehicle development for the global truck operations of the entire Volvo group. The truck companies are Volvo Trucks, Renault Trucks, Mack and Nissan Diesel (3).

In order to manage the increasing complexity of the electronics systems in new generation vehicles a new electrical and electronic architecture has been developed by Volvo 3P. Volvo 3P hopes that this will reduce the development cost, give more flexibility to meet new technologies and standards, to be able to be first on the market with new features, to meet brand differentiation while maintaining a high degree of commonality and achieve multi-site development.

Volvo CE develops electronic control systems for around 150 different machine models such as wheel loaders, haulers, excavators, and road machinery. The electronics system constitutes a more and more important part of the functionality and the business around it in a modern construction machine.

In order to meet the demands on business, safety, and development time VCE adapts the development method to a more product line oriented approach based wholly on an electronic system platform. This includes working on development process, architecture, tools, and system modeling. Therefore VCE will also adapt to the new Volvo 3P architecture in imminent years. The new architecture consists of communication, diagnostics, logging, common software platform, mode management and power state management.

The change to the new architecture will affect many aspects of VCE electronics system such as aftermarket tools, software structure, communication protocols and development tools. The impact of the new architecture introduction on VCE architecture, what the new architecture contains and how it affects the current architecture design at VCE have to be analyzed.
1.3.2 Case study plan

The case study will be divided in two steps. In the first steps an explorative study is performed. This study will answer the question “What will be affected by the architectural changes?” The study will be performed both on Volvo 3P and Volvo CE. This study starts by a pilot study, to collect material for producing necessary interview questions. In this pilot study, approximately three stakeholders at Volvo 3P and at Volvo CE will be asked questions about what areas they believe will be affected by the architectural changes. The responses will serve as a basis for designing the real case study in the first step.

The new architecture will also be investigated through reading of specifications. The first issue to investigate is what degrees of liberty Volvo CE has when implementing a new basic software platform. The reason is to facilitate the understanding of the impact on the rest of the software and sort out the dependencies between the basic software and the rest of the software. Next an account for needed tools must be established. The goal is to map dependencies between development tools, production tools and aftermarket tools. The first study will result in the areas that will be or believed to be affected by the architectural changes. In the next step some interesting areas will be picked out for a deeper analysis. That study will answer the question “How are these areas affected?”

Further to get a general view of the total electronics architecture there are going to be participating in meetings for design change requests. These meetings occur weekly and their purpose is to achieve trade-off decisions for design changes. There will also be participation in meetings between the different Volvo companies and Volvo 3P. In these meetings there will be discussions of what benefits and costs that will be obtained when common parts of the electronic system are used in the different companies. The experience from these meetings will give a deeper understanding about how and what different demands the companies have to fulfill.

2 Research overview

2.1 Current research issues and hot topics

2.1.1 Safety in AUTOSAR and Component-based design

Today the trend in automotive electronics systems are going towards a more product-line oriented design instead of developing a new electronic system for every new car. Hence, there is a need for reusability, flexibility and scalability. The OEMs want to be able to reuse the components in several systems, which also is partly AUTOSAR’s goal. Another goal of AUTOSAR is to reduce the number of ECUs and hence physical wires and physical contact points.

When mixing these goals together the resulting systems will include components from both the OEM and Tier1 suppliers integrated in the same ECUs. To guarantee that the safety requirements of an end-to-end system is fulfilled the safety requirements must be considered in the early design phase. The timing requirements can be analyzed and divided into individual requirements for each component (4) (5).

The ability to guarantee safety requirements demands the system non-functional properties to be predictable, which is achieved by timing isolation and protection against timing faults. One solution might be to use time-triggered scheduling, such as FlexRay communication (4) (6).
It is also important to calculate accurate Worst Case Execution Time, WCET, to predict timing behavior. Industrial systems are going towards more use of multi-cores processors and use of caches, which make it almost impossible to foretell about the execution times (6).

The above mentioned issues are the hot topics in automotive research today. The possibility to predict timing behavior in safety critical embedded systems, when introducing new complex technologies, is a hard nut to crack.

2.2 State of practice

There are several development tools supporting AUTOSAR architectures. Two key players are Mentor Graphics and Vector (7) (8). Both companies are premium members of the AUTOSAR organization and both offer tool suites for development of full AUTOSAR compatible solutions. The tools help the OEMs and Tier1 suppliers to design and map SW components, ECU's, networks, sensors and actuators. They provide a complete AUTOSAR specified basic software stack.

2.3 State of the art

Axelsson (9) made a case study at an automotive OEM company and investigated the interplay between the evolutionary architecting processes and the revolutionary architecting processes. According to this study most of the changes in architecture are evolutionary. Yet are most research performed on the revolutionary architecture changes and how they will affect the quality attributes of the electronics system. A lot of methods have been developed to analyze these affects.

2.3.1 Evaluating methods

SAAM
The Software Analysis Architecture Method, SAAM, was developed by Kazman et al (10). The method is used for evaluating different architecture alternatives for a desired property. It is based on a well understood architecture and is therefore started by providing a clear architecture description. Next concrete tasks typical for the desired property are chosen. For example may the task “Changing the communication protocol” be appropriate for the property “Maintainability”. Each architecture alternative is then analyzed and evaluated for how well it manages to perform the tasks. SAAM gives a structure for the analysis process but does not prescribe any method for how to evaluate the different architecture alternatives.

ALMA
The method underlies several other analysis methods, like the Architecture Level Modifiability Analysis, ALMA (11). ALMA was developed for determining the modifiability level of architecture elements. The first activity is to determine goals for the analysis. The goal might be to predict maintenance cost, perform a risk assessment or select architecture. Then change scenarios are created and their impacts on each architecture element are investigated. The interpretation of the results is based on the determined set of analysis goals.

ATAM
SAAM is also the predecessor of the Architecture Trade-off Analysis Method, ATAM (12). The primary goal of ATAM is to assess the consequences of architectural decisions in the light of quality attributes requirements by identifying
risks, sensitivity points and tradeoff points in the system. This is achieved by finding scenarios, using utility trees and generating system quality attributes.

Most of the work is carried out by smaller stakeholder groups, consisted of architectures, customers and the evaluators. ATAM proposes the use of larger brainstorming meetings with all stakeholders to prioritize the scenarios. The basic idea is to stimulate the creativity and communication of new ideas. The disadvantage of ATAM is that it is very time consuming but the many hours of work may also be a strength since the architecture gets very thoroughly investigated.

AHP
Another method for evaluating different design alternatives is the Analytic Hierarchy Process, AHP. This method starts with identifying architecture goal, criteria and alternatives (13). The stakeholders organize the criteria in a hierarchy by pairwise comparing them against all other criteria. A fundamental scale for the comparisons is used for the judgments that corresponds to which criterion that best fulfill the goal. In the comparison, the smaller element is considered to be one, while the larger element is expressed as a multiple of that unit.

Then the stakeholders pairwise compare the architecture alternatives against each other for each criterion. The hierarchy helps them focus on one criterion at time. The same fundamental scale is used and now it means which alternative that best fulfills the criterion.

AHP is a method for managing complex decisions based on mathematics and psychology. It deals with scaling problems by normalizing the judgments to achieve a relative scale (13). The problem with AHP is that the number of comparisons rapidly increases by the number of alternatives and criteria.

CBAM
Despite the big impact a change of basic software can cause an organization only a few methods investigate these affects. The Cost Benefit Analysis Method, CBAM, (14) is an extension to ATAM and an attempt to map costs and benefits to system quality attributes and business goals by determining the relation between them. CBAM starts where ATAM ends, the ATAM reveals the architectural decisions made and links them to business goals and quality attribute responses followed by CBAM which adds cost to architect decisions and benefits to quality attributes. CBAM also deals with the uncertainty in stakeholders. This uncertainty can be visualized by plotting the costs and benefits of the different architecture alternatives in a graph where smaller areas means a more certain decision.

2.3.2 Software Development

Larsson et al. (15) present a method for analyzing the influences that a change in architecture will have on the development processes. The method uses scenarios to identify the goals and activities needed for an architectural change which then can be used for finding affected processes. They tested the method in a case study at an ABB development unit that was refactoring an industrial control system and mean that the method helped the company to faster adjust the processes and the organization for the new technology. Their observation is that organization, architecture and processes are related to each other and when changing one of these the others may be influenced.

In (16) a case study at a large international company is presented. The company has adopted component-based development using product-line architecture. The authors investigated how the development process was affected by the changes. Most problems were caused by interface or architectural mismatches and encapsulation of service
in components. They concluded a need for an organization that put more resources on overall architecture and component verification in the development process.

2.4 The research community

This project spans over many fields, including embedded real-time systems, automotive systems and software engineering. Interesting research communities can be found in every field.

2.4.1 Key conferences

ICSE, the International Conference on Software Engineering. This is an important conference in the software engineering field. 2010 will it be held in Cape Town, South Africa.

WICSA, the Working IEEE/IFIP Conference on Software Architecture. The aim of WICSA is to enable international interactions and advancement for academia and industry in software architecture.

ECSA, the European Conference on Software Architecture. ECSA is the European equivalent of WICSA. The areas are different architectural angles of software and service engineering. In 2009, the two conferences, WICSA and ECSA, were held together in Cambridge, UK.

SPLC, the International Software and Product Line Conference. This conference covers current and emergent trends within product line research and practices.

ICSR, International Conference on Software Reuse. The goal of ICSR is to present the latest in software reuse and to create relations between practice and research.

2.4.2 Interesting conferences

PROFES, Product Focused Software Development and Process Improvement. PROFES is an international conference that covers improvements and quality in software engineering processes.

CASES, Conference on compilers, architecture and synthesis for embedded systems. CASES covers most interests in embedded systems, such as compilers, architectures, synthesis and embedded systems in general.

EMSOFT, International Conference on Embedded Software. This conference includes all aspects of embedded systems.

CASES and EMSOFT are both parts of the Embedded Systems Week, this year, 2009, in Grenoble, France.

RTCSA, IEEE International Conference on Embedded and Real-Time Computing Systems and Applications. The goal is to promote cooperation and evaluate directions in embedded systems and real-time systems for both academia and industry.

RTAS, IEEE Real-Time and Embedded Technology and Applications Symposium. RTAS covers general aspects of embedded systems. 2010 the conference will be arranged together with four other conferences and will therefore
have two additional tracks on: Hardware/Software Integration and Co-design, Wireless Sensor Networks. The conference will be held in Stockholm.

**SIES, IEEE Symposium on Industrial Embedded Systems.** SIES covers different areas of embedded systems, system-on-chip, network-on-chip, networked embedded systems and embedded applications, such as automotive systems.

**EFTA, IEEE International Conference on Emerging Technologies and Factory Automation.** The conference covers the most within industrial systems and its aim is to bring research and industry together. The scope is not limited to factory automation

**ICECCS, International Conference on Engineering of Complex Computer Systems.** This conference spans over specification, development, validation and verification, and management of complex computer systems.

**SERPS, Software Engineering Research and Practice in Sweden.** The aim is to enable exchanges of early research and state of the art of software engineering between researcher and practitioners in Sweden.

### 2.4.3 Leading research groups

#### 2.4.3.1 SEI, the Carnegie Mellon Software Engineering Institute

SEI is a research and development center situated on campus of Carnegie Mellon University in Pittsburgh, USA. The research areas are management, engineering practices, security etc. The analysis methods ATAM and CBAM originate from SEI.

#### 2.4.3.2 AbsInt

The group originates from the Department for Programming Languages and Compiler Design chaired by Prof. Dr. Reinhard Wilhelm at Saarland University. The members have developed an analyzer that checks time behavior in control software components by computing worst-case execution time (WCET). The aim is to guarantee real-time requirements in safety-critical systems.

#### 2.4.3.3 BESS

BESS stands for Business oriented Engineering of Software-intensive Systems and is a research group at Mälardalen University. The aim is producing solutions for the development of software-intensive systems by cooperation between academia and industry and delivering innovative results usable for the industry.

#### 2.4.3.4 ICES

A research group at Royal Institute of Technology, KTH, Centre in Embedded systems, which consists of several research groups at KTH and industry. They arrange annual conferences, workshops and courses in the field of embedded systems.

#### 2.4.3.5 SAE International

An organization for aerospace and automotive industry that develops common industrial standards. The organization provides conferences, magazines and other events.

### 2.4.4 Courses and Schools
### 2.4.4.1 ARTIST Real Time Summer School

This summer school is organized by ARTIST2, one of nine projects in embedded systems design founded by the European commission for ICT research. The ARTIST2 objective is to create a European research community on embedded system design. This network of Excellence builds connections between researchers and industry and between different topics in embedded systems.

There are three ARTIST Real-time Summer Schools in the world with slightly different contents, one in South America, one in China and one in Europe. A summer school is also planned in the U.S. in 2010. The European summer school always takes place in Autrans near Grenoble in France in September.

### 3 Relation to and relevance for own research

How to deal with safety and predictability in component-based design is of great interest for all future AUTOSAR practitioners. The use of contract-based design (5) affects the early stages of software design when OEMs choosing components for different purposes and the safety work must be integrated from the beginning of that stage.

Today Volvo CE is developing most of their software in-house but a change towards AUTOSAR may have impacts on their possibilities to buy commercial components and hence shorter time-to-market and development costs. It is of great importance to be aware of timing problems and how to deal with them and include this knowledge in their safety processes.

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This is one of several reasons to study impacts from basic software changes and of course to look more at component-based design processes like the study of Crnkovic et al. presented in (16). However, these studies are concentrated on the use of components, whether or not the components consist of application software or basic software. Consequently, there is still a need to look further into basic software impacts.

The method of Larsson et al. (15) investigates the interdependencies between organization, architecture and processes. But the study only reveals how the development processes are affected. Yet there is a need to survey the affects on processes for the whole product lifecycle, such as aftermarket and business strategies.

### 4 References


