Towards Quality Assessment in Integration of Automotive Software and Electronics: An ATAM approach

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ABSTRACT

In this paper we perform a pilot study of evaluation of integration strategies in an automotive electronics system context. We describe the problem of choosing integration strategy and we outline the use of the Architecture Tradeoff and Analysis Method, ATAM, for evaluating integration strategies.

We exemplify the use of the ATAM by evaluating the integration decisions concerning the physical connection of a theoretic example system; a computer controlled automatic gearbox. A utility tree describing the most important qualities of the product is elicited by interviews with system architects and product specialists at Volvo Construction Equipment. We show how an evaluation score card can be used to aid in integration decisions.

Also, perform preliminary analysis and provide some discussion points from the result. This early analysis shows that ATAM has weaknesses in that it is sensitive to errors in the elicitation process and that the weighting of the resulting scenarios can be coarse grained. One strength of the ATAM is that design decisions and quality goals become visible to many stakeholders. Our proposed use of ATAM does not include any cost or effort estimates, but only relative quality estimates.

In our pilot study example we find that the integration of a software component as opposed to integration of a whole ECU, ranks higher with respect to the desired qualities.

Keywords

Integration, Automotive, Electronic Systems, Architecture, ATAM

1. INTRODUCTION

Design of automotive in-vehicle electronic systems is a challenge for Original Equipment Manufacturers, OEMs, due to a large set of functional requirements and stringent quality goals. The system is required to deliver its many functions in a dependable and safe manner, and product costs are to be kept low. The system must fulfill business and life-cycle goals such as being simple to maintain, service, and produce.

The resulting system architecture are often complex and system architecture design is a process with many stakeholders. One way of reasoning around architectural choices is to estimate quality attributes of the envisioned system and then try to quantify the impact of different choices. A structured way of listing quality attributes is by using a utility tree where desired utilities are broken down in branches of more tangible requirements. The leaves of this tree can be scenarios that describe a stakeholder interaction with the system.

1.1 Integration in Automotive Products

Design of automotive in-vehicle electronic systems includes joining together or integrating, functionality developed by several organizations. These sub-systems can be purchased off-the-shelf from a supplier or developed specifically for its purpose by the OEM or the supplier, or a combination of the two. Functionality for sub-systems can be pure software like algorithms or it can be offered with hardware including computer nodes, sensors, actuators, connectors, etc.

Integrating an electronic subsystem is the effort of making it conform to the decided architecture. Thus the integration is concerned with finding a design solution so that the component comply with, e.g., diagnostic strategy, system state management, fault handling. More precisely this could mean developing glue code or gateway functionality or it could mean to specify to a component supplier the system functionality to which the component must conform.

1.2 Problem Description

OEMs often develop architectural guidelines based on the desired qualities and integration solutions should conform to these guidelines. Still integration is difficult. Either guidelines are too rigorous and need to be bent, or guidelines are too vague and fail to aid in design. In this study we investigate the use of the Architecture Tradeoff and Analysis Method, ATAM [3], for the specific problem of automotive electronic system integration. This allows evaluation of integration strategies by making the desired qualities visible and the decisions on tradeoffs structured. In this paper we outline the method and present its usage.

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1.3 Our approach

Our goal is to make the impact of integration decisions visible in terms of the desired properties of the system. Further we want to evaluate different integration strategies to find the one that best support the desired qualities of the product in its life cycle. In order to evaluate success of different integration strategies we need some criteria on how to decide what is favorable.

The approach of this work is to use the ATAM for evaluating different integration strategies in the context of an automotive electronic system. We use the ATAM to analyze impact of design decisions in integration.

In this work we have performed a shortened version of ATAM to demonstrate the approach. By interviews with architects and product specialists, we have elicited a utility tree. The scenarios of the utility tree are then used to evaluate four different integration strategies.

This study is a pilot study where we try the use of ATAM and perform interviews with architects and product specialists at Volvo Construction Equipment, VCE. VCE is an Automotive OEM that develops Construction Equipment vehicles such as haulers, wheel loaders, and excavators. We do not, however, perform the full ATAM and the result is not final as we intend to expand the study. We use an example of a gearbox with realistic specifications to demonstrate the approach.

1.4 Outline of Paper

Section 2 introduces vehicle electronic systems. The properties of a vehicle electronic system is outlined in section 2.1 and the four different integration strategies are presented in 2.2. We introduce an example gearbox in section 2.3. Section 3 describes the ATAM and our deviations from it. In section 4 we describe the elicitation of the utility tree for the electronic system of a construction equipment machine. In section 5 the evaluation of different integration strategies is presented by an example. Section 6 provides initial analysis and discussion topics and section 7 concludes the paper.

2. VEHICLE ELECTRONIC SYSTEMS

In this section we present the context of automotive in-vehicle electronic systems. Further, we describe the notion of integration strategies and we provide a theoretic example of an automotive electronic system intended for integration based on previous studies.

2.1 General Properties

Automotive electronic systems are safety critical, real time systems embedded in mechatronic components. The functions in an automotive vehicle include control of the engine and drive train, driver interface, suspension, comfort functions such as climate control, and audio/video systems. Besides the user functionality of the vehicle, there are numerous functions inside a vehicle that supports the production and service operations in the lifecycle of the product such as diagnostics and test. Sometimes the system and functionality is described as partitioned into subdomains, such as, powertrain, body, chassis, and infotainment. The implementation of the functionality in contemporary vehicles includes distributed computers with I/O to sensors and actuators. Wiring is substantial and bundled in cable harnesses. Control software is often constructed using a dataflow model and communication is often based on the CAN protocol.

The term ‘electronic systems’

In-vehicle computer systems are often labeled electronic systems in automotive applications. Automotive electronics thus includes electronic hardware such as sensors, actuators, Electronic Control Units (ECUs), and cabling, but also the software. The reason for using this term may be the close dependency of software and hardware in many automotive applications. For instance, a braking application is very tightly bound to the hardware for which it is tested and developed. A change of sensors or other hardware components in such an application would likely generate a change of software functionality.

In the following we use the term electronic system to refer to the complete in-vehicle computer system including both software and hardware.

2.2 Integration Strategies

Electronic components can be integrated into an in-vehicle electronic system in different ways. Decisions on integration strategy will affect the quality outcome and lifecycle cost of not only the electronic system, but the complete vehicle. Integrating supplier electronics in automotive networks is challenging because several qualities are pursued simultaneously, much like in architecture design.

What is an integration strategy?

An integration strategy is answers to questions on how a component will be made to fit into system wide schemes and principles. It is the design of interfaces and semantics of interaction between component and system. There may be several schemes to follow such as diagnostic signaling, fault handling, and state management. The component and its function can give rise to ways of interacting that are not covered by the decided system principles and schemes. An example is a mechatronic brake with many fault states that each affect the system state differently. Such issues are included in the integration strategy.

Four common integration strategies

Network topology decisions is part of the integration strategy. To describe the method of evaluating integration strategies we focus on how a function is to interface the system. The four alternative designs are shown in figure 1.

We have chosen to focus on these strategies:

A1. ECU connected directly on a system bus.

A2. ECU connected via a gateway.

A3. Application software component located in existing ECU.

A4. ECU Standalone - not connected to a bus.

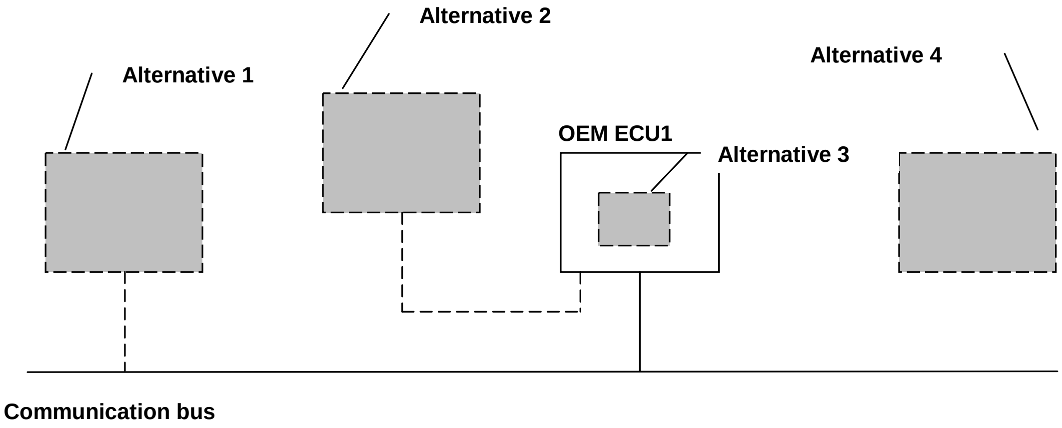

Figure 1. In-vehicle electronic system design by integration.

2.3 Example: Gearbox

Based on a previous study of three cases of real-life mechatronic integration [4], we have developed a theoretical but realistic example of a component intended for integration in an automotive application. The example consists of a mechanical gearbox with a fitted ECU that controls the operation of the automatic gear shifting intended for use in a construction equipment vehicle.

Technical data

The ECU is equipped with the following interfaces:

- A CAN interface
- J1939 protocol for control data on the CAN network
- A serial interface with a proprietary protocol for diagnostics

Application requirements

The gearbox application is dependent on signals that describe the gear lever position, engine speed, vehicle speed, and drive mode.

The application must be able to control engine speed for short periods of time during gearshifting. There are timing requirements on the control messages; latency, periodicity, and jitter are specified.

The application also has a number of error states where gearshifting is not possible.

3. ATAM

The Architecture Tradeoff Analysis Method (ATAM) is a method for evaluating software architectures. In this section, we briefly summarize the original method and then comment on how we applied it for the automotive electronics application.

3.1 The Method

The goal of ATAM is to assess the consequences of architectural decisions in light of quality attributes requirements [3]. Each stakeholder has different quality attributes that they consider to be the most important ones. The top level attributes are typically attributes like safety, performance, maintenance and maintainability but the number of attributes can vary from case to case. A utility tree is created with input from all stakeholders. An example of a utility is shown in figure 2.

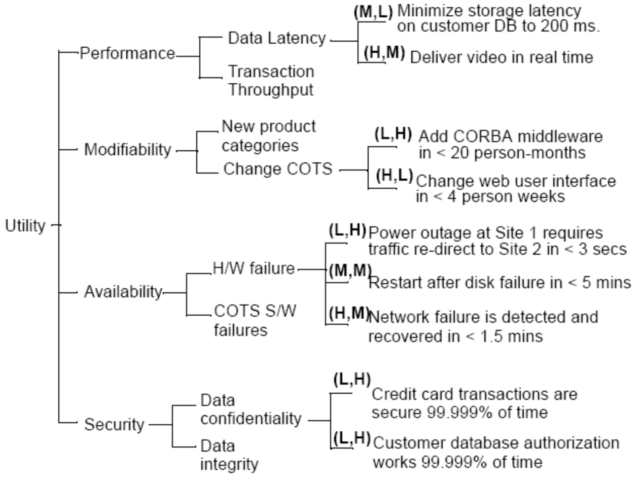

Figure 2. A utility tree

The low level leafs of the utility trees are prioritized, Low (L), Medium (M) or High (H), concerning two different aspects. The first one shows how important this scenario is for the success of the whole system and the second indicates how big a risk it is to achieve such a scenario. The utility tree is only constructed by the architects and the project leader and will therefore only show the architects' view of what is important to the system.

The next step is to perform a brainstorming of scenarios. The scenarios are made up by all stakeholders. The scenarios are comparable to the leaves of the utility tree. Each stakeholder is given a number of votes, typically 30% of the total number of scenarios, and then vote for what each stakeholder consider being the most important one. The result from the voting is then compared with the result from the utility tree. If the result is the same, it is quite certain that the most important attributes are considered in the architectural decision. If not, the view of what are the most crucial attributes for a successful architecture differs between system architects and other stakeholders. In this case some kind of reasoning is necessary between the system architects and other stakeholders to conclude the most important parts.

3.2 Our Approach

In this paper we shorten ATAM to perform a pilot study where the feasibility of ATAM can be tested. ATAM is designed for evaluating software architecture but in the automotive industry the whole electronics architecture is usually considered due to the tight coupling between software and hardware. In this first step we only consider the utility tree constructed for this study. The prioritized leaves/scenarios create a matrix together with the four different integration strategies described earlier. A system architect then determines how well each scenario fits each of the four integration strategies. In this pilot study the system architect making the estimates is the authors, but should be a number of architects performing voting. The strategy that holds the highest value is considered to be the most suitable one in this case.

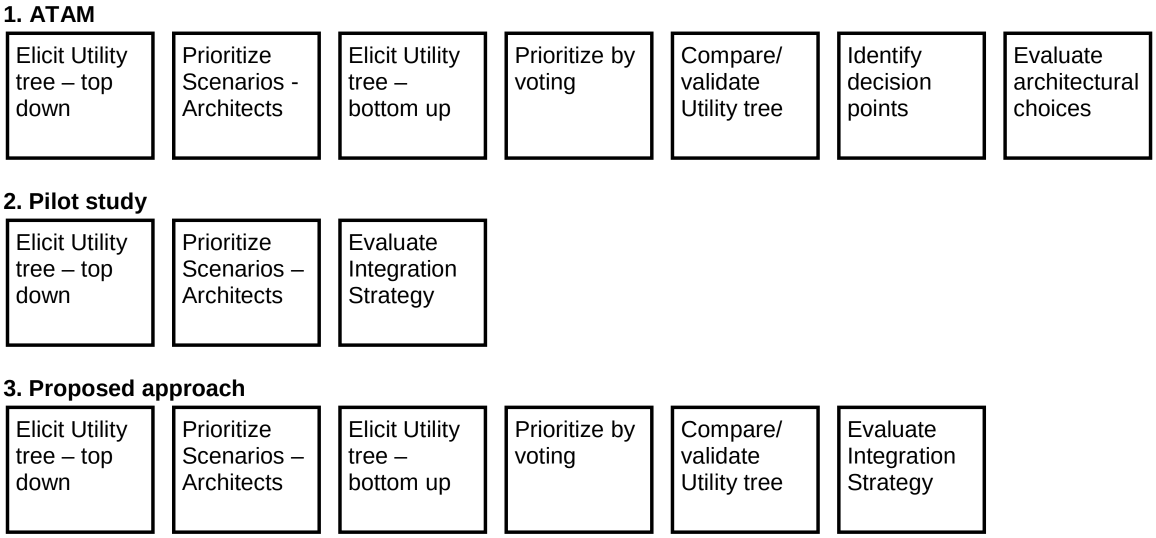

Figure 3. Workflows of ATAM, Our pilot study, and our proposed approach

Figure 3 shows three workflows. First, the general workflow of the ATAM (1.). The difference to our pilot study approach (2.) is the omission of the bottom up elicitation of the utility tree. This allows, in the ATAM approach, for better validation of the correct weighting of scenarios by comparing the top-down with the bottom up elicitation. Also different is the identification of architectural decision points. In ATAM there is a process for identifying them, but in the case of evaluation of integration, we start out with a set of possible designs. Thus, the design space is more fixed from the start in the integration case.

The third work flow (3.) shows the workflow for a larger study where the ATAM is more strictly followed. This proposed approach includes the more rigorous approach of performing both top-down and bottom-up elicitation with more stakeholders. The final evaluation of integration strategies is intended like in the pilot study.

4. ELICITING THE DESIRED QUALITIES

In order to evaluate and compare different technical solutions against each other, we need to know the wanted properties of the system. The idea is that we should find the solution that is most desirable i.e. support us in achieving the wanted properties more than other solutions. Thus, here we seek the qualities that are important to a construction equipment in-vehicle electronic architecture. The ATAM stipulates a step by step method in which a utility tree is constructed by eliciting business drivers and key utilities. The ATAM proposes that this elicitation is done in two workshops including all key personnel.

We have deviated from the stipulated workshop format and elicited a utility tree based on four interview sessions with only two experts individually. First we use interview results from previous work on quality attributes in automotive electronics and software systems [6][7]. These results we, the authors, use to construct an initial utility tree that we then use to guide another round of interviews.

Previous studies on requirements for automotive electronic systems [5][6][7] show that besides the purely operational qualities of the system, life cycle aspects are also very important. Qualities related to service and maintenance are important as they directly relate to the revenue of OEMs. Flexibility and modifiability are also elicited as being important in order to have an efficient development. This includes aspects such as being able to make changes in technology or components easily.

Based on previous studies and previous interviews we produced a utility tree. This first tree consisted of the four qualities Safety, Reliability, Serviceability, and Modifiability. The two respondents were then asked to comment and complement the utility tree. Based on these interviews we refined the utility tree. In the next step we let the respondents prioritize the branches.

4.1 System quality vs. electronic system quality

The wanted qualities of the electronic system are directly derived from the wanted qualities of the overall vehicle. Thus, the wanted properties of the vehicle such as comfort and drivability propagate via some analysis down to what properties the in-vehicle electronic system should have. Availability and versatility are mentioned by the two interviewees as important vehicle properties for heavy machinery, and these are discussed next.

4.1.1 Availability

One of the more important qualities of the product as a whole is availability according to the respondents. The customers of heavy machinery make business of the operational time they get from the machine. A quick but expensive repair is often preferred over a slow cheap one. Thus the requirement for availability yields not only a requirement for high reliability, but also for high serviceability. More precisely the service of the machine should be quick and this means that faults should be found quickly and fixes applied quickly. The cost for the service is not that sensitive, but the cost for the product may still be critical. Clearly, not only the product and its properties can achieve a high serviceability, but in terms of the product the requirements for reliability and serviceability are among the most important ones.

4.1.2 Versatility

The product should be able to perform its functions in different environments and for different purposes. Some products have requirements on versatility in that they should be able to carry different tools.

4.2 Quality Attributes

In this section, we list the quality attributes that we interpret as the highest rated ones for the electronic system properties. We strive to give them precise definitions based on available literature and standards.

4.2.1 Safety

“Safety is freedom from accidents or losses”[8]. The safety of an automotive product is the ability to avoid unsafe behavior. In terms of constructing a vehicle, the safety is the ability of the product system to avoid vehicle system induced accidents. This means for the product never to cause accidents or even prevent the driver from causing accidents. The standard IEC 61508 [9] is an example of requirements on safety related functions of a vehicle. The standard stipulates measures to be taken for achieving pre-defined Safety Integrity Levels, SIL. Derivatives of this standard exist for trains and factory machinery but are under work for both construction machinery and passenger cars.

Safety related functions in a vehicle can be divided into passive and active safety functions. Passive safety functions acts to mitigate consequences of accidents while active safety functions act to prevent accidents from happening.

In computer system terms, safety is to keep the system in a safe state always. To do this a system should employ mechanisms to be informed on failures and make sure functional degradation is done without risk. To an automotive OEM this has several implications; failure detection mechanisms, safe design as well as a design that facilitates safety analysis are desired.

It is important to note that a safe vehicle in not necessarily a reliable vehicle. A vehicle is likely safe if it stops at any indication of a fault e.g. a voltage spike. Thus, a vehicle is not necessarily safer if operational functions like gearshifting are ultra reliable. Instead it is important to detect failures and have safety policies to act and degrade safely. However, in directly safety related functions where no alternative means of actuation are available, e.g. steering, the reliability directly affects safety.

4.2.2 Reliability

The IEEE defines *reliability* as "The ability of a system or component to perform its required functions under stated conditions for a specified period of time" [1]. The ability to provide a function over time often means to provide its function without failures, which means that faults should not propagate to loss of function. Thus, design for reliability includes, apart from high quality components, redundancy and fault handling schemes. Providing a reliable product is a high priority to OEMs and unplanned services are undesired. Fault tolerance is thus a central concept to achieve reliability. The IEEE defines *fault tolerance* as “The ability of a system or component to continue normal operation despite the presence of hardware or software faults” [1].

4.2.3 Modifiability

The IEEE definition of Modifiability is “The degree to which a system or component facilitates the incorporation of changes, once the nature of the desired change has been determined” [2]. Modifiability is thus the ability to modify the solution to facilitate further development. This is mainly an OEM requirement that customers do not value. With modifiability the cost for further development can be kept at a minimum and will indirectly gain stakeholder value in form of a cheaper product or more revenue for the OEM.

4.2.4 Serviceability

Serviceability is the ease to perform services. The support in the system for finding faults is mentioned as crucial in this effort. Thus, a very serviceable system should include a diagnostic functionality that detects many faults and analyses what is the root case. Furthermore a serviceable system allows easy modification to correct the faults. A serviceable system allows for easy change of hardware components and software upgrades. Our definition of Serviceability is thus the IEEE definition of maintainability plus also the ease of finding faults. The IEEE definition of *Maintainability is* “The ease with which a software system or component can be modified to correct faults, improve performance, or other attributes, or adapt to a changed environment” [1].

4.3 Interviews

In this section we discuss the responses by the interviewees when shown the initial utility tree. The respondents are two senior engineers with each more than 20 years experience from vehicle development. The first respondent is a product specialist for wheel loaders and manager for advanced engineering activities. Our second respondent is a system architect for the electronic systems in VCE product lines.

The strategy in the interviews was to elicit experience and factors that come from the business case of automotive OEMs. The questions were related to which quality attributes are the most important and we tried to elaborate on what factors contribute to these. Moreover we tried to provoke answers by asking respondent s to exemplify a perfect or problematic system. The form of interviews were open ended questions and each respondent was interviewed for 1,5 hours.

4.3.1 Safety

Respondents state that the wanted level of safety is difficult to pinpoint. It is clear that some accidents must never happen, but what this means in terms of how much measure must be taken to prevent it is not clearly defined in standards. However, respondents indicate that safety requirements are considered extremely important. Safety requirements differ from other more negotiable requirements in that they can disqualify certain solutions.

One approach to ensure safety is to build systems that are easy to analyze from the safety perspective. Two important points that are stressed by both the respondents is to aim for a solution that is as simple as possible, and to employ solutions that behave in a predictable manner.

Another advice for supporting safety is to fulfil safety standards. This has mostly to do with requirements on the development process. The standard IEC 61508 is applicable at VCE.

Employing a safety system that enforces safe degradation of functionality is also mentioned as one way of achieving safety. This means to have a system state and a system wide function that monitors thinkable erroneous states and performs actions according to decided strategies. An example is a limp home function that put the system in a reduced functional mode and allows only low speed operation if a certain set of error conditions are met. Continuous functions like control functions that control safety related functions should perform with a high reliability to ensure safety.

4.3.2 Reliability

Reliability is mentioned mostly in terms of the reliability of the physical parts. To determine what constitutes a reliable choice in design, several parameters are mentioned. Firstly, there is a need for high quality physical components like sensors, actuators, connectors, and ECUs. One way of determining this high quality is to have guidelines for physical requirements like EMC, moist, vibrations, and dust. Secondly, fault tolerance is mentioned as a means to achieve reliability and redundancy is emphasized as a way of achieving redundancy. Thirdly, testability is mentioned as important to increase reliability. Choosing solutions that are feasible to test is a step in that direction. Simpleness and openness are two factors that should be aimed at.

4.3.3 Modifiability

Easy repartitioning of functionality is mentioned as a factor that eases further development and also enables variants. Also easy change of infrastructure is mentioned. Changes in infrastructure can occur due to some new requirements such as platform technologies or new legal requirements.

4.3.4 Serviceability

Concrete designs to strive for in this respect is said to be having a system wide plan for signalling faults so that diagnostic functionality can see all faults. Aftermarket tool support is also mentioned. An aftermarket tool is a diagnostic tool that connects to the vehicle computer system and can see reported faults and analyse causes.

Easy changes of hardware components are also mentioned as a step into the right direction when it comes to serviceability. Once diagnosis is done and the root cause of failure is determined, the replacements should be easy to perform.

Upgrading software is also said to be central to serviceability. This can be needed both for bug upgrades and for installing new features in the aftermarket.

4.4 Utility Tree and Scenarios

Based on the interviews, the final utility tree is constructed as shown in Figure 4, and this is used as a basis for finding scenarios.

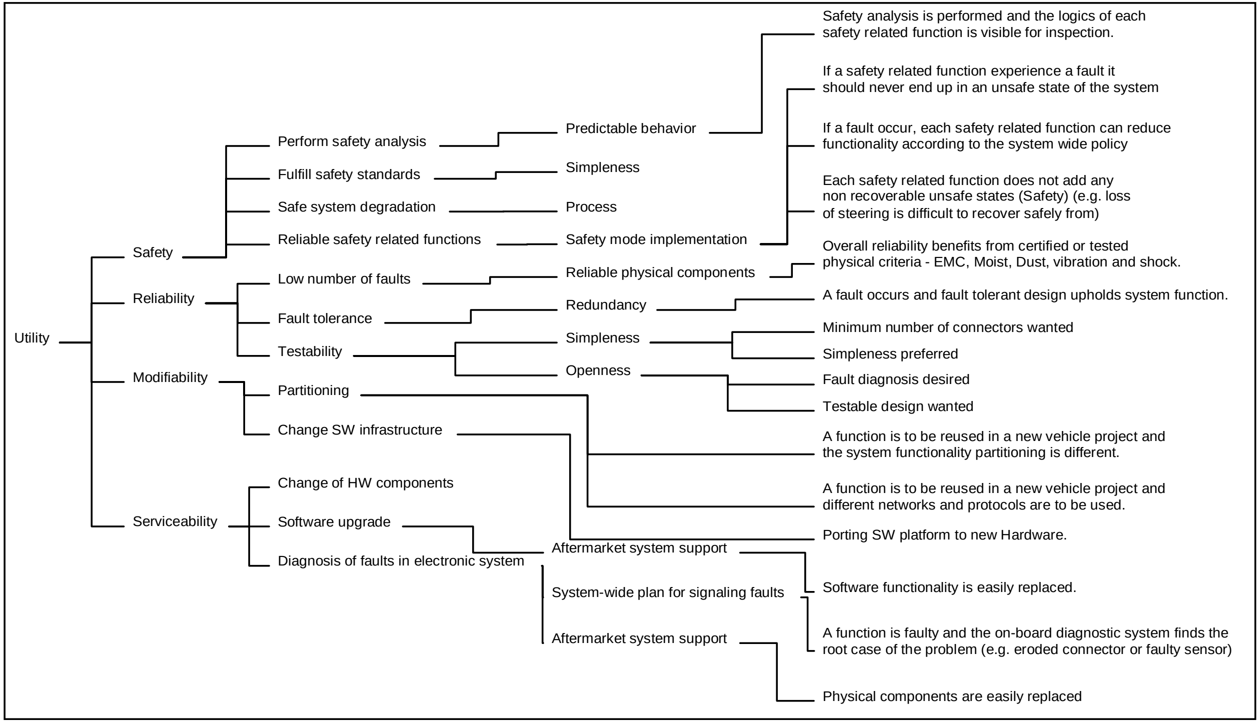

Figure 4. Workflows of ATAM, Our pilot study, and our proposed approach

4.4.1 Scenarios

ATAM states that “A scenario is a short statement describing an interaction of one of the stakeholders with the system”. Here we list the scenarios that we elicited from the interviews with architects and product specialists. The respondents described the business situation related to each quality attribute. Based on these descriptions we listed the following scenarios. This list is a short list for this pilot study. In order to extract a complete list, we would like to validate the scenarios together with the stakeholders. Also, more stakeholders are desirable.

Safety

S1. A safety related function experiences a fault and this does not lead to an unsafe state of the system. (Safety)

S2. The system experiences a fault and each safety related function can reduce functionality according to a system wide policy. (Safety)

S3. Each safety related function does not add any non recoverable unsafe states (Safety) (e.g. loss of steering is difficult to recover safely from)

S4. Safety analysis is performed and the logics of each safety related function is visible for inspection.

Reliability

S5. Overall reliability benefits from certified or tested physical criteria - EMC, Moist, Dust, vibration and shock.

S6. A fault occurs and fault tolerant design upholds system function.

S7. Minimum number of connectors wanted

S8. Testable design wanted

S9. Simpleness preferred

S10. Fault diagnosis desired

Modifiability

S11. A function is to be reused in a new vehicle project and the system functionality partitioning is different.

S12. A function is to be reused in a new vehicle project and different networks and protocols are to be used.

S13. Porting SW platform to new Hardware.

Serviceability

S14. A function is faulty and the on-board diagnostic system finds the root case of the problem (e.g. eroded connector or faulty sensor)

S15. Physical components are easily replaced

S16. Software functionality is easily replaced.

4.5 Prioritizing the Scenarios

In this section we list the importance of each scenarios as interpreted by the interviews. This is not the final rating and the ATAM process is not followed. Rather we prioritize on the basis of the respondents and our own experience. The intention of this incomplete method is to get a weighting so that we can describe the evaluation part in more detail. The final prioritization requires more interviews and voting procedures and will be performed in order to deliver a final result.

The weighting of the scenarios is shown in column 1 of table 1.

5. EVALUATION OF INTEGRATION STRATEGIES

Here, we describe the approach for evaluating the integration strategies with the ATAM. We exemplify the approach by using the example of an automatic gearbox as outlined earlier.

5.1 Evaluation Exemplified with Gearbox

We use the gearbox example from Section 2.3 to produce a score card for integration strategies.

Table 1 shows four columns corresponding to the four alternatives. And each row corresponds to a scenario. For each scenario the four alternatives have been rated as Low, Medium or High. This rating reflects the level of support for the scenario by the each alternative design.

Also, each scenario has an associated weight that corresponds to the importance of the scenario as rated by architects. This rating has not yet been validated by bottom up elicitation with voting, but acts a an indication and allows us to describe the method.

The low, medium, and high ratings have been valued 1,2,and 3 respectively. Both the weighting and the alternative evaluation score receives this weight. For each alternative (A1-A4), we have multiplied the scenario priority rating with the alternative rating and a sum has been calculated at the last row of the table.

Table 1. Quality Evaluation Scores

	A1	**A2**	**A3**	**A4**
S1(H)	M	M	M	L
S2(H)	M	M	M	L
S3(H)	-	-	-	-
S4(M)	M	M	H	M
S5(H)	-	-	-	-
S6(M)	-	-	-	-
S7(L)	-	-	M	M
S8(L)	M	M	M	L
S9(L)	-	-	-	L
S10(M)	M	M	M	L
S11(M)	L	L	H	L
S12(M)	L	L	H	-
S13(L)	L	L	H	L
S14(H)	M	M	M	L
S15(L)	-	-	-	-
S16(L)	M	M	M	L
Sum	35	35	49	22

Legend

Low (L), Medium (M), High (H), No Influence (-)

Reasoning and motivations

S1 and S2. Standalone solution (Alternative 4) has limited ability to perform according to safety policies because of the lack of information sharing.

S3. Choices does not influence fulfillment of this scenario.

S4. White box software is more visible for inspection.

S5. Supposedly less work to do strategy 3, but not necessarily more compliant to physical criteria.

S6. No influence on fault tolerance

S7. Alternative 3 and 4 saves at least one connector.

S8. Alternative 4 is less testable for production tools and development test benches.

S9. Less interactions is simpler for alternative 4.

S10. The achieved quality should be similar except alternative 4 where the lack of information exchange causes lack of diagnostics. The effort of achiving diagnostics could differ.

S11. Repartitioning of alternatives 1,2, and 4 are difficult.

S12. Difficult to reuse 1 and 2. Alternative 3 is highly reusable since it is not dependent on protocol. Alternative 4 does not use the network.

S13. Difficult to move a black box component. Alternative 3 on the other hand has high support for porting.

S14. On board diagnostics are limited in alternative 4.

S15. No affect.

S16. Alternative 4 would require a separate service connector and therefore gets a ‘Low’ score.

6. DISCUSSION

In this section we provide initial analysis of the study. We list a number of discussion points on the use of ATAM and on general findings on integration strategies for automotive electronic systems.

6.1 The use of ATAM

The use of ATAM to evaluate integration strategies seems feasible because of the similarity in the problem of deciding on architectural strategies.

However, the validity of the comparison of alternatives is highly dependent on the relative importance that is judged by the architects and the voting processes in ATAM. ATAM proposes a small number of grades (Low, Medium, High) because stakeholders cannot reliably grade with finer granularity. The result is that the evaluation also gets rather coarse grained. Also, there is a risk of removing important scenarios because of stakeholder uncertainties.

The ATAM does not prescribe how the Low-Medium-High ratings are to be compared. In our approach we have decided to assign the values 1-3 respectively, but other values could be used.

One strong aspect of the ATAM that has been reported is that it provides means of making all requirements visible and allows all stakeholders to get more knowledge on the system and how different design decisions affect system qualities. This, we believe, is true also for integration strategy evaluation. The utility tree and the scenarios provide highly visible results for all the stakeholders.

6.2 Integration Evaluation

In this section we list some reflections on drawbacks and possible improvements for evaluation in integration decisions.

Possible to evaluate other integration decisions

In this work we have shown how to evaluate one decision in an integration strategy. It would be possible to use the method for evaluating several more decisions in an integration strategy. Examples could include design principles or choices in technology.

Cost and Effort

Using ATAM for evaluating integration strategies like we have shown in this paper leads to finding the best choice in terms of the desired qualities given that the utility tree is valid. Still, the effort and the cost of implementing the chosen alternative are not considered. In order to improve the method there may be needed a model of effort or cost estimations

Good for early estimates

The idea with ATAM is to provide somewhat tangible requirements for qualities that are difficult to quantify. Also we have shown that the ATAM is very sensitive to errors in the stakeholder elicitation. One way of reducing this risk is to let the utility tree branch to very precise scenarios and thus provide a more complete and traditional requirement specification. For the most important qualities of the system it may not be enough to make design choices based on imprecise quality attributes. Instead, the effort of eliciting very precise and quantifiable scenarios may be preferred. Working with imprecise utilities may still be useful in early phases where the majority of architectural decisions have not been made.

The Third Alternative a Winner

Based on this pilot study, it would seem that the third design alternative in Figure 1 is preferred for the example system. The third alternative is a software integration and in terms of quality it scores the highest in the evaluation chart. It seems that the example system is a rather typical system, so this could be a general result i.e. software integration meets the quality attributes better than does integration of ECUs.

7. CONCLUSION AND FUTURE WORK

In this paper we have performed a pilot study of evaluation of integration strategies in an automotive electronics system context. We have described the problem of choosing integration strategy and we have outlined the use of the Architecture Tradeoff and Analysis Method, ATAM, for evaluating integration strategies.

We have exemplified the use of ATAM by evaluating the integration decisions concerning the physical connection of an example system. A utility tree has been elicited by interviews with system architects and product specialists at Volvo Construction Equipment. An example system has been outlined by using data from previous studies. We have shown how the evaluation score card can be used to aid in integration decisions.

Also, we have performed preliminary analysis and provided some discussion points from the result. This early analysis shows that ATAM has weaknesses in that it is sensitive to errors in the elicitation process and that the weighting of the resulting scenarios can be coarse grained. One strength of the ATAM is that design decisions and quality goals become visible to many stakeholders.

In order to get more solid basis for decisions in integration strategies, there may be more evaluations needed. Our proposed use of ATAM does not include any cost or effort estimates, but only relative quality estimates.

In our example we find that the integration of a software component as opposed to integration of a whole ECU, ranks higher with respect to the desired qualities.

Future work includes performing this study with more rigorous use of the ATAM. This would yield a more validated utility tree and thus would provide better base for evaluations. The range of decisions in integration strategy can be expanded. Also, models for cost and effort can be used or developed. Also generalization of the results to the whole automotive industry can be investigated.

8. REFERENCES

[1] Institute of Electrical and Electronics Engineers. IEEE Standard Computer Dictionary: A Compilation of IEEE Standard Computer Glossaries. New York, NY: 1990.

[2] Boehm, Barry W.; Brown, John R.; Kaspar, Hans; Lipow, Myron; MacLeod, Gordon J. & Merritt, Michael J. Characteristics of Software Quality. New York, NY: North-Holland Publishing Company, 1978.

[3] Rick Kazman, Mark Klein, Paul Clements, ATAM: Method for Architecture Evaluation, Technical Report, CMU/SEI-2000-TR-004

[4] Fröberg, J., Åkerholm, M., Integration of Electronic Components in Heavy Vehicles: A Study of Integration in Three Cases, Systems Engineering / Test and Evaluation Conference, September 2006 Melbourne.

[5] Fröberg, J., Engineering of Vehicle Electronic Systems: Requirements Reflected in Architecture. Technology Licentiate Thesis, No.26, ISBN 91-88834-41-7, Mälardalen University, 2004

[6] Anders Möller, Mikael Åkerholm, Joakim Fröberg, Mikael Nolin, Industrial Grading of Quality Requirements for Automotive Software Component Technologies, Embedded Real-Time Systems Implementation Workshop in conjunction with the 26th IEEE International Real-Time Systems Symposium, 2005 Miami, USA

[7] Industrial Requirements on Component Technologies for Embedded Systems, Anders Möller, Joakim Fröberg, Mikael Nolin, International Symposium on Component-based Software Engineering (CBSE7), Springer Verlag, Edinburgh, Scotland, May, 2004

[8] Leveson, N., Safeware: System Safety and Computers, Addison-Wesley, 1995.

[9] IEC 61508, Functional Safety of E/E/PES Systems, 1998