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**AN EMPIRICAL EXPLORATION OF REQUIREMENTS  
ENGINEERING FOR HYBRID PRODUCTS**

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# AN EMPIRICAL EXPLORATION OF REQUIREMENTS ENGINEERING FOR HYBRID PRODUCTS

Berkovich, Marina, Technische Universität München, Information Systems (I17), Boltzmannstraße 3, 85748 Garching b. München, DE, berkovic@in.tum.de

Leimeister, Jan Marco, Universität Kassel, Chair for Information Systems, Nora-Platiel-Str. 4, 34127 Kassel, Germany, leimeister@uni-kassel.de

Krcmar, Helmut, Technische Universität München, Chair for Information Systems, Boltzmannstr. 3, 85748 Garching b. München, Germany, krcmar@in.tum.de

## Abstract

*In this paper we report on an empirical study on requirements engineering of hybrid products. Hybrid products (often also referred to as product service systems) – a combination of product, software and service elements – are an emerging trend on the market. Companies intend to offer holistic solutions for customer problems and not single products. The development of hybrid products differs from the development of “classic” products because of the high-level of technological integration of the elements that hybrid products consist of, the interdisciplinarity and the different lifecycles of their single components. We have conducted fifteen expert interviews to explore current practices in requirements engineering in three industries developing hybrid products: automotive, IT-consulting and system integrators, and medical technology. Our results show that most components of hybrid products are developed independently from each other. Based on our empirical insights we have identified requirements and challenges for the design of an integrated requirements engineering process for hybrid products.*

*Keywords: requirements engineering, hybrid product, software, hardware, service, empirical study, product-service systems.*

## 1 INTRODUCTION

The success of a manufacturing company is directly related to the success of its products on the market. And the success of a product on the market depends on its capability to meet the needs and wishes of customers and environment (Beiter et al. 2006, Lindemann 2006, Nuseibeh and Easterbrook 2000). These points are essential for the development process. The development process is also affected by factors such as shortened development and production time, as well as cost pressure (Lindemann 2006, Spath et al. 2001). Further, the quality pressure – to produce better products than competitors – is growing. Thus, products are becoming more and more complex, and customer requirements are becoming more specific and leading to the development of individualized products and services built to individual customer needs (Abramovici and Schulte 2007). Customers have no interest in products or services per se, but they want their problems to be solved. The companies offer not a product, but a solution that is “a customized, integrated combination of products, services and information that solves a customer’s problem” (Sawhney et al. 2006). The distinction between products and services is disappearing and a so called hybrid product emerging (Berkovich et al. 2009, Knackstedt et al. 2008, Leimeister et al. 2009). In contrast to classical hybrid products consisting of a physical product and a service part, we also consider a combination of software and service, and software as a hybrid product (Böhm and Krcmar 2007). Only by coordinating the development process of each element of hybrid products is it possible to achieve a customer’s benefit that is greater than if the product and service were to be bought separately (Schmitz 2008).

The development of hybrid products differs from the development of “classic” products because of the high number of sub-elements, the high level of technological integration and the degree of customer-integration (Leimeister and Glauner 2008, Pahl et al. 2006, Zellner 2008). The literature discusses products – physical products or software – and services separately. In practice, the development of products and services is also reported to take place separately (Leimeister and Glauner 2008, Müller and Blessing 2007).

One of the most important aspects in a development process is the successful handling of the requirements (Brooks 1987, Pohl 2007). Defining and handling the requirements is a very complex and difficult process. Deficiencies in this process often lead to costly project failures (Boehm et al. 2001). Keil (1998) finds that two of the three major risk factors in software development have to do with requirements engineering (RE). RE is especially important for hybrid products which consist of elements with different life-cycles; for example, hardware and software are developed by different disciplines, namely product, software and service engineering. Another aspect is hybrid products aiming at solving specific customer problems. Thus, the RE of hybrid products have to show and consider the different views of the involved disciplines on the RE, and also provide the customer-orientation and coordinated development. For the successful development of hybrid products, well-founded knowledge about the interdependencies of different characteristics of these products, their value-enhancement and the resulting output quality are necessary (Leimeister and Glauner 2008). Thus, it is a very gainful step to develop integrated RE for hybrid products.

This paper presents and discusses practice requirements for the RE process for hybrid products. In the study we first analyzed the literature on product, software and service engineering. Then we conducted a series of expert interviews on RE for hybrid products in practice. We collected empirical data from fifteen interviews in three industries – automotive, consulting and systems integrators, and medical technology. These interviews were the basis for our definition of the requirements and challenges for the design of the RE process for hybrid products from practice.

## **2 RELATED WORK**

To understand the RE for hybrid products, it is important to comprehend what hybrid products are. It is necessary to understand the RE in general and to know how the RE is performed in the three disciplines of product engineering, software engineering and service engineering.

### **2.1 Hybrid Products and Software**

Hybrid products consist either of physical products or software or a combination of these elements and service-components (Becker and Krcmar 2008, Beverungen et al. 2008). There are two main reasons why software is an essential component of hybrid products: First, implementation and consulting activities are very often combined into service bundles (Bonnemeier et al. 2007). Second, the importance of software is growing in general. For example, in the field of embedded systems, producers find that software development often takes more than 50% of the total development costs (Baskerville 1999). In the automotive domain it accounts for 20% to 40% of the production costs (Bender 2005). Today, software is not only a part of the product, but an indispensable part of it: Functionality realized by software cannot be replaced by hardware. Also, the value creation of modern systems relies on software (Liggesmeyer and Rombach 2005). On that account, the strengthened integration of the software development in the overall development process is necessary.

### **2.2 Requirements Engineering in general**

RE is a discipline for handling the requirements, and is an essential part of the development process. Software engineering has already defined a profound understanding of RE as consisting of requirements elicitation, analysis, negotiation and validation. Change management and traceability of requirements are also parts of RE. Several studies illustrate that faulty implementations of the RE

process have an impact on the overall development process (Finkelstein and Dowell 1996, Hall et al. 2002). Failures arising during the RE process resulting in substantial costs for their elimination, especially in the latest phases of the development process (Boehm and Basili 2001, Pohl 2007). The process of RE is one of the most difficult phases of a development process (Damian and Chisan 2006). RE has to involve different stakeholders – users, customers, managers, domain experts, standards, laws, etc. – in order to get the requirements (Cheng and Atlee 2007).

The following two sections discuss each of the following phases of RE: requirements elicitation, requirements analysis, requirements documentation, requirements validation, and change management and traceability.

### 2.3 RE in Product Engineering

This section describes some aspects of the RE in the domain of product development. Our primary source of information was the top-10 textbooks, according to the amazon.de/amazon.com sales ranking (accessed on 09/17/2008). With the focus on the RE process, we selected only the books describing process models for product development (Ehrlenspiel 2002, Lindemann 2006, Pahl et al. 2006). These books contained useful references to other sources, which we then analyzed (Ahrens 2000, Jung 2006, Kruse 1996, Ulrich and Eppinger 2003, VDI-Richtlinien2221). To cover the latest developments in this area, we analyzed the journal articles of the years 1997 to 2008 and conference proceedings from 2002 to 2007. The Chair of Product Development of the TU München (<http://www.pe.mw.tum.de>) provided us with a list of relevant journals and conferences. The results of the analysis are presented below.

**Requirements elicitation:** The main source of requirements is the customer; other sources are legal documents, standards, existing systems, etc. In product engineering (PE), checklists are a widely used technique to elicit requirements (Ehrlenspiel 2002, Pahl et al. 2006). Most analyzed conference-papers and journal articles present minor improvements of existing methods for elicitation. The importance of the customer for a successful product development is emphasized by nearly all approaches, but is restricted to the first phases of the RE process (Jung 2006).

The main task of the requirements analysis is to derive technical requirements from customer requirements. The technical requirements have to be detailed, solution-independent and in a quantified form (Ahrens 2000). Most analyzed conference-papers and journal-articles present variations of the QFD method or put their focus on the management of functional requirements.

**Requirements analysis.** This has the task of resolving conflicts between requirements. Lindemann (2006) and Kruse (1996) purport that it is important to prioritize requirements to resolve conflicts and to define the focus of the development.

**Requirements documentation.** This requirement is very important for the development process, as misunderstandings and misinterpretations are often caused by inadequately documented requirements. Most approaches agree on the basic rules on how requirements are to be formulated: solution-independent, unambiguous, positive formulation, etc. (Lindemann 2006, Ulrich and Eppinger 2003).

**Requirements validation.** The main goal of requirements validation is to ensure that the requirements express the product as the customer needs it. The analyzed approaches describe only the subtasks of checking the requirements for completeness and consistency.

The importance of RE for successful development processes has been recognized in product engineering, but it is often seen as merely the initial step of the development process where the customer places the order. Due to the nature of hybrid products, this view of RE is not sufficient. Hybrid products need an even stronger customer orientation, often leading to customer integration (Leimeister and Glauner 2008, Zellner 2008). Services and software are parts of a hybrid product, but the RE in product development mentions neither the integration of services, nor the parallel development of them. Interdisciplinary products and the integration of software development into the product development are handled only marginally.

## 2.4 RE in Software Engineering

RE is a discipline within software engineering “about defining precisely the problem that the software is to solve” (Cheng and Atlee 2007). We have selected the approach of Sommerville and Kotonya to show the main aspects of RE. This approach defines the phases of RE and takes into consideration the parallel and iterative execution of individual RE phases (see Figure 1).

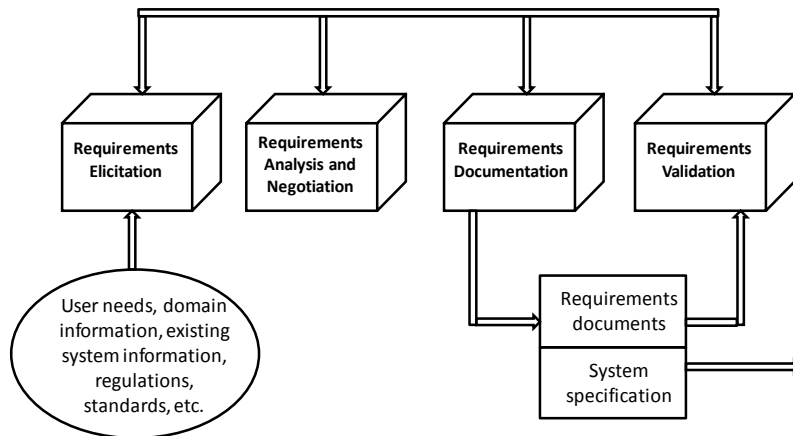


Figure 1 RE process according to Sommerville/Kotonya (1998)

The activities of traceability of requirements and change management are also parts of RE. The following sections discuss the phases of RE and the role of the stakeholders in the RE process.

**Requirements elicitation.** Requirements elicitation is the first phase in the RE process. This activity is defined as “understanding of the goals, objectives, and motives for building a proposed software system” (Cheng and Atlee 2007). It aims at identifying the problem that needs to be solved (Nuseibeh and Easterbrook 2000). For a successful elicitation, it is necessary to consider all different stakeholders (Somerville and Kotonya 1998). The most popular techniques are: interviews that can be defined as a discussion about the system in the development with different stakeholders, workshops based on a group discussion, scenarios showing interactions in the developing system, and observations and brainstorming (Aurum and Wohlin 2005, Pohl 2007, Somerville and Kotonya 1998). Prototyping can also be used to elicit requirements (Arnold et al. 2003).

**Requirements analysis and requirements negotiation.** In this phase the requirements are to be concretized. Afterwards the stakeholders negotiate on these requirements. The goal of the negotiation is to solve the conflicts between the requirements, to specify a set of consistent and complete requirements, and thereby to satisfy all stakeholders (Aurum and Wohlin 2005, Somerville and Kotonya 1998).

**Requirements documentation.** Documenting the requirements is a basis for other RE activities (Pohl 2007). The requirements and the changes of the requirements are to be documented carefully. The common art of documentation is the natural language documentation. Pohl (2007) suggests model based forms of requirements documentation, for example with UML.

**Requirements validation.** The process of validation means to ensure that “models and documentation accurately express the stakeholders’ needs” (Cheng and Atlee 2007). Boehm (1984) purports that validation should answer the question, “Am I building the right product?” The techniques applied for validation are reviews based on reading and analyzing the requirements, checklists, prototyping and walkthroughs (Pohl 2007, Somerville and Kotonya 1998).

**Change management and traceability.** Change management has to verify and evaluate changes of requirements and then to examine its impact for the system in development (Somerville and Kotonya 1998). Thus, change management has to guarantee that the proposed change is documented and analyzed, the costs for the implementation are checked, and the change can be realized. Another aspect

is traceability of requirements describing “the life of a requirement, in both a forwards and backwards direction” (Gotel and Finkelstein 1994).

We conclude that RE of software engineering is well elaborated, but not directly applicable to hybrid products. For example, hardware is seen as system context and therefore as unchangeable. The integration of services into the product is not considered.

## 2.5 RE in Service Engineering

Gill (2004) and Burr and Stephan (2006) define service engineering as follows: service engineering is the systematic development and organization of services by deploying engineering methods, practices and by using tools of the engineering design field. The focus of this paper lies in the use of appropriate methods and instruments.

In the literature there are some different views on service engineering:

- Burr and Stephan (2006) basically see service engineering as the process of developing services. The first step is to collect the ideas in a systematic and effective way. Afterwards the ideas are evaluated and the most auspicious ones selected and documented. Thereafter the requirements are elicited for which the needs and wants of all potential users have to be regarded. The last step is to design the service by defining the following information: technical goals, market goals, etc.
- Schmitz (2000) suggests that service engineering is handled in large parts by marketing divisions. According to him, RE for service engineering is a task that is carried out by qualitative marketing research. To elicit the requirements, the customer should imagine the service and should then express a hypothetical evaluation.
- Ramaswamy (1996) defines services as transaction processes. He separates the quality of a service into quality of service design and quality of service delivery. The service design consists of various steps. The step “Defining Design Attributes” realizes the RE in which the key-customers are identified and their expectations and requirements elicited and prioritized. It appears that RE for services is intended, but no precise methods are provided.
- A process model eliciting customer requirements during a “concept phase” is suggested by Schneider et al. (2006), but no methods are proposed for this activity.

Even though there are several process models for service engineering, they contain no applicable methods. Most approaches agree that it is necessary to elicit the requirements for the services and that the customer is the main source of these requirements. All in all, the role of RE in service engineering remains vague.

## 3 RESEARCH METHOD

In the literature review described above, we found that in the context of RE, hybrid products were not treated as a single unit. We identified several problems regarding the RE of hybrid products in different disciplines. To solve these problems, we conducted a series of semi-standardized expert interviews. The goal of these interviews was to capture current practices in RE in industry and to collect the requirements of an integrated RE for hybrid products. In the course of the study we interviewed fifteen experts in companies within the trade automotive, medical technology, consulting and system-integrators industry, who were involved in the design of hybrid products. These companies produced products consisting of parts that were typical for hybrid products. We perceived experts to be those employed in the field of RE or those who handled the requirements because of their position, such as project managers or business managers

We selected three premium manufacturers from the automotive industry and six companies from the top-25 IT-consulting and system-integrators in Germany ([http://www.luenendonk.de/it\\_beratung.php](http://www.luenendonk.de/it_beratung.php)) of the consulting and system-integrator industry. From the medical technology industry, we selected four companies in which we had contacts. Table 1 shows the characterization scheme according to (IfM 2002).

The interview partner selection relied on theoretical sampling, which is suitable for studying problems that are not understood or not fully understood (Glaser and Strauss 1967).

The interviews were carried out between June 2008 and October 2008. Three interviews were carried out by telephone, and twelve were face-to-face. Table 2 gives a summary of the positions held by the interviewees.

<i>Size</i>	<i>Sales volume 2007 (in million €).</i>	<i>Employees 2007</i>	<i>Number of companies</i>	<i>Number of interviews</i>
big	50+	500+	12	14
medium	1 – 50	10 – 499	1	1
small	up to 1	Less than 10	0	0

*Table 1 Company size & industry (according to (IfM 2002))*

<i>Interviewee</i>	<i>Position of the interviewee</i>	<i>Branch of trade</i>	<i>Type of the interview</i>
Alpha	Member of the Project management group	Automotive	Face-to-face
Beta	Responsible for consulting	Medical technology	Telephone
Gamma	Responsible for requirements engineering of IT	Automotive	Face-to-face
Delta	Responsible for functional requirements engineering	Automotive	Face-to-face
Epsilon	Member of department of Business Engineering, main focus at RE	Automotive	Face-to-face
Zeta	Responsible for Requirements & Usability Engineering	Automotive	Face-to-face
Eta	Responsible at the interface point to requirements engineering	Consulting/System-integrator	Face-to-face
Theta	Managing Director	Consulting/System-integrator	Face-to-face
Iota	Senior Manager Business Area Supply Chain Execution; focus at RE	Consulting/System-integrator	Telephone
Kappa	IT Management Consulting with the interface to RE	Consulting/System-integrator	Face-to-face
Lambda	Executive Partner	Consulting/System-integrator	Face-to-face
My	Principal Health Care, interface to requirements engineering	Consulting/System-integrator	Face-to-face
Ny	Project manager	Medical technology	Face-to-face
Xi	Project manager	Medical technology	Face-to-face
Omikron	Senior Manager Business Area Supply Chain Exec., interface to RE	Medical technology	Telephone

*Table 2 Companies*

The interview guideline was structured according to the phases of RE as defined in software engineering (Aurum and Wohlin 2005, Somerville and Kotonya 1998). In our analysis we paid attention to the activities of each phase and to the methods applied there. Further, we were interested in the cooperation and interdisciplinary work of the involved disciplines and the role of the customer for the RE process. Another aspect which furthers staying in connection with the RE and with the communication with the customer is prototyping. Davis (1992) posits that using a prototype for the understanding of a problem or a solution helps to improve communication between the customer and the developer. The companies were also asked about the role of the RE in the service development and the integration of services in the development process.



The developed interview guideline was split into the following subject areas: general information about the company and the role of the interviewee, general information about the companies' RE, all phases of RE (elicitation, documentation, analysis, negotiation, validation and verification), change management, prototyping, and integration of services (with a special focus on the composition of service- and product development).

The interviews were recorded when it was technically possible and only if the interview partners were in agreement. The records were then transcribed and analysed using Mayring's (2007) techniques.

## 4 FINDINGS

This section summarizes the main results of the interviews. We take a look at each phase of RE as defined in the previous sections. The RE process in general, prototyping and the integration of services are described in greater detail.

Requirements Engineering process: Thirteen (out of 15) of the interviewed partners have an iterative process for RE that relies basically on models suggested in the literature. Only 2 of the interviewed partners do not have an iterative RE process since they deal with maintenance projects and use a change-request process. A minority of companies have a continuous requirements management: they not only keep records of the change requests, but also keep the requirements documentation up-to-date.

In software engineering, the development is usually done in multiple releases. The first release realizes the basic functions. In the development of the second, learning-effects take place and additional functions are realized. By developing in incremental release, the risk of the overall project is minimized.

All companies see the customer as the main source of requirements. A customer can be an external client or an internal department of the same company. Most companies distinguish between internal requirements and laws/standards. In the field of medical technology, the companies rely heavily on market analysis to elicit requirements, a field in which laws and regulations are particularly important.

Two interviewees reported that existing systems were an important source of requirements and needed to be analyzed thoroughly. All companies distinguished between functional and non-functional requirements. Nine (out of 15) of the interviewees reported that in the majority of cases the changes concerned functional requirements. In contrast, only 4 (out of 15) considered the majority of changes to be in the non-functional area. Two (out of 15) were unable to give detailed statements about changes.

Requirements elicitation: All interviewees reported using workshops and interviews to elicit the requirements. Only one interviewee reported observing the users to elicit requirements. Two (out of 15) of the interview partners did not have an explicit elicitation phase because they received the prepared requirements from their customers. The prevalent problems during the elicitation were that the stakeholders did not express their requirements clearly and the different stakeholders had different goals regarding the system in development. A further problem was the different understanding of the requirements by the stakeholders and the developers. In many cases the customer has unrealistic visions regarding the time and costs of the development.

Requirements analysis: With respect to requirements analysis, 14 (out of 15) of the interview partners had a process model. Only one company had no analysis phase since they received sufficiently detailed requirements from their customers. Two interviewees used tools to support the analysis. Three interview partners prioritized the requirements according to a "must-have/should-have/nice-to-have" scheme. The priorities were assigned according to law restrictions, financial aspects and the importance of the requirement for the customer. According to the iterative development described earlier, it is also possible to postpone the requirements until a later release. Only one company did not prioritize the requirements.

**Requirements documentation:** All interview partners used office tools to document the requirements, and thus the requirements were documented in natural language. Most interview partners used templates that precisely defined the structure of the requirements. One interview partner used EPKs (Scheer 1997) to document the business processes. For documentations, special tools were also used: five (out of 15) of the interviewees used Doors, two (out of 15) used CaliberRM. Two (out of 15) had other tools supporting the RE, especially the documentation. Twelve (out of 15) interviewees reported using Office-tools, among others, for the documentation of requirements. Office-tools have the big-disadvantage of not supporting multi-user operations and not supporting version-control. These tools were thus not adequate for the requirements management in large interdisciplinary projects.

**Requirements negotiation:** All interview partners reported conflicts between requirements, the reason for the conflicts being that customers and contractors held different views on the developed product. The common methods of resolving the conflicts were negotiating and holding workshops. The following aspects needed to be considered when resolving conflicts: dates, costs, and performance if the requirements were to be realized. Only one interviewee stated that conflicts were impossible because he had a consistent set of requirements from his customer.

**Requirements validation** has the task of asserting that the developed solution conforms to the requirements. The decision that requirements needed to be realized was taken mostly by customers. The realizing company only gave recommendations. If the company saw that it was impossible to realize a requirement, the customer was consulted. In the area of medical technology, the validation is mandatory by law.

**Change management:** Most interview partners used the change-request process to manage changes of requirements. This process was used when new requirements were added and when existing requirements were changed. Customers often dictated how the change management process was to be done. The expenditures for new requirements and changes were fixed in advance. When deciding whether a change-request should be realized, costs factors and time factors needed to be considered.

**Prototyping:** Prototypes are predominantly used to communicate with customers. The main audience for prototypes was therefore the customer and other stakeholders. The most common form of prototypes were Mock-ups created on paper or with office-tools. Two interviewees also used software-prototypes. The decision as to whether prototypes were to be used depended on the cost-benefit ratio due to the high cost of the development of a prototype.

**Integration of services:** Most companies of our study offered services offered in combination with software or the implementation of the software as part of the service. Typical services were management consulting and IT consulting. Management consulting included process- and organisation consulting, project management, business process analyses. IT consulting can include conception and implementation of software, security assessments, rollout tests, architecture definition, infrastructure and network consulting. An important aspect is the quality assurance of the services that is done according to standards.

## 5 DISCUSSION

On the basis of the interviews, we identified the following demands on the RE for hybrid products.

*Coordinated RE process for the components of a hybrid product:* The RE of the different components of a hybrid product has to be coordinated. Only by doing this can the requirements for the solution as a whole be found, and only in this way can the product fulfil the customer requirements for the entire solution. Today, the RE and development of single components, both in literature and practice, is done separately (Leimeister and Glauner 2008). This empirical study revealed that the RE for products and services was done in parallel but without coordination. The development processes do not consider the changes of single parts. Only at the end of the development the single components are brought together.

*Support incremental development in releases:* In software engineering, incremental development in multiple releases is applied successfully. For hybrid products, a support of incremental development is necessary. Incremental development has the advantage that the fully integrated product is tested not only at the end of the development, but also during different stages of the development process so errors can be found early and the risk of the product is minimized.

*Improvement of the interdisciplinary work between the disciplines:* The single disciplines often have only the overview over their own area and have a distinctive technical mindset with specific terms. These differences in terms and notions lead to interdisciplinary communication difficulties. It is very important to come to a common understanding of the problem to be solved. Only in this way is it possible to realize a harmonized communication between the disciplines. Therefore, already during the RE a common set of terms have to be defined in a glossary. That glossary is a central repository which will be used by all disciplines. In this way, misunderstandings are excluded a priori.

*Stronger integration of the customer into the RE process:* The interviews revealed that the customer was not sufficiently integrated into the development process. The companies did not entirely realize that the customer and his wishes were pivotal for the success of a product. The analysis of the requirements was done without customer-involvement. Thus, the requirements negotiation confronts the customer with concepts and terms of the realization domain which are unknown to him. On account of this, we requested the customer to be integrated into further RE processes, such as analysis and negotiation. The communication with the customer during these phases needs to be done in a way that it bears the context and domain of the customer in mind. Prototypes have good potential for this by visualizing the main concepts of the system in development.

*Careful selection of stakeholders:* The requirements on the developing system have multiple sources, such as customers, users, standards and laws. These sources of requirements are called stakeholders. "A stakeholder is a person or organization who influences the system's requirements or who is impacted by that system" (Glinz and Wieringa 2007). The importance of selecting the right stakeholders is recognized by many authors (Pouloudi and Whitley 1997, Sharp et al. 1999). These authors agree that the selection of the right stakeholders remains a difficult area. A wrong selection of stakeholders or the selection of stakeholders which are not relevant for the system can influence the development negatively. At worst, phases such as requirements elicitation or negotiation have to be repeated. The selection of stakeholders is particularly important in the interdisciplinary context of hybrid products.

*Better tool-support of the requirements management:* Even though there are many tools for documenting and managing requirements, they are rarely used in practice. Instead, office tools (Excel, Word, etc.) are used.

*Better traceability and a version control:* In the context of interdisciplinary work, it is very important to have traceability and a version control system that offers the possibility of tracing which person changed a requirement and restoring old versions of the requirements documentation. The simultaneous work of different people on the requirements specification has to be supported. This so called multi-user capability is not realized by office tools. It therefore becomes necessary to introduce tools that are capable of coping with these demands. What is required is an analysis of whether tools on the market are sufficient or whether individual tools need to be developed.

*Improving requirements negotiation:* In highly interdisciplinary projects, the requirements negotiation phase is especially important because many different stakeholders with different backgrounds have to agree on a common set of requirements. This empirical study has shown that in practice, this phase is not supported by advanced methods. New approaches for the requirements negotiation using win-win methods and tool support by groupware (Boehm et al. 2001) could support this activity more effectively. What is required is an analysis of how these approaches could be adapted for hybrid products and introduced successfully.

*Consideration of changes when the development is complete:* Services should be provided after the development of the hybrid product is complete. The change of the product-lifecycle providing support has an impact on other aspects of hybrid products. The RE for hybrid products must be able to handle the requirements that emerge during the use of the product. Therefore, special methods and processes have to be developed in order to support further development of hybrid products.

*Thorough documentation of the source of the requirements:* The requirements on components of hybrid products are treated differently according to the discipline for which they are intended, and thus need to be documented for relevant disciplines.

## 6 OUTLOOK AND FUTURE STEPS

This study reports on 15 interviews carried out in industry in order to ascertain the state of practice of RE for hybrid products. This empirical study shows that RE for hybrid products is very important, but in practice the single components of hybrid products are developed independently, which is also true for the requirements. From these results, the requirements for the RE of hybrid products were derived. These requirements represent the main fields that have to be addressed in order to establish a comprehensive RE for hybrid products.

As a next step in research, we propose taking a closer look at the RE and development process of one single company. Based on our findings and this analysis, an integrated process for the RE of hybrid products should be developed. The single methods of the RE process also need to be adapted.

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