Development of User Information Products for Complex Technical Systems

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DEVELOPMENT OF USER INFORMATION PRODUCTS FOR COMPLEX TECHNICAL SYSTEMS

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ABSTRACT
Interaction with technological systems is an intrinsic part of daily life. The complexity of these man-made systems has reached unprecedented levels, and challenges the organizations that create and utilize them. At the same time they are often used in environments which imply very high requirements on safety, credibility, and reliability.

Users of a complex system needs support to access and maintain the utility and services the system-of-interest or product, is to provide. Alongside more traditional support like service and maintenance, customer support also includes comprehensive documentation. Despite tremendous development of documentation for complex products, there is still a problem for users to access and understand the information. Development methods for user information products therefore need to be evolved.

The purpose of this study is to explore and describe the development of stakeholder based information products for complex technical systems. The knowledge wanted is a model linking theory to real life applications, i.e. methodologies and tools that can support the development and continuous improvement of stakeholder based information products for complex technical systems. To fulfill the purpose a case study supported by a literature study has been made. The case study focused on a modern combat aircraft, which is considered as a highly complex system with stringent requirements on user information support. A development method for user information products was adapted and then applied and studied during the development of a demonstrator.

The result of the study may be described in two parts. The first part is the identification of methodologies and tools for elicitation of requirements and user information development, from the area of cognitive science and joint systems of man-machine, quality technology and formal requirements management. The second part is the validation of the suggested way of working, tested through the development of the demonstrator. Compared to traditional development work the suggested way of working supplies increased stakeholder focus and a more efficient communication between developers and stakeholders, as well as within the development team. It also facilitates and improves requirements management and the possibility to reduce business risks connected to misinterpretations and disagreements over specifications.
SAMMANFATTNING

Interaktion med tekniska system är en del av det dagliga livet. System byggda av människan har uppnått aldrig tidigare skådade nivåer av komplexitet, vilket ställer nya krav på de organisationer som utvecklar och tillverkar dem. Samtidigt används de ofta i miljöer, som ställer mycket höga krav på säkerhet, trovärdighet och tillförlitlighet.


Syftet med den aktuella studien är att utforska och beskriva utvecklingen av intressentbaserade informationsprodukter för komplexa tekniska system. Den kunskap som söks är en modell som kopplar ihop teori med praktisk tillämpning, dvs arbetssätt och verktyg som kan stödja utveckling och ständiga förbättringar av intressentbaserade informationsprodukter för komplexa tekniska system. För att uppfylla syftet har en fallstudie, stödd av en litteraturstudie, genomförts. Fallstudien fokuserar på ett modernt stridsflygplan, som är ett ytterst komplext system med stränga krav på användarinformation. En utvecklingsmetod för användarinformationsprodukter har anpassats och sedan tillämpats och studerats under utvecklingen av en demonstrator.

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“The good news is that technology can make us smart. In fact, it already has.”

“The bad news is that technology can make us stupid. The technology for creating things has far outstripped our understanding of them.”

Donald A. Norman
1 INTRODUCTION

This first chapter of the thesis serves as an introduction to the problem domain. It presents the purpose of the study and the research questions, supplies its theoretical foundation and outlines the contents of the thesis.

1.1 Complex Technical Systems

Interaction with technological systems is an intrinsic part of daily life, both in the professional and the domestic world. Though with the arrival of the goods of industrialized society, the aggregates of artifacts have become increasingly larger and more complex, and man has in different extent become dependent on information as support for this interaction. These large systems have also become more important to our society (Winner, 1977; Bijker et al., 1987; Ingelstam, 1996a). At the beginning of the 21st century it is hard, or even impossible, to think of life in the industrialized world without these complex systems. Large complex systems have a very wide range of application orientations, from autonomous machines to traffic and transportation, production systems (in terms of manufacturing and industrial process), and other diverse autonomous joint systems of man and machine (Tianfield, 2002). They are ubiquitous and can be found in domains like power distribution, mobile telephony, PC networks, credit card systems, Internet, vehicles, health care, transportation and many others. Especially the information technology (IT) parts of these systems are often large-scale and complex, heterogeneous and “high-tech”. The complexity of these man-made systems has reached unprecedented levels, with the following challenges for the organizations that create and utilize them (ISO/IEC-15288, 2002). At the same time they are used in environments like health care (Graber, 2004) and transportation (Wachs, 2002), which implies very high requirements on safety, credibility and reliability.

As user of a complex system (further referred to as the system-of-interest), man needs support, by user information, to access and maintain the utility and services the system-of-interest or product, is to provide. This support to customer and product has become central for satisfying customers of high-technology and engineering products and is regularly identified as playing a key role in surveys published in trade journals from different areas like the car industry, domestic appliances, aircraft and computing (Goffin, 2000).

The system supplying the necessary support during the operation and use of the system-of-interest, is an enabling system, i.e. “a system that complements a system-of-interest during its life cycle stages but not necessarily contributes
directly to its function during operating” (ISO/IEC-15288, 2002). What is referred to here is a system that supports the system-of-interest by providing maintenance and other support services to users and other stakeholders, with the purpose of assuring the proper and efficient function of the system-of-interest. According to Goffin (2000), the view of product support has broadened over the past decade and Kumar (2003) presents a scope of product support that, alongside more traditional service and maintenance, also includes comprehensive documentation.

The rapid technological growth in aircrafts and their sub systems is a vivid example of the development of such complex systems. Looking at the latest generation of combat aircraft one will find descriptions of an airborne, complex technical system, characterized by an infrastructure built on digital technology and fully integrated computer systems. For these aircrafts, with an estimated operational life for the airframe often spanning over more than thirty years, the building principle of system-of-systems supplies an immense potential for continuous improvement and development during the life cycle. (Lorell et al., 1995; Ahlgren et al., 1998; Sandberg & Strömberg, 1999).

Operational profiles change over time and aircraft also wear and deteriorate during their lifecycle. Due to this and since it is almost impossible in practice to design out maintenance completely; there is a need for a continuously improved support system. Maintenance as well as product and customer support is a necessity and has been defined by Markeset & Kumar (2003) as “the process that compensates for deficiencies in design, in terms of unreliability and quality of the output generated by the product.”. To secure the performance of a complex product at a reasonable cost, it is vital that the design of maintenance and product support concepts are done correctly right from the design phase (Blanchard, 1992; Markeset & Kumar, 2003). The character, scope and allocation of the support needed, are also influenced by the customers’ competencies, as well as the environment for the operation, organizational and cultural issues (Markeset & Kumar, 2003).

During the 1980s and 1990s the technological development has lead to an increased focus for Swedish combat aircraft on availability performance and life cycle cost. This has had impact on the accompanying requirements for increased competence development regarding reliability and maintainability at the organization developing the aircraft. It also requires development of the monitoring processes, of operational performance and support cost, to improve the work with continuous improvements during the operational life
cycle phase of the aircraft. (Kotonoya & Sommerville, 1998; Sandberg & Strömberg, 1999; Schmidt, 2001).

1.2 User Information in Complex Technical Systems

Obviously user information, as an integrated part of the support system, has to be designed and continuously improved so that it renders high usability and customer satisfaction. The design needs to consider both the consequences of new technology introduced in the system-of-interest and the management aspects of an ever-increasing quantity of information. These numerous products, which in daily life are referred to by terms such as publications, technical information, manuals, interactive or on-line help, instructions, checklists or other, are in this thesis gathered under the generic term user information or user information products.

Despite the fact that documentation for complex products has developed tremendously during the last decade, there is still a problem for users to access and understand the information (Markeset & Kumar, 2003). Development methodologies for user information products therefore need to be evolved and it is important to find ways and means to satisfy the needs and requirements on user information. For a complex system, such as a modern aircraft, the user information adds up to a huge amount of highly structured information. One example is the Swedish Saab JAS39 Gripen, for which the publication suite will total well over 100 binders and considerable more than 40 000 A4-pages of user information at a typical site of operation (i.e. squadron or airbase). This is for the aircraft alone. To that one must then add user information for other aircraft related systems and equipment such as Full Mission Simulators, Multi Mission Trainers, a number of weapons, reconnaissance systems, Mission Support System, maintenance ground systems of different kinds, just to mention some. Customers and users (operators, organizations and other stakeholders) of these platforms are confronted with operational and managerial challenges in terms of completely new architectures for computerized sub-systems, decision support, test & monitoring and the aforementioned massive amounts of accompanying information. Design have become more difficult to comprehend, an incomprehensibility that can be seen as one important factor of complexity (Törne, 1996).

Facing those kinds of challenges man has historically developed tools to aid the mind: paper, pencils, sundials, abacuses, computers, the examples are numerous. Norman (1993) calls those kinds of items cognitive artifacts. Norman divides them into physical and mental artifacts, depending on
whether their power mainly lies in their physical properties or the rules and information structure they propose and include in the latter group “procedures and routines, such as mnemonics for remembering or methods for performing tasks”.

Users of technical artifacts or systems in the 21st century frequently run into examples of these mental artifacts in the forms of different user information products. These products - containers of procedures and information - have traditionally been expected to support the customer in two ways, here defined by Weiss (1991):

- Instruction – teaching people how to run or operate the system
- Reference – giving people key facts they could not be expected to memorize

This approach worked well when the user was a well-educated professional (engineer, mathematician, computer scientist or similar), but is according to Weiss (1991) insufficient when the group of users is broadened. This reasoning is also applicable in the context of large, complex technological systems. Not that the average aircraft technician’s or pilot’s education is insufficient, on the contrary. But in spite of the fact that the average user is very knowledgeable, Norman (1993) argues that the rate by which technology and complexity has grown, outstrips that of education and understanding. These cognitive aspects of systems engineering are also discussed by Hollnagel (2002), who talks about a demand-capacity gap (or mismatch) between the increasing level of demanded human cognitive capacity from technological systems vs. the relatively unchanged human mind.

In terms of usability of user information this results among other things in strategic and structural errors in publications systems (Weiss, 1991). Weiss (1991) argues that this can be exemplified by users forced to search and use several sources of information for one task (and needing to ignore most information in the respective source) and to search and jump within sources. To meet these challenges Weiss (1991) also considers the necessity to add functionality and mentions:

- Orientation
- Guidance and motivation
- “Vertical” task-oriented user information (rather than “horizontal” descriptions of hardware structures and implementation).
These changing needs and requirements discussed above, on usability and functionality, raise new challenges for the development and improvement of user information artifacts or products. A challenge reinforced by an expected increase in the rate of changes and modifications of a highly computerized complex technical system like the Gripen aircraft (Lorell et al., 1995; Ahlgren et al., 1998).

These challenges highlight issues such as requirements (“What” information does the user need?) and knowledge, information, communication and availability (“How” is it to be supplied?). These issues also describe a chain of activities, or a process, starting with the design of the system and the user information and ending at the particular place in space and time were the users utilizes the information or knowledge support.

This brings forward new challenges to a support system to satisfy new needs and changing requirements on the user information. To be able to succeed, the manufacturer may attend to core values and concepts of customer-driven quality and design quality. It is of paramount importance to develop processes and methodologies that manage stakeholder requirements properly and that enable continuous improvements. To successfully turn requirements into product qualities, methodologies for formal outlining and structuring of requirements, needs and qualities demanded by users, can supply obvious advantages and this has been shown by, among others, Akao (1992), Herzwurm & Schockert (2003) and Barnett & Raja (1995). For a company developing aircraft systems and accompanying support systems, this includes actively seeking knowledge about the demands of the user as well as his or her capabilities. According to Pinet (2000), it is necessary to strive to integrate this knowledge in the design process, both of the actual airborne platform and its support system.

One of the reasons to approach the issue of models and methodologies for user information development systematically and scientifically is also the lack of research in the domain. Mårdsjö (1992) wrote that information design, or the process of developing technical information for users, was not yet established as a research area in its own right. Close to a decade later Jacobson (2000) writes about information design, that “at present, the theory is sketchy and the case studies are scarce".
1.3 Purpose of the study and research questions

The problems presented above coalesce into the issue of improving user information products as a vital part of the support for complex technical systems. This was condensed into a proposal used as the starting point for the research project (the research project is presented and defined in Section 2.1).

The purpose of the research presented in this thesis is to explore and describe the development of stakeholder based information products for complex technical systems, in order to contribute with knowledge to the area of quality technology applied in user information development. The knowledge wanted is a model linking theory to real life applications.

More specifically the aim is expressed in the following overarching research question:

1. **How may stakeholder based information products for complex technical systems be designed?**

Further on this research question is broken down into two, more detailed, research questions:

2. **What kind of methodologies and tools can support the development of stakeholder based information products for complex technical systems?**

3. **How can a way of working (a methodology making use of appropriate tools) that supports the development of stakeholder based information products for complex technical systems be adapted or constructed?**

1.4 Limitations

The study presented in this thesis is delimited to user information related to users of complex technical systems on an operative level. It focuses primarily on user information on the level of individuals. This approach implies a focus on a way of working for development of user information for complex technical systems concentrating on stakeholder requirements and not on an optimal methodology for information system development.

The concept of user information applied in this thesis does not include the supply of real time information to the operators of the technical system.
1.5 Disposition of the thesis

The disposition of the thesis is illustrated in Figure 1.

Figure 1. The disposition of the thesis.

Chapter 1 gives as an introduction to the problem domain. It presents the purpose of the study and the research questions, supplies its theoretical foundation and outlines the contents of the thesis.

Chapter 2 presents and discusses research background and participants, research strategy, methodologies and design, aspects of data collection and analysis, as well as issues about reliability and validity. Finally an overview of the research process is presented.

Chapter 3 presents and discusses the theoretical frame of reference comprising perspectives on complex technical systems, continuous improvements, user information systems, man-machine-information systems, user information products and methodologies and tools.

Chapter 4 presents the realization of the research process and the empirical material to the reader. The chapter describes the exploration and the iterative analysis of the development of a way of working, the supporting methodologies and tools, including the stakeholder approach and the concept of using a demonstrator as a part of the development strategy. These research activities were all performed in smaller PDSA-cycles within the overarching
PDSA-cycle of the research project (The PDSA-cycle is presented in Section 3.6).

**Chapter 5** presents the overarching results of the research project, which is the suggested way of working for development of user information product, and the demonstrator.

**Chapter 6** summarizes the findings of the research related to the stated purpose and research question. It will also discuss some aspects about reliability and validity.

**Chapter 7** discusses some additional aspects of the findings in the research project. It also presents some suggestions for further research.
2 RESEARCH METHODOLOGY AND APPROACHES

This chapter presents and discusses research background and participants, research strategy, methodologies and design, aspects of data collection and analysis, as well as issues about reliability and validity. Finally an overview of the research process is presented.

2.1 Research background and participants

The research in this study has its origin in a joint academic and industrial project within the Swedish National Aeronautics Research Program number 3, User Information and Usability in Complex Technical Systems (NFFP3-484, from now on referred to as the “NFFP-project”). The NFFP-project started in late 2001 and was finished in March 2004. The Swedish National Aeronautics Research Program is a joint civil and military research program aimed at supporting basic aeronautical research in Sweden.

The purpose of the NFFP-project was to explore and describe the development of stakeholder based information products for complex technical systems in general, and for JAS39 Gripen combat aircraft in particular, in order to contribute with knowledge to the area of user information development. The academic participant in the project has been Division of Quality & Environmental Management, Luleå University of Technology (LTU). The industry participants have been Saab Aerosystems Department for Customer and Product Support in Linköping (Saab) and Sörman Information & Media, Växjö (Sörman).

The knowledge wanted was a model linking theory to real life applications within the industry. Development of user information is an important process at Saab, as publications are a vital component of the support system for Gripen, together with supply, training, maintenance engineering, operational monitoring, engineering services, ground support equipment and logistic analysis (Saab-Aerosystems, 2004). The search for knowledge and improved development methodologies is therefore a vital part of the continuous improvement work at Saab. The project plan (Candell et al., 2002b) also comprised the development of a demonstrator, which could be described as a rudimentary user information product prototype, limited to the purpose of validating a suggested way of working and to supplying an example of how a modern user information product could be designed. The demonstrator may contain structured user information of different types, like for instance descriptions, instructions, checklists, schematics, forms and illustrated parts catalogs.
The Division of Quality & Environmental Management at LTU has contributed to the NFFP project and the thesis mainly through tutoring and guidance of the author as a PhD student at the Division of Quality & Environmental Management. The LTU representative has also monitored and reviewed the work and results of the NFFP project from an academic perspective, and supplied a node for knowledge exchange, cooperation and feedback with the academic community.

Saab - with its main operations focusing on defense, aviation and space – develops manufactures and delivers advanced products and services mainly for the defense market. As a part of Saab, Aerosystems is a major actor in the Swedish defense industry and manufacturer of the JAS39 Gripen combat aircraft. Aerosystems, with more than 1800 employees (Oct. 2003), focuses on the defense market with Gripen as the main product, and with further product areas such as unmanned aerial vehicles, tactical systems, pilot training, simulators and net-based defense. The importance of the aftermarket is stressed by the establishment of a separate Program Management responsible for running that part of the operations. The Saab Group has a total of approximately 13,300 employees and total annual sales in the region of SEK 17,000 million (Saab, 2004).

Sörman Information & Media is a provider of technical information solutions for advanced products and systems. They focus on specialist and business competence in after-sales information and have Swedish National Defense and Swedish industry as major customers. There are around 250 employees in the company (Oct. 2003). Part of the company that is now Sörman Information & Media AB, was for a period during 2000-2002 (which overlapped with the first year of the NFFP-project) a fully-own subsidiary of the Saab group. Sörman participated in the entire project. In their roles as system and software developers they were mainly to contribute to the development, and to apply the suggested way of working during the development of the demonstrator. They also performed different types of reviews and tests during the development and participated in the continuous improvement of the way of working.

The author of this thesis is employed at Saab Customer and Product Support and is connected to the NFFP project through his active participation as a PhD student and project leader. An absolute majority of the research within the NFFP project was carried out by the author in his role as a PhD student, except for the practical software development for the demonstrator, which was done by Sörman personnel.
The empirical data used in this thesis, is collected by the author within the NFFP project. The theoretical work in this thesis has been performed by the author within the NFFP project and as a PhD student at LTU. In practice this means that data and material have been exchanged between the project and this thesis in both directions. This integrated research is referred to as “the research project” in this thesis. The coordination of the NFFP project and the author’s PhD studies are based on the mutual ambition of the author, Saab and LTU to exchange knowledge and experience beyond the scope of the NFFP project both ways between Saab and LTU.

All research is based on some kind of previous knowledge and in this thesis a part of that pre-knowledge is the author’s professional background. The author has worked fifteen years in different positions within the area of maintenance and operation in the defense industry, of which the last seven years have been at Saab. In the cross-functional work performed in the NFFP project the author has mainly contributed with knowledge and experience within the area of maintenance and user information, as a former service and maintenance engineer, technical author and manager.

2.2 Purpose of the research work

Science can in a theoretical perspective be described as activities were researchers produce different kinds of knowledge (Patel & Davidson, 2003). This production of knowledge is to enable the creation of descriptions as well as models and theories, for different phenomena (Holmberg, 1987).

Most scientific studies can be classified according to which type of knowledge they aim to produce, usually exploratory, descriptive or explanatory. An exploratory study has the purpose of creating understanding of a particular problem area, and may be used when the existing knowledge of the area is limited. Descriptive studies are performed with the purpose of describing a certain phenomenon. Explanatory research consists of empirical tests of hypotheses about causal relationships between different phenomena. (Patel, 1987; Patel & Davidson, 2003).

As the purpose of this thesis is “to explore and describe a development methodology for user information in complex technical systems in order to contribute with knowledge to the area”, the purpose is both exploratory and descriptive. The exploration of the domain will generate knowledge to be used for improvement of user information development, thus being a part of the continuous improvement work at the participating companies and other interested parties. The descriptive approach has, among other properties, the
ability to communicate information about a more general phenomenon to different stakeholders, by placing the subject matter in a broader context (Yin, 1994). The descriptive approach supports a structured study of important aspects of a process for user information development that consider satisfaction of stakeholder needs as a central product quality.

2.3 Research approach

Looking at research as knowledge generation, Holmberg (1987) talks about the way of proofing or deduction, and the way of exploration or induction, as two alternative roads. Deduction has existing theory and concepts as its points of departure, which are tested, and delivers acceptance (or not) of the theory tested (Gummesson, 2000). Induction can be described as an approach based on empirical, or real-world data, where the results of the study according to Gummesson (2000) primarily generate new theory.

Gummesson (2000) also argues that “After the initial stages, all types of research become an iteration between the deductive and inductive.”. This is referred to as abductive research, which is to be seen as a combination of deduction and induction, rather than regarding it as a third approach. (Gummesson, 2000). Alvesson & Sköldberg (1994) describe abduction as a process originating in a deductive approach, where empirical material is collected based on a theoretical framework, followed by an inductive phase were theory is developed on the basis of the empirical data collected in the first phase. Though an important aspect of abduction, according to Alvesson & Sköldberg (1994), is that the process also encompass a gradual development of the area of empirical application, as well as an adjustment and refinement of the theory.

The research process in this thesis started parallel with the NFFP project. The approach is in the initial phase deductive due to the ambition to look into earlier research for a theoretical framework of knowledge about, and methodology for, development of user information products for complex technical systems. The purpose of this theoretical framework is to supply a base and guidance for the collection of empirical data, and the adaptation of a data analysis model used for the analysis of stakeholder requirements, and a way of working for development of user information products in complex technical systems.

The analysis model is then applied, exploring the empirical domain and data from the JAS39 Gripen complex technical system, drawing conclusions from a preliminary requirements elicitation. This knowledge is then used to evolve
and refine the continued empirical work during the development of a demonstrator product, in parallel to a final inductive phase, forming a more generalized way of working for development of user information products.

The aim of this study is not to produce a strictly formal theory and therefore it does not use a formal deduction. Instead the approach is more applied and aiming at theory that Gomm et al. (2000) describe as a “mental construct that orders the phenomena or inquiry into them”. This decision is also based on the purpose of this thesis to achieve “a model linking theory to real life applications”.

Successfully addressing the research questions in this thesis will:

- Supply normative conclusions on management of stakeholder requirements on user information products in the particular environment.
- Produce normative knowledge on the application of a way of working for stakeholder driven development of user information.

Research approaches utilizing numerical measurement during data collection as well as statistical processing and analysis, are often referred to as quantitative. Qualitative approaches include collection of “soft” data like interviews, and often verbal analysis of text material. (Patel & Davidson, 2003).

The type of data and information confronted in the empirical part of the study, are mostly of a qualitative nature. This, together with the fact that exploration of meaning and understanding of the studied process is of main interest, calls for a qualitative study approach.

2.4 Research strategy

The purpose of the research, as stated in the general research question, has an intrinsic vagueness due to the lack of previous research and deeper theoretical knowledge about the problem domain. A sound research strategy according to Yin (1994) for a first phase of the study is in such cases to increase knowledge by literature studies, and to build on existing theory from different domains to provide a theoretical basis for the following work. For this study this comprises suitable perspectives on the domain of user information (or information design, or technical information), focusing on existing research within, or connected, to this domain.
According to Yin (1994) the choice of research strategy is a choice of a way of collecting and analyzing empirical evidence, and different strategies have different pros and cons. Yin (1994) presents three conditions for the choice of research strategy:

- Type of research question
- The investigator’s extent of control over behavioral events
- Degree of focus on contemporary vs. historical events.

These conditions and their relation to five major research strategies are presented in Table 1.

Table 1. Relevant situations for different research strategy (Yin, 1994).

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Form of Research Question</th>
<th>Requires Control over Behavioral Events?</th>
<th>Focuses on Contemporary Events?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment</td>
<td>How, why</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Survey</td>
<td>Who, what, where, how many, how much</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Archival Analysis</td>
<td>Who, what, where, how many, how much</td>
<td>No</td>
<td>Yes/No</td>
</tr>
<tr>
<td>History</td>
<td>How, why</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Case Study</td>
<td>How, why</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

This is to be compared to the research questions in the thesis:

- How may stakeholder based information products for complex technical system be designed?
- What kind of methodologies and tools can support the development of stakeholder based information products for complex technical systems?
- How can a way of working (a methodology making use of appropriate tools) that supports the development of stakeholder based information products for complex technical systems be adapted or constructed?

As the research questions mainly focus on “How”, the control over behavioral events is estimated as limited and the study focuses on contemporary events, this perspective supports a decision to choose case studies as a preferred strategy. An advantage of a case study strategy is also
that it is able to support the potential needs of this study to contain elements that are exploratory as well as descriptive and explanatory (Yin, 1994).

The development of a demonstrator may also be regarded as a form of methodology or tool, and can be included in the “What”-question. “What”-questions of exploratory character may, according to Yin (1994), be addressed with any of the strategies applicable. The case study strategy is also supported by the literature study, which builds a theoretical framework of knowledge of the area.

A primary distinction in case study design is, according to Yin (1994), between single and multiple case designs. Under many circumstances the single-case study is an appropriate design, analogous to a single experiment and justifiable especially for the unusual or rare case and when the conduct of a multiple-case study requires means of resources and time beyond a single researcher. Single case study is in turn divided between holistic or embedded. The embedded case-study design includes more than one unit of analysis, i.e. when within a single-case, attention also is given to a sub-unit or subunits. Holistic designs, on the other hand, are said to be used if the case study examines only the global nature of a program or organization. (Yin, 1994).

The phenomenon that this study is to explore and describe is the design of stakeholder based information products for complex technical systems. This implies a unit of analysis, i.e. the level of inquiry that the study will focus on, that is a way of working for a team or organization to develop stakeholder based information products. This suggests, according to Yin (1994), a holistic case study design. Though the methodology and tools that support the development of stakeholder based information products for complex technical systems, including the stakeholder approach and the concept of using a demonstrator as a part of the development strategy, are also important for the understanding of the explored and described phenomena.

The discussion above leads towards a single-case embedded design. The comprehensive qualitative approach of the study focuses as much on the process and context of information product development, as on specific details. The main unit of analysis is the way of working for a team or organization to develop stakeholder based information products. The supporting methodologies and tools including the stakeholder approach and the concept of using a demonstrator as a part of the development strategy are sub-units of analysis.
2.5 Data collection

There exist several sources for data collection (or sources of evidence) that can be used in a case study according to Yin (1994), who presents six main sources of evidence: documentation, archival records, interviews, direct and participant observations and physical artifacts. All these ways with their strengths and weaknesses are presented in Table 2. However, the starting point for qualitative research is that individuals have common experiences and circumstances in an organization or profession, and that it is possible to identify common patterns and describe them. Still the situation of each individual is unique, and they can contribute with unique information and knowledge to the research (Patel, 1987).

The data connected to the units and sub-units of analysis, needed to address the purpose and research questions of this thesis, is mostly collected by the author for the purpose of the presented study. This is called primary data, to be compared with secondary data, which is data already collected by other people and then used by the researcher (Dahmström, 1996). According to Dahmström (1996) advantages with primary data is that relevance is likely to be higher than for secondary data, and that it is also easier for the researcher to evaluate primary data and assess its reliability (Dahmström, 1996).

The data collection for this study is encompassing direct as well as participant observations, action research and document studies, as methodologies for collecting data. These are consequences of the purpose of the project, the goals and research questions as well as the chosen research strategy and the circumstances for the data collection described earlier.

The border between participant observations and action research is not obvious. According to Patel (1987) action research is characterized by the strivings to reduce the distance between theoretical knowledge and practical application. Gummesson (2000) describes action research as involving participation with active intervention in processes of decision making, implementation and change.
**Table 2. Six sources of evidence: strengths and weaknesses (Yin, 1994).**

<table>
<thead>
<tr>
<th>Source of Evidence</th>
<th>Strengths</th>
<th>Weaknesses</th>
</tr>
</thead>
</table>
| Documentation      | - Stable – can be reviewed repeatedly  
 |                     - Unobtrusive – not created as a result of the case study  
 |                     - Exact – contains exact names, references, and details of an event  
 |                     - Broad coverage – long span of time, many events, and many settings  
 |                     - Retrievability – may be low  
 |                     - Biased selectivity, if collection is incomplete  
 |                     - Reporting bias – reflects (unknown) bias of author  
 |                     - Access – may be deliberately blocked  
| Archival Records   | - Same as above for documentation  
 |                     - Precise and quantitative  
 |                     - Same as above for documentation  
 |                     - Accessibility due to privacy reasons  
| Interviews         | - Targeted – focus directly on case study topic  
 |                     - Insightful – provide perceived causal inference  
 |                     - Bias due to poorly constructed questions  
 |                     - Response bias  
 |                     - Inaccuracies due to poor recall  
 |                     - Reflexivity – interviews give what interviewer wants to hear  
| Direct Observations| - Reality – cover events in real time  
 |                     - Contextual – cover context of event  
 |                     - Time-consuming  
 |                     - Selectivity – unless broad coverage  
 |                     - Reflexivity – events may proceed differently because they are being observed  
 |                     - Cost – hours needed by human observers  
| Participant-Observations | - Same as above for direct observations  
 |                     - Insightful into interpersonal behavior and motives  
 |                     - Same as above for direct observations  
 |                     - Bias due to investigator’s manipulation of events  
| Physical Artifacts | - Insightful into cultural features  
 |                     - Insightful into technical operations  
 |                     - Selectivity  
 |                     - Availability  

The origin of the study presented in this thesis is a defined problem of practical application, addressed partly through action research. On the flipside for direct and participant observations is that they are time consuming and selective, which might restrict the range of material studied (Yin, 1994). Such observations might also be biased due to the presence and participation of the researcher.

These disadvantages must be balanced against the need for access that Gummesson (2000) describes as essential to establish, when dealing with decision processes and processes of implementation. This access is also essential for the decision of the character, scope and allocation of the support needed for a system (Markeset & Kumar, 2003). Decisions about support also assumes knowledge about the environment for the operation, organizational and cultural issues, according to Markeset & Kumar (2003). Therefore access is important when one need to study the joint system of man and machine Studies which are to be done in real life, in its social and organizational context rather than outside it, which is stressed by Hoc et al. (1995) and Hutchins (1995). However, the close involvement of the researcher is also a potential source of bias of the observations. Actions to reduce this risk in this research project has, amongst other things, been to submit notes for review to participants in interviews and workshops as well as reviewing the material in the cross functional team.

Another potential impact of the bias of the action researcher is according to Gummesson (2000) the formulation of the research question and the selection of the domain for empirical study, as well as the origin and organization of the study or its purpose in a context of application. However, on the positive side Gummesson (2000) argues that the same bias that might influence in these aspects negatively, also contributes positively to the relevance of the research and its empirical grounding, i.e. a good connection to reality.

The author’s work on the study presented in this thesis was performed both in the role as an industry PhD. student and as a Saab employee. As such, access was granted to unique knowledge, experience and empirical material. The close involvement and the author’s multiple roles, or so called action research as described in the literature (Patel & Tibelius, 1987; Gummesson, 2000; Bryman, 2001), brings forward special aspects of the research process.

The roles and involvement of the author and the demonstrator development pointed towards direct and participant observations and action research, as the main ways of collecting data. According to Yin (1994) and Gummesson
these are methods for collecting information, which supply unique access to context and interpersonal behavior, as well as insight into cultural features and technical operations.

### 2.5.1 The Literature Study

The theory and hypotheses from the literature studies are to be analyzed in connection to their methodological consequences for the stated research question. This leads to a more detailed methodological approach. According to Bryman (2001), this approach should drive the following process of gathering empirical data.

The initial literature study for the research was aimed at collecting data about how stakeholder based information products for a complex technical system could be designed. As the study continued, focus moved towards methodologies and tools that could be adapted or constructed to support the development of stakeholder based information products for complex technical systems in general, and for the JAS39 Gripen in particular. This data was collected from different books, scientific journals and trade journals as well as databases.

Primary point of departure for the search for books was the Swedish National Library Data System (LIBRIS), which includes foreign titles (literature). Documents, journals, research articles and papers were searched for in scientific databases like, Science Citation Index, Academic Search Elite, Emerald, Aerospace CSA and American Institute of Aeronautics and Astronautics (AIAA).

Keywords were selected from pre-knowledge and a broad range of literature from the areas of user information (technical information), systems engineering, cognitive systems engineering and product development. This resulted in the following keywords: author/-ing, communication, complex, customer, design, development, driven, information, large, quality, requirement/-s, support, system, technical, usability, user and write/-ing. The searches, performed using the terms in different combinations, generated a vast number of hits from a large number of scientific disciplines, and these titles and bibliographic data were evaluated considering the purpose of the study. Thereafter followed a reduction of the vast material through an evaluation of the abstracts of the articles, and the final selection of literature was read in its entirety.
2.5.2 The Case Study
The direction towards an area for a case study is pointed out by the purpose of the research. The origin of the research problem is user information development for complex technical systems used in environments which demand very high requirements on safety, credibility, and are connected to the aerospace domain (Candell et al., 2002a).

Different case study objects were considered that might be suitable regarding relevance and validity, and there are obviously many complex and critical systems that may be of interest, like process or power industry systems and public transportation. The choice fell finally on the JAS39 Gripen system and its context, which fulfilled the requirements mentioned above and was regarded as representative example. This choice was also influenced by the requirements on practical access to different types of qualified data, as well as limitations of the project regarding time and resources, which excluded other aircraft candidates manufactured or operated abroad.

The empirical data from the JAS39 Gripen system was collected for the purpose of studying the application of the suggested way of working, that were adapted to support the development of stakeholder based information products for complex technical systems in general, and JAS39 Gripen in particular. This data was mainly collected in the forms of requirements, notes and other statements from workshops and interviews, but also from documents.

The application case is the development of an information product demonstrator within the research project. Stakeholders that supply the requirements on the demonstrator development were selected with respect to the purpose of the study and the given practical limitations of the research project. Personnel from Sörman, with the participation of the author, performed the development of the demonstrator.

2.6 Data Analysis
Yin describes the analysis of case study data as consisting of “examining, categorizing, tabulating, or otherwise recombining the evidence to address the initial propositions of the study” (Yin, 1994). Though there are few well defined, established and widely accepted rules for the analysis of qualitative data, unlike for the analysis of quantitative data (Yin, 1994; Bryman, 2001).

Miles & Huberman (1994) presents an overarching view on the analysis of qualitative data as the tasks of data reduction, data display and conclusion
drawing. The analysis in this thesis has adapted Miles & Hubermans view, and has mainly been performed as data reduction, interpretation of data, data display and conclusion drawing.

It is necessary, according to Yin (1994), that every investigation starts with a general analytic strategy as a guide for choices of what to analyze and why. A preferred strategy is to rely on the theoretical propositions that led to the case study (Yin, 1994). Although there are no such direct propositions in the purpose or primary research question of this thesis, the two more detailed research questions that matured in the light of the initial theoretical study, can be regarded as indirect propositions.

In order to identify the potential of the studied methodologies and tools to support the development of stakeholder based information products, and how they might be adapted or constructed, a preliminary requirements elicitation is performed after the initial literature study. The preliminary requirements elicitation comprises a sample of stakeholder requirements as well as a limited and small-scale application of the identified methodologies and tools “candidates”.

Requirements are documented, structured and analyzed using the so-called seven management tools (7MT), mainly in affinity diagrams and by formal matrix methodologies with adapted elements of Quality Function Deployment methodology (QFD); see Mizuno (1988) and Akao (1992). Data in the form of natural language regarding stakeholder and JAS39 system context, is mainly documented and analyzed through notes and narrative texts, as narrative knowledge is an attractive approach to connect theory and practice (Czarniawska, 1999).

The approach to perform analyses continuously during a qualitative study, is based the fact that it is often practical as it may supply knowledge and ideas for the development and improvement of the following work (Bryman, 2001; Patel & Davidson, 2003). The results and experiences from the preliminary requirements elicitation are used as feedback for the continuing literature study and a refined adaption of the suggested way of working.

The application of the suggested way of working is closely analyzed during, and after it’s their application in the process of developing the demonstrator, to establish its effect on the process and the result. The demonstrator development process comprises collection of additional stakeholder requirements and empirical material regarding system and user contexts, as
well as the actual development work applying and further adapting and refining the suggested way of working.

2.7 Reliability and validity

The conception of validity in qualitative research comprises the entire research process, and is to lesser extent confined to the process and technique of measuring as in quantitative studies. Qualitative research is driven by the ambition to discover phenomena, to interpret and understand the meaning of deeper values, as well as to describe perceptions or a culture. If, for instance, the researcher gets different answers asking a person the same question on different occasions, it is in a quantitative study regarded as a sign of low reliability. This is not necessarily the case in a qualitative study, as it may indicate that the person interviewed has changed his view of the matter, learnt something or that the circumstances of the issue have changed. To the qualitative researcher this change might very well supply additional information and become an asset, rather than a liability. The reliability should be viewed in the circumstances of each unique situation. From this perspective the concept of reliability is to be seen as converging with the concept of validity in qualitative studies. (Patel & Davidson, 2003).

It is also easily verified with rudimentary logic, that a test can be reliable without being valid, but not the other way around, i.e. reliability is necessary but not enough to assure the quality of research. To achieve that, the research also needs to be valid.

Yin (1994) discusses two types of validity applicable for exploratory and descriptive case studies. One is construct validity, which is to establish the correct operational measures for the concepts being studied. The use of multiple sources, establishing chains of evidence, as well as letting key informants review draft study reports during data collection and composition, are ways to increase construct validity. The other is external validity, which is about establishing the domain to which the study’s findings can be generalized. As case studies do not rely on statistical generalization (as for instance surveys do), the possibility to generalize depends on replication logic and the ability to analytically generalize from the results. (Yin, 1994).

The goal is to minimize bias and errors in the study. To keep a case study protocol during data collection and to maintain a structured filing system, are effective ways to increase reliability (Yin, 1994). Different actions are applied in the research project presented in this thesis to increase the reliability. One example is to improve the quality of the notes from the
workshops and the pilot interview, by presenting them to the participants for review; another is the use of a laptop for direct notations in the software handling the requirements matrices during the development working sessions; other actions are case study protocol and a structured filing system for all project documentation and data files.

The reliability and validity of the work performed within the research project is also continuously reviewed. The review is both internal by the cross functional team and by the LTU representative, and external through regular issuing of project progress reports to NFFP as well as through the continuous follow up by a NFFP supervisor appointed at the Swedish Defense Materiel Administration. At the end of the project the research project and the results are also reviewed by independent reviewers from LTU, Saab and Sörman.

2.8 The research process
The research process and its main activities are presented in Figure 2. The PDSA-cycle is presented in Section 3.6.

Plan
The research design is planned and documented in a detailed project plan. A literature study is performed, collecting data about important aspects of stakeholder based information products for a complex technical system, and how they could be designed. The theoretical study results in a concept for a suggested development methodology and supporting tools.

Do
Development methodology and tools are adapted into a way of working (a methodology making use of appropriate tools) and tested in a preliminary requirements elicitation where stakeholder requirements are elicited through the performance of a workshop. Data is also collected from the development process in terms of results and experiences, which is evaluated and supplies guidance for further literature studies and an evolved way of working for user information development. This suggested way of working is in a second iteration of the sub-cycle applied in the demonstrator development.
Study
Empirical results from the preliminary requirements elicitation, and then from the development way of working during the demonstrator development as well as design results and experiences, are continuously evaluated. The analysis results in different corrections and improvements that are introduced before, and continuously during, the demonstrator development.

Act
The way of working during the preliminary requirements elicitation and the demonstrator development is documented and described as it develops until the end of the project. The conclusive experiences and results, as the development of the demonstrator, are carefully analyzed and allowed to impact on the suggested way of working presented in this thesis. The research-process presented generates knowledge, as well as identifies, adapts explore and describe a way of working for development of user information products for complex technical systems that can contribute to improved stakeholder satisfaction.
3 THEORETICAL PERSPECTIVES

This third chapter presents and discusses the theoretical frame of reference comprising perspectives on complex technical systems, continuous improvements, user information systems, man-machine-information systems, user information products and methodologies and tools.

It is not the intention of this theoretical presentation to supply an inventory or complete overview of the respective theoretical domains utilized in the study.

3.1 Complex technical systems

Deming defines a man-made system as “a network of interdependent components that work together to try to accomplish the aim of the system”. According to Deming there must be an aim for the system, which is clear to everyone within it and the aim must include plans for the future. Management of a system is necessary and requires knowledge of the interrelationships between all the components in the system, as well as of the people working in it. (Deming, 1994).

The international standard ISO/IEC 15288: Systems Engineering - System life cycle processes, defines a system as ”a combination of interacting elements organized to achieve one or more stated purposes” (ISO/IEC-15288, 2002). In the case of this study these elements form a socio-technical system, i.e. a complex system of man and machine, which exists in a physical environment as well as in a social context of organization, application and praxis.

Rasmussen et al. (1990) also use the term system of interest and define a socio-technical system (or “system of work”) as “an ensemble of cooperating agents performing a purposive transformation by means of a complex of technical resources (tools, machinery, equipment, installations, etc.).”. According to Rasmussen et al. (1990), the work environment, defined as the part of the world that is being serviced by the system of work, is described in formats of:

- Agents: *Who* is doing it?
- Work domain: *What* is being done?
- Objectives and constraints. E.g. demands on product quality.
- Technical resources: By *means* of what is it being done?
- Customer: *Who* is being serviced?
Ingelstam (1996b) presents a general and aggregated view of a system as a number of objects, which in some way are related. Though for the term complex system to be applicable, it is not enough with trivial relations, they need to be extensive or complicated in some respect.

Blanchard (2001), in turn, supplies a more extensive definition:

A 'system' is a construct or collection of different elements that together produce results not obtainable by the elements alone. The elements, or parts, can include people, hardware, software, facilities, policies, and documents; that is, all things required to produce system-level results. The results include system-level qualities, properties, characteristics, functions, behavior, and performance. The value added by the system as a whole, beyond that contributed independently by the parts, is primarily created by the relationship among the parts; that is, how they are interconnected.

This is a definition of a complex system of man and machine that, by including issues like facilities and policies, also clearly brings the system context into consideration. The organization that uses the system in their operation is for the purpose of this study defined as the operator and the user as the one that in different roles utilizes or exploits the system at first hand, i.e. the end user of a finished product.

Blanchard’s definition points towards the original incitement for a system in terms of requirements and needs which can explain the importance of designing a system, what effect it will have for the customer as well as financial consequences. This business opportunity obviously implies the existence of both a supplier and a customer, who both can be regarded as the original stakeholders. They will enjoy, or suffer from the final result. This is the source where the original and most aggregated requirements are born, which should direct the development of a system as a product.

Boarders and limits for a system can from an analytical perspective be defined by boundaries or boundary conditions, that are the role or function of the system in a given context or environment (Rasmussen et al., 1990). The identification of the system-of-interest in the general environment requires both a description of the constituents of the system, as well as the coupling to the environment, according to Rasmussen et al. (1990; 1994). Though according to Törne (1996) it might be necessary to use abstraction and decomposition to understand a complex system. This means that information or a specific feature that is unnecessary for the understanding is hidden, or
that details in the whole design are hidden in order to highlight a specific element.

Adding the dimension of time in the form of a life cycle perspective on systems and systems development helps to some extent to grasp the extensive scope of large complex technical systems. There are different approaches to the concept of life cycle perspectives, though they are often focusing on particular properties of the system during its lifetime, like technical reliability (O’Connor, 1991), logistics (Blanchard, 1992) or life-cycle cost and economic analysis (Fabrycky & Blanchard, 1991). A life cycle perspective also needs to address the importance of the support system and continuous improvements for a system-of-interest with a life expected to span three decades (Sandberg & Strömberg, 1999).

A more comprehensive and for this thesis more applicable, approach which connects to the perspective presented above, is supplied by the ISO/IEC standard Systems engineering – System life cycle processes, which establishes a common framework for describing the life cycle of man-made systems. Selected sets of the processes supplied by the standard can be applied throughout the life cycle for managing and performing the stages of a system's life cycle. This is to be accomplished by the involvement of all interested parties with the end goal of achieving customer satisfaction. (ISO/IEC-15288, 2002).

The ISO/IEC standard supplies a detailed separation of a system’s life cycle into several stages (ISO/IEC-15288, 2002) and there are four stages that are of particular interest for establishing a life cycle perspective on systems for this study:

- Development stage
- Production stage
- Utilization stage
- Support stage

The Development Stage is a detailed technical refinement of the system requirements and a design solution that transforms these into one or more feasible products that enable a service during the utilization stage. Operator interfaces are specified, analyzed, designed, tested and evaluated and the requirements on production, training and support facilities are defined. This stage should also ensure that the aspects of production, utilization and support and their enabling system’s requirements are integrated in the design, by involving all interested stakeholders. (ISO/IEC-15288, 2002).
The Production Stage begins with the approval to produce the system-of-interest and production may continue throughout the remainder of the system’s life cycle. During this stage the product may change and the enabling systems may need to be reconfigured in order to continue evolving a cost effective service from the stakeholder viewpoint. The production stage may overlap with the development, utilization and support stages. (ISO/IEC-15288, 2002)

The Utilization Stage starts when the system is installed and taken into use. The stage comprises the operation of the product to deliver the required services with continued operational and cost effectiveness and the stage ends when the system-of-interest is taken out of service. (ISO/IEC-15288, 2002)

The Support Stage begins with provisioning of maintenance, logistics and other support for the operation and use of the system-of-interest, although the planning for the stage begins in the preceding stages. The support stage ends with the retirement of the system-of-interest and termination of support services. The support stage includes monitoring the performance of the support system and services. This operational monitoring comprises identification, classification and reporting of anomalies, deficiencies and failures of the support system and services. Activities that may result from the identification and analysis of problems include maintenance as well as minor and major modification of the support system and services. (ISO/IEC-15288, 2002)

As discussed in the introduction of this thesis, users of a complex system need support to access and maintain the utility and services the system-of-interest or product, is to provide. The description of the support stage above illustrates the interaction between the system-of-interest and the enabling support system during the stage where the system-of-interest is operational. Each enabling system has a life cycle of its own and as a system in its own right, it may when suitable be treated as a system-of-interest. (ISO/IEC-15288, 2002)

3.2 Joint systems of man and machine

The definitions above establish a view of a joint complex technical system of man and machine that passes through different stages during its life cycle. This view brings forward a number of properties outside the system-of-interest. It also raises the issue about the characteristics of the interdependence between man and machine.
Hollnagel (1995) describes the joint system as “the unique combination of people and machines that is needed to carry out a given task or provide a specific function.”. As a consequence of that, Hollnagel also defines expertise not as “the individual mastery of discrete tasks, but as a quality that exists in the social context of praxis” (Hollnagel et al., 1995).

A consequence of these statements is that it is very difficult to draw a clear line between the performance of man and the performance of the machine, when discussing human interaction with technology in the form of a complex system. Research about poor human performance in terms of human errors, illuminates the problem of separating man and machine in a system. In his discussion of the so-called “new view of human error”, Dekker (2003) regards human error as a symptom of trouble deeper inside the system, rather than a shortcoming of an accused individual “who should have known better or tried harder”.

To facilitate the study of the human action in the joint complex technical system we need therefore to define to some extent the interaction between man and machine. The following assumptions are adapted from Rasmussen et al. (1990):

- Tasks or missions demand the user to make deliberate choices and decisions, that he or she takes in consideration goals and limitations as well as investigating (or being familiar with) the boundaries of acceptable performance.
- The joint system is thought of as evolutionary, i.e. it is to some extent self-organizing and adaptive.
- The joint system is goal directed and justified from the purposes it serves in a certain environment.
- There is a great diversity of behavioral patterns and a number of action alternatives.

This defines an interaction that can be thought of as a “space of possibilities”, see Figure 3.

The picture that evolves of man in a joint system is one that is something beyond a mere operator. As one that operates (from Latin operatus, opus - “to work”) to perform a function, the group of people envisaged is more limited than with the concept of a user (Merriam-Webster, 1993). A user is someone that uses or is the end user, the consumer of a finished product. As the systems definition adopted talks about people in general, it is more correct for
the purpose of this study to refer to the people in the joint system that utilize or exploit user information, as users. Though the user might very well in a given situation also be the one operating a system, i.e. the one ”who is in charge of controlling the system and who also has the responsibility for the system’s performance.” (Hollnagel et al., 1995). This also allows the aerospace term operator to be reserved for the organization (company, airline, air force, or other) that uses the system in their operation.

![Figure 3. Constraints of human behavior (Rasmussen et al., 1994).](image)

A consequence of the definition of the system, its context and the user, one ends up with the user being someone capable of producing an effect using different resources and whose action in turn is based on certain criteria and values.

One is often prone to think that we as humans are in complete control of the machines, but with complex systems it is practically impossible for either man or machine to achieve complete control over the other (Hollnagel et al., 1995). There are simply too many and too complex couplings and interactions to be covered by design for that to be feasible.

### 3.3 Continuous improvements

The approach of user information for complex technical systems used in this thesis - what information the user requires, how to produce it and how to
make it available to the user – is intimately connected to fundamental theory of quality technology. This approach comprises mainly theory about customer-focused development:

- Man as stakeholder
- System view: the joint system in its context
- Continuous improvements: the idea of adaption and evolution due to constantly changing goals
- Socio-technical system
- Context.

The ambition to continuously adapt and improve a system obviously requires knowledge about the overarching goals of the system, but also about what qualities that is desired by the stakeholders regarding user information support. The concept of quality has many interpretations and Deming presents a view that ”quality should be aimed at the needs of the customers, present and future” (Deming, 1986) and that “a product or a service possesses quality if it helps somebody and enjoys a good and sustainable market” (Deming, 1994). Crosby in turn defines product quality as “conformance to requirements” (Crosby, 1979). Mizuno (1988) puts forward yet another perspective, which focuses on product quality, when he uses Juran’s definition “fitness for use” (Juran, 1999). Though in addition to that Mizuno (1988) also stresses the importance of the characteristics which a product must posses if it is to be used in the intended manner, as the consumer buys the product’s usefulness rather than the product itself. All these views focus on the satisfaction of customer needs and expectations. This view is expanded by Bergman & Klefsjö (2003), who argue that quality of a product is not just to satisfy customer needs and expectations, but its ability to satisfy and preferably exceed them.

In a systems perspective this demand for quality is defined by customer needs and expectations on the output, i.e. products or services, from a system (by Rasmussen et. al (1990) defined as objectives). The view applied in the framework, supplied in the ISO/IEC Standard 15288 (2002), involves feedback from some kind of operational monitoring during the system-of-interests utilization stage, which is exploited to improve both the system-of-interest and the support system. As the systems studied in this thesis are socio-technical, changes are not only of a technical character but may also be induced by change of for instance operational profiles, organizational change and replacement of personnel or new legislation.
There are several dimensions of product quality for goods and some are according to Bergman & Klefsjö (2003):

- Reliability, measuring the availability performance in terms of how often problems occur and how serious they are.
- Safety, i.e. that the product does not cause damage to people or property.
- Maintainability, describing how easy it is to detect, isolate and correct problems.
- Performance that is important for the customer like speed, durability or size.

This approach is also applicable to services and some dimension of service quality (Zeithaml et al., 1990):

- Reliability, regarding the regularity of the performance of the service, likes for instance punctuality and precision concerning routines for information and invoicing.
- Trustworthiness, i.e. that the customer experiences the supplier as trustworthy.
- Availability, referring to the ease by which the customer can contact the supplier.
- Easy communication, regarding the supplier’s ability to communicate in a way that suits the customer.
- Environment or context, which is the physical surroundings, equipment etc. for the performance of the service.

To sum up, the quality of the output from a system is in many ways connected to the extent which the customer can trust the supplier. Viewed in the long life cycle perspective of a complex technical system it is most important that the suppliers of a system or product establish processes that enable a good understanding of the changing requirements of different stakeholders (Kotonoya & Sommerville, 1998; Herzwurm & Schockert, 2003). Successfully applying concepts of customer focus and system view will positively contribute to continuous improvements and the quality of the output generated by the system-of-interest, support system or product and in the end to customer satisfaction. However, the concept discussed above need to be practically applied.

Key words for successful product development are according to Bergman & Klefsjö (2003), requirements, concepts and improvement. This describes an
iterative product development model in three steps on different product levels, from product families, to products and sub-systems and down to (but not including) detailed design solutions. The requirement step implies the collection, analysis and transformation of customer needs and expectations into product requirements. The concept step implies a generation of several concepts that satisfy the product requirements. The last step, improvement, implies an improvement of the chosen concept through the use of systematic ways of working. (Bergman & Klefsjö, 2003).

The significance of requirements as a key driver, emerge clearly in the process described above. However there are different interpretations of the meaning of the word requirement. In some studies the word requirement is used almost as a synonym to specification. This is unfortunate, as this constrains the interest to technical or organizational system solutions. In ISO/IEC Standard 15288 it is pointed out that requirements are expressed in terms of needs, wants, desires, expectations and perceived constraints (ISO/IEC-15288, 2002). This allows a broader range of stakeholder requirements to be considered including, but not restrained to, the needs and requirements imposed by society, constraints imposed by a customer organization and the capabilities and limiting characteristics of operators.

Work with requirements contains the process of identifying, analyzing and documenting the requirements for a particular system, defined as Requirements Engineering (RE) and Requirements Management (RM) which is the management of that process as well as the information it generates. (Davis, 1993; Macaulay, 1996; Kotonoya & Sommerville, 1998).

3.4 User Information
The term user information refers in this thesis to a spectrum of information types that support the users in operational activities during different types of tasks, as well as knowledge focused information for education, training and other non-operative tasks. Today, this implies a very wide domain of information products such as descriptions, instructions, user manuals, on-line-help, check lists, illustrated spare parts catalogs and functional and wiring diagrams, among many others.

Technical user information can be approached as an interface between man and technology (Mårdsjö, 1992; Mårdsjö & Carlshamre, 2000) and it can thereby be seen as a part of the joint system of man and machine. As such it exists to great extent for the purpose of communicating intention or instruction about a technical system to humans. This implies that the author
or designer that develops a user information product have envisions about the connections between the purpose and properties of the information (in terms of message and media), the system-of-interest, as well as about the abilities of the human recipient. These envisions are likely to be based on a mix of experience and theoretical knowledge from different domains. To create a well-founded theoretical base for the study, this section investigates those concepts and theoretical domains, establishing applicable perspectives on information, systems and humans.

3.4.1 User information and information design

Within the joint system the application of user information in complex technical systems can be seen as a functionality that transfers intentions, solves problems or achieves certain goals. Communication of user information to users is thereby a means for goal fulfillment for the system. As an interface between humans and technology (Mårdsjö & Carlshamre, 2000), user information is vital for the performance of a complex technical system. The user needs to have a reasonable degree of understanding of how to get the machine or system to function (Hollnagel et al., 1995). User information and theoretical knowledge in whatever form, plays de facto an important role as an enabler or facilitator of understanding (Jonsson, 2001).

For that purpose user information also serves a vital function in communicating information from the designers of the system and the high level stakeholders, to those who are to operate and interact with it. Though today information design, or the process of developing technical information for users, is not yet an established knowledge domain (Mårdsjö, 1992). Instead one has to search wider for knowledge about concepts such as information, knowledge and communication, which are inherent in information design.

3.4.2 Information, knowledge and communication

Perspectives on user information that are of interest are cognition and understanding, which are closely related to the issue of communicating information and knowledge. The joint system’s perspective and the role of man as a user of machines, points towards a view of user information for the purpose of this study, as a tool for both information and knowledge communication. This approach to joint system implies that means, goals and the techniques to reach them are communicated between actors such as system designers, users other and stakeholders.

Knowledge in the classic sense to “know” is closely related to the ability to express the knowledge in words. Though to “know how”, for instance how to ride a bike, is a different matter (Ingelstam, 1996b). The proficiency to ride a
bike has little or nothing to do with the rider’s ability to describe the
differential equations describing the motion of the bike. The latter type of
knowledge is more likely to be communicated through written information
than the first. So if one by information primarily means structured data in the
form of text and pictures and by knowledge means both to “know” and to
“know how”, there is a difference.

By coupling the question of information and knowledge to types of human
interaction and control in a joint system, one can establish relations between
different levels of cognitive control and the types of user information they
require (knowledge based, rule based or skill based). This is important for the
ability to understand requirements on information and knowledge for
different system actors i.e. users, from a system-goal perspective. Table 3
presents different levels of cognitive control (Rasmussen et al., 1994). From
each level one can then develop the model and make couplings to different
information types, according to whatever user, responsibility, liability,
context and task that is to be analyzed.

Table 3 shows a distinct separation in respect of time, were the knowledge
and rule based modes of cognitive control have asynchronous temporal
characteristics, i.e. allow the user to refer to sources of non-synchronous-
information. This is a possibility denied or rendered much more difficult for
skill-based control and operation in ‘real time’. This is of help for the
building of a model for user information development, which most likely
should exclude handling information connected to skill-based cognitive
control.

Independent of whether the transfer of information or knowledge is through
the user information product, within the design team or between designers
and stakeholders, the question also contains the component of
communication. Etymologically it is from Latin communicatus, to impart,
participate, to share (Merriam-Webster, 1993). In more common language,
though, one often refers to the actual process of sharing, or communicating
with the purpose of transferring for example a message.
Table 3. Levels of cognitive control mode (Rasmussen et al., 1994).

<table>
<thead>
<tr>
<th>Mode of cognitive control</th>
<th>Mental functions</th>
<th>Temporal characteristics</th>
<th>Related to real world</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge based</td>
<td>Planning in terms of Functional reasoning by Means of symbolic model</td>
<td>Achronic, that is temporal scale is not maintained in causal reasoning</td>
<td>As can be</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rule based</td>
<td>Planning in terms of recall of past and rehearsal of future, predicted scenarios</td>
<td>Diachronic, that is temporal scale is maintained but not synchronized</td>
<td>As has been and may be</td>
</tr>
<tr>
<td></td>
<td>Attention on cue classification and choice of action alternatives</td>
<td>Synchronic, that is operation in the actual time slot, but not synchronous</td>
<td>As is</td>
</tr>
<tr>
<td>Skill based</td>
<td>Data driven chaining of sub-routines with interrupt to conscious, rule-based choice in case of ambiguity or deviation from current state of the internal world mode</td>
<td>Synchronous with real world, operation in ‘real time’</td>
<td>As is</td>
</tr>
</tbody>
</table>

The domain of communication studies can very roughly be divided in two main schools, one that sees communication as the transfer of messages and the other sees it as creation and exchange of meaning (Fiske, 1982). The former has its main groundings in Shannon and Weaver’s model of communication (Shannon, 1948). This is basically a linear model that focuses on the channel and the media for transmission, how senders and receivers encode and decode and on efficiency and accuracy. See Figure 4.

![Figure 4. Shannon and Weaver’s model of communication (Fiske, 1982).](image-url)
The second school sees communication as the creation and exchange of meaning and is concerned with the role of the message or text in a socio-cultural context (Fiske, 1982). This comprises the use of semiotics (the science of signs and meanings) as the main methodology of study. The human receiving the message is not thought of only as a receiver but as an active part in the communication process, influenced by environment and culture. This concept supports the previous presented approach of joint systems and cognition “in the wild”, i.e. cognitive activity as an activity in a context often distributed across multiple agents rather than isolated in a single individual (Hutchins, 1995).

3.4.3 Applied knowledge - competence and development of expertise

To work with technology or machines we need to be practical experts rather than theoretical (Hollnagel et al., 1995). A usable definition of expertise could be tailored as the availability of operational knowledge, acquired through a prolonged experience with the system strongly linked to action goals and the available resources (Hollnagel et al., 1995). In the case of aerospace system it is also founded on formal education and training as well as on experience of the actual system. Though there are models addressing the differences in behavior between experts and novices, they lack specifications on the development and formalization of expertise in complex and rich domains (Kjaer-Hansen, 1995) and are therefore of little help to this study.

However, the fact that technical user information exists, is an example of an assumption that a purpose, intention or an instruction, can be separated from the physical action that implements the instruction. Information about an action is possible to handle separately outside the knowledge domain of the original context, where the action takes or took place. This implies that the separately handled information (a sort of expertise) can be put in an object, i.e. a product.

Another consequence of this separation is that a set of (dysfunctional) instructions might not necessarily be able to transfer purposes or intentions (Cooley, 2000). From this point of view a important part of designing user information products and the trade (or art) of user information, is very much about being proficient in interpreting or decoding contexts as well as in assessing, selecting and designing the information. This again highlights the importance of a methodology capable of effective handling of contextual requirements and needs.
3.4.4 Technical information
In general, the product development process is of great importance for both production and usage cost, as well as for a number of quality aspects about a product (Bergman & Klefsjö, 2003). This is also applicable to user information for large systems, in this respect a product among others. An important part of this process is the ability to effectively manage requirements, not least from an economic point of view (Karlsson, 1995). User information has an impact on a number of different users and stakeholders and several of them have their own requirements. The following sections deal with the fact that there may be a wide variety of actors that are stakeholders.

A consequence of choosing the system and cognitive perspective above is also that (with absence of other forcing circumstances) the choice of media for the transfer of information will be a secondary issue. Design of information for users is primarily an issue about content and meaning and should according to Jacobson (Jacobson, 2000), not primarily take off in discussions about media or technology for the transfer of the message. However, studies by Sonesson (2000) and Jernbäcker (2003) discuss the advantages of utilizing small computers compared to traditional print, to supply user information for operative technical military personal. Similar experiences are presented by Drury (2000), whose study showed that a computer-based system of work cards for aircraft inspection was a significant improvement on the original paper-based solution.

In the end aspects of both content and technology need to be taken care of as the process of supplying user information can be described as a chain of functions, starting at the design of the actual technical system and ending at that time and place where the users need support. Throughout the stages in this process large numbers of requirements of all kinds need to be collected, managed and implemented into the product, to be able to satisfy the needs of the different users at the end.

3.5 User information products
This section investigates theory about products in general and particularly user information products, in the perspectives of requirements and development.

3.5.1 Requirements for user information development
The development of technology and the increasing complexity of technological systems gives birth to new and higher requirements on user
information (Horn, 2000). This implies that traditional reactive and analytical methodologies for quality assurance are no longer sufficient. New and more rigorous requirements will most likely lead to the development of new functionality and new information products. For this purpose the need arises for proactive approaches for handling requirements and quality assurance, methodologies that develop the collection and understanding of requirements and demands from users and other stakeholders.

Seen from a systems perspective, system design could be described as an issue of envisioning or predicting, “To design is to speculate about the impact of the object-to-be-realized as a source of change in a field of practice”, Hollnagel (2002). This impact might be formulated in the form of different design aspect as:

- Usability
- Efficiency
- Safety
- Maintainability
- Co-operation (enhancing communication)
- Controllability
- Learning

However a design criterion like “good human-machine-interaction” (HMI) is not a goal or a purpose in its own right. The primary (design) goal must always be that the joint system of human and machine will be able to fulfill its goal or purpose. Therefore design criteria must be based on requirements that reflect real user needs of for instance HMI, rather than details in a man-machine-interface (MMI). Primarily it might be assumed that the design work should have its point of departure in the goals for the system and what means these might implicate, rather than to focus on activities were those goals and ends are implicit (Hollnagel, 2002). Goals and ends are questions about “why” and means about “what” and “how”. This gives a point of departure in terms of a systems description and requirements that is cognitive rather than physical.

System stakeholders are humans or organizations, affected by the system and who have more or less obvious influence over the system requirements. Among stakeholders are users, operative management, personal involved in product development and product support, as well as authorities and external organizations (Kotonoya & Sommerville, 1998). It is necessary to identify the important stakeholders and their requirements, not least to be able to
explore actual or potential requirements conflicts. In such cases the conflicts need to be thoroughly analyzed and accounted for.

Both RE and RM activities utilize a number of methodologies and tools in the different steps of the process such as (Davis, 1993; Macaulay, 1996; Kotoyona & Sommerville, 1998):

- Requirements identification
- Requirements analysis
- Requirements documentation

Hickey & Davis (2004), define requirements elicitation as “learning, uncovering, extracting, surfacing, or discovering needs of customers, users and other potential stakeholders.”. Requirements elicitation can therefore utilize several different methodologies and tools:

- Abstraction
- Brainstorming
- Interviews
- Reuse of earlier requirements
- User workshops

Requirements analysis comprises clarification and prioritization of requirements. This is a work intensive sub-process, requiring thorough experience and judgment from the participants. Tools, which facilitate a structured and systematic approach, are for instance checklists and interaction matrices, used to map overlapping and conflicting requirements. These types of problems need to be handled by clarification and possibly some compromise solution.

Work with clarification of requirements and identification of interactions might also be systemized with the help of methodologies such as Quality Function Deployment (QFD), presented later in this thesis (see Section 3.6).

Requirements documentation highlights questions about what needs to be required regarding the formulation and content of the requirements. Work with documentation highlights the paramount importance of a completed set of requirements with the following characteristics (ANSI/IEEE-STD-830, 1984):
• Correct: The requirement shall state something that the system shall meet.
• Unambiguous: The requirement shall have only one interpretation. As a minimum, this requires that each characteristic of the final system be described using a single unique term.
• Complete: The requirement shall be both determined and significant.
• Consistent: The requirement shall not conflict with other requirements.
• Ranked for Importance and/or Stability: The requirement shall be ranked for importance and/or stability if it has an identifier to indicate its importance or stability.
• Verifiable: The requirement shall have some cost-effective methodology with which a human or machine can check that the system meets the requirement.
• Modifiable: The requirement shall be possible to change easily, completely and consistently without affecting the structure and style of the requirement specification.
• Traceable: The requirement shall have a clear development from its origin to its furthest development.

Although often hard to distinguish, software requirements are also regularly divided into functional or non-functional requirements. Functional requirements aim to describe the functions of the software and the non-functional requirements aim to describe the remaining and required aspects related to the system and its use. (Karlsson, 1998).

For the management of requirements documentation different tools might be helpful, such as a requirements database. The required sophistication of such tools depends among other things on the amount of requirements and how dynamic the requirements management is expected to become. The management of the process and the documentation produced is especially important in a dynamic development environment. (Söderholm, 2003).

During the requirements analysis and documentation it is important to integrate the handling of stakeholder requirements and the specification of system properties. Unfortunately, it is not uncommon with a considerable amount of overlapping work, due to the separation between user and system requirements. This divergence creates confusion and might also lead to duplication of the work with requirements verification. Instead one should consider operational goals and requirements superior to both stakeholder requirements and systems specifications (Alexander, 2002).
3.5.2 Products

The introduction of requirements, system and product qualities, leads the discussion closer to the concept of products and a need to define it in connection to the presented view on systems and the process of product development.

The word product is often associated with the physical result of a process or action in terms of tangible goods. Though broadly defined a product may also be the output from a purely intellectual process in the form of an immaterial asset such as an idea, consist of a service or a mix of such entities.

Kotler (1997) supplies input for the understanding of what a product is:

”A product is anything that can be offered to satisfy a need or a want. Occasionally we will use other terms for product as offering or solution”
“A product consists of as many as three components: physical good(s), service(s), and idea(s).“
“The importance of physical products lies not so much in owning them as in obtaining the services they render ... Thus physical products are really vehicles that delivers services to us.”.

A similar view exists within the area of quality technology, here represented by Mizuno (1988): “the consumer buys the product’s usefulness rather than the product itself.”

The views presented above raises soft aspects of the product concept, focusing on services, utility and value. A product within the framework of this study should be regarded as physical objects, services, ideas, results or a defined combination thereof, offering utility and value.

Fabrycky & Blanchard (1991) and Mizuno (1988) converge in the idea of utility defined by the products ability to satisfy the customer needs that was its “raison d'être”. Through this it is possible to connect the definition of a product and its value to the concept of product qualities. According to Shewhart (1931), the concept of quality is about the ability to satisfy human needs by the production of products, with characteristics and attributes that fulfill those needs.

Shewhart describes the quality of an object in different aspects and he refers to its etymological origin in the Latin word “qualitas - of what kind”. A central wording as he also express the quality of an object as ”something” so
integrated in the object that one can not change this "something" without changing the object. However, the concept of quality is also described as a more traditional attribute of some sort, or a quantitative value. (Shewart, 1980 (1931)).

Hence one can argue that it is, at least in theory, possible for an individual customer to assign a value to a parameter or variable, which describes the monetary value of the product. This opens up the possibility, if needed, to connect the issues about utility and value of user information, to economic concepts and perspectives. A note for this discussion is that the value a customer might attach to a product sometimes has little or no connection to the price of the product.

In the context of this study it might also be of interest to pay attention to another division of products. If a product primarily aims to directly satisfy the needs of the customer, it is often called consumer goods. But if it satisfies the customer indirectly, as a part of a production or development process, it may be called producer, industrial or investment goods (Fabrycky & Blanchard, 1991; Kotler, 1997). In the first case the customer (buyer) and the user is the same person, but in the case of the producer goods they are often different individuals and stakeholders and thereby introduces more than one perspective on the product. These are different cases, which may very well lead to different processes for elicitation of requirements and the design of the product.

Though customer’s or user’s concepts of products on a high level may be deceptive references for product development, as different stakeholders see the product from totally different perspectives. The one interested in what the product does, may see performance and technical function as most important. On the other hand someone who looks at what the product is, may primarily be forming his or her opinion on physical attributes and so on (Clark & Fujimoto, 1991).

The communication around and about the product should, if possible, rather have its starting point in the stated requirements and needs of the stakeholders, as well as the ones unexpressed (basic needs) and latent or unknown (see Figure 5). This requires a methodology supplying comprehensive support both for eliciting requirements and needs as well as for product development.
3.5.3 Product development

A significant part of the life cycle cost (LCC) for a given system is committed through decisions made as early as in the conceptual or preliminary design of the system. According to Fabrycky & Blanchard (1991) this part could reach the magnitude of two thirds of the total LCC, see Figure 6.

It is therefore most important that the methodology for product development of a system contributes to minimize the number of changes after the initial design stages. To achieve this, the system should be developed step by step through transformations emanating from the stakeholder requirements, which are gradually clarified and realized before finally ending up in a finished system product.
User information can, from a product perspective, be seen as a so-called multi-component product, partly consisting of services. Bergman & Klefsjö (2003) describe services as different from goods, as services can be said to be produced at the same time that they are “consumed” or create value for the customer. According to Friedrichs Grängsjö (2001) a multi-component product is characterized among other things, by the fact that the consumption is in some way done in interaction with the supplier. That makes the customer a part of the production process and hence several actors might influence the customer’s perception of the service product.

This (above and beyond the fact earlier discussed concerning user information products, that the customer and user not necessarily are the same individual) puts forward demands on models and methodologies for this kind of product development, that they can handle several different kinds of stakeholders and have the potential to support requirements prioritization.
3.6 Quality management - methodologies and tools

As the way of working for development of user information products in this study almost exclusively focuses on the collection, structuring and analysis of verbal information, focus will be on methodologies and tools supporting these types of activities.

To address the challenge of quality many modern organizations look upon quality issues as an integrated part of their operations. This approach, often called Total Quality Management (TQM), means a continuous striving to satisfy and preferably exceed, customer needs and expectations. It also includes that this should be done to the lowest possible cost by the application of continuous improvements, everybody’s commitment and with focus on the organization’s processes. (Bergman & Klefsjö, 2003).

From this aggregated perspective quality management can be regarded as a management system aiming at increased customer satisfaction. TQM as a management system is in turn built on values, methodologies and tools, see Figure 7 (Hellsten & Klefsjö, 2000).

![Figure 7. Total Quality Management seen as a management system consisting of core values, methodologies and tools. (Hellsten & Klefsjö, 2000).](image)

Values are an important part as they are the basis of the culture of the organization and also the basis of goals set by the organization (Hellsten &
Klefsjö, 2000). Core values which should be the basis for the quality culture are: focus on customers and processes, base decisions on fact, let everybody be committed, improve continuously and committed leadership. (Bergman & Klefsjö, 2003)

Systems thinking is another central concept discussed in connection to TQM, described as the ability to see the different processes in the organization in their entirety (Bergman & Klefsjö, 2003). System thinking focuses on interrelationships and patterns of change, instead of static snapshots. This is a set of general principles that have been distilled during the twentieth century, spanning fields such as social sciences, engineering and management (Senge, 1990). Systems thinking is important for the work with continuous improvements, as the latter can have great impact on balances between product development and production processes according to Bergman & Klefsjö (2003). System thinking is also explicitly discussed by Deming (1994) as a vital part of his cycle for continuous improvements, presented as the Shewhart cycle for learning and improvement, the PDSA-cycle. See Figure 8.

Figure 8. Cycle for improvement and learning. Figure from Deming (1994).

The practice of user information design for complex technical systems exists to great extent within a context of a continuously changing system-of-interest and support system, as discussed earlier. Improvements, modifications and new development of these systems often have to pay attention to changing
stakeholder requirements and needs, legacy issues and technology. This view of changes in complex technical systems fits very well into the concept of TQM and continuous improvement.

Methodologies are ways of working in the organization to reach the goals. Examples of methodologies are Quality Function Deployment (QFD), Design of Experiments (DoE) and Self-Assessment. Tools are in turn concrete and well-defined elements that can support an organization’s way of working. Sometimes tools may have a statistical basis, to support decision-making or facilitate the analysis of data. Other tools are mainly used to collect structure and analyze verbal information. Examples of tools that support the methodologies mentioned above are the House of Quality (HoQ), factorial design sheets, FMEA-sheets and Fault Trees and the seven management tools. (Hellsten & Klefsjö, 2000).

The principal methodologies, useful for managing requirements in the context of complex systems, are Quality Function Deployment, abbreviated QFD, (Akao, 1992; Cristiano et al., 2001; Govers, 2001; Akao & Mazur, 2003), Value Analysis (Elias, 1998; Kermode et al., 2000), Soft Systems Methodology (Checkland, 1999; Probert, 1999) and combinations thereof (Schmidt, 1997; Dearden & Howard, 1998; Ho et al., 2000; da Silva et al., 2004).

Another methodology is Value Analysis, described by Kermode et al. (2000) as aiming at identifying, quantifying and rectifying weaknesses in products and processes by providing a set of functions at a minimum cost. Within value analysis, the so-called "job plan" is a process implementing the concept. It is linked to several other methodologies and tools, commonly in use in product and process development.

According to Checkland (1999), cited by Bergvall-Kåreborn (2002), Soft Systems Methodology uses “models of human activity systems to explore with the actors in a real-world problem situation their purposeful actions which accommodate different actors’ perceptions, judgments and values". Within Soft Systems Methodology, several precise methodologies and tools have been developed, e.g. CATWOE (Smyth & Checkland, 1976) and PQR (Checkland, 1999).

CATWOE stands for Customers, Actors, Transformations, "Weltanschauung" (“world view”), Owners and Environmental constraints.
PQR refers to "Do P by Q in order to contribute to achieving R" and the related answers to the questions "What to do (P), How to do it (Q) and Why do it (R)".

Attempts of combining QFD with other methodologies have resulted in adaptations of QFD, making use of tools from the supporting methodologies. QFD is often mentioned as a linked or enabling methodology in the description of competing methodologies. These facts support the choice of QFD as the primary methodology to be used in the analysis and management of user information requirements.

3.6.1 QFD – The methodology

Yoji Akao (1992) defines QFD as "a method for developing a design quality aimed at satisfying the consumer and then translating the consumer's demands into design targets and major quality assurance points to be used throughout the production phase".

Quality Function Deployment enables transfer of requirements to the design process through matrix diagrams (see Section 3.6.2). By doing so the original needs and requirements of the customer ("what") is systematically transformed into product qualities ("how") through a controlled and traceable process (Akao, 1992). See Figure 9.

![Figure 9. Matrix diagram, development of requirements to product qualities. Figure inspired by Akao (Akao, 1992).](image-url)
Characteristics of QFD are:

- Stakeholder and customer focus.
- Cross-functional work.
- A structured methodology of working, with system level analysis.
- Clear and distinct documentation, enabling traceability.

In essence it is about translating the “word-of-the-customer” to the “word-of-the-company” and QFD enables the collection of the “word-of-the-customer” with reference to a certain product (Schütte, 2002). It is of great importance that this methodology is used to describe how a system is developed by stepwise transformations through a number of models or representations. The first model or representation consists of the requirements of external stakeholders. This representation is then transformed in a suitable number of steps, in which successive clarifications and realizations are introduced. The final step results in a finished tested and approved system product, for instance a physical product, software or a service.

QFD also enables a systematic communication between stakeholders and design team (Karlsson, 1998) and is thereby useful both for the specification and development of a product (physical goods as well as services). A clear communication supports and enhances both the handling of functional system qualities, i.e. such that supply directly observable results, as well as non-functional qualities, i.e. qualities supplying only indirectly observable results.

The use of QFD for requirements management and development of user information shows similarities with its application in software development. There are several similar problems in both these disciplines regarding management of requirements and quality assurance. Requirements are often based on soft or fuzzy ideas about “user friendliness” or “efficiency” for both software and user information.

To routinely collect user requirements through a bottom-up-process (as opposed to a top-down, goal-means–analysis) tends to produce long lists of functionality and performance requirements. This will still leave the problem of identifying, quantifying and measuring more aggregated demands and needs more or less unattended. It is also necessary to prioritize among competing and sometimes conflicting requirements in order to be able to sort out those that are most important for the satisfaction of customer needs. Prioritization and selection processes must consider the importance of different demands as well the different costs associated with their
QFD is in general terms addressing these issues, though it will need to be adapted to fully fit the purpose of user information development.

In the first place it is important though to keep a broad perspective on requirements collection, to ensure that a wide spectrum of both known and unknown requirements is gathered. As it is important that a study of a joint system is made in the real world, as argued by Hollnagel et al. (1995) and one must during the requirements collection also assure proper attention to influential organizational and social contexts in which the system exists or is planned to exist in.

QFD is a useful methodology in the translation of user demands and requirements to relevant specifications. This process of breaking down user demands and requirements is supported by the use of tools from the set of 7 Management Tools, preferable affinity diagrams (Klefsjö et al., 1999; Bergman & Klefsjö, 2003) and also from the set of 7 Product Planning Tools (mostly described in papers in the Japanese language and briefly described in English, e.g. in Cristiano et al. (2001)).

QFD can, in the way it has been used in product development, be subdivided into four steps: Product planning, Parts deployment, Process planning and Production planning (Bergman & Klefsjö, 2003). Analogues to the first two of these steps are of primary interest for this study:

**Product planning**
The purpose of adapting this part is mainly to preliminary design and test a methodology for capture and translation of user-stakeholder demands and requirements into product qualities. The output from the product planning process should be a number of product characteristics important to user-stakeholders, preferable accompanied with measurable design characteristics that are possible to prioritize.

**Parts deployment**
This step aims to choose the best design concept for fulfilling requirements and goals for the design qualities or characteristics. Another desired output is identification of parts or components (sub-systems) critical for the product.

QFD has numerous applications and is used in different contexts, of which software development is one example (Yoshizawa et al., 1992; Chan & Wu,
An interesting approach is presented by Barnett & Raja (1995) who divides the process into four different steps:

- Customer deployment
- Business process deployment
- Functional requirements deployment
- Procedural requirements deployment

The number of steps and their designations are not governing the use of the QFD methodology. QFD has to be adapted to the problem under study. In an extensive literature review by Chan & Wu (2002), the adaptation and use of the QFD methodology has been identified within a vast number of problem areas. Within software development interesting adaptations have been made and a comprehensive model has been developed by Zultner (1993). This way of working is built on two phases:

- Requirement identification
- Requirement analysis

These are followed by work along three tracks:

- Functional development
- Information development
- Service development

In a development process there are also implicit requirements, which are hidden in text descriptions and graphical models. Most RE researchers agree that to develop a system that corresponds to the needs and expectations of the users, these implicit requirements must be fulfilled as well. If they are implemented in the system, they are also affected if changes are made and must be taken into account, e.g. when an impact analysis is performed concerning a requested change. Usually, these requirements are not dealt with when RM is discussed, but the questions still remain: How can dependencies between implicit requirements and between implicit and explicit requirements be managed in order to provide a complete basis for impact analysis? How can we store additional relevant information about implicit requirements to use as a basis for various decisions during the requirements work? (Grehag, 2001).

QFD and the issue of user information from a design quality and customer requirements point-of-view, shows several similarities with QFD in software
development. Requirements are often ‘soft’ and are difficult to measure (Akao, 1992). A ‘bottom-up’ procedure that gathers user requirements tends to end up with long lists of desired functions and performance requirements. It is therefore important to narrow the application of QFD (Akao, 1992). On the other hand this is seemingly contradictory to the challenge of keeping a broad perspective on customer requirements during the design process.

3.6.2 Two sets of tools
The so called seven management tools (7MT), listed below, are established and powerful means of assistance for managing unfiltered and unstructured verbal information (Klefsjö et al., 1999):

- Affinity diagrams
- Interrelationship diagraphs
- Tree Diagram
- Matrix Diagram
- Matrix Data Analysis
- Process Decision Program Chart
- Arrow diagram

Of the seven tools the combination of affinity diagrams, tree diagrams and matrix diagrams is effective for identification of problems and thereafter finding and prioritizing solutions (Bergman & Klefsjö, 2003).

Affinity diagrams are suitable to elicit requirements and to visualize associations among pieces of verbal information. The work is preferably done by the members of the design team through interviews and brainstorming sessions at workshops with stakeholders. The requirements are structured at the workshop by the stakeholders and the facilitators under affinity headings.

Matrix diagrams are highly functional for identifying and assessing connections and interdependencies between different factors (Klefsjö et al., 1999). The methodology of interest for this study, is applying matrix diagram as integration with the application of Quality Function Deployment (QFD). Quality Function Deployment enables transfer of requirements to the design process through matrix diagrams. By doing so the original needs and requirements of the customer (“what”) is systematically transformed into product qualities (“how”) through a controlled and traceable process (Akao, 1992).
A focus in Japan has lately, according to the limited amount of available literature in English, been on the development of new techniques to enhance the QFD methodology for development of new products. There is also ongoing research in stronger models of QFD for cost deployment and a focus on the development of an integrated approach for the capture and analysis of customer data, referred to as “The Seven Product Planning Tools.” (Cristiano et al., 2001).

These tools, when used in the manner prescribed by the JUSE, allow product planners to apply QFD to totally new products. While the tools are often used individually, the strengths of the 7PP tools are their flow and systematic approach. The tools are:

1. Questionaire Survey
2. Positioning
3. Concept Checklist
4. Concept Tables
5. Conjoint analysis
6. Quality Table (House of Quality)

3.7 Requirements management - methodologies and tools

It is very important to assure a complete collection of requirements as requirements are to drive the system design and operation (Kar & Baily, 1996). This is an act of balancing between an excess of requirement driving unnecessary costs and hindering an optimum system solution and insufficient requirements that can cause large amounts of rework as the requirements are instead likely to be deduced during later stages of development when the implementing cost is higher (Carson, 1998). Requirements also play an important role in verification and validation in different stages of a development process. Verification and validation can be described as the process where one determines whether the requirements for a system or a component are complete and correct, or if the finished product complies with specified requirements (IEEE-STD-630, 1990). This is applicable both to more “soft” requirements and expectations from users and “hard” requirements such as legal contracts or environmental legislation.

Though the troublesome issue of assuring that all relevant stakeholders are consulted has received less attention than other areas which depend on it, such as scenario-based requirements, involving users in development and negotiating between different viewpoints (Sharp et al., 1999).
Definitions available are amongst others the ISO/IEC standard (ISO/IEC-15288, 2002), which defines the term stakeholder as “a party having a right, share or claim in a system or in its possession of characteristics that meet that party’s needs and expectations”. According to Macaulay (1994) four categories of stakeholder in any computer system can be identified:

1. Those responsible for design and development
2. Those with a financial interest, responsible for its sale or purchase
3. Those responsible for introduction and maintenance
4. Those who have an interest in its use

This list corresponds with the view presented by Karlsson (1998) who lists users, developers, customers, environmental regulations and company standards as examples of many different stakeholders involved in large-scale software systems.

The definitions of stakeholders in existing literature are often vague and can lead one astray when selecting stakeholders. (Sharp et al., 1999). Though the approach for stakeholder identification presented earlier in the theoretical discussions in this chapter, reduces the risk of omitting important stakeholders. The stakeholder identification for the study presented in this thesis is therefore based on the view of the system-of-interest presented by Rasmussen (1990) and discussed in Section 3.1. The search for stakeholders is guided by the same questions that allow the system and its agents as well as its work environment (defined as the part of the world that is being serviced by the system of work) to be ”mapped-out” (Rasmussen et al., 1990). The questions raised are (once again):

- **Agents**: Who is doing it?
- **Work domain**: What is being done?
- **Objectives and constraints**: E.g. demands on product quality.
- **Technical resources**: By means of what is it being done?
- **Customer**: Who is being serviced?

Compared with more traditional methodologies, more support is provided by socially oriented methodologies for user involvement in design, facilitating the degree of user–designer communication and the capture of requirements, according to Coughlan & Macredie (2002). They also state that the primary reason for the existence of communication problems could be traced to the
fact that system design and development is to a great extent a behavioral process and that human and organizational elements have an important impact on the design.
4 RESEARCH PROCESS AND EMPIRICAL MATERIAL

This chapter presents the realization of the research process and the empirical material to the reader. The chapter describes the exploration and the iterative analysis of the development of a way of working, the supporting methodologies and tools, including the stakeholder approach and the concept of using a demonstrator as a part of the development strategy. These research activities were all performed in smaller PDSA-cycles within the overarching PDSA-cycle of the research project.

4.1 The Realization of the Research Process

The analysis in the research project has been performed continuously within several smaller sub-cycles (see Figure 1, Section 2.8) during the empirical work, which are presented in this chapter. The analysis of the overarching PDSA-cycle of the research project is presented in Chapter 5.

Sections 4.2-4.5 present the initial empirical studies that lay down and analyze the contexts and prerequisites for the case study. This is followed by a description in Sections 4.6-4.10 of the exploration and iterative analysis of contexts and prerequisites together with the elicited requirements, roles and activities during the development of a way of working and the development of the demonstrator.

The development of the way of working and the demonstrator was performed in smaller PDSA-sequences towards established and clear goals. The cycles included theoretical studies, either individually or the cross-functional team, followed by practical work focused in, and around, the adapted QFD-matrices. During the research project the cross-functional team was constituted of 2-3 developers from Sörman and the author of this thesis. The way of working emphasizes a holistic view of the system-of-interest, which positively contributes to the ability of the cross functional team to optimize the design towards the approved goals. It also promotes continuous and interactive feedback between the participants, and follow-up of the results towards project plans. The results of these analysis then forms new action plans, containing both theoretical and practical work applied in the next cycle. Hereby a continuous knowledge transfer and a verification and validation of the progress were achieved. This in turn made it possible to identify in early stages of the development problems and needs for adaption, or change, in the way of working and the demonstrator design.
4.2 A Complex System and its User Information - JAS39 Gripen

The empirical material originates from the JAS39 Gripen aircraft which is the system-of-interest in this study, parts of its the support system, the technicians supporting and maintaining it, as well as the pilots, who fly the aircraft. The empirical material supplies the big picture of the world of this system-of-interest and parts of the support system, and thereby clues to unexpressed and unknown needs of different stakeholders. The empirical study views the world of the system-of-interest from a user information perspective, and does not explicitly study other parts of the support system such as material support, training, facilities or maintenance engineering.

Cues to understanding the design of the complex system that was to become the Gripen fighter can be found in the innovative thinking behind the project in the early 1980s. The fighter project was based on the need for a multi-role (or swing-role) airborne platform. The seemingly contradictive needs were to have an aircraft and support system with performance superior to its predecessors, but to make it cheaper to produce and easier to operate. (Sandberg & Strömberg, 1999).

The preceding generation of combat aircrafts (the third, represented among others by Mig-29, F-16, F/A-18 and JA37 Viggen) does utilize computers, but then together with separate digital systems. The platforms are also large and heavy and this increases the operating costs. The lack of integrated infrastructure also makes it difficult to introduce new functionality and utilize new technology, which in turn accelerates the aging of the system. (Lorell et al., 1995).

The Gripen project aimed at breaking the trend at the time of increasingly larger and, especially with respect of the operating and maintenance costs, more and more expensive aircrafts. This was to be done by exploitation of new technology. The result was an aircraft that was built with new materials, highly computerized and had an information management capability that eases the pilot’s workload. As such, Gripen was the first of the so called fourth generation aircrafts, (Hewson, 1995; Ahlgren et al., 1998; Griffiths, 1999; North, 1999).

The fourth generation combat aircrafts (4G) are defined by Lorell et al. (1995) and Ahlgren (1998) as system aircrafts with supersonic performance, digital infrastructure and fully integrated computer systems that utilize a common database through standardized interfaces. In the Gripen case this comprises more than 20 subsystems for flight control, weapons, hydraulics,
display and maneuvering and others; sub-systems that all are capable of supplying, transmitting and receiving information.

The communication is carried out through data busses and is administrated by a central systems computer. Together, they build a system with theoretically an infinite number of possible combinations. The building principle of a system-of-systems supplies an immense potential for development, but also an extremely complex aircraft system.

When the perspective is broadened to comprise the entire weapon system it will, besides the aircraft, include parts of the basing system, air traffic and combat control systems and the support system with its functions for training, operation, maintenance and material support. All of these systems are in turn to be regarded as complex, to great extent computerized and to different degrees integrated, or interfacing with the Gripen aircraft system.

The user information system, or the publication suite, as it is often called, is a vital part of the support system. The development of the present Gripen publication suite is originally formed by a number of key factors. One was a decision to create a role of a so called general aircraft technician, instead of several cadres of technicians specialized in different disciplines like engine, avionics, weapon and so on. A solution mainly enabled by the new technical means to radically increase the aircraft’s built-in-test. This was driven by the need to lower the operating cost and simplify the operation, together with tactical demands of the wartime operation on dispersed bases (Sandberg & Strömberg, 1999). Another requirement was to keep the Swedish model of using conscripts as aircraft mechanics. These prerequisites in turn created requirements on the design of the technical system, i.e. the aircraft. As mentioned, an increased use of, among other things built-in-test, was to simplify and make flight line operation (FLO) and operational level maintenance more effective with less resources. The Swedish concept of dispersed bases for operations put a unique demand on maintenance and reliability (North, 1999), and together with the new technology applied it would obviously have an impact on the need for user information.

The point of departure for the development of the present Gripen publication suite was formed by a Publications Supplement (IG-JAS, 1988) to the original contract between IG JAS (the joint venture of suppliers of the Gripen system) and the Swedish Defense Material Administration (“Försvarsmaterielverken”, FMV). The supplement does not in detail specify the requirements on the publications, but does supply general guidelines about
the use of international publications standards and digital publications management.

The contract and the supplement was interpreted by a joint working group of FMV, the IG JAS parties, the Swedish Armed Forces (“Försvarsmakten”, FM) representatives (formally the Sub-committee for Publications, of the Working Group Maintenance aircraft 39). The mission was to take practical decisions and establish directions and rules for the development of the publications system, which later resulted in the Publications standard 94 (PUB94). This standard was originally a collection of IG JAS internal quality documents regarding content, structure, illustrations, layout, and amendment service. This was later, on the demand of the customer FMV, integrated as a part of the official publications system. However, in spite of the ambition to apply new thinking and technology for the design of the technical aircraft system, the publications supplement to the contract was heavily influenced by the structure, layout and content of the publications for the predecessor, the Saab 37 Viggen aircraft (3rd generation). FMV and FM frequently used these legacy publications as references during the development of the Gripen publications, and the arguments were that the design of the new Gripen suite should essentially be based on the same principles that were familiar to the existing cadres of aircraft technicians. (Candell, 2001).

Though factors like the great shift in aircraft technology, as well as the considerably greater amount of technical information and the anticipated higher rate of functional development, did lead to some changes of these principles:

- A split of the old type of aircrew manual into a Flight Manual (“Särskild Föarinstruktion”, SFI) and a General Aircraft Description (“Allmänn Beskrivning Flygplan”, ABF).

- The use of original design documentation for the aircraft technician’s electric and functional schematic diagrams.

- Integration of simplified technical descriptions in the maintenance instructions (though these were later replaced by separate, more detailed technical sub-system descriptions, “Detaljerad Beskrivning Flygplan”, DBF and a complementary Aircraft Test Description, “Testbeskrivning flygplan”, TBF).
The publication suite for Gripen consists of a large number of publications connected to the aircraft type, together comprising the equivalent of more than 40,000 A4-pages (see Figure 12, Section 4.5). In addition to this information, which is only for the Gripen aircraft type, pilots and technicians are confronted with considerable amounts of general information not uniquely produced for Gripen. These comprise, for instance, different types of civilian and military flight information, tactical and safety directions. The users of the Gripen work within a gigantic information complex, of which some pieces are crucial and must be perfectly memorized like emergency checklists. Other pieces, like infrequently used maintenance and repair instructions are used a few times during an entire career. However, to assure the operability of the aircraft, every piece has to be in place and to be accessible for the user when and where the need arises.

Naturally this raises far-reaching requirements on classification and structuring of the user information. One division of publications bound to Gripen, is the separation of operating and maintenance publications. The first category refers to information needed by the pilot for flying, and the latter to information and instructions needed to maintain the aircraft.

The content and structure of the suite is defined and regulated in the Publication standard mentioned earlier, PUB94, which by itself fills a full A4-binder. It comprises everything from the hardware and functional division of the Gripen aircraft into material groups (sub-systems), the use of Standard Generalized Markup Language, SGML (ISO-8879, 1986) in documents, digital publication management, to the use of structure, headlines and rules for different types of illustrations and schematics. The Gripen user information is managed in entities called Data modules (DM), which could be a chapter in a sub-system description or an instruction for a separate maintenance activity. Each DM has its unique ID-code according to the international publication standard 1000D issued by the European Association of Aerospace Industries, AECMA (AECMA, 2004). The AECMA specification has been produced to establish standards for the documentation of any civil or military vehicle or equipment. It is based on international standards such as SGML, Extensible Markup Language, XML and Computer Graphics Metafile, CGM (for illustrations), for production and use of electronic documentation (AECMA, 2004). The coding of the documents adheres to the division of the aircraft systems into material groups, and supplies information about the type of information or maintenance activities the document contains.
On an aggregated level the classification and structuring of the user information for Gripen is based on the needs to create as coherent and usable technical documentation as possible. This ambition must however subordinate itself to the top level and non-negotiable requirement of flight safety and practical circumstances and limitations for the adaptation of such a formidable information complex.

The increasing complexity of the aircraft obviously implies an increasing complexity for the publications suite. The amount of information is successively increasing, and this in turn leads to more frequent amendments and an increasing demand on configuration and version control of the user information. To manage this challenge it is necessary to utilize computerized information systems. Both the new production and the amendment service of the Gripen user information is almost completely done through the use of a computerized authoring and document management systems. Deliveries are made on digital media but these are mainly “carriers”, and the daily access and use of the information is still to great extent through A4-hard copy in binders with dividers.

4.3 Product information life cycle

Below is a model of a life cycle perspective on product information built on data collected from Saab Aerospace and Sörman (Candell et al., 2001; Saab-Aerosystems, 2002a, b). The life cycle view is similar to that of the ISO/IEC standard 15288 (ISO/IEC-15288, 2002) which is also partly utilized at Saab. See Figure 10. By identifying and analyzing the life cycle perspective of product information connected to large technical systems, the resulting model contributes with a deeper understanding of stakeholders as well as the existing context for development and production user information products to the study.

Comprehensive documentation is a part of the product support (Kumar, 2003) and is thereby a part of the enabling systems to the system-of-interest. The development of user information products is to a large extent based on product information produced during the development stage of the system-of-interest. Although the development stage of a complex technical system produces a wide variety of information, the vast majority is product or system related. This information is primarily produced by different kinds of (system- and sub-system) designers and software developers, but also by technical authors (or information designers). Sub-contractors, external suppliers and consultants also add different types of information and knowledge to the manufacturers’ information supply process.
Figure 10. The life cycle of product information (Candell et al., 2001)
During the production stage the technical authors increase their part in the total information production. At this point the divergence between technical product and system related information and information aimed specially towards the end-user also becomes more visible. Information is consumed both during the production of the actual product, as well as during the development of user information. Often the information products aimed for the users are tested and verified before delivery.

In the utilization and support stages, when the system or product is operative at the operating organization, product or system related information as a part of the system-of-interest as well as the support system, is produced as regular amendment services as well as when up-dates and add-ons are designed. This information production is performed both by technical authors and designers. End-user information for operation, maintenance, up-dates and add-ons is produced by technical authors.

The different information producers are, at best, utilizing the same information production system and databases, to enable cooperation and rational re-use. The trend towards even larger and more complex technical systems is raising a never-ending list of requirements, demanding continuous improvement of products and processes to assure cost effectiveness and quality. Stakeholders in this environment are obviously not one homogenous group, but represent a number of different types of users. They are also actors with different roles in different constellations, such as in a developing team, a project or line organization and as existing and potential system owners, operators and others.

4.4 Users and Other Stakeholders

The understanding of the process of managing requirements during the life cycle as described in the previous section is increased by also viewing the process from a decision process perspective. This analysis illuminates the central role of communication of and about, requirements between different stakeholders and developers as well as between users and the procurer in the operator organization during the development process.

To have the opportunity or obligation to form the process and prioritize requirements is to exercise influence or power on the design and the outcome of the system. The work in the different stages can therefore be viewed as a process with a number of different actors or stakeholders. Two obvious sub-groups identified in the study of the product information life cycle, presented in the previous section, are the different users and those who design the
system. A third, less obvious one, is the information designers (technical author or writers) who do the hands on work, implementing the communication between the designers (content matter experts) and users.

These and other stakeholders (both from the customer side and from the supplier side), taking part in the production process for user information, have to act within frameworks of values and organizational structures for handling requirements, development and production. These are formal structures, shaped and organized to meet the ends of the company or organization by controlling which actors are to be allowed (or forced) to make what decisions and which requirements, problems and solutions that are to be handled at different decision forums at what time.

These structures and processes will however not guarantee that individual actors act according to a decided collective rational. It is not to be taken for granted that different actors equally understand aggregated goals of the organization that they are equally interpreted or, at worst, are prioritized before individual goals or ambitions. Organizations usually try to minimize these risks by establishing an active management and formal processes. It is not unlikely that there are several (sometimes competing) goal hierarchies in the organization, that they are unknown to some personal, or at least unclear. A worst-case scenario is that work is characterized by goal conflicts and unclear preferences, where it is difficult to understand what stakeholders and requirements that are valid and with which priority. This will not necessarily mean that individual stakeholders have unclear preferences. On the contrary is it likely that they have a better understanding of their own preferences, than those of the company or the project. This, together with a lack of knowledge about requirement priorities and preferences in other parts of the organization, might lead to sub optimization towards the common goals, seen from an organizational or project perspective. (Candell & Schmidt, 1991).

This description defines and raises the fundamental need for a formal approach to stakeholders and requirements, i.e. a methodology for specification and development, to ensure that the right requirements are used and to supply traceability as well as the ability to verify and validate those requirements.

The data collection and analysis to identify stakeholders was done in the research project mainly through literature studies, the exploration of the author’s pre-knowledge and by the use of the software developers experience from stakeholder identification in software development at Sörman. The
stakeholder identification was also supported by use of the approach presented in Section 3.7 and by the view of system life cycle processes presented in the ISO/IEC Standard 15288 (ISO/IEC-15288, 2002). The empirical material was analyzed and structured in three main groups of stakeholders presented below. The work was performed both individually and in working session with the cross functional team.

Authorities
The socio-technical perspective on large technical systems adapted in this study brings forward the facts that the system-of-interest exists within a larger framework of legislation and social values that are governing different aspects of the systems functions.

The Civil Aviation Administration (“Luftfartsverket”, LFV) is the Swedish aviation safety authority. LFV issue aviation safety regulations and standards, inspects and scrutinizes individuals, organizations or certain products before they are granted admission to the aviation system. This includes also comprises design, manufacturing, operation and maintenance of aircraft, the operational environment including airports and air traffic control systems and the performance of the personnel involved (Luftfartsverket, 2003). The authority also performs technical approvals including type approvals, maintenance and production, maintenance training, air navigation services, security and analysis. (Saab, 2003).

LFV has direct and indirect requirements on user information (publications) that should be provided to assure the safe operation and maintenance of aircraft. This is done through the utilization of for example Joint Aviation Regulations, JAR (Joint-Aviation-Authorities, 2003a, b). Regulations for Military Aviation, which are issued by the Swedish Armed Forces (1998a; 1998b; 2003). Publications issued by authorities are, with some few exceptions, rarely utilized directly by pilots or technicians in the operation of aircrafts. Although such publications do have great impact indirectly on the internal processes, rules, regulations and publications at manufacturers as well as both civil and military operators.

Other examples of authorities that have direct or indirect impact on requirements regarding user information are legislative bodies that regulate the labor market and environmental issues.
Manufacturers
As an authorized design organization and aircraft manufacturer within the military or civilian aviation system, a company must keep and supply a vast amount of publications. This is to some extent valid both for the owner of the particular aircraft type certificate and for sub-contractors. These publications are reviewed by the authorities and must meet certain requirements and standards to enable and assure the safe operation and maintenance of the aircraft. The aircraft must also adhere to a great number of legislative requirements regarding product safety and liability that often reach beyond those demanded by the aviation authorities.

On an aggregated level all these requirements end up in the manufacturer’s ability to satisfy the user-operators demands on the aircraft and its operability. In practice this is handled internally within the organization by the issuing of rules and regulations for controlling processes and personnel.

In turn the manufacturer also has requirements on users and operators. Product liability is connected to requirements for the operator to follow procedures, use correct maintenance equipment and supply required training for the personal and so on.

Users and Producers of User Information
In addition to the two large organizations presented above, that present requirements of great influence, vast groups of different stakeholders in the form users and producers of user information, was identified in the empirical study of the JAS39 Gripen system. These stakeholders are by no means homogeneous groups in respect of their requirements. The example of operation of combat aircrafts comprises a number of different occupational groups, representing a great variety of stakeholders from different professions. Some important stakeholders that were identified are:

- Pilots who are operators of the flying aircraft.
- Aircraft technicians who operate and work with the aircraft and its sub-systems on the ground.
- Educators and training personnel training pilots and technicians.
- Ground control personnel.
- Intelligence officers.
- Managers, administrators and technicians planning the operation and maintenance of the aircraft.
- Technicians and engineers in the aerospace industry working with depot level maintenance.
• Fire fighters and rescue personnel at the operating sites.
• Materiel administration representatives responsible for procurement and life cycle management of the system-of-interest as well as enabling systems.

The identification, collection and analysis of data regarding stakeholders resulted in a better understanding of the different groups found in the overlapping areas of system-of-interest, support system and user information products. An overview of these groups is presented in Figure 11. Users and stakeholders all apply their own, more or less unique perspective on the aircraft and its support system. Though the top-level goal is shared, the means by which they work towards it is often quite different. At the same time they are in many cases utilizing the same type of information. It is therefore necessary that a management process for these stakeholders’ demands and requirements on user information must take these facts in consideration.

Following the identification of stakeholders and the study of stakeholder data, the empirical material was analyzed within the cross functional team and a group of key stakeholders to be utilized for the demonstrator development was selected. The group comprised:

• Aircraft technicians who operate and work with the aircraft and its sub-system on the ground.
• Educators and training personnel training pilots and technicians.
• Pilots who are operators of the flying aircraft (preliminary requirements elicitation only).

This decision was mainly based on practical limitations of the study and the need of valid and usable requirements for the demonstrator development. Aircraft technicians and pilots are also the largest two separate groups of users of technical information. The prerequisite condition of retained possibilities to draw generalized conclusions from the process of stakeholder identification and requirements elicitation, was also assessed to have been met, as the ways of working would be the practically the same irrespectively of the type of stakeholder.
Figure 11. The complicated system of different groups of user information stakeholders and users (ovals), dispersed among the overlapping areas of system-of-interest, support system and user information products, which all to various extent are influenced by requirements from authorities, system manufacturers, the environment and the social context.

To increase the value of the information supplied by stakeholder requirements, the aim in the research project was to complement the empirical material about the selected stakeholder groups with descriptions of system environment and contexts, use cases and other types of information. This is in line with the view presented by Fiske (1982), that all communication is an act of creation and exchange of meaning and in this case the goal was to facilitate the communication between stakeholders and designers by connecting the requirements to their socio-cultural context. Carlshamre (2001) presents a view, where the requirements documentation plays a central role in the activities of requirements engineering as the main tangible product, although the perhaps the most important product, understanding, is still intangible.

Ways to make this understanding more tangible are presented by Liu & Yu (2004), who put forward the usefulness of scenario-oriented models that
present possible ways in which a system can be used to accomplish some desired functions. This could be a sequence over time of interaction events between the intended software and its environment (composed of other systems and humans). A scenario can be expressed in different forms including narrative or structured text, pictures, animation, maps and so on. (Liu & Yu, 2004).

This was done in the study by complementing the empirical material with descriptions of systems environment and contexts compiled into what further on will be referred to as use-cases. The use-cases was put together mainly from notes from the workshops, literature, the author’s pre-knowledge as well as studies done at Sörman and were then analyzed in the cross functional team. The empirical material about the selected stakeholders and the use-cases are presented in the Sections 4.5-4.9.

4.5 The Aircraft Technician – an important Stakeholder

As aircraft technicians are key personnel for the effective operation of the aircraft, more data was collected through literature studies, of amongst other documents the training plan for aircrafts technicians (Swedish-Armed-Forces, 2000) and the domain knowledge of the author and the Sörman developers. This materiel were studied and analyzed in more detail.

The technical personnel that work with the Gripen aircraft could roughly be divided into two categories:

- Military aircraft mechanics (conscripts) and technicians (technical officers) at a squadron operating Gripen aircrafts (flight line operation and operational maintenance level, O-level).
- Civilian technicians at intermediate and depot level maintenance workshops.

This comes from the division of technical work into different maintenance levels. The daily operation of the aircraft is supported by so-called operational level maintenance, which is performed on the flight line or in local workshops, on site at the air wing. For the operational level maintenance, the primary users of technical publications are aircraft technicians and conscript aircraft mechanics. They are mainly doing on-aircraft service and maintenance, i.e. working with the complete aircraft. At intermediate and depot level maintenance workshops the users are civilian technicians and engineers and the maintenance is both made on and off-aircraft, i.e. on equipment and components removed from the airframe. This
gives a natural separation between military and civilian technicians, operational and intermediate or depot level maintenance and finally between a complete aircraft versus removed equipment and components (see Figure 12).

The aircraft mechanics at the air wing are conscripts trained during their military service. Their civilian education and pre-knowledge varies and is of small importance for their ability in the position as aircraft mechanics in the Air Force. Military aircraft technicians in the Swedish air force are technical officers specialized in the profession of aircraft technicians. Their education in aircraft engineering is a part of their officers training in the air force. When they enter officers training they have in general an equivalent of a senior high school education in engineering or natural sciences and experience from their military service as aircraft mechanics.

The goal for the aircraft technicians’ type training on the Gripen aircraft is the ability to work in line maintenance service and at the service platoon. The type training is separated in two phases, the first comprising the basic type training and the second focusing on line maintenance, a deeper training on engine technology and fault localization.

The training plan (Swedish-Armed-Forces, 2000) uses a so-called ability model as a tool to clarify training goals, quality and requirement levels as well as for planning, analysis and evaluation of the training. This ability model integrated and applied as a pedagogical fundament in earlier versions of the armed forces general training regulations is influenced by the taxonomy by Bloom (1984). Bloom’s taxonomy supplies principles for the co-ordination of passive and active knowledge with different levels of abilities to apply education in real life activities (see Bloom (1984) for a thorough discussion). The importance of a formal handling of different user ability levels and levels of cognitive control in a design perspective, is obvious. The ability of different users constitutes needs and requirements that affect the design of the user information, as this has great impact on what kind of information is to be supplied to a particular user in different situations. This principle also highlights the relevance of a joint system approach of user information. Seen on a systems level this approach supports among other things the work to balance user information for test and fault localization. This is partly done through built-in-test in the technical system itself and partly through manual fault localization through the use of written instructions.
The user information produced by the aircraft manufacturer is first of all made to make the operation of the aircraft safe and effective. From a top level of view this is secured through the compliance with the rules and requirements of the airworthiness authorities. The user information is of cause adapted to the aircraft type and for Gripen, to a certain extent to the particular demands of each operator (customer or air force). In the case of the Swedish Air Force publications they are approved and formally issued by the Armed Forces Material Administration, which is responsible for operational issues regarding all Swedish military air vehicles. Publications used for industry level maintenance are mainly third party (subcontractor) documentation that is version and configuration controlled and when needed adapted, by the aircraft manufacturer (Saab in the Gripen case).

The bound-to-type user information for Gripen comprises a number of different publications, presented in Figure 12. The publications that are especially important for this study are commented below:

- **Aircraft Maintenance Manuals (AMM).** The purpose with the AMM is mainly to supply the operator (air force) with the plans and instructions necessary to maintain airworthiness and secure the operation of the aircraft. It is also used as documentation during training of technicians and mechanics.

- **General Aircraft Description (ABF).** This publication is mainly aimed towards the pilot and describes the functionality of the aircraft and its systems, as well as the interaction with the human-machine-interface in the cockpit. Hence it is also a useful information source for aircraft technicians both during training, operation of the aircraft and maintenance.

- **Detailed Aircraft Descriptions (DBF).** These detailed descriptions of the aircraft system should, together with the General Description and the Aircraft Test Description (below) meet the information need of the specialist technician during training, qualified maintenance tasks and manual fault localization.

- **The Aircraft Test Description (TBF) is to supply the aircraft technician with in-depth understanding of the aircraft’s built in safety checks, functional monitoring and fault localization. TBF also doubles as training documentation during training regarding aspects of tests.**

- **Functional and Wiring Schematics (FSB, ESB).** These schematics are used together with other publications for maintenance, fault localization, repair and training.
Figure 12. The existing publications suite for JAS39 Gripen (Saab, 2000).
• Illustrated Parts Catalog Aircraft and Engine (RKF, RKM). The catalogs are mainly used for identification and ordering of spare parts, but also supply detailed reference information on the configuration of equipment and installations.
• Repair Handbook. The repair handbook supplies information for peacetime repair of the airframe, installation and electric wiring and other parts of the aircraft.
• Fire and Rescue Instructions. These are instructions for the actions that can be performed by fire and rescue personnel.

The fact that it is important for the aircraft technician as a user to have a good grasp of the publication suite became evident during the analysis of the empirical material. This result is confirmed by the fact that it is explicitly stressed in the curriculum as one of seven knowledge areas to be mastered by the aircraft technicians (Swedish-Armed-Forces, 2000).

4.6 Aircraft Technicians Requirements
To collect requirements data from aircraft technicians, a work-shop was performed at a F10 Air wing Squadron operating the JAS39 Gripen, eliciting a preliminary sample (Candell & Akersten, 2002). The study object was aircraft technicians and their requirements on operational level maintenance instructions and descriptions, as key users.

4.6.1 Elicitation of a preliminary requirements sample
The goal of the preliminary elicitation was to:

• Test the preliminary theoretical grounding.
• Test the approach with workshop sessions for requirements elicitation.
• Gain experience of the QFD product-planning matrix.
• Analyze and gain results and experience from the empirical findings.

The analysis of the preliminary requirements sample was limited to the product planning matrix and adapted to the following steps:

1. Gather and organize customer requirements
2. Establish quality elements
3. Establish relationships in the relationship matrix
4. Work through correlation matrix
5. Preliminary analysis of planning matrix
The elicitation and organizing of requirements was performed as a workshop with brainstorming and structuring of requirement notes in affinity diagrams. One week before the session the Squadron technicians and a PM were sent with a short background and presentation of the research project. They were also given four questions as ‘starters’ for their own thinking process on the issue (Candell & Akersten, 2002), an approach inspired by Andersson (1991), Bergman & Klefsjö (2003) and Magidson & Brandyberry (2001). Akao (1992) also highlights the importance of clear communication of the product concept and the basic functions of the product.

The workshop was performed on-site at the F10 airbase and lasted during a whole day. During the workshop the author functioned as secretary and moderator together with a systems developer from Sörman. The day at the Squadron generated more than 40 statements about aircraft technicians’ experience of user information and their requirements. Statements with affinity between them were arranged by the focus group and resulted in 12 different headings of which one was explored to a second level, resulting in another three headings (Candell & Akersten, 2002). The requirements were also prioritized regarding their primary effect, whether they would contribute mainly to either flight time production or flight safety. To improve the validity of the information a draft of the report was sent to the participants for review.

4.6.2 Analysis of preliminary Requirements and Quality Elements
The empirical material from the F10 session was brought back to the cross functional team. To facilitate the insertion of customer requirements into an adapted House of Quality (HoQ) matrix, the organizing and compiling of statements (re-wording) and headings, to requirement expressions (Akao, 1992), was integrated in the same process (i.e. the transfer of statements/headings from the affinity diagram to HoQ “What”-column) (Candell & Akersten, 2002). These were documented in the Customer requirements, First level column and then broken down and re-worded into Second level requirements. This resulted in 15 First level and 31 Second level objects. An excerpt from the F10 HoQ matrix is presented in Appendix 1 (Candell & Akersten, 2002). The original requirements were also documented in a requirements list, see Appendix 2 (Candell et al., 2003).

These initial working sessions also applied the approach of adapting user information design to types of levels of cognitive control, as discussed in Chapter 3. The requirements were therefore assigned to types by the team, depending on whether it was primarily estimated to affect the product’s
functionality for knowledge construction, ruled based information, as an information system or its HMI (Human-Machine-Interface).

These customer requirements were translated into quality elements by the cross-functional team in the HoQ. Quality elements are design elements measurable in a quality evaluation (Akao, 1992). For the purpose of this study it was not necessary to generate quality characteristics (measurable individual aspects) for each design element. The ambition was to produce general qualities that did not point towards, or suggest particular technologies or implementation strategies. The elements were then organized in affinity groups.

As no analysis of competing products was to be done, work went on with the relationship matrix and then the correlation matrix. Three levels of strength of relationship were used in the relationship matrix and two in the correlation matrix. Graphical symbols were used to facilitate the forthcoming analysis. Preliminary degrees of importance were appointed to the first level requirements (demanded qualities) based on the two way prioritization made by the aircraft technicians at the F10 workshop and a not was made on the requirement-statements prioritized.

4.7 Fighter Pilots and User Information

The pilot is obviously also key personnel and stakeholder for the effective operation of the aircraft and more data was also needed regarding this group. A complementary literature study of the pilots and the context for their work was performed and analyzed. Following that, a surveying interview was done with an experienced pilot flying the JAS39 Gripen at TUDAS (Tactical Development JAS39 Gripen), to elicit preliminary requirements and gain additional experience of the pilot user context (Candell & Akersten, 2002). The interview was documented with notes taken during the session and a facsimile figure of the drawings made on a whiteboard, see Appendix 3 (Candell & Akersten, 2002). To increase the validity the edited notes and the figure where then reviewed and approved by the pilot.

The main task for an officer in flight service in the Swedish air force is piloting the JAS39 Gripen combat aircraft. In this system they perform the role of fighter, attack and reconnaissance pilot and during some missions it is required that they switch between the different roles. A smaller number of pilots, who work as engineers in flight service, have a Master’s degree in engineering and the same flight training as the other officers in flight service. Their job spans between performing test flights and having the technical
responsibility for the aircraft at an airbase, to working as test pilots and with material development at the Defense Material Administration.

When discussing pilot’s user information one should keep in mind the paramount importance of this group of key users. As the final and sole link between the huge amount of effort behind a technically combat ready aircraft and the performance that is the reason of existence for the weapon system, proper information and knowledge support for the pilot is very cost effective.

On one hand the modern combat pilot may be described as a cog in a machinery of distributed knowledge, unauthorized to invent or create his own procedures for the basic operation of the platform. On the contrary, the pilot is supposed to be very predictable in this respect, i.e. everybody should be just as proficient and follow the same procedures. On the other hand though, training to be a combat pilot is not just a formal issue about training the pilots to be good ‘stick-and-rudder-men’. It is also about picking up implicit and contextual knowledge in an environment, which is achieved through participation (Jonsson, 2001). Cognitive science talks about this type of learning in terms of “organizational learning” and “learning in context”, describing the cognitive properties of culture in technical and social systems (Jonsson, 2001).

Obviously the theory in the domain is also a vital part of the pilot’s training. Though by concentrating on the use of theoretical knowledge as a mediating tool for the individual’s own understanding, it becomes less important whether the knowledge is transferred through spoken lectures or dialog, on CD-ROM, a book or any other way (Jonsson, 2001).

The literature study had presented a picture of Gripen pilot as a user group that is fairly homogeneous (compared to the great variety of technicians and engineers working with the aircraft). Although the group of aviators still spans from new pilots in training to highly trained test pilots with long experience of the aircraft type, they have a clear and common goal in the safe and effective use of the aircraft. In Sweden the pilots also have a common background and experiences from the one air force flight academy that trains combat pilots.

This view of the pilots as a stakeholder group was confirmed in the interview with a Gripen pilot. “Traditional” publications are most frequently used during initial training and are later used as reference, though often as a second or third choice after alternatives such as consulting more experienced
colleagues or revivifying the issue at hand in Multi Mission Trainers (MMT) or Full Motion Simulators (FMS) (see Appendix 3). For the purpose of training the documentation could be improved regarding the support of the integration and systems thinking in JAS39. As the general aircraft description (Allmänn Beskrivning Flygplan, ABF) is a hardware structured reference publication, it is insufficient in its pedagogical support for communicating the desired mental models, or constructs, of the integrated systems to the students.

The interface or integration between the manufacturer’s user information and the context of a pilot’s daily operational praxis and environment is also open to improvement. This comprises air force specific user information like the Handbook JAS39 (HAJAS), Tactical directives JAS (TAJAS), Operational security instructions (OSF), weapon handbooks and other publications, as well as MMT and other simulators.

### 4.8 User Roles and Tasks

The results of the analysis of the material collected at the F10 Squadron and in the pilot interview indicated that better understanding of the roles and tasks of aircraft technicians and pilots was needed. To collect this complementary requirements and information about roles and tasks a second workshop was performed with training personnel from Gripen Customer Support at Saab.

This group consisted of personnel working with training of aircraft technicians and training needs analysts and a planner of pilot training. The workshop was performed with the same procedures as the one at the F10 Squadron. One of the trainers, who are a former Air force fighter pilot and an experienced civilian test pilot and instructor, supplied the main work on pilot roles and tasks.

To improve the validity of the information, the workshop was closed with the activity of jointly verifying the correctness of all the big sheets with notes on them, marking each note with numbers corresponding to its affinity heading. Representatives of the workshop participants afterwards reviewed the documentation of the affinity diagrams, also in order to contribute positively to the validity of the results. The requirements on user information where documented in the requirements list.

The findings presented a relatively small number of roles (19) and tasks (11) for the aircraft technician (Candell et al., 2003), to a great extent characterized by the earlier mentioned principle of a general aircraft
technician. All technicians are able to work with all systems on the aircraft, increasing flexibility and redundancy to the manning of the aircraft operation. Though the senior technicians are to some extent specialized on different system groups, this is not only to promote expertise, but also to facilitate the continuous education to keep up with the rapid development of different sub-systems. A more distinct difference between roles is instead the division between operational level maintenance on one side and intermediate and industry level maintenance on the other. Especially the last category showed potential to comprise a countless numbers of roles and tasks. Examples of the different roles from the Saab workshop are presented in Appendix 4 (Candell et al., 2003).

The collected material displayed great variation in levels of description used to define the different the roles. A few competence areas are directly connected to sub-systems of the aircraft (like the rescue system and the engine) were identified as specific roles. Others, particular on intermediate and industry level, were gathered in more aggregated affinity groups. The analysis showed that this might be a result of the type of experience that participants represented.

Concerning the tasks of the aircraft technician, a picture arose which to a great extent was in accordance with the current maintenance concept and user information structure. Examples of roles and tasks are presented in Appendix 4 and 5 (Candell et al., 2003). A fact worth noticing was the occurrence of the affinity group called Communication-Information. In the existing user information products or system, there are no functionalities corresponding or interfacing with these types of tasks.

The analysis of different pilot roles and tasks that emerged during the workshop showed a fairly clear high-level pattern of division between the operative pilot roles and that as a teacher or trainer, either on the ground or in the air (examples of roles and tasks are presented in Appendix 4 and 5). The tasks are to great extent similar and do not depend on which role the pilot is acting in. This agreed to great extent with the picture that arose during the theoretical study, a picture of a fairly homogenous work system (see Section 4.7). It also confirmed the picture of multiple and highly different types of sources that the pilots use to find user information (see Appendix 3).

The analysis of data from the second workshop, together with that from the pilot interview, lead to the decision to not continue a pilot track in the study. This was based on several reasons. The study had so far indicated that there were complicated interrelationships between real time and non-real time
information supply to the pilot. One example of this is emergency checklists, which are supplied both in printed flight manuals, as well as in real time in the cockpit when faults occur. The empirical material about aircraft technician and pilot requirements so far also presented strong indications of two disparate work systems and contexts. The practical complications in terms of limited resources, as well as the foreseen complications with the demonstrator development, was evaluated and regarded as unfeasible to handle within the scope of the project.

4.9 Use cases – Flight Line Operation

The knowledge about stakeholders, roles, tasks and context that evolved mainly during the theoretical studies and the workshops, was integrated, described and documented in context descriptions and representative use cases. This material was delimited to an aircraft technician performing flight line operations (FLO) and fault localization activities. The choice to study FLO is based on the fact that it may be described as a technical center of flight operations, where aircrafts are made ready for the sortie and are received after landing. The tasks performed in FLO are often time critical and, with few exceptions, critical for flight safety. Many decisions are made in FLO about how to handle faults and other problems and user information is a vital part of such decision processes. The aircraft technician must for example decide whether it is possible to take care of a problem at the flight line and to have the aircraft ready in time, or if it is necessary to move it to the hangar for further fault localization and repair. This choice also delimits the study to a defined part of the social context and environment of the studied system-of-interest, JAS39 Gripen.

The material describing contexts and prerequisites was explored and analyzed in iterative cycles together with the elicitated requirements, roles and tasks during the initial development of a way of working and the development of the demonstrator. The results were documented by the author and representatives from Sörman in use cases in the form of the following narrative descriptions (Section 4.9.1) and used in the development of the way of working and the demonstrator.

The use-case approach was also practiced in business projects at Sörman (Sonesson, 2000; Jernbäcker, 2003), from where parts of the empirical material originate. The use cases were utilized in the work of the cross functional team as a complementing, indirect expression of requirements, mainly using natural language to communicate information and knowledge difficult to express in a more formal requirements notation.
The collection of material for the use cases from literature, documents and the empirical study and the analysis and development of them, helped to build knowledge about the studied stakeholders, their interaction with the system-of-interest and the support system, as well as the context and environment for their work. The use cases supplied references on these issues during the demonstrator development and contributed later positively to the usability of the demonstrator specification.

4.9.1 Use of the existing Line Maintenance Instructions

To collect knowledge about the aircraft technician’s daily work with flight line operations (FLO), a closer look was taken at the use of the Line Maintenance Instructions (SKI), which is a part of the AMM (UHF02). This publication is divided in three parts with Part 1 and 2 in two separate A4-binders, containing line maintenance instructions, armament alternatives instructions and frequently used service instructions. Part 3 is a small format binder fitting in the leg pocket of the uniform and containing the same information in abbreviated form and as checklists and tables. Being the most frequently used binder, it is often used for verifying things like alarms from the aircraft’s built-in-test and other deviations that might be allowed in accordance to specification and therefore disregarded under particular circumstances.

All the binders can also contain urgent or temporary changes, which are printed on yellow pages for easy recognition. These are rapidly dispatched and bypass the ordinary and slower distribution process. The binder can be and is, updated frequently and with short intervals, as it is of outmost importance for the flight safety that all information is correct and applicable to the particular aircraft individual the technician is working on. For this reason it is most important that the technicians always know the content of the latest yellow pages.

Individual reminders and notes also occur from time to time in these binders, although they are formally prohibited due to the safety risk implied by non-official information that may be invalid. Examples of individual reminders and notes that are used are:

- A compilation of all alarm number and fault codes list
- Small size schematics (with key to the signs) of some sub-systems that have more frequent problems
All in all the empirical material indicates that the SKI-binders to a certain extent regulate the performance of the aircraft technicians daily activities and that the flight safety critical and time-consuming task of changing paper sheets is regarded as an awkward and old-fashioned procedure to assure up-to-date user information.

Below follows three use-cases, or descriptions, of the aircraft technicians’ use of the SKI:

**Flight line turnaround**
Taking care of the aircraft that has just landed at the flight line and making it ready for another sortie is called turnaround. The aircraft technician in charge of a ground crew in flight line operation is the commanding officer of a group of five aircraft mechanics. Depending on the workload (number of aircrafts to be serviced, armament alternatives, available time and so on) the tasks are divided in different ways. The individual activities are all regulated in the SKI, but are possible to perform with lesser personal, which is the usual case during normal peacetime operations. The wartime requirement to turn around a Gripen for a standard fighter sortie is very short and demand in praxis that the members of the crew all know their personal tasks by heart. They refer to the SKI only when taking someone else’s place, for data on different settings or when they for some reason may be in doubt about a tool or a particular procedure. The SKI, written in the form of an instruction, is in this case mainly used as a reference for the particular task of aircraft turnaround.

**Amendment service**
The SKI binders are personal items. The owner who uses it is personally responsible for both the updating of the information and that he or she knows and understands changes and restrictions, both urgent or temporary changes (yellow pages) and ordinary amendments (white pages) that are in force. The SKI binder is updated by the issuing of amendment packages to each registered owner. Today, this is a distribution of paper hard copy. The receiver is personally responsible for taking out and disposing of old pages and putting in the new ones. When possible all technicians are gathered in a meeting, like the morning briefing, for a common run-through of the new changes and amendments.

**Failure warnings, alarms and fault localization**
If any equipment fails to pass the pre-flight safety check during turnaround, or when the aircraft’s functional monitoring has generated fault reports
during the flight, corrective maintenance actions are initialized by a formal report (TRAB) and a logbook entry describing the problem (see Figure 13).

Receiving the fault report with the failure warning number from the pilot or reading it from one of the displays in cockpit, the technician first of all checks if it is listed as an allowed deviation. If that is the case, the causes of the occurrence are explained, like for instance a certain combination of operations and maneuvers performed in a special system mode. The technician verifies the circumstances with the pilot and possibly with recorded flight data and the warning or alarm does not lead to any further action and is "written off".

If the failure warning number is not listed as an allowed deviation the technician refers to the aircraft maintenance manuals (AMM/UHF) for further advice. The utilization of the publication suite for fault localization is presented in Figure 14. Depending on the type of fault and what systems it concerns different actions are taken, though in general the fault localization starts with running different built-in-tests via the computer displays in cockpit. The test results and the AMM then supply further instructions and references (see Figure 13) and suggestions for units that should be replaced, or give instructions for other necessary actions. Some actions require the technician to read and take notes on detailed hexadecimal error codes, which are then used for continued fault localization with support from user information in AMM, schematics and manual fault localization.

4.9.2 Tests with Interactive Line Maintenance Instructions

Below follows the presentation of two constructed, hypothetical scenarios (or use-cases) presented in narrative form. They were built on pre-knowledge, literature studies and the knowledge from the empirical material and use cases and evolved with ideas of how a future computer based, interactive SKI might work in real life. Findings in the literature studies discuss the advantages of utilizing small computers to supply user information for operative technical military personal (see Section 3.4.4). A small computer that goes into the pockets of the uniform, would offers a graphical interface, comparable with the existing SKI Part 3 binders.
Figure 13. Example of Saab JAS39 Gripen AMM instructions for fault localization. Figure from Saab JAS39 Gripen AMM.
Figure 14. The utilization of the publication suite for fault localization. Figure from Saab JAS39 Gripen AMM.
The analysis made by the cross functional team indicated that a computerized interactive solution would offer faster and easier access to a larger information quantity, infinitely more possibilities to adapt and vary the ways of access, presentation and search and interact with the huge amounts of information connected to the operation of an aircraft. It would also most probably facilitate and speed up the procedures of updating the individual user information considerably compared to the existing routines.

The hypothetical scenarios aimed at stimulating the creative work within the cross functional team and could be viewed as “text-prototypes” or “dry runs” of the demonstrator, allowing a limited validation of the development concepts and ideas discussed within the team.

**Flight line operations of JAS39 Gripen during field conditions**

It’s freezing and a brisk wind is blowing when the ground crew drives away in a great hurry towards the area for flight line operations and the turnaround of an incoming Gripen fighter. The crew consists of Lieutenant Hansson who is in command and five conscript aircraft mechanics. Everybody wears gloves and warm clothing as the temperature at the dispersed base in the middle of the night has dropped several degrees below freezing point.

Mechanic 1 brings out and turns on his Interactive User Information Device (IUD). The IUD, a rugged COTS computer (commercial-off-the-shelf) with a backlight touch-screen and a size of a thin A5-binder, has been connected in the vehicle for recharging and updating during the crew’s rest period. As he logs on Mechanic 1 notices that the latest update, that’s arrived via the squadrons secure hybrid WLAN (wireless local area network), is just 20 minutes old.

The turnaround order dispatched to the crew contained information about a probable malfunctioning radio unit on the incoming two-seater. As they drive off Lieutenant Hansson calls the Service platoon over the radio, just to find them busy with another aircraft. The service platoon promises to send a driver with three potential “replacement candidates” to the area for flight line operations. With no support from the service platoon Mechanic 1 and 2 have to prepare to change any of the units themselves. They quickly bring up the IUD to read through the remove-and-install instructions and how to run the following functional checks, as they know the procedures differ from the same job on the more familiar single-seater. Mechanic 1 make three virtual binders on the IUD-navigation bar and puts in them the different instructions.
necessary for the probable scenarios, before he turns the computer into standby and puts it in his leg-pocket.

The conscripts are experienced and everybody knows the standard procedures when the fighter pulls to a stop at the assigned place. The need to fault isolate the malfunctioning units is confirmed with the pilot and after running some built-in-tests Mechanic 1 has verified which one to replace. He performs the task, reading the step-by-step instructions on the IUD. On top of the extra work with the radio one of the other mechanics runs into unexpected problems with the hydraulics, as the system doesn’t pass the automatic safety check. Lieutenant Hansson, who’s fairly fresh from training, wants to quickly verify the procedures for dealing with the problem and brings out his IUD, which he chooses to operate with the attached pen as it lets him keep his gloves on. Lieutenant Hansson knows hydraulics is in SKI Part 2, divider 3 and quickly reads through the procedure. To assure that there are no temporary changes or amendments, he performs a quick search on hydraulics for the particular aircraft individual by entering its tail number. There are no occurrences of “yellow-pages” and together with one of the mechanics he successfully fault localize and addresses the problem.

Thanks to the fast access to the necessary information the crews were able to successfully respond to the short noticed problems and they have the aircraft ready for take-off just in time when the new aircrew arrives.

Fault localization at the flight line at the Squadrons peacetime airbase

Lieutenant Månstedt and conscript mechanic Johansson are turning around a Gripen that has just landed. They put on their hearing protectors and wait for the aircraft. When the pilot has read the Quick Report from the aircrafts monitoring system and stopped the engine it’s time to go on with the turnaround procedures.

The pilot reports the occurrence of a Functional Monitoring (FM) alarm number 1034. Lieutenant Månstedt brings out her interactive user information device (IUD) from her pocket. By clicking on the FM quick access button and entering the alarm number she accesses the deviation list. It tells her that the occurrence of this alarm is normal and allowed during particular flight conditions. She discusses the issue with the pilot and they agree that this is what had happened and the fault report is written off without any further action.
If the alarm is not in the deviation list a cross-reference is supplied to the appropriate AMM instructions for thorough fault localization. An alternate way of access is through a general Fault Localization (FL) instruction and a graphical outline of the step-by-step procedure of FL.

4.10 Specification and Development of the Demonstrator

Analysis, results and the practical experience of working with the material from the workshops and the presented use-cases above, confirmed the potential of the adapted QFD-matrix approach to user information development. The developers assessment the results from the analysis of preliminary requirements and quality elements (see Section 4.6.2), was that they were satisfying. The way of working was experienced as less driven by technology and detailed solutions and did instead provide an increased focus on high-level performance and non-functional requirements, than traditional development methodologies.

At that point the practical work in the research project with the demonstrator development accelerated. So far the initial development efforts had mainly contributed to the development of the way of working. Around this time the way of working reached a higher level of maturity and it contributed to an increasing extent to the progress with the demonstrator development. As a consequence, the focus in the cross functional team slowly shifted and the analysis efforts could to greater extent be concentrated on the demonstrator development, than on the development of the way of working.

The collected data in the form of elicitated requirements was complemented with Gripen aircraft technician requirements, collected and documented by Sörman in a business project. That data had been elicited by one of the Sörman developers in a similar way at workshops at the F7 and F10 air wing, though without the use of affinity diagrams (Jernbäcker, 2003).

After the structuring and translation of the complementary requirements, the development of the demonstrator continued with the analysis of the complete set of requirements entered and re-worded in the Requirements list (examples of requirements are presented in Appendix 2).

These requirements (“What” in the words of the company) were then analyzed and transformed to quality elements (“How” in the words of the company) by the cross functional team in the Transformation matrix, see Appendix 6 (Candell et al., 2003). The transformation was made in an adapted QFD-matrix, similar to the House-of-Quality (HOQ) used in the
initial test, though without drawing the “roof”. A roof on the matrix was judged to become unwieldy, as the matrices were expected to grow to a considerable size. Instead the correlation between quality elements was documented numerically. This was done by the use of the unique id-number that was assigned to each affected quality element, which was assigned as attributes to the elements that had an effect on each other. The work with the Transformation matrix generated 36 quality elements.

Clarifying notes were documented for the quality elements in the matrix where it was needed. During this work a continuous correlation between requirements and quality elements was performed to assure that all requirements were taken care of and that no redundant quality elements were entered. The correlation was classified depending on the strength between requirements and quality elements, either as a strong, moderate or weak relation. When this part of the analysis was finished and the team had reached consensus on the quality elements, a correlation in between them was made, noted as positive or negative. The quality elements described, on an aggregated level, the required performance or functionality, without mentioning means to accomplish them. These activities were performed in several joint working session by the cross functional team, separated in time to enable individual analysis of the progress and results.

During the work with the Transformation matrix the “levels of cognitive control”-attribute, assigned to requirements from the preliminary requirements elicitation, was not that often referred to by the software developers. To facilitate the work in the matrix, a complementary attribute was introduced by the Sörman personnel, assigned to the Transformed Quality element ('How' in words of the company) in the Transformation matrix (Appendix 6) into three groups:

- Support & Situation: functionality aimed at general support or support in particular situations
- Information carrier: functionality connected to storage and transfer of information
- Information administration: functionality aimed at administrative management of the information content in the demonstrator

This attribute was mainly used as an aid for the internal work by the Sörman developers with software applications. Documenting it in the Transformation matrix allowed them to connect and trace this particular type of professional information to the original stakeholder requirements.
The deployment in the following Functional deployment matrix was performed in the same way in the same type of matrix. An extract is presented in Appendix 7 (Candell et al., 2003). The quality elements from the preceding matrix were here transformed to more detailed functions, work which was to great extent influenced by the Sörman developers. During the work with the matrix frequent references were made to the use-cases and the original stakeholder requirements, to clarify questions that were raised. In the functional deployment matrix a correlation was made to assure that all quality elements were taken care of and that no redundant functions were designed, although it was decided that classification of the strengths would not be necessary for the continuing work.

In the research project the limited number of requirements and the decision to use existing structured information, led to the choice to deploy all requirements in one sequence of matrices. However, an experience during the development work was that sub-groups of quality elements evolved within the matrices that pointed primarily towards implementation of the functions either in hardware and software, structured information or services. This experience, supported by findings in the literature study (Zultner, 1993), indicated that to support a bigger development project, a larger amount of requirements may be stratified and deployed in different matrices depending on their primary impact on either hardware and software, or structured information or services (see Section 3.6.1). The result of this analysis of the development work so far, indicated that this solution would be a practical way to supply the different professionals in a cross-functional development team with correct requirements and specification, relevant for the final implementation within their area of expertise. It was thought, that with a considerable larger amount of requirements, the matrices would otherwise be impossible to overview and the information load might become unmanageable and confusing for the individual groups of software and hardware developers or information designers.

This resulted in three “channels” or tracks in the suggested way of working: functional development, information development and services, each with its individual deployment in QFD-matrices. Although it was stressed that the development should still be performed within a cross-functional organization.

In the research project and the development of the demonstrator the approach with three “channels” or tracks was not applied, as the demonstrator was to use already existing structured information from the Gripen publication.
system and it was decided that none of the required services like amendment services or network communication, were to be functionally implemented in the demonstrator due to practical reasons.

Gradually the formal deployment and work with the matrices reached a maturity level where consensus on the demonstrator design was established between the different parties in the cross-functional team. The design documentation at this stage comprised the following documents:

- A requirements list containing 112 requirement objects with attributes
- A transformation matrix (translated requirements to quality elements) containing 36 quality elements with attributes and notes, correlated with each other and the 112 requirement objects.
- A functional deployment matrix (quality elements to functions) containing 26 functions with notes, correlated with the 36 quality elements.
- Lists with roles and task
- Environment and context description
- Use case descriptions (narrative)
- Working notes
- Project reports

(Extracts from the Requirements List and the matrices are presented in the Appendixes.)

This design documentation was then used to define the demonstrator as a product, which was done by compiling the documentation into a demonstrator specification. This stand-alone document also comprised descriptions of the required hardware and the specification illustrated how the challenge of formally contracting this type development work might be addressed. The specification is integrating information beyond a traditional specification, but does not include any formal contractual wordings.

The issuing of the specification had been preceded by minor studies and tests of the software and solutions considered for the demonstrator. However, it was not until formal approval of the specification, that the earnest efforts to implement the demonstrator application software started.

The frequency of meetings dropped considerably during the period when the demonstrator application software was implemented and regular reporting and discussions were mainly handled by e-mail or phone. At the end of the
development of the demonstrator the implemented functions from the functional deployment matrix were traced “backwards” through the development matrices to the requirements list. A final matrix was compiled for the main purpose of verification, where the functions from the Functional deployment matrix were correlated against the features implemented in the demonstrator application, see Appendix 8 (Benitez et al., 2003). This allowed a verification of the original requirements that was the final verification and validation of the finished product. This was facilitated by the use of a requirements register and development matrices.

Per definition the demonstrator is its own documentation, but after the formal completion of the demonstrator a rudimentary description was made of the design, presenting some features and examples of implemented functionality. Examples from the description are presented in Appendix 9 (Candell, 2004).
5 RESULTS - A SUGGESTED WAY OF WORKING

This chapter presents the overarching results of the research project, which is the suggested way of working for development of user information products and the demonstrator. The presentation is not a process description, but rather an annotated roadmap.

5.1 A suggested way of working for user information development

The iterative analysis of the development of a way of working and the demonstrator in smaller PDSA-cycles described in the previous chapter, showed how stakeholder based information products may be designed and how methodologies and tools may be adapted, forming a way of working, to support such development work. The result of this research is a suggested way of working for user information development and a demonstrator, illustrating this way of working and providing a prototype for a user information product. The suggested way of working is based on numerous results from the development of the demonstrator. The demonstrator is presented in Section 5.2.


Figure 15. The way of working for development of user information products within a framework that supports the development. Figure inspired by Söderholm (2003).
Important results are that the way of working should be applied within a supporting framework of stakeholder requirements, the system-of-interest and its support system and in the social context and environment for the operation. See Figure 15.

The suggested way of working is illustrated in Figure 16 and some particularly important tasks are marked with the letters A-E and commented upon below.

**Task A** comprises identification and documentation of stakeholder groups and individual stakeholders. The way of working requires a view on both the system-of-interest and the support system, as joint systems of man and machine in an environment and a social context, which is in line with the theoretical perspectives in Sections 3.1-3.2. This facilitates the identification of stakeholders and the understanding of the function of user information in a given system, which in turn contributes positively to a more complete elicitation of relevant requirements. Findings both in the literature study (Rasmussen et al., 1990; Rasmussen et al., 1994; Hollnagel et al., 1995; Hutchins, 1995) and the early phases of the case study, showed that a view on the complex technical systems as socio-technical and joint systems of man and machine, results in a broader approach to the process of identifying relevant stakeholders. This work is preferably done in cross-functional workshops utilizing different combinations of the tools among the 7MT (see Section 3.6.2) and documented in tree or affinity diagrams and maps containing the system-of-interest, support system and stakeholders placed in their environment and social context (see Figure 11 for an example).

**Task B** involves elicitation of empirical data and information about stakeholder requirements and prioritizations, as well as the structuring of these requirements in suitable affinity groups or in other suitable structures. The literature study (see Section 3.7) and the case study showed that it is important that the requirements elicitation and information collection is performed so that it captures both expressed and unexpressed requirements from the stakeholders. Collection of this type of information is valuable during user information development. This task should therefore aim to discover and explore needs unknown to the stakeholders, as the goal for the product development is not just to satisfy customer needs and expectations, but to preferably exceed them (Bergman & Klefsjö, 2003).
Figure 16. The suggested way of working for development of user information products. Important tasks are marked with the letters A-E.
The importance of a completed set of requirements that is amongst other things correct and unambiguous is stressed by the results from the literature study (see section 3.5 and 3.7).

To improve the understanding of these individual requirements as drivers for new development and of a continuous improvement of a system, the results from the literature study showed that it is also necessary to gather knowledge about overarching of the goals of the system, as well as about the qualities that are desired by the stakeholders (see Sections 3.3-3.5). This type of information and requirements should be documented in the product definition either as text or preferably, as derived requirements.

An adapted and documented cognitive science perspective on different types of human interaction and control should support the elicitation of requirements in a joint system (see Sections 3.1-3.2). This perspective enables the structuring of requirements and user information, depending on relations between information types and levels of cognitive control, which in turn to some extent facilitates both functional development and development of structured information. Task B should therefore comprise the initial attachment of attributes needed to facilitate the product development process.

One classification of requirements that facilitates the development work to some extent, is depending on whether the primary impact is judged to be on the user information products information system (A), human-machine-interface (HMI), knowledge construction (K) or rule-based information (R), (see Section 3.4.2). This classification is based on the results from the literature studies and the concepts of levels of cognitive control mode and what type of user information that can supply support for different levels (Rasmussen et al., 1990).

The results from the demonstrator development show that use of attributes facilitates the development work, by allowing good traceability of the requirements in different dimensions and by enabling quick sorting of the requirements in different categories. The case study also showed that it is feasible to attach new attributes later during the development process if the need arises.

The importance of identification of customer requirements was stressed by the findings in the literature studies (Andersson, 1991; Akao, 1992). The use of workshops for elicitation requirements was also shown to be an efficient way to collect vital additional information besides the requirements. This was
validated by the frequent demand and utilization of this information during the development work. It also proved to be a clear advantage for the members of the cross functional team to participate in the workshops during the requirements elicitation, a result supported by the findings in the literature study (Andersson, 1991). The workshops provided the participating team members with a valuable and common foundation of informal knowledge about different stakeholders, their expressed and unexpressed requirements and needs, as well as the contexts of interest.

The following are findings from the workshops, which were performed as traditional brainstorm sessions for creating affinity diagrams:

- It is important that participant stakeholders have a good understanding of the purpose of the workshop. A suitable number of days before the workshop the participant stakeholders were presented with a memo about the background of the project. This is an approach supported by several researchers (Andersson, 1991; Magidson & Brandyberry, 2001; Bergman & Klefsjö, 2003). The memo communicates important information to the stakeholders about the fundamental functions and product concepts for the product or system to be developed (Akao, 1992).

- Stakeholders’ ideas or preferences regarding requirements prioritization are important. Findings during the workshops showed that such ideas might be elicited in connection to the affinity diagrams by assigning the information as attributes to the notes. This information may also supply cues on other important attributes for the requirement objects.

- Notes from the informal discussions at the workshops are valuable, as they supplied highly usable information and cues on important attributes for the requirement objects and vital aspects of the system environment and context.

These original statements are preferably transferred into some kind of requirement record such as a register or database, which can facilitate the requirements management significantly. The original requirements may, in addition to the basic mandatory attributes, be complemented with attributes in steps as the need arises for additions during the development of the way of working. The analysis of the literature (IEEE-STD-1233, 1998; Kotonoya & Sommerville, 1998) and experiences in the research project resulted in a
suggested set of attributes that was viewed as useful during the demonstrator development:

- Id (unique identity)
- Date
- Requirement type (knowledge construction, rule-based information, information system, HMI)
- Source (workshop, interview or other)
- Stakeholders
- Task or Use Case
- Affected Role/Role Description
- Priority
- Impact (primarily on flight safety or flight time production)
- Parent of- (Id)
- Child of- (Id)
- Description
- Affinity Heading
- Reworded Requirement. (in design team language)
- Translated Requirement. (“what” in design team language)
- Group (S, B, I)
- Notes

Task C consists of translations of stakeholder requirements (“word-of-the-customer”) to the language of the development team (“word-of-the-company”). Findings in the literature study suggest that this may be done in several steps (Akao, 1992). The results from the literature study also stress that to be useful for the development, the information from the stakeholders about wanted qualities must be systematically analyzed (Akao, 1992; Gustafsson, 1996; Karlsson, 1998). Great caution and consideration about the language and nomenclature of the different team members, is also important to avoid misunderstandings within the team, as well as distortion of the original requirements. The different types of requirements are directed to the appropriate development track depending on assessed primary impact, though a particular requirement can occur in more than one development track (see Section 3.6.1).

Tasks D and E involves the transformation and correlation of requirements and quality elements into functions, performed in one or more matrices for each track. They constitutes the actual development work within the cross functional team through the use of the adapted QFD-matrices (see Section
3.6.1). The purpose of the deployment in the QFD-matrices is to transform the stakeholder requirements to product qualities (Akao, 1992), considering the requirements of the system-of-interest and its support system, as well as the impact and prerequisites from environmental and social context. Results from demonstrator development indicate that derived requirements may be moved or copied between QFD-matrices in different tracks, as the need arises. The requirements are broken down in the required number of adapted QFD-matrices, until the output has reached the level of detail that is desired for the implementation of the product.

According to Akao (1992), the deployment in matrices enables the development team to:

- Analyze systematically the structures of the quality demanded by the stakeholders in their own words.
- Indicate relationships between these demanded qualities and certain quality characteristics.
- Convert customer demands into counterpart characteristics.
- Develop a design quality.

It results in defined functions to be implemented by hardware and software, structured information or services, or combinations thereof.

The results from the demonstrator development indicate that moving from task D to E should likely include some kind of checkpoint in the form of a compiled product definition or specification. In the definition the results from the adapted QFD-matrices from the different tracks are integrated together with the other types of important design information. This final design proposal is preferably verified and validated against the original requirements before it is approved. The product may then serve as a reference, formally approved by the parties in a contract or other agreement on implementation and production. The unabridged development matrices and the use-case descriptions are preferably attached to the product definition (in the research project the demonstrator specification), as it is highly usable for the software developers. If the need arises in a real world application, a well-defined subset or selection of the requirements could be defined for to satisfy legal aspects of the business contract. This can then complement the verification and validation of the finished product in respect to conformance to legal aspects of the contract.
Task E then comprises the practical work with the implementation of the design. The designed functions are most likely implemented through a combination of software and hardware as well as through the production of structured information. The results from the literature studies (see Section 3.4.4) and the results from the demonstrator development, indicate that tasks D and E must balance a exploitation of new technology (“technology push”), with the view that design of information for users should not primarily focus on the choice of media or technology for the transfer of information; see Jacobson (2000). Preparation for delivery of the decided services may be implemented in either Functional or Information development, or through the establishment of unique service processes, or through a combination of the different solutions.

Task F comprises the final verification and validation of the finished product, utilizing the product definition containing the original requirements, QFD-matrices and use-case descriptions. Verification and validation can be described as the process where one determines whether the finished product fulfills the requirements or conditions imposed by the product definition (see Section 3.7). This should obviously comprise the product’s ability to satisfy and preferably exceed, stakeholder requirements and expectations (which is the focus for the study presented in this thesis), but also legal aspects of conformance to specification and contract. A final matrix may be compiled for the main purpose of verification, where the functions from functional deployment matrices can be correlated against the features in the developed user information product (see Appendix 8).

The verification and validation can be performed both by tracing implemented functions back to the original requirements and “forward” by tracing original requirements to functions implemented in the demonstrator. By exploiting notes and applicable attributes it is also feasible to connect requirements and functions to separate parts of context and environmental description as well as use cases.

5.2 The Demonstrator

The development of the demonstrator is a result of the application of the suggested way of working in the research project. It supplies a validation of the way of working and a user information product prototype that exemplifies how future user information products for complex technical systems may be designed. It uses existing structured information from the JAS39 Gripen system to achieve a high level of realism and thereby also creates realistic conditions for a validation of the demonstrator.
The more detailed goals have evolved through the use of the results from the initial parts of the research project. In the initial phases there has been a holistic focus, which during the following cyclic work has shifted towards a more detailed focus and on adding sub-functions or sub-units of structured information.

The design has paid special attention to the central aspect of time in user information support. Some user tasks demand information support close to real time and others allow the user to put the activity or role ”on hold” to obtain the required information or knowledge.

The functionality in the demonstrator has mainly been implemented through the use of commercial-of-the-shelf software (COTS) and partly through the design of new software. These applications allow storage, presentation and an interactive exploitation of the user information according to the requirements elicitation in the research project.

The software application is run on COTS hardware with properties such as extreme durability to environmental effects and a touch sensitive screen, which contributes to fulfilling stated requirements on usability.

The information content is also adapted and structured according to the requirements. The overarching information structure is the ”backbone” in the central ActiView application. This information structure may be adapted either to mirror the physical structure of the system-of-interest or sub-system, a document structure, a functional structure or step-by-step instructions. The information content is supplied to the application in the form of manuscripts containing text sections (data modules), illustrations, external references and links. The manuscript contains information about where the content elements are to be placed in the overarching ActiView structure (SGML or XML coded according to the AECMA standard). If the user information product is to contain animation or video, these are described in separate manuscripts and story-boards (this is not implemented in the demonstrator in the research project).

The production of information content is performed in different ways, mainly by technical authors or information designers, illustrators and software developers. The work may comprise:

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1 ActiView is a registered trademark of Sörman Information & Media AB
• Writing or adapting text sections (data modules).
• Editing of text sections and creating links.
• Drawing or adapting illustrations.
• Adding point or click sensitive areas in illustrations.
• Conversion of 3D-illustrations or CAD-data.
• Creation of animations or movies.
• Conversion between different mark-up languages (SGML, XML).

All information elements are the compiled and added to the overarching information structure and the content is configuration and version controlled through the use of an XML data file. The architecture allows a successive build-up, adding and removing of separate information elements and is therefore easy to maintain and control. In the research project the demonstrator utilizes, with few exceptions, existing information elements (data modules and illustrations) from the Gripen publication suite.

The human-machine-interface (HMI) is controlled mainly through the adapted ActiView application and it allows the user to control what information is to be presented and in what way by selecting different options. Together with the design of the overarching structure the HMI contributes positively to an increased usability by enhanced orientation and guidance. When possible the user information is structured task or role orientated to minimize the need to jump between different data modules and references. In the extremely complicated information structure of the aircraft, the user is sometimes still required to search and use several data modules of information for one task and functionality is implemented to facilitate the access and orientation where this has been unavoidable.

The user interface also allows connections to systems outside the demonstrator, such as operational monitoring systems, materiel support systems, fault report systems and others, though this is not implemented in the research project. Illustrations of the demonstrator hardware and examples from the user interface are presented in Appendix 9.
6 CONCLUSIONS

This sixth chapter will summarize the findings of the research related to the stated purpose and research question. It will also discuss some aspects about reliability and validity.

6.1 Addressing the research questions

The purpose of the research presented in this thesis is to explore and describe the development of stakeholder based information products for complex technical systems, in order to contribute with knowledge to the area of quality technology applied in user information development.

This purpose was to be fulfilled by answering the two research questions:

- What kind of methodologies and tools can support the development of stakeholder based information products for complex technical systems?

- How can a way of working (a methodology making use of appropriate tools) that supports the development of stakeholder based information products for complex technical systems be adapted or constructed?

The chosen methodology to answer the research questions was a combination of a literature study and a case study.

The first research question was addressed primarily by the initial investigations of the theoretical domains. The theory studied indicated that an approach of complex technical systems as stakeholder based and joint systems of man and machine, could contribute positively to the design of user information products for these systems. It supplies the scientific tools to take in account extra-system properties and requirements, which according to cognitive scientists is very important. A joint system needs be to studied in real life, in its social and organizational context, rather than outside it (Hoc et al., 1995). The systems view and the stakeholder approach contributed positively to the identification of relevant stakeholders and the collection of a broad range of requirements. As a result of this, the collection of important information regarding social contexts of praxis and environment was facilitated. The theory studied also brought forward QFD and matrix diagrams as possible methodologies and tools to support the design of stakeholder based information products for complex technical systems (see Section 3.6). Within the case study a preliminary requirements elicitation
structured in affinity diagrams and a small-scale application in an adapted QFD-matrix was performed. QFD was central to the approach, as it provided support for the important move from high level customer needs to more detailed technical requirements (Akao, 1992; Barnett & Raja, 1995). The results showed that the QFD methodology, matrix and affinity diagrams, combined with the system view, could support the development of stakeholder based information products for complex technical systems.

The second research question was mainly answered within the case study. The results of the development of the demonstrator showed that the use of the matrix diagrams could be adapted to transfer of requirements to the design process and thereby support the development of stakeholder based user information products. This comprised, for example, documentation of correlation between quality elements and functions numerically as attributes, instead of graphically in the so-called House of Quality (HoQ) roof and the concept of requirements deployment in matrices in three different tracks for development of functions, structured information and services. However, due to the limited number of requirements and practical limitation of the research project the deployment of the requirements for the demonstrator development was made in a single sequence of matrices. Through the adaptations, the use of QFD to systematically transform original needs and requirements of the customer into product qualities became better adjusted to support the development of the demonstrator.

The theoretical study also contributed to the purpose of the study by creating knowledge in the area of quality technology applied in user information development. This was supplied through the establishment of a theoretical base for the study, which at the outset of the project was identified as missing due to the fact that information design is not yet established as a research area. This base rests on applicable parts of cognitive science and a concept of joint systems (Rasmussen et al., 1990; Rasmussen et al., 1994; Hollnagel et al., 1995; Hutchins, 1995) and within the domain of quality technology, on the utilization and integration of formal requirements management (Zultner, 1993), the so called seven management tools (Mizuno, 1988; Klefsjö et al., 1999) and Quality Function Deployment (Akao, 1992; Herzwurm & Schockert, 2003).

However, the structuring of requirements according to types of levels of cognitive control did not become as valuable as expected during the demonstrator development. This may to some extent be explained by the fact that the demonstrator was to use existing information from the Gripen
publication suit, already structured to some extent in this perspective. Another cause may be that not enough efforts were made to extract this type of information during the requirements elicitation.

The development of the way of working and the demonstrator was performed in smaller PDSA-sequences towards established and clear goals. The cycles included theoretical studies, either individually or in the cross-functional team, followed by practical application focused on and around, the adapted QFD-matrices, which constituted the pivotal point of the development work. The way of working facilitated a holistic view on the system-of-interest, which helped the cross functional team to optimize the design towards system goals. It also promoted continuous and interactive feedback between the participants and follow-up of the results towards project plans. This analysis resulted in turn, in new action plans containing both theoretical and practical work applied in the next cycle. Thereby, a continuous knowledge transfer and a verification and validation of the progress were achieved and problems and needs of adaption or change of the design were possible to identify in early stages of the development. This was a way of working that proved to contribute positively to the adherence to project plans and to avoid costly and resource consuming re-work.

The developed way of working also helped to build a common frame of reference for the requirements and interpretation of contexts for the demonstrator development. This framework went beyond the integration of project unique information and knowledge in the individual’s professional role and grew during the project to a significant knowledge about the other team members’ professional domains as well.

By applying the developed way of working to develop the demonstrator, the demonstrator concept contributed positively to the validity of the suggested way of working. I also presented a tangible result in the form of a user information product prototype that supplied an example of how a modern user information product could be designed. The result from the demonstrator development in the form of a finished prototype, contribute to the purpose of the study, as is supplies a connection between the developed way of working and real life applications.

During the demonstrator development it proved to be vital that the actual design work was performed by the complete cross-functional team. The discussions connected to the work with the matrices and design decisions, generated an informal and continuously growing common base of reference
and development “record”, that had impact on the development of the demonstrator. The fact that it is difficult to document this kind of information in its entirety in notes or protocols is a problem which may contribute negatively to the traceability to requirements and thereby the validity of the way of working. This problem can probably be reduced by keeping a more formal and extensive design protocol, connected or integrated with the requirements database.

It is also vital that the team consists of representatives of all the disciplines applied in the entire development process, from market analysis and stakeholder identification through design, production and sales, to customer and product support. In the research project these roles were represented by a limited number of individuals, which may have biased the interpretation of the requirements. To reduce the impact of such bias a suggestion from one of the external reviewers was that the requirements transformation and deployment may be performed in to parallel teams and the results could then be compared and integrated in the later stages of the functional deployment.

The knowledge and experience of the way of working increased successively at Sörman during the research project. The feedback contributed significantly to the adaptation of the QFD-matrix-methodology and these cross-functional working sessions proved to be of decisive importance for the communication and transfer of information within the team.

The design documentation and the specification showed to be valuable assets, according to the software developers. During the software development there were very few issues that needed to be sorted out. A majority of the questions that did arise were resolved by utilization of these documents, which allowed the software developer to easily trace design decisions back to original requirements.

6.2 Reliability and validity of the research results

This section reflects on the issues of reliability and validity of the realization and the results of the research project, seen from the perspectives discussed in Section 2.7.

When looking at the results of the presented study there are some aspects that should be considered. In the literature study a wide range of different databases was covered in order to take in a number of different views on the studied problem domain. As this resulted in a vast amount of information the result of the choice of methodology may have lead to key-references being
missed, which would have negative impact on the validity of the literature study. To minimize this risk, the author used a wide range of starting points within the different areas, supplied in the literature as well as from the pre-knowledge within the cross functional team. The search for key references has also been discussed in scientific seminars within the quality discipline at two different universities and during different PhD courses, as well as with a number of specialists within the industry.

The fact that the demonstrator development was done in one track, instead of three as in the suggested way of working, may also contribute negatively to the validity and the possibilities to generalize the study’s findings. The two main reasons for this decision where that the purpose of the research project did not comprise a full function prototype and that the demonstrator was to utilize existing structured information, due to lack of resources for production of new structured information. However, the demonstrator development did comprise deployment of requirements and quality elements on both structured information and services within the matrices (see Appendix 8). Although they where not implemented with features in the finished prototype, the deployment, as well as findings in the literature study (Zultner, 1993) indicates that the approach with three track is valid and is more a issue of scale than of development principles (see Section 3.6.1).

The pre-knowledge of the author is mainly from the area of customer and product support within the defense industry and this has probably influenced the work in the research project. To reduce the negative impact of this bias, a formalized research design has been adapted and decisions in the study have often been preceded by discourse with colleagues at the university, as well as within the cross functional team. On the positive side this pre-knowledge has facilitated access to documents and empirical material that may have been more difficult to discover for an external researcher.

In the case study the empirical data collection and the different professional knowledge within the cross-functional team, has provided access to different sources of evidence and thereby supplied a data triangulation, which should affect the validity positively. To increase the reliability a case study protocol and a structured filing system for collected data has been used in the study. Other actions were, for instance, the handling of the notes from the workshops, which were presented to the participants for review. Still another action was the use of a laptop for direct notations in the software handling the requirements matrices during the development working sessions.
The reports of the final results of the NFFP-project have also been externally reviewed and approved at the end of the project. This review was performed by three independent reviewers: Professor Uday Kumar, Division of Operation and Maintenance Engineering LTU, Technical Fellow Integrated Logistic Support (ILS) Göran Rydman M.Sc., Saab and Project Manager Ulf Jansson M.Sc., Sörman Information & Media. None of the reviewers were involved in the research project, although Rydman and Jansson are employed by the companies that participate in the research project.

These different measures have probably augmented the application of a broad and less biased study of the phenomena and contribute positively to the reliability and validity of the study.
7 DISCUSSION

This chapter discusses some additional aspects of the findings in the research project. It also presents some suggestions for further research.

7.1 Experiences of the way of working and the demonstrator development

The result of the research project may be viewed from two perspectives. The first is the development of a way of working to support the development of user information products for complex technical systems. The second perspective is the dual use of the development of a demonstrator, both as a means for validating the suggested way of working and as methodology for product development.

The way of working developed in the research project was to a great extent a result of the use of iterative PDSA-cycles within the development process. The cycles included theoretical studies, either individually or in the cross-functional team, followed by practical work in the QFD-matrices. This contributed positively to the adherence to project plans and to avoiding costly and resource consuming re-work. The way of working also enabled the building of a common frame of reference for the requirements and context. This framework went beyond the integration of project unique information and knowledge in the individual’s professional role and grew during the project to a significant knowledge about the other team members’ professional domains as well.

On the negative side was the fact that developers experienced the initial stages of development work as sluggish. Much of the work with the initial matrices was spent learning and understanding the concept of QFD. The philosophy of using non-functional requirements and original user statements and requirements as input to the design work generated a certain amount of discourse. Though as the experience grew and with the arrival of positive effects, the attitude changed.

A factor that influenced the design, according to the developers, was the consideration of unexpressed requirements within the project, in terms of pre-knowledge on both the stakeholder and developer side. There is a floating boundary between what is documented in original requirements and in notes in different matrices and knowledge that has been internalized in the individual developer during the process of eliciting requirements and developing the system. Some of this can be ascribed to the fact that both
parties nourish ideas and values about the other part and this has an impact on communication and interpretation of what is said and expressed in writing. One example is that stakeholders frequently use existing applications and systems as reference when expressing requirements. This can be functional, but might also restrict their expressions in an uncreative way and might lead to strange requirements tied to prerequisites like for instance obsolete technology.

The knowledge that has been internalized in the individual developer also builds the professional skill that enables the developer to connect to and transform the requirements expressed by the stakeholders, into functionality implemented in the system. However, this may also pose a potential risk as it can drive the design away from the original stakeholder requirements. This transformation of requirements is however to a great extent documented in the different matrices and possible to trace. By adding notes on from the discussions and about assumption made for different transformations, the risk for misinterpretations can be reduced.

The coordination of unexpressed requirements with those expressed can be exemplified by the considerations made by the cross functional between different requirements and the knowledge of environment and context gained through study visits, use cases and other sources. Together these different sources of input will guide the developers in their choices. These sometimes undocumented and informal decision processes might on the other side also be potential sources of conflicts, if the parties are unclear in their communication and assumptions.

According to the software developers in the research project, the suggested way of working in a cross-functional team using the adapted QFD-matrix, supplies increased focus on stakeholder requirements. A result which is also supported by results from the literature study (Karlsson, 1998). The results from the research project also show that the use of the adapted QFD-matrices contributes to a more efficient communication between developers and stakeholders as well as within the development team, compared to traditional development work. It also facilitates and improves requirements management and the possibility to reduce business risks connected to misinterpretations and disagreements over specifications. These experiences are summed up as follows:

- Stakeholder focus is often insufficient in traditional development work, where one group of people develops a formal specification, which is
then handed over to a sub-contractor or another group that develops and implements the design. Traditional development work focuses primarily on conformance to the formal specification, rather than to satisfy and preferably exceed, stakeholder needs and expectations. The suggested way of working in this thesis results in an increased stakeholder focus.

- In traditional development, methodology and specifications there are difficulties in managing and communicating knowledge between the parties in a development project about unexpressed and unknown needs of the stakeholders and about the context of the system-of-interest.

- In traditional development work, there is often an information and knowledge gap between pre-studies and development phases, which complicates development work and impairs the ability to trace formal requirements in the specification to the original requirements and needs of the stakeholders.

- Problems with inadequate requirements management and specifications often have expensive business consequences.

The demonstrator developed in the research project is a new computerized system for presentation of user information, aimed at aircraft technicians working with the JAS39 Gripen aircraft in the Air Force. It illustrates functions for presentation and management of user information and is implemented with the use of commercial-of-the-shelf technology (COTS) adapted and developed by Sörman. As a result of the research project the product prototype exemplifies a concept of how a future user information support might be supplied.

Prototyping as a development methodology is an inexpensive and quick way to way to build a preliminary version of a system, giving users and developers a chance to interact with a temporary version of the proposed system (Checkland & Holwell, 2000). The utilization of a demonstrator as an integrated part of the suggested way of working in the research project showed obvious advantages, as discussed in Chapters 4-6. The efficiency and the confidence are increased in the development work as it supplies concrete possibilities to verify and to some extent it can validate partial results comparatively early in the development project.

The demonstrator specification may also be used as a means of reaching consensus about the operational concept for the demonstrator, between different stakeholders such as buyers, developers, support representatives and users. The final design can then embody the knowledge and experiences
gained from the involvement of users and other stakeholders during the prototype development. These experiences from the research project are supported by Checkland & Hollwell (2000), who argues that this approach is common with decision systems and so-called expert systems and also relevant to systems based on COTS applications. These advantages, which obviously also may have positive economic effects, are likely to be more pronounced in bigger projects where small deficiencies or delays can quickly incur large costs. Prototyping does, however, still require a solid input in terms of purpose, requirements and other data about the system being developed.

In the research project the importance of prioritization in the workshop was played down, as the ambition was to achieve a broad and unbiased elicitation. This fact rendered few comments from the development team at the time. However, a high-level prioritization was made by the aircraft technicians at the F10 workshop, regarding the requirements connection to flight safety and flight time production. In the end these were considered to have had limited impact on the development work, according to the developers. Later on in the development work the opinion within the cross functional team were that this was a shortcoming and that issues of prioritization would have been facilitated by access to more elaborated stakeholder prioritizations.

One explanation of this might be the developers perception that they had let implicit requirements, in the form of legacy practices and system solutions, more or less unconsciously influence the prioritization of requirements. This may also be described as a flaw in the requirements elicitation and the detailed control and follow up of the development work. Another ambition during the demonstrator development was to perform a broad and unbiased assessment of explicit stakeholder requirements on detailed functionality or features, though indirectly detailed requirements may have had an impact, as they were referred to every now and then in the discussions in the cross functional team. This bias might to some extent be balanced by the frequent utilization of the design documentation to trace design decisions back to original requirements. This implies that the developers indirectly perform a more or less continuous verification during their development work. This in turn contributes positively to the quality of the finished product.

Altogether these experiences emphasize the importance of securing a broad and representative selection of stakeholders for the collection of requirements and needs and to consider a more formal prioritization of the requirements related to high-level goals of the system-of-interest.
The findings during the demonstrator development also indicate that there is no formal problem to mix old and new requirements in the way of working, as long as they are valid. This increases the usability of the way of working for development work within a continuously improving complex technical system.

7.2 Future research

The study presented in this thesis points towards several different issues to consider for further research. In this section the author presents some suggestions for further research that arose during the research project, but were not pursued within the scope this study.

The findings in the presented study indicates that user information is integrated and is an important part of enabling systems for customer and product support and may become an even more important part in the future. Trends within the industry studied point towards challenges in the aftermarket area that will focus on products and services connected to the customers’ and other stakeholders’ needs of high system safety and reliability and an efficient support system. Examples of such products and services are modifications, spares, user information, maintenance, support system development and technical support. Development of these products, aimed at satisfying the customer’s present and future needs of support solutions, raises new requirements on methodologies and tools for the operations that develop, produce and deliver the products.

Increased pressure on functionality and economy makes it easier for customers and other stakeholders to get rid of obsolete requirements, unnecessary features and bad suppliers. Developers and suppliers therefore need to develop an improved capability to elicit, analyze and understand the actual requirements and needs of customers, even unexpressed and unknown. This highlights the need to develop and establish methodologies and tools that can support a formalized requirements engineering and management, especially of non-functional requirements, as input for requirements prioritization and value analysis. Within this problem area, it is important to study the roles and powers of various stakeholders and network of stakeholders, regarding the system-of-interest as well as the enabling systems.

Further work could preferably develop these approaches and work to adapt them to the area of requirement prioritization, which presents a number of interesting methodologies and techniques. Requirements selection and
prioritization have successfully been addressed by several authors (Andersson, 1991; Karlsson, 1995; Gustafsson, 1996; Karlsson & Ryan, 1997; Karlsson et al., 1998).

Further work with requirements elicitation may also be improved by the use of so called focus groups, a technique where data is collected through group interaction on a topic decided by the researcher (Wibeck, 2000). Another area of interest may be to explore the potential of re-using the application of QFD for development of a product evaluation methodology.

Within the explicit area of user information, research about information products that support organizational learning and learning in context may become increasingly important. This was exemplified within the research project by the needs of the JAS39 pilots. The study showed that different information sources in the pilot environment needed better integration and interfaces with other systems or artifacts such as Multi Mission Trainers, Full Mission Simulators, Mission Support Systems an others. It should also comprise efforts to structure information better towards the way pilots operate and utilize the aircraft, rather than how it is technically implemented.

The possibilities to improve the approach of using use-cases as development documentation may be explored by developing the use of narrative stories as development documentation and to describe and define usability criteria.

Findings in the study also indicate that a better understanding of the interdependence between roles, tasks and requirements on user information may contribute positively to the development of user information. On a less aggregated level (like equipment or component) roles are by definition less system unique and more general technical roles and tasks are to a greater extent characterized by the competence in a particular technological knowledge domain. This is a phenomenon that may influence the possibilities for a more efficient reuse of user information in complex technical systems.
REFERENCES


Appendix 1

Extract from F10 HoQ matrix
Flight technicians requirements derived from
Standards diagram [Transferring vid.
(1), BV 1, 2002-05-15, KI 06-15-01 (family)
diagram]
Appendix 2

Extract from Requirements List
### Requirements list

#### Ver 1

**SlöM 03-05-19**

1) **Type**
   - Knowledge Construction: The requirement primarily affects:
   - R: Ruled based information
   - IS: Information System
   - HMI: Human Machine Interface

#### Ändringshistorik:

- F10 AC Techs, 2002-05-15
- F7 AC Techs, 2000-11-27
- F10 AC Techs, 2001-06-25
- Saab GC Training, 2003-03-05
- SIoM Växjö, 2003-05-19

#### Notes 2003-05-19

**Req-1 2002-05-15** IS F10 AC Techs

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<td>Informationen ordnad efter situation/aktivitet/sys. integration</td>
<td>Användaren vill ha en möjlighet att söka och ordna informationen så att den stödjer honom i varje enskild situation. Dvs en koppling av individens roll i varje situation till sammanhanget och omständigheterna kring.</td>
<td>Varje enskild situation ska definieras och avgränsningar för vilka som ska beaktas i demonstratorten ska göras.</td>
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<td></td>
<td></td>
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<td></td>
</tr>
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<td>Req-3</td>
<td>2002-05-15</td>
<td>IS</td>
<td>F10 AC Techs</td>
<td>FTP</td>
<td>Viss information finns utspredd i flera UHF. Skulle vara bra om den kunde samlas i en och samma UHF, tex larmnummer, RUF-variabler.</td>
<td>Informationen ordnad efter situation/aktivitet/sys.integreation</td>
<td>Användaren vill ha en möjlighet att söka och ordna informationen så att den stödjer honom i varje enskild situation. Dvs en koppling av individens roll i varje situation till sammanhanget och omständigheterna kring.</td>
<td>Varje enskild situation ska definieras och avgränsningar för vilka som ska beaktas i demonstratorten ska göras.</td>
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**Appendix 2**

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Appendix 3

Notes from Pilot Interview
1 A BRIEF DISCUSSION ON USER
INFORMATION FOR JAS39 GRIPEN
- A PILOTS POINT OF VIEW

Time: 2002-06-12, 7.30-8.45.
Place: PUMAx-room at Customer Support, Saab Linköping.
Participants: Olov Candell, Saab and Hans Einerth, TUJAS.

The discussion was performed as an informal interview with notes taken on the answers in
Swedish during the session. The notes were assembled and translated after the session and
entered in this PM together with the drawings and text from the whiteboard used
(Picture 1).

2 NOTES FROM INTERVIEW/DISCUSSION

On and around, the question about what information sources a Gripen pilot primarily rely on
in daily operations, why and strength-and-weaknesses with different sources:

Becoming a pilot is very much ‘learning-by-doing’, it is a lot of things that are difficult to
communicate and that one needs to experience first hand.

It is faster and easier to ask a more experienced colleague about something you want to know,
than to start by looking things up in the publications. They are often able to communicate not
just the answer to the question but also the important ‘look-and-feel’ of how things work
‘live’.

Information and knowledge about flight safety is much more than just technical
characteristics and data of the aircraft. One example is the great amount of knowledge
transferred between pilots during the daily debriefs on the squadron.

Publications as general aircraft description (ABF) are mostly used during initial training. It is
to help the student to gain a mental model of the system. The simplification of the systems is
all right for this purpose.

Using the ABF is frustrating as the information on a topic is scattered in a number of different
places that might even be hard to find. The structure does not support the way a pilot uses the
aircraft and its subsystem. One example is information about using the automatic canon,
which is spread throughout at least four different chapters.

After completed training the pilot uses ABF mainly as reference.
MMT (Multi Mission Trainer) is utilized as a “dynamic reference” where the pilot can verify functionality and learn thing in practice.

During training the pilot is more prone to fall back on rules for action and control. A more experienced pilot is less actively ‘referring’ to the explicit rule, but more aware and driven by the reason why there is a rule in the first place (different levels of understanding demands different types of information or knowledge support).

Flight manual (SFI) is too much influenced by the need of the manufactures (Saab) to cover legal aspects and avoid potential liability claims. This sometimes results in too much text and less practically relevant information. One example is that information of more general character ought to be placed in separate chapters instead of in checklists.

The PLA (Mission Support system, planning and analysis) is vital part in the ‘hardware’ structure supplying information support to the pilot. The use of PLA is connected to the use of Weapon handbooks. An intelligence officer, who also is the main user of PLA user manuals, supports work at PLA.

The UTA (Mission Support system, evaluation and analysis) has obvious educating qualities about the performance of the aircraft, as well as the pilot’s work in the cockpit. The use of UTA is connected to information in SFI. As with PLA, the pilots work with UTA is often supported by an intelligence officer.

Coordination between SFI and Line Maintenance Instructions (SKI) could be improved.
Picture 1

Facsimile from whiteboard; interview-discussion with Hans Einerth TUJAS, 2002-06-12

Problem ej med i denna skiss:
- Kommunikation m flygteknikern (behövs ”översättning”)
- Koordinering SKI-SFI kan förbättras
Appendix 4

Extract from List of Roles

Aircraft Technician and Pilot
"Vilka roller, ur ett användarinformationsperspektiv, skulle du vilja identifiera för flygtekniker respektive piloter som arbetar med Gripensystemet?"

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Appendix 5

Extract from List of Tasks

Aircraft Technician and Pilot
**Tasks - Tech & Pilot**


1) **Type**
The requirement primarily affects:

- **K**: Knowledge Construction
- **R**: Ruled based information
- **IS**: Information System
- **HMI**: Human Machine Interface

"Vilka aktiviter eller aktivitetsområden, ur ett användarinformationsperspektiv, skulle du vilja identifiera för flygtekniker respektive piloter som arbetar med Gripensystemet?"

<table>
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<th>Id</th>
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<td></td>
<td>Tech, planering</td>
<td></td>
</tr>
<tr>
<td>Tas-14</td>
<td>2003-03-05</td>
<td>Saab GC Training</td>
<td>Trainer</td>
<td>Drift</td>
<td>Tech</td>
<td></td>
<td></td>
<td></td>
<td>Tech Underhåll, förebyggande</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 6

Extract from Transformation Matrix
### Transformed to Quality element ('How' in words of the company)

#### Type
- **K**: Knowledge Construction
- **R**: Ruled based information
- **A**: Architecture
- **HMI**: Human Machine Interface

#### Group
- **S**: Stödja & Situation
- **B**: Bärare av information
- **I**: Informationsadministration

#### Symbols representing strength of relationship in the relationship matrix:
- X: strong relation
- y: moderate relation
- z: Weak relation

#### Notes
- Användaren vill ha en möjlighet att söka och ordna informationen så att den stödjer honom i enskilda situationer. Dvs en koppling av situation till individens roll och sammanhang.
- Användaren vill ha en möjlighet att söka och ordna informationen så att den stödjer honom i enskilda situationer. Dvs en koppling av situation till individens roll och sammanhang.
- Användaren vill ha en möjlighet att söka och ordna informationen så att den stödjer honom i enskilda situationer. Dvs en koppling av situation till individens roll och sammanhang.
- Användaren vill ha en möjlighet att söka och ordna informationen så att den stödjer honom i enskilda situationer. Dvs en koppling av situation till individens roll och sammanhang.
- Användaren vill kunna verifiera att det är senaste informationen. Vissa delar av regelsystemet är tillämpiga.

<table>
<thead>
<tr>
<th>Id</th>
<th>Group</th>
<th>K</th>
<th>R</th>
<th>IS</th>
<th>HMI</th>
<th>Description</th>
<th>Translated Req ('What' in words of the company) from the Req/list/Kravtabell</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Req-1</td>
<td>S</td>
<td>X</td>
<td>HMI</td>
<td>Lag &quot;[vokalhelhetstaktik integration...]&quot; Användaren vill ha en möjlighet att söka och ordna informationen så att den stödjer honom i varje enskild situation. Dvs en koppling av individens roll i varje situation till sammanhanget och omständigheterna kring situationen.</td>
<td>Användaren vill ha en möjlighet att söka och ordna informationen så att den stödjer honom i varje enskild situation. Dvs en koppling av individens roll i varje situation till sammanhanget och omständigheterna kring situationen.</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Req-2</td>
<td>B</td>
<td>K</td>
<td>R</td>
<td>Arbetade pub info för genomförande av ett arbete. Tex TS2 (Tillsyn 2, Stol)</td>
<td>Varje enskild situation ska definieras och avgöringar får vilka som ska beaktas i demonstratöms skåeras.</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>
Appendix 7

Extract from Functional Deployment Matrix
### Functional deployment Matrix

**Type**
The requirement primarily affects:
- **K**: Knowledge Construction
- **R**: Ruled based information
- **A**: Architecture
- **HMI**: Human Machine Interface

**Impact**
The requirement is prioritized due to impact on:
- **FS**: Flight Safety
- **FTP**: Flight Time Production

**Group**
- **B**: Bärare av information
- **I**: Informationsadministration

---

<table>
<thead>
<tr>
<th>Id</th>
<th>Group</th>
<th>Func-01</th>
<th>Func-02</th>
<th>Func-03</th>
<th>Func-04</th>
<th>Func-05</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Description</td>
<td>Notes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>Användaren får möjlighet att utifrån materielgruppsnedbrytning (befintlig struktur), materielstruktur, fysisk placering eller funktionsträd kunna navigera i informationsmängden till en begränsad del av dokumentationen. Märka upp informationen med exempelvis &quot;ingår i situation XX, YY, ZZZ&quot; för att möjliggöra urval utifrån situationen. Urval XX ger den samlade informationsmängden som användaren behöver för att lösa situationen XX.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>Avancerad fritextsökning som funktion som utnyttjar &quot;taggningen av informationen&quot;, söker från utpekad nod och nedåt i underliggande noder, från gjort urval söker i den begränsade informationsmängden.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>Replicering från original till klient varje natt.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>Versionsnummer synligt i dokumentet.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>För att hantera uppdateringar görs märkning på DM med både ändringsnummer och affärsdatum.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Symbols representing strength of relationship in the relationship matrix:**
- X = strong relation
- Y = moderate relation
- Z = Weak relation

**Id**

- **Traf. 01.01**
- **Traf. 01.02**
- **Traf. 01.03**
- **Traf. 01.04**

---

**Requirement from the Transformation Matrix**

**Quality Elements**

- **(Deployed 'How's' in words of the company)**

**Transformed Req ('How's' in words of the company)**

- **‘How’**
  - Användaren vill ha en möjlighet att söka och ordna informationen så att den stödjer honom i enskilda situationer. Dvs en koppling av situation till individens roll och sammanhang.
- **‘What’**
  - Användaren vill kunna välja detaljdjup på informationen.

---

**Notes**

- **For att hantera uppdateringar görs märkning på DM med både ändringsnummer och affärsdatum.**
Appendix 8

Extract from Demonstrator Quality Function Matrix
- function to Demonstrator features
# Demontrator Quality Function Matrix

**Id**

<table>
<thead>
<tr>
<th>Func-01</th>
<th>Func-02</th>
<th>Func-03</th>
<th>Func-04</th>
<th>Func-05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Användaren får möjlighet att: utifrån materielgruppambrytning (befintlig struktur), materielstruktur, fysisk placering eller funktionstid kunna navigera i informationsmängden till en begränsad del av dokumentationen.</td>
<td>Märka upp informationen med exempelvis &quot;Ingår i situation XX, YY, ZZZ&quot; för att möjliggöra urval utifrån situationen. Urval XX ger den samlade informationsmängden som användaren behöver för att lösa situationen XX.</td>
<td>Avancerad fritextsökning som funktion som utnyttjar &quot;taggningen av informationen&quot;, söker från utpekad nod och nedåt i underliggande noder, från gjort utvald söker i den begränsade informationsmängden.</td>
<td>Replikering från original till klient varje natt. Not applicable</td>
<td>Versionsnummer synligt i dokumentet. AECMA DM-kod</td>
</tr>
<tr>
<td>Användaren kan navigera i valda informationsstrukturer via navigeringslistan.</td>
<td>Användaren kan skapa och spara egenskruvarade navigeringslistor eller knippen med nav.lister.</td>
<td>Knapp förberedd (platsbärande) för access till sökformulär.</td>
<td>Inga tillämpningar i Demonstratort</td>
<td>Beror av vilket innehåll som används i Demonstratort (dokumenttyper). Ej applikabel med utnyttjat information (JAS39 Publictioner)</td>
</tr>
</tbody>
</table>

**Notes**

- X
- O

**Quality Functions**

*How in Demontrator*

Quality Elements, Deployed "How's" in words of the company.

*How in Demontrator*

Quality Elements (in words of the company) is realised in Demonstrator ("features")

---

**Id**

<table>
<thead>
<tr>
<th>Func-01</th>
<th>Func-02</th>
<th>Func-03</th>
<th>Func-04</th>
<th>Func-05</th>
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<tbody>
<tr>
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<td>Versionsnummer synligt i dokumentet. AECMA DM-kod</td>
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**Notes**

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**Notes**

- X
- O

**Quality Functions**

*How in Demontrator*

Quality Elements, Deployed "How's" in words of the company.

*How in Demontrator*

Quality Elements (in words of the company) is realised in Demonstrator ("features")

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**Notes**

- X
- O

**Quality Functions**

*How in Demontrator*

Quality Elements, Deployed "How's" in words of the company.

*How in Demontrator*

Quality Elements (in words of the company) is realised in Demonstrator ("features")
Appendix 9

Illustration examples from Demonstrator software and hardware
Ändringsmeddelande nummer 50

Datum: 2000-09-12

1 Ändringsanledning

Tabell 1. Ändringsanledning

<table>
<thead>
<tr>
<th>Föreskrift</th>
<th>Ändringsanledning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Länk J1-A-03-TÅ-00-23A-200A, Kap 2.1.16</td>
<td>Åtgärder vid misslyckad plundring av videobandspelare (VBS)</td>
</tr>
<tr>
<td>Länk J1-A-03-TÅ-00-57A-200A, Kap 2.1.14</td>
<td>Kontrollera huvuddäcken med avseende på &quot;bulor&quot;</td>
</tr>
</tbody>
</table>

A navigation bar is placed in the top left corner of the presentation window. It displays the structure of the document headings for the document currently chose by the user.

If the user jumps to other documents, another navigation bar is added for that document above the previous bar, and so on for every new document that is opened.
Temporär ändring nummer 56

Ändring: Tillägg till Kapitel 2.1 "Mottagning av fpl".
Giltighetstid: Tills vidare. Utredning pågår.
Gäller: 39A och 39B

Kontrollera huvuddäcken med avseende på "bulor".

1 Orientering

Problem har konstaterats med separationer i vissa huvuddäck. Däckexplosion har skett i ett fall. Orsaken till detta utreds för närvarande av däck tillverkaren i samarbete med Celsius, FMV och Saab.

Med anledning av ovanstående utförs en kontroll av huvuddäck vid mottagning av fpl.

2 Åtgärder

Slitbaneseparation yttrar sig som "bulor", de sitter vanligtvis på däckets insida på övergången till slitbanan, se Bild 1.

The user can create and save a personally designed navigation bar or cluster of navigation bars.
The navigation bar is connected to the fault isolation tree, and thereby give the user better orientation.

It supply the user with a graphical view of the chronological sequence of choices made during the fault isolation work.
Ändringsmeddelande nummer 50

Datum: 2000-09-12

1 Ändringsanledning

Tabell 1. Ändringsanledning

<table>
<thead>
<tr>
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</tr>
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<td>Kontrollera huvuddäcken med avseende på &quot;bulor&quot;.</td>
</tr>
</tbody>
</table>

A search form is accessed through a button, (prepared with a place holder).
Ruggad (kraftigt miljöskyddad) dator med pekskärm

- Operativsystem Windows XP
- Processor x86 arkitektur och 600 Mhz klockfrekevns
- Compact Flash 1 GB
- RAM 256 MB
- 8,4 " färgskärm med 32 bitars färgdjup. TFT SVGA, Transreflective, 120 graders synvinkel, 0-100% reglerbar ljusstyrka.
- 5 timmars batterikapacitet vid kontinuerlig användning
- USB-port
- vikt 1,2 kg