CHALMERS

Getting to Know the User of ARTHUR Weapon Locating System

A Step towards Use-Oriented Product Development

Master of Science Thesis [in the Master Degree Programme Industrial Design Engineering]

FREDRIK ANDERSSON
TAINA FLINK

Department of Product and Production Development
Division of Design & Human Factors
CHALMERS UNIVERSITY OF TECHNOLOGY
Göteborg, Sweden, 2010

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Sweden
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Cover: [The ARTHUR Weapon Locating System and the two personas developed, see chapter 3.2 and 7.1 for further informtion. Pictures by Saab Group, Boston, ImageryMajestic, Denson and Irusta]

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ABSTRACT

ARTHUR WLS is an ARTillery HUnting Radar Weapon Locating System, used to locate firing artillery weapons so that they can be disarmed and to estimate the impact points so that people on the ground can be warned. ARTHUR is developed by Saab Electronic Defence Systems. This thesis studies the users of ARTHUR and is an example of how a company can study their users' needs and behaviors in order to take human factors into account. It demonstrates how this knowledge can be conveyed into the product development organization, so that it comes to use. This will be done by creating a booklet of information on the user and includes pointers and methods of how to take the user and usage in account in the design process.

In the field of human factors, knowing your user is the key to success. When product development turns use-oriented, large competitive advantages will be gained. Theory suggests that human factors integration can be achieved in three ways; education, enforcement and end-user involvement. The basis for understanding user's needs is not the study of needs as such, but the study of activities and actions since needs cannot be detected directly. In this thesis, this is further complicated by the military culture and the fact that the users themselves are hard to reach.

The extensive data collection was carried out through interviews within the company and a telephone interview with an operator, surveys sent out to ARTHUR operators in four countries, observing deployment of the system as well as reading articles from the Danish artillery's mission in Afghanistan. The data was analyzed by, among other things, finding causes and consequences for the problems, issues and disturbances found. By analyzing the engineers as intended users of the booklet as well as their existing design process, requirements for the booklet were found. One of these requirements was to make the user present in the mind of the designer during the design process, and for this scenarios and personas were created out of the collected data.

Conclusively, the research carried out adds substantially to the knowledge of ARTHUR users and ARTHUR user behavior at Saab. The fact that the authors have not met the users in person probably contributes to the extent of the result but not the reliability of the result itself. The most important recommendation to succeed in human factors integration and in developing more usable products is to involve the end-user to a greater extent.

PREFACE

This is the master's thesis of Fredrik Andersson and Taina Flink and has been completed as a part of the master in Industrial Design Engineering. It has been carried out at the division of Design and Human Factors at the department of Product and Production Development at Chalmers University of Technology in Gothenburg, Sweden. The initiator of the project is Saab Electronic Defence Systems in Gothenburg where the project has been conducted. The master thesis has been running from February 2010 to August 2010 and constitutes 30 ETCS.

We would like to thank our examiner, Anna-Lisa Osvalder, for her warm support, and our tutor at Chalmers, Lars-Ola Bligård, for his deep involvement and for sharing his experience of both theory and practice of human factors.

We would also like to thank the many employees of Saab Electronic Defence Systems who have taken the time to be interviewed and letting us observe them in their work. A special thanks also to Torgny Hansson, the initiator of the project, for giving us the opportunity to undertake this project and for his valuable insights as well as our tutor at Saab, Jan Rydén, for his support, willingness to help and keen interest in our work. Last but not least, we would like to thank Gustav Klock and Robert Nilsson who are advocates of human factors at Saab, and have been mentoring us throughout the project. Thank you for your feedback and encouragement.

ABBREVIATIONS

ARTHUR	Artillery Hunting Radar
DEFSTAN	Defence Standard by the British Ministry of Defence
EDS	Electronic Defence Systems
FOB	Forward operating base
HF	Human Factors
HFE	Human Factors Engineering
HFI	Human Factors Integration
INS	Inertial Navigation System
MOTS	Military off the shelf
RCU	Remote Control Unit
TRU	Transceiver Unit
WLS	Weapons Loctaing System

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1 INTRODUCTION

1.1 Background

In the product development area there are major gains in considering human factors and adapting a product to its user, especially in performance. Traditionally, humans are thought of as adaptable compared to the tools they use in their work and therefore they have often had to adapt to less than perfect working situations. Adaptability is indeed a human quality, but it comes at a price. When adapting to a bad working situation, such as having to lean extensively to reach an often-used button, total system performance will decrease. If a user is understimulated from repetitive or monotonous tasks, remaining alert for any long period of time will be difficult. Human factors is about admitting and accepting that we are humans, which means that we need to adapt the technology around us to our human needs, weaknesses and strengths. Otherwise we will be continuously disappointed by poor performance of human-machine systems, which is any system in which a human interacts with a physical object to reach a goal.

Companies developing products used by humans therefore have everything to gain by considering human factors in their product development process. To do this, one needs to truly know the users of the product being developed. Learning about their needs and behaviors is vital for a successful design. These things are especially important in a military context where system performance can affect the outcome of a mission and staying alert or not can be the difference between life and death. Yet, in this context, where the need for user adaption is great, achieving it can be very difficult. Complaining about problems and admitting personal limitations is not something commonly associated with a military mindset and it takes hard work with proper requirements elicitation methods to get to that information. In addition, secrecy surrounding everything that concerns military organizations can be a problem. It might be impossible to even meet with the users for this reason.

Saab Electronic Defence Systems (Saab EDS) is a business unit within Saab Group, which is a company that focuses on military defense and civil security. Saab Group shares no ownership structure what so ever with the Swedish car manufacturer Saab and they should not be confused. One of the products developed at Saab EDS is the ARTillery HUnting Radar Weapon Locating System abbreviated to "ARTHUR WLS" or "ARTHUR" for short. The product basically reassembles a container truck with an antenna on the roof and is used to find artillery projectiles in mid air and to calculate their origin and landing spot.

ARTHUR is a successful product, but there is little communication between the radar operators who use ARTHUR out in the field, and the engineers that continuously develop the system at Saab. Current customer contact can be found within the departments that deal with service and repairs, the customer education department and the market department. These departments of course have other interests than requirements elicitation and user studies and little information useful to the design process is gathered here. In the company in general, there is a high level of knowledge about the product and the technology that it utilizes, but little knowledge of how it is actually used and who the users are. What are their characteristics, measurements, attitudes and needs? This is information that is sought after in many parts of the company, but the answers are yet to be found.

To get to this information is important, since it could potentially bring large competitive advantages in product design. But accessing that kind of user information is not enough in it self. To make proper use of the data, some level of human factors engineering (HFE) skills are required. How does one design a workstation so that it fits both someone that is tall and someone that is short? There are guidelines and rules for this, but they cannot be blindly applied. Guidelines are always general and need to be interpreted and applied to the specific situation by a human factors engineer. Even if those skills are acquired, it is still not enough. They must also be applied in the right way to the product development process. Human factors is not something that can be added afterwards, but rather something that needs to be an integrated part of the process. If a human factors evaluation is performed at the final stage of a product development process, it is likely that all suggested changes would become very expensive. Adapting a product to human strengths and weaknesses needs to be done throughout the entire process, usually already in the requirement specification phase. If done, there are large payoffs, for instance the product performance can be increased substantially at a low cost. Changing a design early, when it is still in a computer-modeling phase, or even in a requirement specification phase, takes a few hours. Changing a design when it is in a prototyping phase could take months and is associated with major costs. The worst scenario is to not consider human factors at all. Then the customer will complain after delivery, which could not only cost a small fortune, it could also damage customer relations and even the brand value. This thesis stems from the need for the type of user information that is not yet present within the company.

1.2 Purpose

The purpose of this thesis is to increase the understanding of the radar operator's working environment in ARTHUR, and to increase the knowledge about human factors engineering at the company.

1.3 Goal

The goal is to collect relevant information and knowledge about the users and how they use ARTHUR as well as to produce material that conveys knowledge about the user in an accessible way to be used by the engineers who develop ARTHUR in their work.

1.4 Delimitations

The emphasis throughout the thesis has been to create an understanding for the operator rather than to find solutions for problems found. The result will be in the form of guidelines rather than concrete suggestions for improvement in order for the information not to expire as fast and for it to be able to be applied in unforeseeable circumstances that can arise.

The focus has been on the system as a whole, and details of the system have only been studied when it was required in order to gain an increased understanding of the entirety. Neither the system software has been dealt with, nor the technical principals for the system.

1.5 Research Questions

The questions to be answered in this thesis are;

- Who are the users of ARTHUR and how do they use the system?
- How can this information be conveyed to the engineers at Saab?
- What is the first step towards implementing human factors in the development of ARTHUR?

1.6 Work Structure

The methods used to find answers to the research questions were selected based on experience from previous use-oriented projects at Industrial Design Engineering at Chalmers, and on the possibilities of the current situation. The entire process is visualized in figure 1. Getting close to the user and learning about his or her needs and requirements was considered first priority. When sufficient information was gathered, it would have to be analyzed to become meaningful. The resulting findings would then need to be processed into something that could be implemented at the company, so that the information could come to use.

Answering the first research question: who the users of ARTHUR are and how they use the system required the use of investigative methods. The radar operators turned out to be difficult to meet with, and they unfortunately had to be stud-

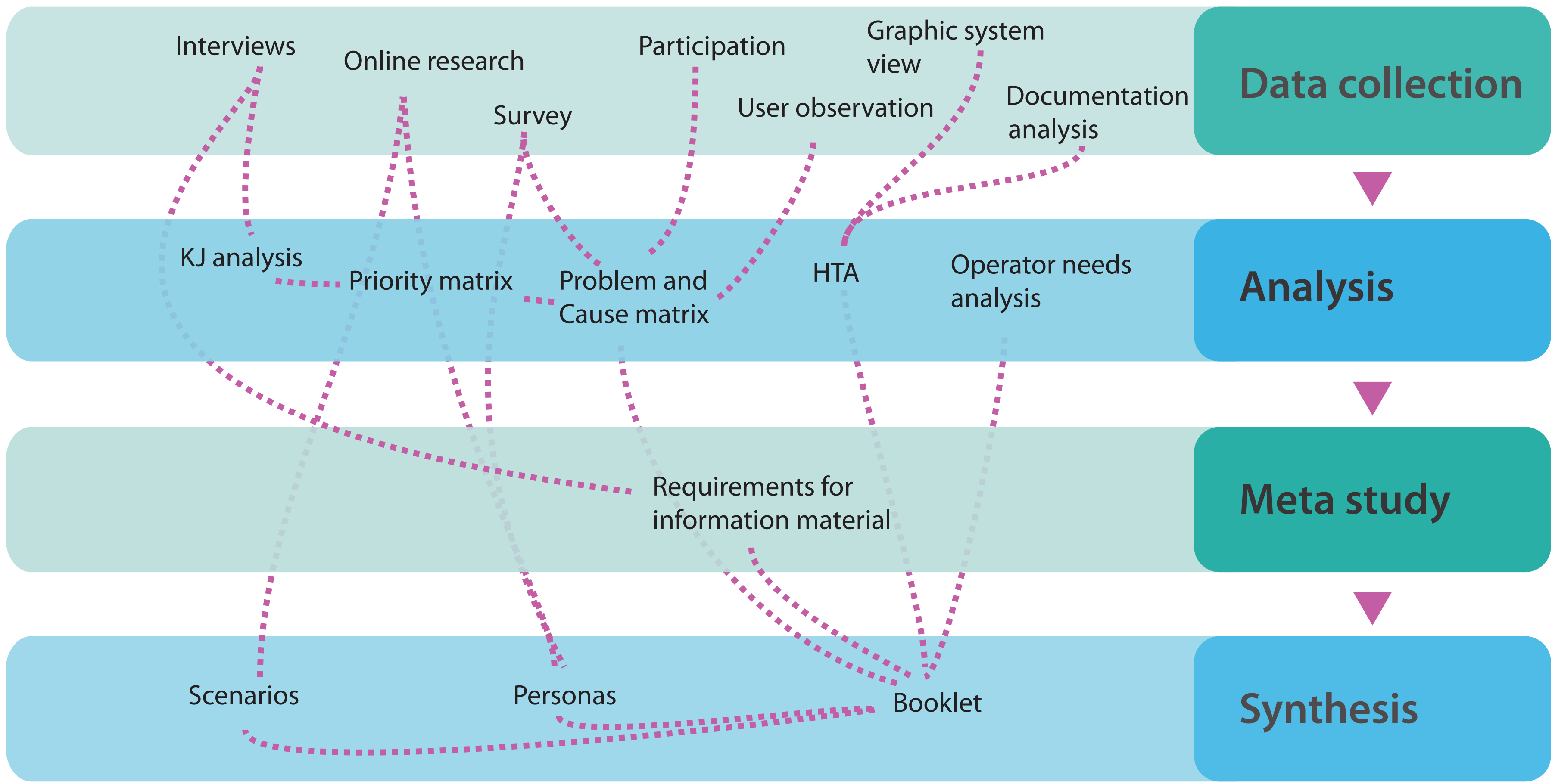


Figure 1. *A visualization of the working process. The stages of data collection, analysis, meta-study and synthesis are divided into the methods that were used or the results.*

ied indirectly instead of in person. It was known that communication between the users and the developers was sparse, and it was suspected that this gap could have led to a difference in perception on how ARTHUR was to be used. If this gap between the company perspective and the user perspective were to be closed, both of them would have to be studied.

Interviews with employees were used to collect the knowledge that already existed within the company but that was spread out in different locations. Eleven interviews were performed at several different departments. Studies of company material, such as the operators' manual and marketing brochures, together with participation activities, completed the data collection of the company perspective.

To get to the user perspective without actually meeting with the users, methods that were aimed at getting close to them were used. A user observation was conducted with Saab system verifiers acting as users, an experienced Czech ARTHUR operator was interviewed by telephone and a detailed survey was sent out to ARTHUR users of several countries. Online research resulted in articles from Artilleriet.dk on the use of ARTHUR in Afghanistan and on the radar operators' everyday life there.

The next challenge was to extract explicit knowledge from the collected information. The interviews were transcribed and run through a KJ-analysis to create meaningful groups of data. The groups were ranked by importance and relevance in a priority matrix, so that energy could be focused were it was needed the most. A problem-cause matrix based on the groups from the KJ-analysis turned the data into specific observed problems and issues. Data from the observations and the surveys were also put in the problem-cause matrix.

It was soon apparent that this thesis should not lead to a design suggestion for Saab. That would be worth very little, as it would have to be adapted to new circumstances quite soon, since in the world of product development, conditions change quickly. That adaption would have to be done without access to human factors expertise, and would therefore soon lose its value. Instead, the knowledge of human factors and of the ARTHUR users would have to be transferred into the company's own development process, so that it could remain an active part of it. It could then contribute to future designs and continue to be useful for a long period of time.

The gathered knowledge about the users had to be conveyed to the engineers working with the development of ARTHUR. To find the best way to present the information, theory in the field of human factors integration was studied. In addition to this, another user study, a "meta-study" was performed. This time the packaged knowledge was the product and the engineers were the users. This study led to a set of requirements for a booklet with both information about the ARTHUR radar operators as well as human factors guidelines and theory relevant to the situation. The user information was presented mainly in the shape of personas and use scenarios in the booklet. Two life-size paper figures were also built, so that the personas always could be present at the company.

2 THEORY

2.1 Human Factors

“Human factors” is the US equivalent to the European term “ergonomics”, and is described by Traub (1996) as a multi-disciplinary science with two major objectives. The first is to enhance work efficiency by reducing errors and increase productivity. The second is to enhance certain desirable human values, such as safety, comfort, job satisfaction, and reduced stress and fatigue. The field of human factors also includes human factors engineering and human factors integration. Chapanis (1991, cited in Human Factors and Ergonomics Society, 2005) defines human factors engineering (HFE) as ”the application of human factors information to the design of tools, machines, systems, tasks, jobs, and environments for safe, comfortable, and effective human use”. Human factors integration (HFI) is defined as ”a systematic process for identifying, tracking and resolving human related issues ensuring a balanced development of both technologies and human aspects of capability” (Ministry of Defence, 2008).

The discipline of human factors places people as the center of attention in product development. Systems cannot be truly integrated without the proper combination of users (including maintainers), the technology or equipment used, and the environment within which the equipment will be operated. Taking people into account is a key principle for human factors and it is now a part of the national and international standard called ‘Human-centered design processes for interactive systems’ (Harvey, 2004).

The standard stresses that making interactive systems human-centered brings considerable benefits by increasing usability thus making systems:

- Easier to understand and use, thus reducing training and support costs;
- That improve user satisfaction and reduce discomfort and stress;
- That improve user productivity and operational efficiency of organizations;
- That improve product quality, and provide a competitive advantage.

The standard also lays down four key principles for the human-centered approach to design:

- Encourage the active involvement of users in design, and clearly understand the user and task requirements;

- Establish the appropriate allocation of functions between users and technology;

- Iterate design solutions;

- Adopt a multi-disciplinary approach to system design.

One way of describing the field of human factors is by looking at common misconceptions of it. Pheasant (1996 cited in Högberg, 2005 and in Noyes, 2004) states five misconceptions that designers usually hold towards human factors.

1. This design is satisfactory for me – it will, therefore, be satisfactory for everybody else.

This would only be true if the designer also happens to be the only customer (which might very well turn out to be the case if this misconception is not broken). There is a great diversity in anthropometrics as well as personalities between individuals and groups of people, and therefore designs need to be tested and verified with actual users.

2. This design is satisfactory for the average person – it will, therefore, be satisfactory for everybody else.

If one takes into account several body measures at the same time, there is no average person. Virtually no one has the exact average measures on all limbs as stated by Daniels (1952, cited in Högberg, 2005)

3. The variability of human beings is so great that it cannot possibly be catered for in any design – but since people are wonderfully adaptable it does not matter anyway.

Just because people are prone to adapt, there lies a great responsibility with the designer to foresee the issues and adapt the design to the user. In that way system performance can be maximized and risks minimized. When a user adapts to an imperfect design, performance is decreased.

4. Ergonomics is expensive and since products are actually purchased on appearance and styling, ergonomic considerations may conveniently be ignored.

Ergonomics (or human factors) need to be considered as an integrated part of a "value creating package" (Högberg 2005) among other design aspects, such as appearance and styling. Proper use of ergonomics can even save money in the long run by decreasing the need for training, errors and late redesigns (Cullen, 2005).

5. Ergonomics is an excellent idea. I always design things with ergonomics in mind – but I do it intuitively and rely on my common sense so I do not need tables of data or empirical studies.

Subjective opinions are not sufficient to create successful products. Input from end-user representatives, ergonomics specialists and support systems are needed to add objectivity.

2.1.1 *Human Factors Integration (HFI)*

There are different views on the importance of human factors aspects depending on the industry. In the industry of consumer products, the buyer is the user, and human issues therefore have a strong effect on sales. Sales are easy to measure and that makes benefits of a human factors focus explicit. In military industry on the other hand, there is a great gap between the person that decides on what system to buy and the actual end-user of the system. This, in combination with the disciplinary culture typical of military organizations creates a situation where the user needs to adapt to the system, rather than the other way around. In this setting, consideration of human issues usually only comes as a result of requirements from authorities, as stated by Rizvi et al. (2009). "… This means that the company would prefer technically advanced products, rather than products which would boast perfect human system integration" (Rizvi et al., 2009).

To add to the dilemma, the benefits of adapting a human centered view in product development can be hard to see, while the costs of it are much more apparent. Bruseberg (2008) states that "Making a good case for HFI in financial terms is often considered as difficult, both by HFI and non-HFI practitioners". However, there have been some studies of the actual cost benefits of human factors. The United States' defense program MANPRINT reports some examples of large cost avoidances when considering human factors. One example is the T-800 aero-engine. The old system required a total of 134 different tools for effective maintenance, leading to costly equipment inventories and manuals as well as extensive training courses. An analysis of the maintenance schedules and required tools resulted in a new engine with far lower through-life costs because it only needed a maximum of six tools for any maintenance task. Another example is a small series of studies investigating human error during the use of an Anti-Aircraft Missile System. Because hit probabilities were increased to the extent that significantly fewer missiles were needed during training, the studies resulted in a multi-million dollar cost avoidance (Harvey, 2004).

Traub (1996) points out that there is an inherent resistance to human factors in many organizations, due to the discipline being associated with unnecessary costs and the belief that human factors can be carried out intuitively by designers. He calls this the barrier to human factors integration, which can be overcome in three ways; education, enforcement and end-user involvement.

Designers and engineers must be educated in the fact that human factors is actually a discipline, and not solely an application of guidelines. Traub points out that there is not a guideline in the world that if applied blindly would ensure a usable product. Similar thoughts can be found in Booher's (2003) principles for human factors integration. Although his principles are about integrating human factors in an acquisition process, many of these principles can be considered applicable to a product development process as well. What Booher calls the perhaps most important principle is about using highly qualified practitioners. Experts in the field best apply most of the tools and techniques used by the HFI domains. Checklists cannot replace the technical judgment of people possessing the required formal education and on job experience, and simply imposing constraints on the system developer cannot solve HFI issues. Fulton Suri and Marsh (2000, cited in Högberg 2005) argue that human factors practitioners need to translate human factors information into a form which stimulates well-thought out user-centered design ideas, and that designers commonly prefer to get precise data instead of general guidelines.

According to Traub, the design should be based on the four critical factors to ensure a usable product;

- The target audience
- The environment that the user and equipment operates in
- The equipment's capability and constraints
- The task that the user has to conduct

Booher's principle of "Focus on human-centered design" states, in a similar but more general way, that a "system" should be defined more widely than the hardware and software that industrial companies build and that the requirements should be specified for a system in such terms as to incorporate operators and maintainers as a natural part of the system. Traub points out that an appreciation of the methods and techniques used by human factors specialists is crucial if designers and engineers are to obtain a holistic awareness of the human factors process. These methods are used to identify the user information requirements, the user control requirements and areas of unacceptable physical or mental workload. Once the user requirements have been specified they should be integrated with the system requirements. In order for it to be done in an uncompetitive manner, education must promote an understanding of what the human factors activities are and how the results of these activities contribute to the design solution improving its system performance. Together with education, examples of how the application of human factors has provided financial rewards are paramount (Traub, 1996). Booher also mentions education as a very important principle for HFI success. He points out that education and training is needed not only for the practitioners, but also for the rest of those involved in the systems development process to be aware of the importance of human performance. In a case study by Waterson and Kolose (2010), the view that the human factors team need more engineering knowledge and experience is mentioned as a barrier to integration. Likewise, it is pointed out in the same case study that extending the knowledge of human factors among engineers through familiarization courses is seen as an essential enabler for HFI.

Traub (1996) mentions enforcement as a key part of achieving human factors integration. Since the benefits of human factors are not always apparent, Traub means that customers should enforce suppliers to address human factors such as the Ministry of defense has done in the UK by weighting human factors in bids and proposals with as much as 30%. Enforcement can also be applied through internal company procedures. Booher's principles touch upon enforcement as well. His principle of «Source selection policy» mentions that the HFI should be the discriminating factor in awarding a contract, and the principle of «Top-level leadership» states that top-level leadership should actively encourage HFI participation in top-level decision processes. Traub also points out that human factors must be integrated formally into the design process of the company. In the case study by Waterson and Kolose (2010), enforcement by the human factors team themselves was seen as an important mechanism for success of HFI. The team attempted to actively push HF into design and raise awareness among other project members about the value of considering HF in design activities.

The third part of human factors integration, according to Traub, is by end-user involvement. For a commercial product, the end-users' perceptions of its usability will be a determining factor for its success or failure. In military products, however, this is true to a lesser extent. User working groups should nevertheless be used to determine how the end-user understands, inputs, accesses and retrieves information.

In Booher's (2003) principles, the quantification of human parameters is further brought up as a factor for HFI success. Since the system is designed to certain quantifiable specifications, the requirements concerning human factors must be described quantifiably as well. Human parameters include data both from the human as a measurable entity, such as body size and information processing capabilities, and from the point of view of human performance such as time and error performance on tasks. Booher also sees test and evaluation/assessments as a principle for HFI. He argues that for each stage of design and development, it is important that a process is in place to evaluate how well the supplier is meeting all the goals and constraints imposed by all the human factors associated with the development of the system.

As for when human factors should be integrated in a design process, most agree that it should be done early on. Traub (1996) states that human factors should be introduced at the earliest stages of development in order for system and subsystem configurations to satisfy performance requirements. Cullen (2007) reasons further that HFI is equally important for new projects as well as upgrades. For new projects, it is necessary that human factors involvement is used to address issues early that otherwise would be costly or time consuming if dealt with later on. In the case of upgrades, HF is particularly important since new and old equipment may be integrated and needs to be compatible. Cullen (2007) suggests that human factors support can be provided in the following aspects of engineering design in a typical development project:

- Workplace design; to make sure that operators are positioned in a way that tasks, in particular those relating to communication, are facilitated.

- Workstation layout; the placement of equipment on and around the workstation should be such that it is visible and within easy reach.

- Workstation design in terms of physical dimension, including seating, should be such that it minimizes the risk of operator discomfort.

- Human-machine interface designs, including alarms, to make sure operators are delivered the proper information required to take action.

- Human error analysis involving the identification of potential operator errors

2.2 The User

A system usually has various types of users that interact differently with the system and thus have different requirements on the system. Users are commonly classified into four different roles; primary user, secondary user, side user and co-user. The primary user is the person most people would refer to as the user. It is the person that uses a product for its main purpose, for example someone who drills holes in a wall with a drill. The secondary user is someone who uses a product but not for its primary purpose. In the case of the drill, this would be the sales person or a repairman. A side user is a person who is affected by the product without being a primary or secondary user, such as a person in a room where the drill is being used. A co-user is someone who works or collaborates with a primary or secondary user, but who is not directly interacting with the product. This would be a craftsman working together with someone who is drilling. A person can have multiple roles in a system; for instance, someone can be both the primary and secondary user as in the case of a driver who also services his car (Osvalder et al, 2009).

2.2.1 *Finding User Needs*

An understanding of the users' needs increases the likelihood of producing a successful product and the extent to which a product satisfies user requirements is seen as one of the most essential factors in product development (Karlsson, 1996). No matter how much access to marketing research the designers and engineers have, they usually need more thorough descriptions of customer needs than what is made available by the typical marketing study (Griffin & Hauser, cited in Karlsson 1996). In order for the information to be passed from the user to the designer, the information has to be elicited. It needs to be formulated in statements that express the user needs and expressed as design criteria useful in the development process.

User requirements can be defined as "those requirements which the user has for the artifact in use, and which are manifested by the problems arising in context and/or articulated as problems, wishes or desires by the user" (Karlsson, 1996). The basis for understanding these requirements and needs are, according to Karlsson (1996) not the study of needs as such, but the study of activities and actions. Needs cannot be detected directly. They become visible by the actions that the individual takes to fulfill its needs and the problems and consequences that occur when trying to do so. It is by studying those actions and problems that one may identify what the underlying needs might be.

User requirements are more than just what the users specifically express to want in a product. The Kano model, figure 2, describes and classifies the product characteristics and their effect on the customer's perceived quality and satisfaction . The threshold or basic attributes are the must-haves of a product in order for the product to be successful. The basic needs are easy to distinguish from other attributes due to the fact that the customer will remain neutral even with a better execution of these aspects (Good Design Practice Program, 2010). Seatbelts in a car are an example of a basic need. It is unlikely that a consumer would mention this as a demand in a new car model, but if they were missing the customer would never buy the car (Karlsson, 2006). Unlike the basic needs, the performance needs are directly related to customer satisfaction. This means that increased functionality or quality of execution results in increased customer satisfaction and decreased functionality results in more dissatisfaction. The price of the product is often related to these attributes, and it is these attributes that are expressed by the customer. The third characteristic is the attractive attributes or delighters. The customer will get great satisfaction from these features and is willing to pay a higher price for them, but satisfaction will not decrease below neutral if the product lacks these features (Good Design Practice Program, 2010. These features are often solutions to problems that the user was not clear of having, or a technical solution that was not known to be possible. They are often unexpected by customers and are hard to find when looking for needs. This is why they are sometimes called latent needs. It is usually within this category that companies find possibilities to compete with each other to find these latent needs and to find different solutions for these needs. Product developers are able to find these latent needs through a user observation by for instance watching how a user has solved a problem on their own or even developed the product further (Karlsson, 2006).

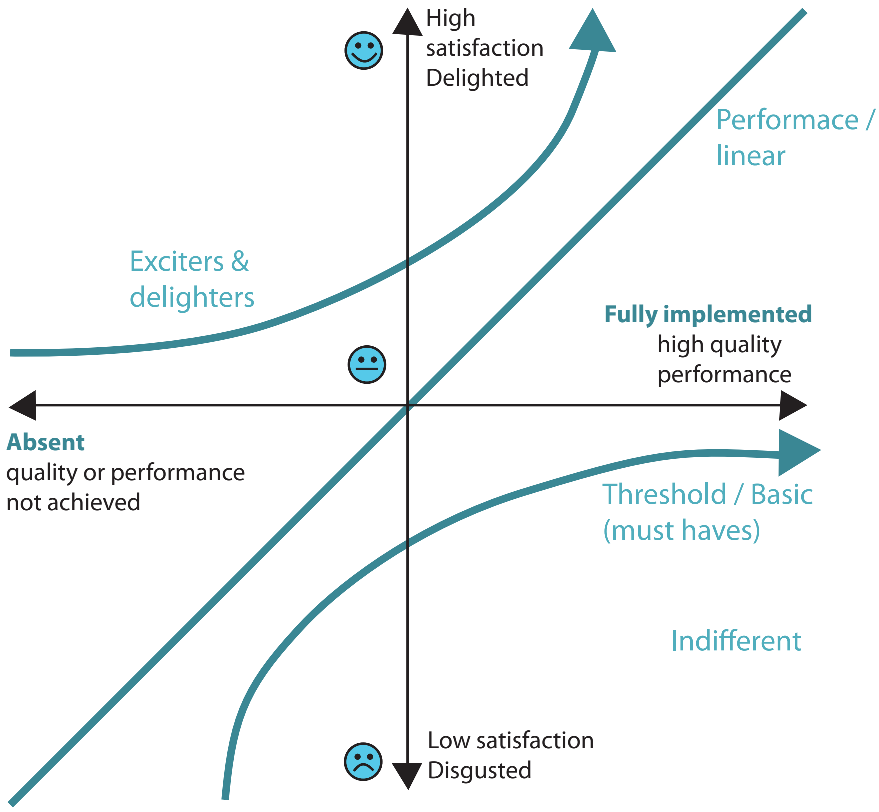


Figure 2. *The diagram displays how three different types of requirements affect the user satisfaction related to their grade of fullfilment according to Kano (figure adapted from Good Design Practice Program, 2010).*

According to the Kano model, product differentiation can either be gained by a high level of execution of the performance needs or the inclusion of one or more 'delighter' features. Some users of the Kano model suggest that an additional set of attributes should be classified as 'enragers'. These would be features that enrage either through their absence or inclusion in the product. It is important to remember that customer expectations change over time. For instance, a cup holder in a car may be today's delighter, but in the future it will probably be expected (Good Design Practice Program, 2010).

The information that is accessible through e.g. question-based methods is information that is consciously reflected upon and actions with a conscious goal. Other actions, which are done by routine and are not conscious to the user, are not easily accessible. These actions are the ones the user performs but is not able to explain how it is done. In order to bring out reflection over actions observation-based methods are required.

According to an empirical study by Karlsson (1996), not all requirements are equally accessible. Requirements can be described in different ways depending on how the information was brought out; it can be captured, elicited or emergent. To capture requirements suggests that requirements are evasive but out there somewhere, and can be captured. Some information is easily triggered and brought forward as problems or difficulties when a product is tested. Information is accessible due to the fact that the users are already aware of the problems and have reflected upon them. In other words; the information is captured. The term eliciting implies that requirements are found among people. The elicited requirements can become evident in the way users describe how they try to overcome obstacles or the way they behave in a specific situation. An example of this is compensating behavior, which is used in order to work around a problem or to reach an intended goal. The users do not necessarily reflect upon these behaviors as problems because the situations are expected and worked into the routine or because the user had already compensated for the undesired consequence. Therefore one may need to probe with questions or provocative descriptions of other ways to use a product to find the useful requirements. The third category of requirements can be described as emergent. These requirements are usually not obvious until the new product is implemented in the actual use situation. This is why evaluation of prototypes becomes so important. Since only requirements from the first category, i.e those aspects already reflected upon, can be captured by strict formal methods, it is impossible to get the total requirement picture by only using these methods. In order to capture the complete picture, methods of probing, provoking and observing must be used.

2.2.2 Hierarchy of user needs

Jordan's theory (1999, cited in Högberg 2005) of user needs distinguishes between three types of needs and organizes them in a hierarchy, as seen in figure 3. The basic need that has to be fulfilled first is the need for Functionality. If a product does not provide the relevant functionality, it will never be appreciated. A phone that cannot be used for making calls will not be successful, no matter how beautiful it might be. When a product is functional, doing its job in a good way, the next level can be addressed; Usability. Is the product easy to understand and use? Can it be operated efficiently? Only when both of these levels of needs are fulfilled, the third level called Pleasure, can be reached. This relates to affection, emotions and joy of use. This is where competitive advantages can be gained, but only if Functionality and Usability are already taken into account.

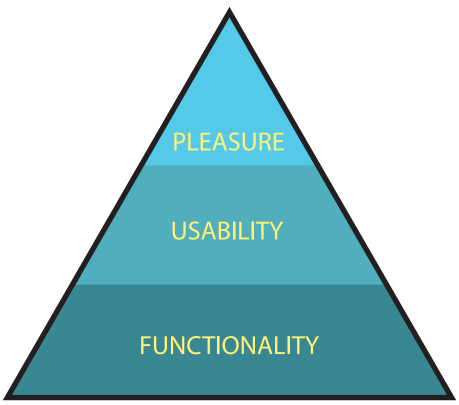


Figure 3. *The hierarchy of user needs can be visualised as a pyramid.*

3 CONTEXT

In this chapter the context surrounding the thesis is described. Theories on military culture are dealt with, along with a more thorough product description and the current design process at Saab.

3.1 Military Culture

In order to understand the users better it is of importance to look into their culture. Although military culture varies over national cultures, the armed forces are an institution with a very particular organizational culture, with beliefs, values and symbolic productions shared by all members of the organization. According to Burk (1999) military culture consists of at least four elements; discipline, professional ethos, ceremonies and etiquette and espirit de corps and cohesion. Each element can be derived to be an attempt to deal with the uncertainty of war by imposing some pattern to it and by investing meaning and significance to it. The element of discipline refers to the orderly conduct of military personnel, regularly prescribed by their commanding officers. This provides the armed forces with a collection of patterned actions that can be used to quickly adapt to battle. A less obvious aim with discipline is to ritualize the violence of war in order to set it apart from ordinary life. Ethos is the guiding beliefs of a person (Merriam-Webster online, 2010), and the element of professional ethos stands for the ideal of the officer corps as heroic and technically as well as morally competent. What the civilians and those in the military imagine the professional officers to be like is what defines their worth and virtue in terms of their preparation to fight wars. Military ceremonies and etiquette make up an elaborate ritual and play the role to mask and/or control anxieties and ignorance as well as affirm the solidarity with others. Morale is a product of cohesion and espirit de corps. Cohesion refers to the feeling of identity and comradeship that soldiers hold for those in their military unit. Espirit de corps on the other hand refers to the commitment and pride soldiers take in a larger military establishment to which their unit belongs. This element refers to the beliefs and attachments that contribute to soldiers' willingness to perform their mission.

Military culture also contains a multitude of social structures that differ from the civilian world. According to Kirke's model (Kirke, 2002), the social structures in the British Army consist of formal command structures, informal structures, loyalty/identity structures and functional structures. The formal command structures include the rank structure, clear hierarchical patterns used by the armed forces and the bodily attitudes that are expected of a soldier. The informal structures are the unspoken rules, customs and attitudes of relationships between different ranks, especially how close a relationship is accepted to be. It also includes the special circumstances when rank is unimportant, such as on the sports field. The loyalty/identity structure consists of a set of ideas, assumptions and expectations centered on the concept of belonging in different levels. The functional structure is made up of ideas, rules and conventions of behavior that are connected with carrying out what soldiers call soldierly tasks.

3.2 The Product

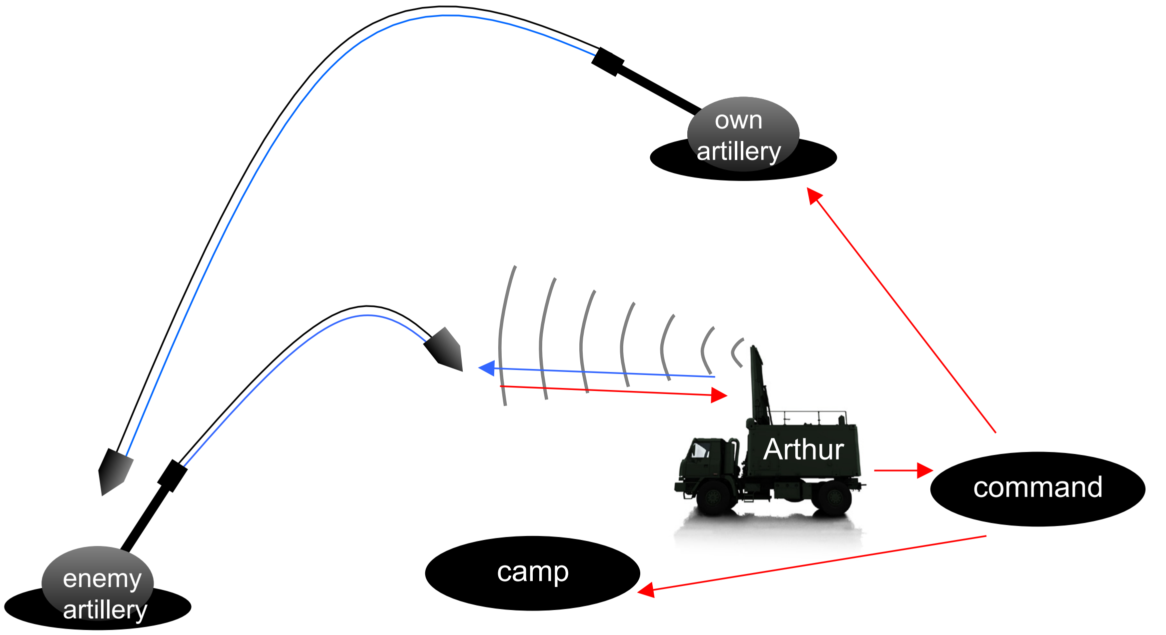
ARTHUR WLS, as seen in figure 4, is an ARTillery HUnting Radar Weapon Locating System, developed to do two things. It enables a military commander to locate firing artillery weapons, so that they can be disarmed. ARTHUR also estimates the impact points, which means that the people on the ground can be warned in advance. ARTHUR accomplishes these things by tracking a projectile's position in mid-air and calculates its trajectory. ARTHUR can be operated by a single person, and can be deployed or disassembled in less than two minutes. The operator can perform his work at a workstation from inside the shelter of the truck, or remotely with sufficient communication equipment. The working range is up to 60km. ARTHUR is mobile, and is used in many different types of terrain. More than 60 units have been sold as of 2010, to customers such as Czech Republic, Denmark,

Figure 4. *ARTHUR modC demo is deployed in a snowy landscape. The radar antenna is raised and the ladder to the shelter is mounted.*

Greece, Norway, Spain, Sweden and the UK. It has been used on missions in Afghanistan since 2002 and in Iraq since 2003.

ARTHUR consists of a shelter mounted on a cross-country truck with a large rectangular antenna on the roof. The shelter contains all the radar equipment as well as two operator workstations, see figure 5. The workstation consists of an adjustable padded seat; two vertically distributed flat screens and built-in rugged keyboard and trackball. Above the workstation there is a ventilation shaft with adjustable vents. The shelter has a ceiling height of about 160 cm and is accessed through a pull-down metal ladder. There are versions of ARTHUR where a tracked vehicle is used instead. There, a modified shelter is mounted on a tracked vehicle

Figure 5. *The interior of the shelter of modC demo. Top left: the shelter seen from the workstations, the data processing unit panel is lifted off. Top right: the workstation. Lower left: the door and the operator seat closest to the door. Lower right: the workstation furthest from the door, with its chair missing.*



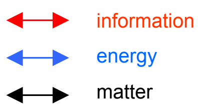


Figure 6. *The enemy projectile is caught by the ARTHUR radar, and its trajcetory and point of origin is calculated. Information is transferred to command, which sends out a warning to the ones about to get hit, as well as target coordinates to artillery. The figure illustrates the flow of information, energy and mass by color coding.*

trailer. ARTHUR is camouflaged in both cases after its intended environment, which could be forest green or desert beige for example. The functionality of ARTHUR is displayed in figure 6.

The most recent generation of ARTHUR is called ModC, and its predecessors are consequently called ModA and ModB. Since ARTHUR is customized to fit each client's needs, the products vary within the generation. Saab owns one copy of ARTHUR, called the ModC demo, which is used for research and development. The ModC demo version is the latest physical version of ARTHUR, which is why it has been the starting-point for this thesis. There is a more recent model under development but since it is not implemented yet, the changes that have been made are not possible to consider in cases where a physical product is needed. . When it comes to the interior of ARTHUR or placement of equipment, ARTHUR in general refers to ARTHUR ModC demo if not otherwise stated.

3.3 The Company

Saab Group provides products and services to both the civil security and military defence market. Its most important markets today are Europe, South Africa, Australia and the US. Saab employs about 13200 people, and the annual sales are about 25 MSEK. Saab is since 2010 divided into five business areas: Aeronautics, Dynamics, Electronic Defence Systems, Security and Defence Solutions, and Support and Services (Saab Group, 2010).

Saab Electronic Defence Systems (Saab EDS) is a business unit focusing on microwave and antenna technology with 2 600 employees. They have advanced airborne, ground-based and naval radar systems in their product portfolio, as well as an a range of services such as training and technical support. Key elements in their products are radar, UV and laser sensors as well as jammers, decoys and counter-measures dispenser systems. They have more than 50 years experience of electronic warfare and radar development and so far 3,000 radars have been delivered worldwide. Their systems have been delivered to all Swedish Air Force combat aircrafts and are in use with several European air forces, in the US, in the Middle East, South and South East Asia and Africa (Saab Group, 2010).

At the department of Mechanics and Cabling at Saab EDS, where this project has been conducted, the flow of work tasks can be seen as the following: A requirements specification is received from a department at the system level. Mechanics and Cabling works as a supporting group at the subsystem level and one or two mechanists, or “system mechanists”, refine the requirements specification so that it can be used for design work. The requirements are then delegated to design engineers who either find an existing component that meets the demands, or order the design of a new component. In the later case the design engineer puts requirements of the space the component may take. The person receiving the order starts designing the component from the received requirements. To find solutions to design problems, designers often use online resources rather than asking colleagues. When the designer has developed concepts and also throughout the development process, he calls for a meeting with selected people to discuss the design. There is usually a discussion where the goal is to fulfill everyone’s wishes. A person responsible for the designs is usually present at the meeting; otherwise the responsibility has been delegated to someone who is attending (Rydén, 2010).

The process described above lacks user involvement. The user needs are not taken into account, other than as remaining requirements from the decade old initial user study that was performed for the very first ARTHUR. At some points in later years, design concepts have been developed in shorter projects in collaboration with external design firms, students and human factors specialists. The concepts have not integrated with the everyday work process, and are considered inspiration rather than something that can be directly applied, which of course is also the purpose of a concept. Sometimes human factors engineers from other departments are consulted on specific topics, such as when a seat is to be changed. All in all, these scarse contacts with human factors indicate that there is a healthy interest at the department but there needs to be a more lasting contact with human factors knowledge if the product development process is going to be affected.

4 DATA COLLECTION

4.1 Process description

It is not easy to get to know the users when they are not around. Therefore one of the first things undertaken in the project was to start arranging for a trip to visit real users of ARTHUR, radar operators in the British Army. Waiting for that, there were still things that could be done without the presence of real radar operators.

To extract existing knowledge from the company, interviews were performed at several different departments. The aim was always to get as close to the user as possible, and when people could not answer a specific question there was often a recommendation of someone else that probably could. These recommendations drove the interviewing process forward and created a net of connections across the company. It was considered that the saturation point was reached after eleven interviews, when further interviews no longer provided new information.

The next step of understanding the users was to observe them in action. Since no real users were available, system verifiers at the company were used instead. Wearing combat gear, two system verifiers carried out typical ARTHUR operator tasks while being videotaped. This method of observation revealed requirements and issues that not even the verifiers themselves were aware of.

A great source of user information was found online. The military news site artilleriet.dk turned out to carry quite a lot of articles covering the Danish artillery's use of ARTHUR in Afghanistan. This gave an insight into the daily life of an ARTHUR operator as well as a bigger picture of how ARTHUR is used strategically.

The planned trip to visit users turned out taking too long to arrange, and could not be carried out within the timeframe of the project. To get even closer to the real users, without the possibility of actually meeting and observing them, surveys were considered a good option. Except from one telephone interview with a Czech ARTHUR operator, the surveys provided the only point of contact with real users. The operators of four different countries answered the surveys.

The documentation analysis was carried out by studying the operator's manual. This was a source of information representing Saab's opinion on how things should be done and it was considered important knowledge to balance the user perspective. A participation activity was also carried out where an analyst got to perform operator tasks in order to get the feeling of what it is like to work inside ARTHUR. A graphic system view was constructed so that the authors could visualize the components that interact with the ARTHUR system in its entirety.

4.2 Interviews

4.2.1 *Theory*

Interviews are the most common way to gather subjective and qualitative data. A semi-structured interview is something between a structured interview, where questions are formed beforehand and the interviewee answers them either freely or by selecting an answer from a predetermined scale, and an unstructured interview, where the interviewee is asked open questions and can freely express his or her opinion. In a semi-structured interview the structure has been formed in advance, but the interviewer can freely choose the order and ask appropriate follow-up questions. The advantage of an interview as a data collecting method is that it is flexible. The interviewer can gain knowledge of what people think and request explanations when needed. It is also resource-efficient compared to other methods. However, one disadvantage is what is known as the interview effect, meaning that the interviewee adapts their responses to satisfy the interviewer (Osvalder et al, 2009). The outcome also depends on the ability of the interviewer to follow up on details, (Sutcliffe, 2002). The interview can benefit from being performed in an environment that the interviewee feels familiar in, e.g. the working place. It is easier to relax there and there could also be objects around that can be used to demonstrate work tasks.

4.2.2 *Implementation*

A total number of eleven semi-structured interviews were conducted to find information about the system and its users. The interviewees consisted mostly of people from within the company, such as people from marketing, product management, project management, customer training and system verifiers. Telephone interviews were conducted when it was not possible to meet in person, such as when interviewing a Czech operator. Most interviews were performed in the department of the interviewee, and when possible even inside the shelter of ARTHUR. An audio recorder was used to free up mental resources from the interviewers to ask follow-up questions and as memory aid when analyzing the results. The interviews lasted forty minutes on average.

4.2.3 *Result*

The interviews generated different kinds of knowledge depending on at which department the interview was performed. In the customer-training department, interviews (Barryd, Sairanen, 2010) provided information more related to user behavior and how that behavior might vary between cultures. These, in combination with a telephone interview with an experienced Czech operator (Travnikova, 2010), were the most helpful in gathering user needs. An interesting example is the realization that operators actually drink lots of beverages, both hot and cold, in the shelter, despite it being forbidden in some customers' organizations. This is mostly to stay awake, since the job can be monotonous and tiring. Some countries´ operators even bring in electric kettles and coffee brewers for this purpose. Also, weapons, helmets, combat harnesses and clothes are often put on the floor and seat backs. There they might be in the way or get stepped on.

The big picture and longer time perspective of ARTHUR came from product management and project management interviews (Stenström, Frostad, Wilkensson, 2010). ARTHUR was originally developed to serve on huge battlefields chasing artillery. The battlefield of today is smaller and more fragmented. The task of "force protection" is new, and it means staying put for a long time, watching over a camp or an airfield. This generates a new situation for the operator, who might experience difficulties staying awake. It also means that focus has shifted from weapon locating towards landing spot calculation. Since ARTHUR is a flexible system, the workstation also needs to be flexible to allow for both quick, rushed use and for monotonous, long term monitoring.

Company interviews rendered plenty of knowledge on how the system works and how it has been developed. Although they did not reveal much about how ARTHUR is actually used in reality, despite thorough probing during interviews.

Market department interviews (Hansson, Hellgren & Rechenberg and Wolfram, 2010) resulted in knowledge about how ARTHUR is sold to a new or existing customer. Selling a radar system to a country is not done quickly. It is a process over many years, at least five, and a relationship that continues even after delivery, through service contracts and training programs. The military branch of sales and marketing is quite different from the consumer product branch. Ergonomic aspects are generally not highly regarded, and even price plays little role in the purchasing decision in the military domain. Instead, factors such as diplomatic relations between countries and reinvestment deals are considered more important. This is not always true however; northern European countries for example do have some demands on usability and ergonomics, even though they might be low on their list of priorities. However, one future customer is actually demanding that the product development process is to be in line with a comprehensive standard for ergonomics. The interviews at the market department also showed that Saab carries out semi-annual user group meetings, where ARTHUR customers meet up to discuss their experiences. This is an opportunity for ARTHUR users across the world to come together and exchange experiences regarding their work. Each country is given the chance to present their experiences with ARTHUR to their fellow user group participants, and discussions can take place. Even though this sounds like the perfect opportunity to gather information from the real users, the user group is mostly a forum for technical issues and error reporting, and the aspect of user needs is not really addressed. People in contact with ARTHUR systems in use, for example those performing advanced repairs on site, are naturally not trained in the art of needs elicitation. The interviews that helped the most were the ones with real end-users or with people close to them, like customer trainers.

4.3 Surveys

4.3.1 *Theory*

Surveys and questionnaires are good ways of approaching remote or otherwise hard-to-reach users. Putting together a survey is difficult, since every question has to be crystal clear and unambiguous. Preferably a pilot test should be performed to highlight potential misinterpretations. Once manufactured, the survey can easily be distributed to a great amount of people. The difficulty lies in getting answers, and the bias that comes with the fact that only people with time to spare will answer them, according to Sutcliffe (2002).

4.3.2 *Implementation*

In order to get some quantitative data about users of the system, and at the same time get more subjective opinions of what problems the users have encountered, an open-ended survey was sent to operators in a few different countries where the system is used. A few quantitative questions were included to gather some material about what kinds of people actually use ARTHUR. Height, gender, age and years of experience with the product were among these questions. Height was not included in the surveys sent to the UK, but added later to the ones sent to the other countries. The main part of the survey was dedicated to open-ended questions with the purpose to elicit potential problems and compensating behaviors from the users. Effort was put on designing the questions in a way that "tricks" the respondent, who is exclusively of military background, to offer answers without feeling that they admit to using the radar system in a way that may not be allowed.

4.3.3 *Result*

Eight Danes, five Norwegians, one South Korean and fourteen British, all of them ARTHUR operators, answered the survey, see figure 7. All participants were male except for one female among the Norwegians. The Danish operators were of heights ranging from one that was 167 cm to two over 190 cm (191 and 193). Among the Norwegians, the men ranged from 174 to 190 and the female was 166. The Korean was 171 cm and was 32 years old. The Danes' ages ranged between 21 and 29, the Norwegians were aged between 20 and 24 and the British were 21 to 39.

The operator's experience with ARTHUR ranged from one month to five years for the Danes, one and a half years to four years for the Norwegian operators, one to seven years for the British and the Korean had five months of experience. On the question of sensations of pain after a long working shift, five Danes reported headaches from the noise, and three reported pain in the back. Of those two, one also reported pain in neck and thighs. Out of the five Norwegians, three reported headaches and one reported of pain in back and feet. Among the British, four

Figure 7. *Statistics of the respondants are visualised in an infographic. The data is sorted by age and grouped by nationality.*

Figure 8. *Reports of strain are plotted in the figure with colored stars. The color represents the nationality of the respondent and the position represents where on the body the strain was located.*

reported headaches out of which one mentioned long hours watching the screen as a possible cause, four reported back pain of which three specifically mentioned the lower back, one mentioned pain in lower legs and one legs in general due to the lack of leg room, see figure 8. One British felt pain in bums and hips, and another mentioned pain in the wrist. The Korean reported headache from the noise as well, along with fatigue. He also felt that the air in the shelter was too dry. Additionally, one Dane reported having troubles falling asleep after a shift in ARTHUR.

Five British mentioned Radar theory as the hardest thing to learn, and four mention navigating in the menu system as the hardest part. Two of them mention that it is hard because there are several ways to do one thing. One British thinks the hardest part is remembering the correct sequence of deployment. Four of the Danes express that the hardest thing to learn or get used to is to separate ghost echoes from real targets. One Danish participant says “I think a beginner tends to panic a bit and not taking it calm. You got to look at the data before making your choice if it’s a real target or a ghost target.” Among the Norwegians, two operators thought the positioning of the radar is the trickiest part. Four Norwegians also mention the positioning as the most time-consuming for beginners. Three of the Danes mentioned the same thing, two thought filter change was the most time-consuming, two mentioned finding the right menu in the menu system and two mentioned maintenance. The Korean also mentioned maintenance as the trickiest part.

Four Danes and eleven British agree that the combat gear gets in the way when working with ARTHUR, while one British claim it is never in the way. When taking the gear off, one Dane says that it usually ends up “on the other seat, behind the seat, ones own seat, in my lap (annoying), outside (inconvenient)", and the others express similar locations, including the floor. Five British mention getting in and out of the vehicle as problematic when wearing combat gear and three mention it being difficult to maneuver inside. Two report getting caught in the camouflage nets when wearing gear and two mention the backpacks being in the way when using the radios. All Norwegians agree that wearing combat gear gets in the way. Three people mention it being in the way when getting in and out of the shelter, and two pointed out that it is impossible to wear the gear while seated. Three people hang their gear on the back of their seats, one puts everything on the support leg outside, and one reports putting the gear on the floor. Four British report leaving their gear outside, three put it on the back of the seats, one leaves it on the floor and one leaves it in the driver cabin. The Korean reports the combat gear getting in the way when using the RCU laptop, which is a mobile extension of the ARTHUR software, and the Inertial Navigation System (INS). In the Korean ARTHUR the INS is located close to the floor on the middle of the wall with the door.

Eleven British request more storage space. Five of them, along with three Norwegians, the Korean and one Dane, request a storage space for personal equipment and gear. One Dane suggests making the current storage spaces bigger so it can hold radio equipment and one suggests not having the compartments overlap. Three British want more storage for documentation and folders and one of the Norwegians suggested having a box to the right of the desk to keep stationery. Two British would like more storage for tools. One Norwegian mentioned that they bring a water carrier inside the shelter, which takes up a lot of space. They also have a garbage bag that they "eventually kick to pieces because the only place there is room for it is by the feet". The Korean points out that the space to do maintenance is too small.

On the question of personal modifications, one Danish participant mentioned that he had done a computer holder over the keyboard, which can be assumed to be for a personal laptop to watch movies on, since he states that he does that when there is nothing else to do. One Dane also mentions that someone has "...made a basic guide called: "Sgt. West's guide to basic radarring". It's like a small paperback containing FAQ's". One British has made "some kind of step into the rear cab to reduce falling in and out of the cabin" and another has made a pull down flat table to work on. One Norwegian has added a hanger for the headset and a railing on top of the radar cabinet to be able to put things there without them falling down. Another Norwegian mentions that there has been weapon holders placed on the wall behind the chairs, but that they do not fit the weapons they use nowadays.

One Norwegian complains about the desk space, and that there is no place to put binders or the RCU laptop. The laptop needs a lot of room because of its many chords, which usually have to be placed over the other operator's keyboard. One British suggests the "emergency stop button could be moved somewhere where it won't accidentally be pushed". Seven British want the keyboard to be sunken in the desk and one wants a more flat keyboard, so that applications do not go off when folders are placed on the desk. Four British would want the same problem solved with having a cover over the keyboard or having the keyboard flip up when needed. One Dane was annoyed by the position of the track ball and another Dane, along with three British, thought changing filters was hard because of bad reach. Two British also thought greasing points should be more easily accessible and one thought that covers could be easier to remove. The Korean is annoyed by the placement of the INS; that it is too low (in the Korean ARTHUR the INS is placed on the same wall as the door, between the door and the operator's seat close to the floor). He thinks it is difficult to read messages, and would prefer to have it by the desk instead. The Korean mentions another problem of reach as well. He has problems reaching the handle that releases the ladder, and says most of his colleagues are not tall enough to reach it.

When there is not much to do during a shift, one Norwegian says that he plays games with his co-operator, reads or watches movies on his personal laptop. Another states that he plays games on the RCU laptop, and one mentions sleeping. Three people mention things that are job-related, such as just watching the screen, listening in on the communication and checking the position area. Seven Danes and four British reported that they use their personal laptops to either watch movies or listen to music, or both. Four Danes and four British read books, one Dane and one British play games on their cell phone and the other Danes eat, exercise, clean, draw, play games on portable gaming consoles or prepare for maintenance. Two British do written work, two sit and talk, two check calculations and mission data and one cleans. The Korean reports reading a book or studying the manual.

Three Norwegians and three Danes complain that it is too loud in the shelter and want better sound insulation. One Dane points out that noise from the air conditioning is too loud and annoying, and that it should be insulated better. Two Norwegians request sounds when an alarm pops up and two Danes and one British would want the sound from the middle speaker to be louder. One Dane also suggests that the computer screens should decrease in brightness when the door opens just like the lighting does in night-mode and four British request a blackout switch for all lighting when the door opens. One British thinks the lighting is not enough to light up the shelter fully.

Opinions on physical ergonomics include one Dane calling for a more adjustable computer screen and a Norwegian who would want the possibility of adjusting the height of the seat. Three British would want more room to adjust the seat, three want lighter seats and three suggest adding quick release clamps to make it easier to take the seats out for maintenance. One British thinks the seat is uncomfortable, that it is "stiff and very awkward" and two think they are very good. Four Danes would like to have a better seat, including preferences for "normal chairs that you can move around", "a bit more ergonomic" chairs, similar to truck seats where you can adjust many things and chairs with more support like a racing car seat. One Dane added the comment "so your back still would work in about ten years" to his opinion of a more adjustable chair. A fifth Dane suggested adding seat warmers to the chairs for the winter. A Dane of 185 cm complained that the desk should "be positioned so a grown-up can have his legs under it".

The keyboard was requested by a Dane to have no gaps between the keys so that dirt cannot get down between them. A Dane questioned the need for a trackball instead of a mouse and another Dane as well as three British suggested putting in a mouse instead of the trackball. A third Dane along with two British pointed out that it gets dirty very easily, and when it does, the cursor moves more slowly. Two Norwegians had also noticed that the trackball gets worn out pretty quickly and that the moving of the cursor is more difficult. Two British did not think the track ball is good enough and one wanted it smaller. The Korean feels that the trackball and keys should be moved down next to the keyboard since they are hard to reach and would also like to use a numeric keypad. Two Norwegians feel that there are many keys on the keyboard that they never use.

The surveys included some information about the use of ARTHUR in Afghanistan, since the Danes have been deployed there. One Dane suggests that the internal generator could be removed since they never use it in Afghanistan, because it cannot handle the heat. The same person also points out that ARTHUR is primarily stationary once deployed.

4.4 Participation

4.4.1 *Theory*

To understand a user's work situation on a detailed level, the analyst can try to perform the daily tasks of a user, under his or her guidance. Sutcliffe (2002) considers this to be a powerful method to learn about work difficulties. Trying a task yourself can reveal its complexity that was not seen when the expert user performed it. It could be difficult to record this method since the analyst is busy with taking part in it, but it can bring forth knowledge that was unconcious even to the user (Sutcliffe, 2002).

4.4.2 *Implementation*

One analyst at a time was seated at the work desk in the ModC demo, to perform common operator tasks under the guidance of a system verifier with extensive knowledge of the ARTHUR human-machine interface. Physical interactions took place with the trackball, its double set up of three buttons, and with the keyboard, see figure 9. The system verifier explained where to click and with which buttons. The analysts asked clarifying questions. Parts of the interaction were recorded on video.

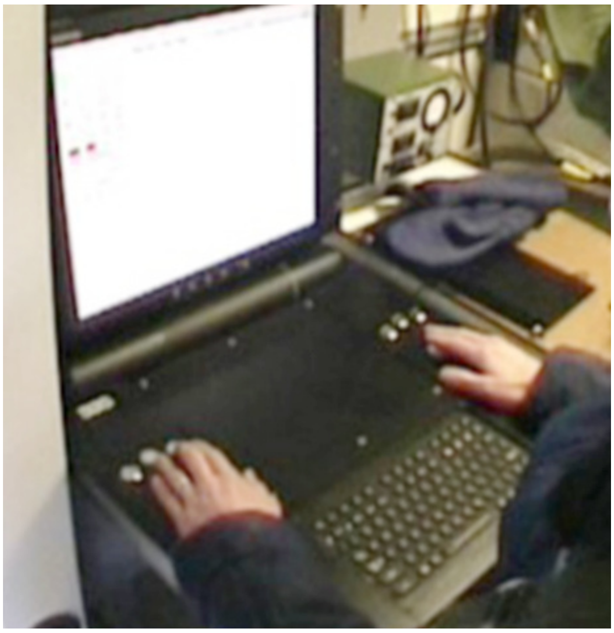


Figure 9*. The picture illustrates the layout of keyboard, trackball and buttons in front of the screen.*

4.4.3 *Result*

During the participation sessions it became apparent that using the trackball was not an easy thing to do. The hand and fingers had to be bent in awkward angles to efficiently manipulate the trackball and the buttons around it. If one wants to keep the fingers positioned on the buttons while rolling the ball in order to be able to press the buttons quickly, the trackball has to be maneuvered with the thumb, causing an imprecise cursor movement. The buttons themselves needed quite a lot of force to press down compared to regular mouse buttons. Some interface features require that the one button is pressed while the ball is rolled, and that is not easy to do with the current configuration.

4.5 Documentation Analysis

4.5.1 *Theory*

Reading through and analyzing documentation of an investigated system can be fruitful if the documentation is up to date and sufficiently detailed. The image gathered from documentation says very little of how a system is really used though, and more about its designed or intended use. To see how it is really used one needs to use observational methods instead.

4.5.2 *Implementation*

The manual of ARTHUR was looked through, and chapters concerning deployment were carefully read to record information regarding the steps a user should go through. This was done in order to gain an understanding of how the system is used. The marketing brochures were also looked at in order to create an understanding of what Saab wants to convey to their buyers.

4.5.3 *Result*

The steps of deployment were collected chronologically in a rather extensive list in order to gain an understanding of the deployment of ARTHUR as well as to prepare for the user observation. The list is, unfortunately, company-restricted information. The marketing brochures have showed that Saab finds deployment time, technical performance as well as the intended military use and benefits important.

4.6 User Observation

4.6.1 *Theory*

A user test is an experimental method where actual users interact with a system by performing a number of relevant tasks (Nielsen, 1993 cited in Osvalder et al, 2009). The idea is to gain an understanding of how the product performs under natural conditions. For this to be possible, it is important that the investigator tries to make sure that his or her presence is minimal (Jordan, 1998). The observation could also be a hidden observation, where the participants do not know that they are being watched, although that raises some ethical issues. The test should be videoed, and the video footage analyzed to find results that are hard to catch by the mere eye, such as awkward working positions and how the user moves around. Sometimes the participants need to be experts, but most often, the user test is used to test the abilities of first-time users or novices and how correctly they handle the product (Osvalder et al, 2009). The number of errors can then be calculated as a measurement of the product's usability.

Think aloud is a method where the participants speak about what they are doing and thinking when performing a task. The advantage of this method is that it is possible to understand what problems the user has with the interface and why they arise, and can be a good source of prescriptive data. A possible disadvantage is that it can be argued that the think aloud protocol can interfere with the task the participant is performing, since the participant is in fact performing two tasks; using the product and verbalizing what is done. The difficulties that the user encounters with the product could possibly be derived to the verbalization and not the actual product. However, when the verbalization interferes with the task and the participant gets quiet, it also gives a measurement of when the task gets demanding. Another disadvantage is the risk of the participant rationalizing his actions since he is explaining them to the investigator, and thus not giving the true picture of how a task is performed in reality (Jordan, 1998).

4.6.2 *Implementation*

A simulated user observation was conducted because of the geographical distance to real end-users. The participants were two system verifiers, since first-time users could not be tested. The system verifiers work with ARTHUR to test and verify that the system works as it should. They work in ARTHUR almost on a daily basis and one of them has military experience with the Giraffe system, which is similar to ARTHUR but bigger.

The observation was conducted in the truck mounted ARTHUR ModC demo at one of Saabs measuring grounds, with helmets and combat vests as mediating objects, see figure 10. The tasks were divided into four rounds. Round one consisted of deployment of the system with no preparation beforehand as if the level of threat is low and where both operators cooperate. This scenario takes about 15 minutes. In round two, the level of threat was high, and the deployment was done as fast as possible. In this scenario the power plant and the navigation system was already on as it would be in a real situation where ARTHUR is performing mobile missions. The quick deployment consists of pretty much just opening the door and raising the antenna, and takes under two minutes. In the third round, one operator was asked to perform the deployment by himself, using think aloud methodology. In the final round, one participant was asked to change a few default settings in the interface.

Figure 10. *The two system verifiers that helped in performing the user observation. Here one is flipping the Man-Aloft switch beore raising the antenna.*

The user study was an open observation, where the participants knew that they were being filmed. They were filmed with one stationary camera inside the shelter and two cameras outside to cover all their movement. The think aloud talk was recorded with a mobile phone attached to the participant. Apart from observing usage, another important motive of the study was to teach the authors how the system works.

Figure 11. *To the left: the power plant display is difficult to read when wearing a helmet. To the right: the user grabs protruding objects to support balance inside the shelter.*

4.6.3 *Result*

The main result from simulated user observation was the many working positions that were captured from screen shots from the movies as well as the positions in which the combat gear gets in the way. An essential issue that was found thanks to the observations was that the display of the power plant could not be read with the helmet on, since the power plant unit was placed too close to the ceiling to be able to have the eyes at the same height as the display. It was necessary that the viewing angle was horizontal, since the glare from the lamp right next to it was impeding any other viewing angle, see figure 11. It was further confirmed that the seats were too close to each other when the user had combat gear on. The users could only be seated from the side facing the other chair, which also meant that both users could not take a seat simultaneously.

An interesting result was seeing where the users grabbed for support when entering the shelter. It was clear that a second handle was needed, since every time someone entered the shelter, they grabbed something for support, either the doorframe or the battery unit that stands right inside the door, as seen in figure 11. It also became very clear why the Inertial Navigation System (INS) is situated down on the floor right by the door to the right. It turned out that the INS was the very first thing that had to be turned on after the power has been turned on, and since it takes about 15 minutes to warm up and it has to be warmed up before the antenna can be raised, this is a crucial part of the deployment. When the INS was placed as low as it is and close to the door, it meant that it could be turned on by standing on the ladder without having to enter the shelter, thus saving a couple of seconds of deployment time. A prerequisite for this is of course that the battery switch is also reachable from the ladder.

The tested users were not experts at using the system in real situations, so the results of the test should be seen more general than in a normal user study. The other results, such as the movement pattern and the working positions, can be considered so general that they would most probably be true in reality as well.

4.7 Graphic System View

4.7.1 *Theory*

A Graphic System View is a flow chart depicting how information, mass and energy move between components in a human-machine system. According to Sanders and McCormick (1993) a system in the area of human factors should be composed of human and machine components that interact to reach a goal that could not be reached by the components individually.

4.7.2 *Implementation*

To develop an understanding of ARTHUR as a part of a bigger system, the main components of ARTHUR were identified as well as their interaction with components outside ARTHUR. The interaction type was labeled information, energy or matter and the direction of the interaction was identified. The interactions were communicated through arrows showing type and direction. In the case of interaction between the operator and command and control there are different scenarios. In most cases information is sent through the radio, but sometimes there is interaction directly between the operator and the command and control in the form of either verbal or written communication. Both scenarios were added in the system view.

4.7.3 *Result*

The following components and system goal were identified:

Components:	Operator, workstation, power plant, radio, antenna, signal and data processing unit, environment and command and control.
System goal:	To register information about the environment, and to transfer this information upwards in the chain of command.

The operator interacts with the workstation and the radio equipment by receiving and sending information. The radio also receives information from the workstation and passes this information on to the command and control. The operator can also communicate directly with command and control, both by sending or receiving information or matter. The workstation communicates with the signal and data processing unit by sending and receiving information. The unit forwards the information received to the antenna, which transmits energy to the environment in the form of electromagnetic waves. The antenna receives information from the environment and forwards this to the signal and data processing unit for interpretation. The power plant provides energy for the workstation, the signal and data processing unit and the antenna.

The "environment" component was defined as the environment that can be seen by the antenna only. There is also an environment outside the entire system under scrutiny, which is outside the scope of this system view, but not to be confused with the "environment" component below. The visualization makes it clear that the operator's only interaction with the environment is through the workstation. Indirectly the operator also interacts with the world outside the shelter through the radio or command and control. Nevertheless, the visualization verifies how important the workstation is to the operator. See figure 12.

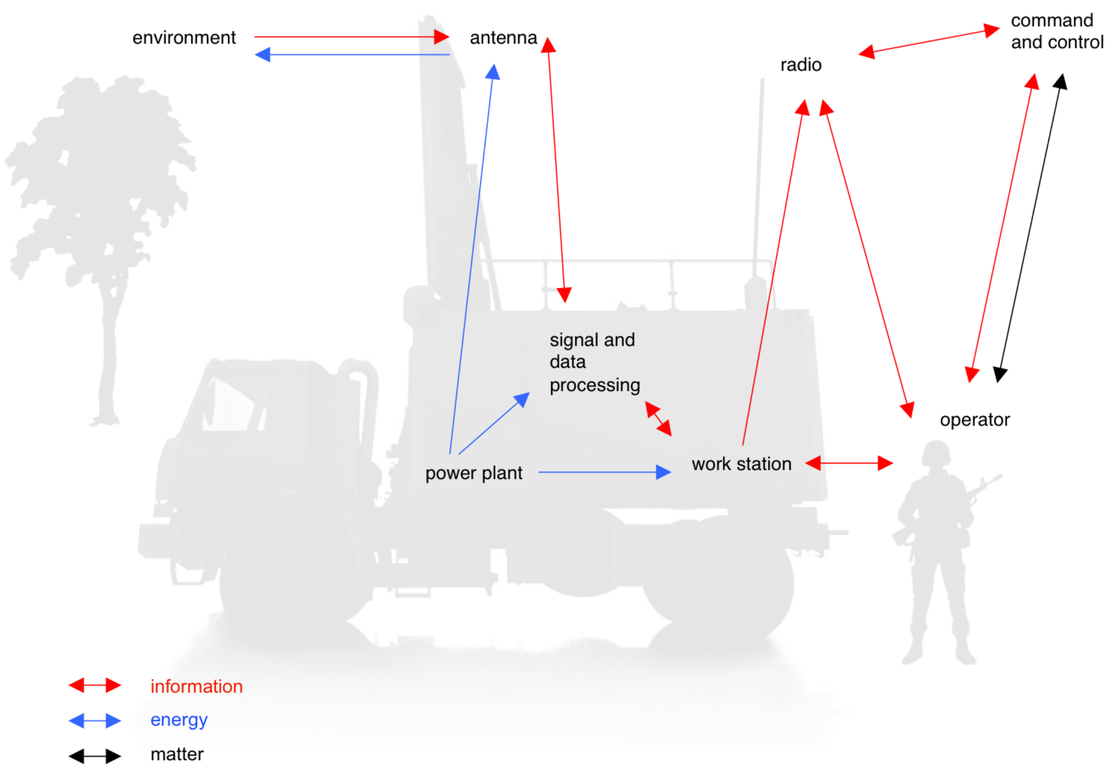


Figure 12. *An illustration of the flow of energy, information and matter within the ARTHUR WLS.*

4.8 Online Research

4.8.1 *Theory*

Almost all products that are produced leave a trace on the Internet. This trace can be of varying quality depending on the source, but can provide valuable insights in the general or extreme opinions of a product, or even voice the opinion of the user.

4.8.2 *Implementation*

The Internet serch was completed through the search engine Google (www.google.com) and the video sharing website YouTube (www.youtube.com). The search results were critically screened, and two hits were considered worth investigating further. These were an old video commercial of ARTHUR and articles about the Danish Artillery unit's work with ARTHUR in Afghanistan published on the Danish Artillery's website. The articles were written in Danish, and were translated to English and Swedish through the automatic online translation service Google Translate (http://translate.google.com). Specific words that were not translated correctly have been double-checked with the online dictionary Tradusa (www.tradusa.se). Some information found in the articles such as the name of the big camp, were futher researched online, which lead to news articles that further increased the author's knowledge.

4.8.3 *Result*

The six-minute long ARTHUR commercial found on YouTube (Scurck, 2007) gave an insight in how the tracked vehicle version of ARTHUR is deployed and used, as well as what the purpose of ARTHUR is. The commercial also mirrored the features that the company is most proud to point out. Additionally, it gave the authors a closer contact to the product since it was seen moving in a natural environment.

Another source of valuable user information was found online at the website of the online newspaper artilleriet.dk. On the website, they publish articles about their daily life on their mission in Afghanistan. Reading the articles has brought a picture of how ARTHUR is actually used on real missions, what the operators' living conditions are like, and what they think about ARTHUR. This information has been a prerequisite for creating scenarios based on actual user information and not just information from Saab on how ARTHUR is supposed to be used. The reports of the Danish Artillery's mission in Afghanistan from 2006 to 2009 have provided first-hand information about the reality with ARTHUR. The Danish artillery has four ARTHUR:s in Afghanistan, of which three are operational and one can be inspected or repaired. The Danish forces has 29 soldiers working with ARTHUR in Afghanistan. Their main mission is to protect the biggest British camp, Camp Bastion, from attacks and secure the area for British, Danish and other nation's forces moving in and out of the camp. They also take part in semi-mobile missions around the province. Every radar team consists of six solders, three soldiers in a utility vehicle and three soldiers in the radar. When stationed at a camp or a Forward Operating Base (FOB), ARTHUR is manned 24 hours a day as well as guarded from the outside at all times.

A FOB is a logistics and support area where supplies are stored, vehicles are maintained or repaired and where headquarter detachments are based. In the larger ones, the soldiers can receive mail, get medical care and there are facilities such as showers and recreation centers to help relieve the stress of deployment and missions “outside the wire” (see figure 13) (Briefing: FOBs the closest thing to home in Iraq, Anon., 2008). In the articles, the life at the FOBs is described as very different from the life at Camp Bastion. For instance, the dress code differs. At the FOBs the British walk around in shorts and bare-chested, while the Danes wear a casual summer outfit of shorts and t-shirt supplied by the Army.

The Danes have good relations to the British; they help them with surveillance, fire control and they even eat together at some bases. The Danes have also cooperated with the Estonian and Canadian forces, which have both appreciated their presence and the help from the ARTHUR radar in various semi-mobile missions.

Figure 13. *The collage shows examples of the environment in which the ARTHUR operator spends his or her time. The top left image shows radar operators relaxing (Danish Defence, AOCDEN, 2008). The top right image shows a toilet at a FOB (Danish Defence, AOCDEN, 2007a). The bottom left (Danish Defence, 2007b) and bottom right (Danish Defence, 2009) images show ARTHUR deployed and performing static observations.*

In most cases, allies request help from ARTHUR if a division or base has been fired upon several times and they need help to locate where the fire comes from. In one of those cases, that meant a trip for ARTHUR of 40 km. Three of the Danish ARTHUR:s have also been positioned at Kandahar Airfield while one was performing semi-mobile missions. The Airfield is fired upon sometimes, and ARTHUR is valued for its contributions to prevent further attacks.

It is never mentioned in the articles that ARTHUR is used on a mobile mission. The semi-mobile missions usually mean that ARTHUR relocates for a shorter period of time. When they talk about moving ARTHUR, it is never deployed on the way and always escorted by allied forces. In one article, ARTHUR was being moved and had stopped at a camp for the night, when a British officer rushed to their tent to have them deploy ARTHUR. But since they had put all their belongings inside the shelter, not expecting having to deploy, it took them over 20 minutes to get ARTHUR to surveil the area.

There is big difference of the level of luxury of the different bases and camps. In some they sleep in tents and sleeping bags, while in others they have containers with beds and proper showers. Most, but not all of them, have Internet, telephone and electricity.

4.9 Summary

The extensive data collection resulted in various types of information. Interviews with employees at Saab gathered the knowledge that different departments have about the user. Marketing and project development knew about problems that customers have with the existing products, mainly hardware problems and service issues. Customer training is at the other end of the user spectra, and has knowledge about what is hard to learn about the system and in some cases how they use ARTHUR in the field. The simulated user observation was also a way to gain knowledge about the system from within the company. Two system verifiers carried out typical ARTHUR operator tasks while being videotaped and this showed how the system is deployed as well as what problems and issues a user comes across when operating ARTHUR in combat gear. The documentation analysis was carried out by studying the user's manual and the marketing brochures. This information also represented a company view of usage without the refinement of actual usage experience as well as the image the company conveys.

The online research resulted in an invaluable source for learning about the environment ARTHUR is used in. The articles about the Danish artillery's missions in Afghanistan were a considerable contributor for the insight to the daily life of an operator in missions. They also provided examples of how ARTHUR is utilized. Another good insight into the actual users' view on ARTHUR was the surveys that were sent out to Denmark, Norway, UK and South Korea. They resulted in both qualitative and quantitative data, and shed light on many issues, some of which were predicted and some that were new issues.

5 ANALYSIS

For a complete analysis of the data collected, it was necessary to take apart the pieces and work through all the collected data. This was first done in a KJ-analysis, where all the transcribed interviews were broken up into quotations. These were then put into intuitionally emerging groups that were labeled after their content. Each group label was organized by priority to create a way to deal with the vast amounts of data and the many groups that emerged. This was done in a so-called priority matrix.

The same group labels were then used as headings in the forming of a problem-cause matrix. This was a method to go through all issues and problems that had appeared either in interviews, observations or surveys. All data was scanned for problems, and the findings were placed in the problem-cause matrix. The matrix lists the causes and effects of the observed problems. Observed behaviors could thereby be connected to design features and that made them more easily altered. It is easier to see how to change a design, than how to change someone's behavior. By listing the effects of the issues and behaviors, their importance was also magnified. Some potential effects even included death, and that makes the underlying issue hard to ignore.

A user needs analysis was conducted by simply writing down general human and specifically military and radar operator needs, ordered in a mind map way. This mind map was used to make sure basic human needs as well as more specific ones were brought up and kept in mind during the project. To make sure that no parts of the interactions between operator and machine were overlooked, a Hierarchical Task Analysis (HTA) was produced. It aided in creating an overview of the tasks that are performed when operating ARTHUR.

5.1 KJ-analysis

5.1.1 *Theory*

A KJ-analysis, or affinity diagram as it is also called, is a way to organize large amounts of verbal data and create a graspable whole as a way to communicate the data efficiently (Karlsson, 2006). The verbal data can come from observations, interviews or brainstorming sessions. This bottom-up approach results in categories that represent the large amount of data behind. The data is written down on small pieces of paper, one sentence or quote per piece. The papers are drawn one at a time and placed together with another if it is related, or alone if it is not related to any of the previous papers. When all papers are placed, natural groups will have appeared. The essential link between the quotes constitutes the name of the group, and a category is born (Balanced Scorecard Institute, 1998).

5.1.2 *Implementation*

Relevant quotes from the interviews were grouped with the help of a KJ-analysis. The results of the user observation and the surveys were not included in the KJ-analysis, since it was mostly the interview data that needed to become more graspable and organized. In the end, it turned out to be a good decision due to the fact that the results from the user observations and surveys were already quite concrete and could easily be sorted into the already existing categories in the problem and cause matrix, see chapter 5.3. In addition to this, the quotes from the interviews were already a great amount to sort into groups, and a KJ-analysis could hardly be done with any more information.

5.1.3 *Result*

The analysis resulted in the following groups: sales, handling of information, maintenance, placement, discomforts, body size, computer interface, language, human factors-attitude, military tactics, automation, tasks, safety, behavior, time, competitors, standardization, daily work, ARTHUR-Saab attitude, roles and performance.

5.2 Priority Matrix

5.2.1 *Theory*

The resulting groups from the KJ-analysis were so many, that an overview of the whole problem spectra was hard to achieve. Further processing was needed to get there. The 21 headings were considered to include content of varying importance to the project, and this variation was utilized to manufacture a priority matrix.

5.2.2 *Implementation*

All headings from the KJ-analysis were evaluated against two scales called “Long-Term – Short-Term” and “Connection to Human Factors”, and placed accordingly on a two-axis diagram in figure 13. These scales were chosen since the project is aimed at short-term solutions since it aims at finding the first steps for human factors integration, and since it is in the field of human factors. Thus, groups of problems that can be seen as solvable on a short-term and closely related to human factors could be seen as most worthy of attention. A grading of three steps on each scale was used, which created a grid of nine boxes on the resulting diagram. This was considered to be a sufficiently rough grading, since the method is subjective and therefore the resulting priority becomes subjective as well.

5.2.3 *Result*

The result can be seen n figure 14. Headings appearing in the corner of "Short-Term" and "Strong Human Factors Connection" can be seen as the top priority, and headings in the opposite corner of the diagram can be considered to be the least relevant. A diagonal line between the two corners dictates the order of priority for all other boxes, and the boxes in the same color have the same priority.

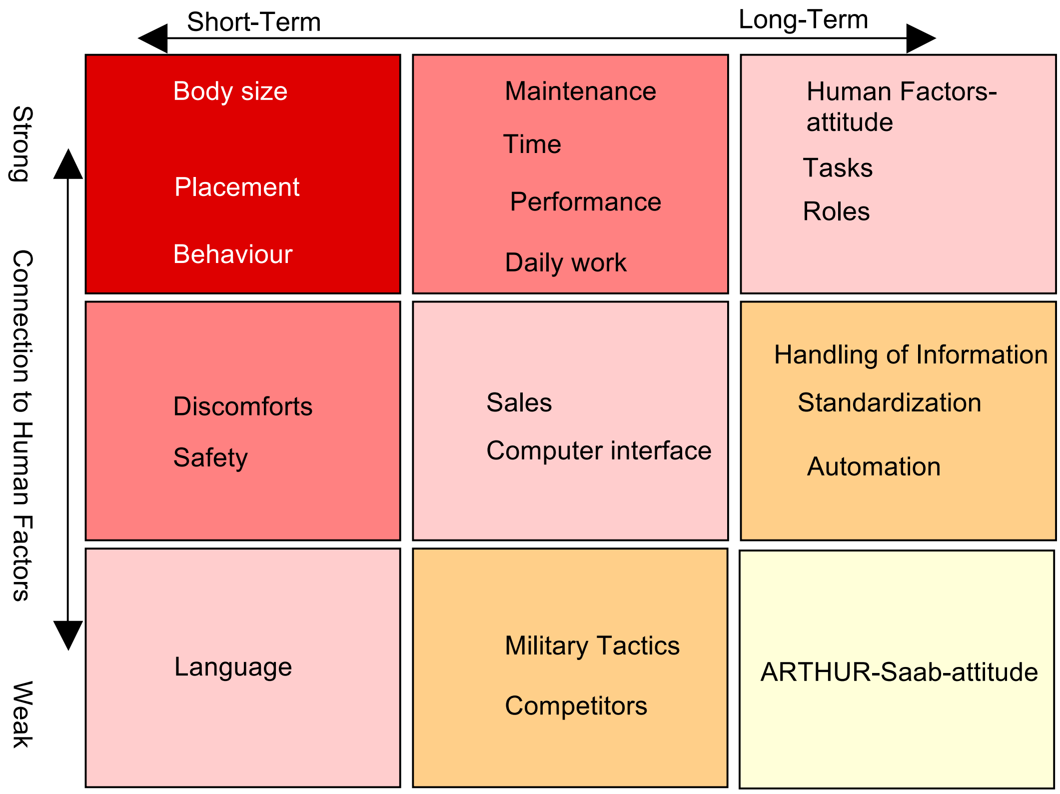


Figure 14. *The three headings in the upper left box, Body size, Placement and Behavior, are the most important ones in the diagram. ARTHUR-Saab-attitude, in the bottom right corner, is the least important.*

5.3 Problem and Cause Matrix

5.3.1 *Theory*

To find the underlying problems of the statements from the interviews and surveys as well as observed behavior, a problem and cause matrix was needed. When analyzing the possible causes, consequences and possible actions of an observed problem, the bigger picture starts to clarify. Through the problem and cause matrix the effects of the current design also become apparent. The point with the matrix is to gather a complete and multifaceted picture of the problem that will enlighten the surprise demands and that has potential of being a good basis of the development work.

5.3.2 *Implementation*

Each statement from the interviews, surveys and observations was analyzed, and where an underlying problem could be found it was put in a matrix. Further, the possible cause of the problem, the consequences of the problem and possible action that could be taken to avoid the problem were listed along with each problem.

5.3.3 *Result*

For the entire matrix, see appendix I. Below, in figure 15, is an example taken from the matrix.

The problem and cause matrix was a good way to try to find the surprise demands and to pinpoint the compensating behavior that occurs and that might occur when the system is not optimal. As for the column of possible actions, it becomes almost a pre-brainstorming of solutions. Although it is an early stage to think about solutions, it was useful to have the column there in order to find clarity in the cause and consequences. In some cases it was not immediately clear which phenomena is a cause and which is a consequence. In the example below, an observed problem could be the lack of handles and the consequence could be that protruding parts are grabbed. The cause of the lack of handles would then be that handles have never been added to the design, which is pointless to point out in every case that something is lacking. The action would then repeatedly be to add handles to the design. In these situations it was helpful to have all the four fields to verify that the thinking was consistent and that there was a higher gain with the matrix than to produce a list of what the system is lacking.

	Observed Problem	Possible Cause	Consequences	Possible Action
Behavior	Grabs protruding objects and surfaces when entering the shelter.	Lack of handles to grab.	Grabs battery switch protection, night curtain, CDU and doorpost. Things break. Operator might fall.	Design things that look like handles so that they actually work like handles. Add handles inside the shelter. Add surfaces to push yourself forward from. Add a handle outside door, opposite side of door hinges.

Figure 15. *This figure shows the headings used in the Problem and Cause Matrix, with and example of how it was filled out.*

5.4 Operator Needs Analysis

5.4.1 *Theory*

When only looking at the actual data that was collected, there was a risk of missing the basic needs. This is a top-down way to look at the situation, since it starts out on an abstract level and increases in detail as the mind map branches out further. This tool elicitates existing knowledge and structures it in a new way. It does not lead to a finalized list of needs that have to be fulfilled, but rather puts the user of the tool in the right mindset and aids in keeping the end-user's needs in mind. It also takes into consideration common basic human needs, such as the need of feeling safe and to feel companionship, which might otherwise be overlooked or taken for granted.

5.4.2 *Implementation*

The quality of the results of this method is related to the amount of domain knowledge available to the people applying it. Therefore it was not used until a substantial amount of interviewing and studies of the system had been performed. Needs listed at the end of the branches were often formulated as single words, but their meaning can be interpreted by following their track from the main node.

A visual tree diagram was created to isolate the needs of the ARTHUR operator. The central node was titled "Operator Needs" and from there five branches were drawn; body, mental, communication, safety and information. These were further branched out to cover the imaginable span of needs of an ARTHUR operator.

5.4.3 *Result*

The analyzed needs of the operator were divided into safety needs, need of information, need of communication, body needs and mental needs, see figure 16.

5.5 Hierarchical Task Analysis (HTA)

5.5.1 *Theory*

According to Ainsworth (2004) a HTA is a method for identifying, organizing and visually representing the tasks and sub-tasks that are included in a complex activity. The method consists of describing the goal of an activity in different levels of detail, starting off with a very high level and dividing this goal down in different sub-goals that must be fulfilled so as to ensure that the main goal is met. For instance the goal of controlling temperature could be divided into three sub-goals for maintaining the current temperature, increasing it or decreasing it. It is recommended that each sub-goal is not broken down to more than seven or eight sub-tasks to ensure that no important tasks are missed.

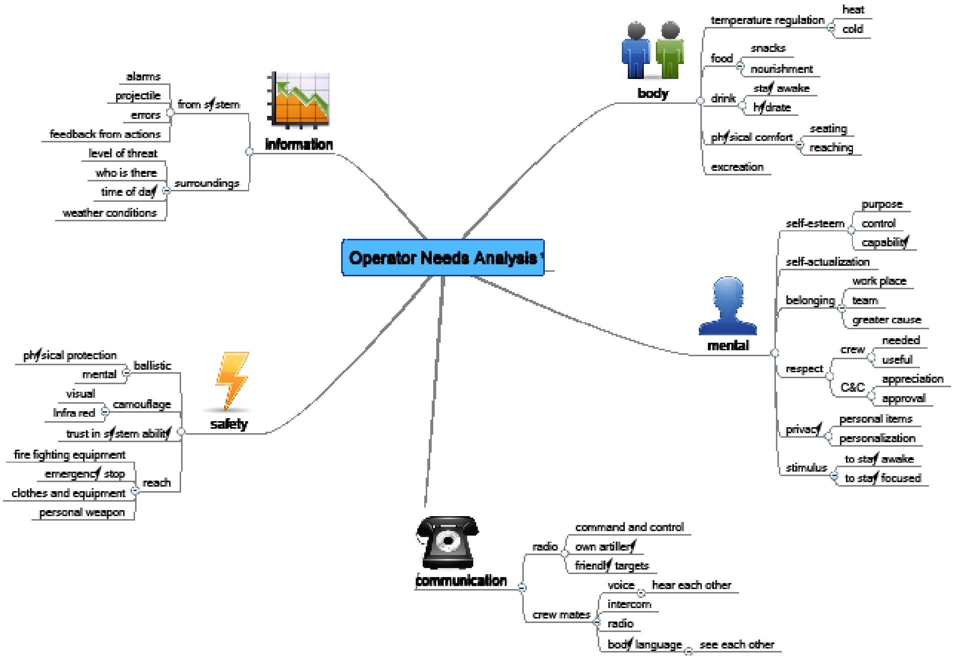


Figure 16. *The mindmap visualises the needs of the ARTHUR operator, arranged into branches that increase in detail as they spread out.*

The result is a hierarchically organized set of task descriptions, taken to the level of detail sufficient for the analyst. The purpose of the HTA is to provide a framework to understand the relationships between different elements of a task and to ensure that no tasks included in an activity are missed. In order to avoid unwanted complexity within the HTA, it is often preferable to create several HTAs as opposed to trying to cover all situations in a single one. It is generally recommended that separate HTAs should be produced in cases of different scenarios, different operational modes and when tasks are undertaken by different persons.

5.5.2 *Implementation*

The use of ARTHUR was divided into two scenarios: static camp protection and mobile missions.

5.5.3 *Result*

See Appendix II.

6 META-STUDY

It became apparent that the presentation of information was crucial for the success of the result. The best way to present the information and what information should be presented was analyzed in a meta-study, where the users were now the engineers at the company.

6.1 Process

Even though the problem and cause matrix contained all problems and disturbances in the interaction between the user and the product, it was necessary to present this information in a way that would make it useful in the design process. General information about the user was also necessary to present. To educate the engineers in how to consider human factors was considered the next best thing to employing a specialist in the field to the development team. When human factors is not officially considered in the design process, the authors felt that the knowledge about the user and usage might go to waste if it is not presented in a clear and applicable manner in order to be useful for the design engineers and the system engineers at the company. For this knowledge to live on after the thesis is presented, a meta-study was initiated. First, theory about human factors integration was studied. Then, the users, who were now the engineers, were studied in order to find out how they will potentially use the information. For this, the design process at the company needed to be understood. Requirements could then be specified, which would make the compilation of information specifically designed for taking human factors and applying it to the design engineering process of ARTHUR.

6.2 Result

An interview with an engineer was conducted in order to understand what the design process looks like today. It turned out that both the design engineer, who actually designs the parts of ARTHUR and decides their position in the shelter, and a system mechanist, who turns the customer's demands into engineering requirements, could benefit from using the collected information in their work.

Furthermore, the study of the engineers and the company revealed that most employees seem to have a good grip of how the product works, but less knowledge of how it is really used. This information is nevertheless sought after. Some employees have copies of the British Ministry of Defence´s DEFENCE STANDARD

(2008) available, but it is not used as a natural part of the design process in general. DEFSTAN is a comprehensive work that among other things contains numerous guidelines and explanatory illustrations on the subject of human factors. It is especially fitting to be used at Saab EDS since it has a military focus, even though large parts of it are applicable in the civil field as well. The reason that it is not used very extensively could be that it takes some knowledge in the area of human factors to interpret DEFSTAN and convert the information to design requirements.

The user group that is arranged annually with ARTHUR users is, in its existing form, not as good a tool as it could be at extracting user requirements. There is no structured use of methods to elicit requirements (Hellgren, 2010). This means that one cannot rely on the user groups to gather information about the users. That is not what they are aimed for today, even though they could be in the future.

These realizations meant that the knowledge passed forward to the engineers would have to work as a source for user requirements as well as provide the usage context as a basis for requirements elicitation, at least until human factors is considered properly in the development process. Since the knowledge is both general information about the user and specific requirements, a booklet was seen as a good format for forwarding the knowledge. The interviewed engineer confirmed that a booklet would be a good format, since they do not use other booklets in their daily work and it sounded like an interesting format.

6.3 Requirements

Through studying the engineers as intended users of the booklet as well as their existing design process, the requirements for the booklet were specified. The booklet should:

1. Be able to be used as a checklist for making sure human factors has been considered in the design.

This requirement came from the interviews, and was something that was requested in order for the booklet to make the most use in the design process.

2. Be able to be used as a checklist to evaluate the usability aspects of the product.

This was also requested by the interviewees. They wanted a quick way to find out how user friendly their product is.

3. The checklist should not be open for individual interpretations

This requirement was a request from the interviews since it was important that the statements on the checklist are specific and easy to judge whether the statements is true or false. Theory confirms that designers commonly prefer to get precise data (Fulton Suri & Marsh 2000, cited in Högberg 2005).

4. Make the user present in the mind of the designer during the design process.

This was considered important since the designers do not know enough about the user to consider his or her traits in their design. It does not come intuitively for the designers to try to find this infromation either, so it was important to make the designers constantly reminded of the user in order for them to start designing more for the user.

5. Contain background information for those who want the complete picture.

This requirements was put up to cater to the need to read the booklet in many levels. It should not be necessary to read the booklet from front to back, but for tose who have the time to get a more detailed knowledge, it should be possible to find it in the booklet.

6. Not inhibit the engineer's own creativity in problem solving but guide him in the right direction.

The authors did not want to step on anyone's feet and make them feel like some-one is telling them how to do their job. This requirement was put up to make sure the designers feel like they are solving the problems themselves, but that they can find useful facts to help them with the human factors part in the booklet.

7. Be easy to find the information needed for a specific part.

This requirement arose in the realization that the engineers might not always have time to use the booklet if it is necessary to read the whole thing. It then be-came important that the reader easily finds what he or she needs.

8. Be general enough to be applicable in several future projects.

Since the goal was to introduce human factors in the development process, it was seen as important that the information could be used in future and just when it is introduced.

7 SYNTHESIS

The booklet was developed with the goal to fulfill all the mentioned requirements. As a part of the requirement to make the designer think of the user during the design process, personas and scenarios were created and included in the booklet. Giving the designer a clear understanding of what the user is like, how he or she behaves and how his or her days are spent will be of tremendous help in the design process. As theory suggests, it is important to know the target audience, the environment that the user and equipment operates in and the task that the user has to conduct in order to design usable products.

To further make the user present in the mind of the designers, life-size paper figures were made. These figures could then be placed in a meeting room or in the hallway to remind the designers who their users are.

7.1 Personas

7.1.1 *Theory*

A “persona” is a fictional person, a character, created to represent a typical or critical end-user. Personas work as a way to focus on the user and design with the user in mind, instead of having yourself as the model. According to Pruitt and Grudin, (2003) the most important benefit of using personas lies in creating common grounds for communication between people involved in a product development project. Pruitt and Grudin claim to have successfully used personas to communicate a broad range of user related information, such as market research and ethnographic studies, to several project participants. A persona can communicate this kind of hard-to-grasp information in a very accessible way. It does this by utilizing our inherent human capability to predict behaviors from our existing knowledge of other people. We tend to extrapolate from what information we have available, to guess what other people will do. This psychological feature, by Pruitt and Grudin (2003) referred to as “Theory of Mind”, makes us able to for instance think “what would Sarah think about this?” if we have sufficient information about the persona Sarah.

Usually, a persona consists of a photograph and descriptive text or bullets. It is normally less than one page long, so that it is easy to read. The text gives the reader a feeling of who the persona is, and it should contain enough details to make the persona believable. It should feel as if the persona is a real person. It is then easy to remember it and make predictions from it (Pruitt and Grudin, 2003).

A persona works best when it is detailed, up to date and based on solid empirical data about the user group it represents. However, collecting data takes a lot of time, and in short-term projects several months on interviews and observations can unfortunately seldom be spent. Still, designing for someone is always better than designing for no one, and a slightly researched persona can add a lot of value even if it cannot be used as extensively as a well-researched one. In lack of real data, using stereotypes is a quick way to create an interesting persona. In the same way as a movie character is very exaggerated and one dimensional to be able to catch the interest of the audience quickly, a persona in a short-term project can utilize stereotypical traits (Pruitt and Grudin, 2003).

When choosing the easy road of stereotypical personas, however, there is a risk to be aware of. As Adlin and Pruitt (2006) points out; "It may give rise to empathy. But once in place, a stereotype could lead team members to ignore inconsistent evidence about real use. Stereotypes can lead to systematic, irradicable errors in predicting behavior". So a persona based more on stereotypes than on research of the target group could be helpful in engaging people and have them start thinking about the user, but a well-researched persona will generate more accurate predictions about the real user's behavior.

7.1.2 *Implementation*

Looking at the diversity of Saab's customers for the product ARTHUR, it was found that at least two personas were needed. The nationalities of the two personas were selected primarily based on availability of information and combat experience. Difference in culture played a secondary role in the choice. Denmark is a customer that has used ARTHUR rather extensively under real conditions. There are relatively large amounts of information available online (Artilleriet.dk) about their use of ARTHUR in Afghanistan. The survey that was sent out to ARTHUR operators got eight responses from Denmark. Because of these facts one of the personas was chosen to be a Dane. The other persona is from the Czech Republic, as a telephone interview was performed with an operator from this country, and there was quite a lot of information available from that. The Czech ARTHUR:s have also been used in the battlefield of Afghanistan.

The Danish persona is female, not because most Danish operators are women, but because of the diversity it creates as well as since at least two of the operators in Afghanistan are women(Larsen, 2008). It was considered important to break the potential prejudice that all military personnel are male. Naturally, the other persona was decided then to be male, corresponding to the 27:1 ratio of males among the respondents to the survey. The Danish persona was named Else Poulsen, and the Czech persona was named Radek Novák. This was from the criterion that the names should be pronounceable in both English and Swedish, and representative of the countries from which the personas stem. Else is the 18:th most common female given name in Denmark as of 2010 (Danmarks Statistik, 2010a) and Poulsen is the 17:th most common surname. Radek is the 25th most common Czech name (Ministerstvo vnitra statistiky (Interior Ministry statistics), 2007b) and Novak is the most common Czech surname (Ministerstvo vnitra statistiky (Interior Ministry statistics), 2007a). This makes Radek Novák a plausible name for the Czech persona.

The two personas are differentiated in age to create a span covering most operators. The survey sent out to ARTHUR operators revealed that the oldest Danish operator to respond was 29 years old, and that age was then given to Else. Even though there were older respondents from both South Korea and the UK it was considered important to know that someone among the Danish operators actually could be of the age chosen, to ensure credibility in the persona. To balance this, Radek was decided to be 20 years old, matching two of the five Norwegian respondents in lack of data from Czech operators.

Danish conscripts are on average 180.6 cm tall as of 2006 (Danmarks Statistik, 2010b) and Czech men are on average 180.3 cm (Disabled World, 2008) This means that both Danes and Czech people are among the tallest in the world. Since there is a great difference in height among the users of ARTHUR, who today include South Korean as well as taller Scandinavians, Radek was selected to be 189 cm tall and Else to be 162 cm tall. Making Else rather short is also important since Asian operators have been reported to have issues with reaching things, such as the ladder, both in an interview (Barryd, 2010) and in the survey.

To add personality and make the personas feel real, details of family were invented. To make Else feel more human she also got a weakness; she is a smoker who has difficulties to quit. This weakness is also used to imply that work in ARTHUR could be boring during long shifts. The smoking habit is supported by statistics indicating that 22% of Danish women over the age of 15 are smokers (Them Kjær, 2010). Most of the details about both Else and Radeks behaviors, feelings, motivators and fears are based on answers to the survey. A highly detailed breakdown of all persona traits with references to their sources can be found in Appendix III and is useful if the personas are to be updated in the future and adapted to new circumstances.

7.1.3 *Result*

7.1.3.1 **Else Poulsen**

Name: Else Poulsen
Age: 29 years
Height: 162 cm

Else Poulsen is a sergeant in the Danish army. She is 29 years old and works as an ARTHUR radar operator. Being 162 cm tall, this suits her well. She can almost stand upright inside the shelter. Else is engaged to Niels, whom she met during conscription. He now works with human resources at the municipality in Ringsted, one hour from Copenhagen. Else and Niels got engaged just before Else went on a foreign mission to Afghanistan. This was partly to strengthen their relationship, and partly in order to be left alone from some of her male colleagues.

Before starting her military career, Else studied to be a physical education teacher. She quit half way through when she realized that sitting down indoors and attending lectures was not her thing. Also, being a former soccer player, she missed the physical challenge that she was expecting from the education. Else recently decided to stop smoking, but out on a mission she finds it difficult. She often feels restless and uneasy during the long shifts in ARTHUR, when there is nothing to do. At those times it is hard to stay off the cigarettes. Other ways to pass the time is by reading books, texting her fiancé or other friends back in Denmark, or by talking to the other operator if he is there. If he is not in the shelter, Else opens up the door to be able to talk to her colleagues outside. She always looks forward to breakfast and dinner in the British cookhouse. The food is good and the British colleagues are very nice.

The toughest part of being an ARTHUR operator, from Else point of view, is that you need to sit down a lot and the fact that you need to investigate lots of "ghost targets", or false targets. Being away from Niels for a long time is of course also tough, but it feels good to have someone back home waiting for her. She is always happy to receive books and films by mail from him.

Figure 17. *Else in her combat gear (picture: Boston, ImageryMajestic, Irusta, 200?).*

Else likes the Army. She especially appreciates the general positive view on physical exercise. She really likes the challenge of handling such a complex technical system as ARTHUR, and being the one who sits on important information. Else feels that she has an important task. After four years with ARTHUR she is starting to get a bit bored though. She knows this job inside and out, and it feels like she might have grown out of ARTHUR:s small shelter after all. Else is pondering if she should continue in the military and develop her military career, or if she should quit and do something else.

7.1.3.1 **Radek Novák**

Figure 18. *Radek is a tall soldier (picture: Denson, ImageryMajestic, Irusta, 200?).*

Name: Radek Novák
Age: 20 years
Height: 189 cm

Radek Novák is a tall soldier in the Czech army, measuring 189 cm. After completing his conscription as a radio operator, 20-year-old Radek wanted to continue his career in the armed forces. Since he knew English the best in his platoon, his officers offered him to train to become a radar operator for the ARTHUR system. He thought this suited him very well, and he put his language skills to good use during the training course with the Swedes.

Now, after six months working with ARTHUR, Radek is looking forward to going on Foreign Service. He feels that it is a good way to see the world and experience some adventure. His older brother Damek has been to Iraq as an infantryman and he tells Radek fascinating stories of his times in Iraq. Radek's mother is very proud to have two sons in the military, but his little sister worries about Radek leaving on a dangerous mission abroad.

Rumor has it that people watch a lot of movies during the downtime that they often have at missions abroad, and to Radek that sounds great. That is why he is saving up money for a new laptop that he can both watch movies on and play computer games. As kind of a computer geek, Radek gets annoyed with the fixation of paper maps in the military. He finds it a drag to transfer coordinates and targets by hand and he would like to get rid of that task. Once he tried complaining to an officer about this, but he got told off and has never brought it up since.

Radek has learned to handle ARTHUR quite well, but he is still worried that he will make a mistake when it really matters. He finds it difficult to navigate the menus under pressure. Since he is tall it is taxing to sit in ARTHUR for any longer period of time. The combat harness and helmet comes off as soon as he enters the shelter. Sometimes he even takes off his boots to get some extra legroom.

7.1.3.1 **Cardboard figures**

Life-size cardboard figures were manufactured in order to communicate whom the personas are, to make people remember them as well as to visualize their size, see figure 19. One for each persona was made in a 1:1 scale through gluing paper prints on large pieces of cardboard and cutting out the silhouettes. Cardboard supports were constructed so that the figures could stand by themselves, and the entire figures were made foldable to allow for transportation and storage. They were equipped with removable helmets and combat harnesses, also made from cardboard. To convey the text-based information about the personas they were equipped with removable speech bubbles with condensed persona descriptions. The two life-size paper versions of the personas conveyed the height of Radek and Else, and also visualized the added bulkiness that comes with wearing combat gear. Smaller desktop versions of the cardboard figures were also created. At about 30 cm tall they can be kept at the work desk of i.e. a design engineer or a system mechanist to help them keep the user in mind.

Figure 19. *Else and Radek printed as life-size cardboard figures with combat gear and a speech bubble.*

7.2 Scenarios

7.2.1 *Theory*

A user interaction scenario is a story about people and their activities (Carroll & Rosson, 1990, cited in Rosson & Carroll 2002). Scenarios are descriptions of how users interact with a product; what goals they try to achieve, what procedures they use or do not use, successfully or unsuccessfully, as well as what interpretations people have of what happens to them. The characteristic elements of scenarios are, according to Rosson and Carroll (2002), the setting in which the product is used, the actors involved, the task goals, the plans of converting a goal into a behavior, the evaluation when interpreting the situation, the actions carried out as well as the external events that is produced by features of the settings. Scenarios help designers respond to current needs while also anticipating new needs, and focus on the needs and concerns of people in the real world. The advantage of scenarios is that everyone can understand them (Rosson & Carroll, 2002).

Scenarios can be used to capture requirements. There are some drawbacks however. Scenarios can be misleading if they are over-developed or thoughtlessly applied. Depending on the focus of the scenario, it may be strongly domain specific and limiting its use more broadly. Scenarios are also limited in their coverage and time span. One advantage of scenarios is that even if people might have difficulties with other expressions of derived system requirements, most people can understand stories and scenarios. Scenarios also tend to make requirements explicit that were considered obvious and therefore only considered implicitly in the development process (MacLeod, 2008).

7.2.2 *Implementation*

Two scenarios of use were designed. The most important cases were picked out and named "mobile" and "static". They paint a picture of how it would be to work in these two situations and they create a connection to the operator. The thought was that the mobile and the static scenario would be as different as possible, so that the reader can imagine two completely different situations that both need to be considered when designing or in the handling of system requirements. In the mobile scenario everything needs to be done fast and the level of threat is high, and in the static one the surveillance is more of a routine job. It is imperative that ARTHUR works well in both scenarios; the static one that is the most common one and the mobile which is very critical.

The mobile scenario has not been described in the Danish articles; they do not seem to use ARTHUR that way. It might be that they do not need this functionality, or because they never use the internal generator due to the heat. Still it serves a purpose to depict a mobile scenario as it mirrors the original idea with ARTHUR and it might be much needed by other countries in other environments. It also serves as a good reminder that things might need to happen quickly sometimes. Designing for the extreme case of mobile use could give benefits also in static use, in the same way as the TV remote which was originally designed for people bound to a wheel chair, showed to be useful also for people who are not handicapped.

Even though the mobile scenario has not been taken straight out of reality per se, it is based on information from the Danish articles. The scenarios are generalized so that they could be about any nation. This choice was made in order to keep the scenarios applicable and up to date for a longer time. The articles reveal that there are 6 soldiers in an ARTHUR team, 3 in the ARTHUR truck and 3 in a utility vehicle (Sender granater tilbage, Anon., 2006). However, in the scenario they are 2 in the ARTHUR because that would be more likely for any other nation. The Danish ARTHUR is the only truck-mounted version of ARTHUR where you are allowed to sit in the operator's seat in the shelter when driving and since the cabin only comfortably fits two soldiers, it is more likely that most ARTHUR teams would divide their men this way.

To base the mobile scenario on reality as well, events that occured in the Danish articles were used even if the the mission in the article where the events were found did not occur on the kind of mobile missions that Saab developed ARTHUR for. For instance, in one of the Danish articles, ARTHUR is being moved in a convoy at night to a Forward Operating Base. A British utility vehicle runs into an Improvised Explosive Device, an IED, and it slows them down to wait for the vehicle to be towed. There are also warnings of an ambush on the radio (Søndergaard Larsen, 2007b). In another article, one of the operators says that he does not think about the fact that the mortars cause damage, that he was just focused on his task (Søndergaard Larsen, 2007a). The parts with the handling of the system are taken from the user observation performed at Saab, such as how ARTHUR is deployed in a mobile scenario.

The static scenario is taken more directly from the articles, since the Danish ARTHUR's missions are mostly camp protection; see Appendix IV for the complete list of references. There was information about the Danish task of protecting the entrance of the biggest camp in Afghanistan, Camp Bastion (Sender granater tilbage, Anon., 2006). The name was changed, however, to Camp Fernandez, so as not to constrain the scenario to take place in Afghanistan. The climate in the scenarion was not changed from desert however, in order to be able to use pictures from the Danish articles. Some facts were also retrieved from the surveys sent out to Denmark, such as what they do when there is nothing work-related to do in ARTHUR during a shift.

7.2.3 *Result*

Only the static scenrio can be published due to the sensitive information used in the creation of the mobile scenario.

7.2.3.1 **Static Scenario**

Characteristics: *Staying put, continuous monitoring, working shifts, fighting boredom.*

Figure 20. *An ARTHUR truck surveils the desert (Danish Defence, 2009).*

It takes quite an operation to protect a huge camp like Camp Fernandez. The ARTHUR division is a part of this massive operation. It has been positioned in a Forward Operating Base (FOB) about 15 km away from Camp Fernandez, out in the desert in the middle of nowhere. The mission is to monitor the entrance of the camp to make sure allies and their own forces make it to and from Camp Fernandez safely. It is known that the enemy is located in the mountains near by, so the ARTHUR division knows that if a mortar attack would occur, it would probably be from somewhere in those mountains.

The division has been at this FOB for three weeks now, and the operator is getting a bit tired of the rough conditions here. He is longing for the luxury of Camp Fernandez. He especially misses the cooked food in the mess hall and the shower blocks. Here at the FOB, the menu is field rations. There is not even lighting here, so when night falls they usually hang out in the tents playing board games. When they go to bed here, it is in sleeping bags instead of mattresses. At the FOB, ARTHUR surveils the surroundings 24 hours a day. They are six operators that take turns, so they have to sit for eight-hour shifts inside ARTHUR.

The operator has done everything he needs to do during his shift. He has already checked all the instruments and ordered some spare filters and fuses from Camp Fernandez. Now he is thinking of putting on the movie that the previous shift operators left for him. But then he remembers that it is Sunday, and that means that he needs to stay extra alert. Sundays are referred to as “holy shit Sundays” here since they have noticed that the enemy often attack on this day of the week. The common belief is that the enemy does prayer on Fridays, plan its attacks on Saturdays and then carry them out on Sundays. So instead of watching a movie, he takes off his jacket and boosts the air-conditioning to stay fresh and alert. He hangs his jacket over the back of his chair, and gets up to get his water bottle from his combat vest that is stowed away in a corner. Despite his attempts he almost falls asleep from the humming and lack of amusement. The system is performing well, everything looks as it should and all he can do now is wait for an alarm to sound. Fortunately, they have not been attacked this close to Camp Fernandez in a long time, but that is no reason to doze off. He starts talking to the operator next to him who is also bored. Through the open door they can see the guard outside, and they engage him in the conversation too. The guard gives up after a while; it is exhausting to shout over the loud buzzing of the radar. The guard outside tells the operators that the daily shipment has arrived. It is the highlight of the operators’ day, especially if there is something in the mail for him. He cannot leave the shelter, but the co-operator can go outside and say hi to the driver. The shipment comes from Camp Fernandez with supplies like fuel, food and water. Today the shipment also contains the filters and fuses he ordered as well as toilet paper, but unfortunately no mail.

7.3 Booklet

7.3.1 *Implementation*

From looking at the design process at Saab it was learned that the designers use online resources in their work. Because of this, in addition to the requirement that it should be easy to find the right information, it was considered whether the booklet should be an interactive digital document or if it should be something that is printed and kept on the desk. It was seen as important that it could be used both in the computer and be printed so that it could be brought along to a meeting or to the vehicle workshop and therefore the thought of an interactive document was ignored.

The information in the booklet was mainly collected from the problem and cause matrix and completed with background information to convey the complete picture of the usage problems. Even though the information is taken from a problem -oriented text, the text in the booklet was written in an informative manner. Information from the ministry of defence’s standartd DEFSTAN was also added as an introduction from anthropometrics and general work environment guidelines.

7.3.2 *Result*

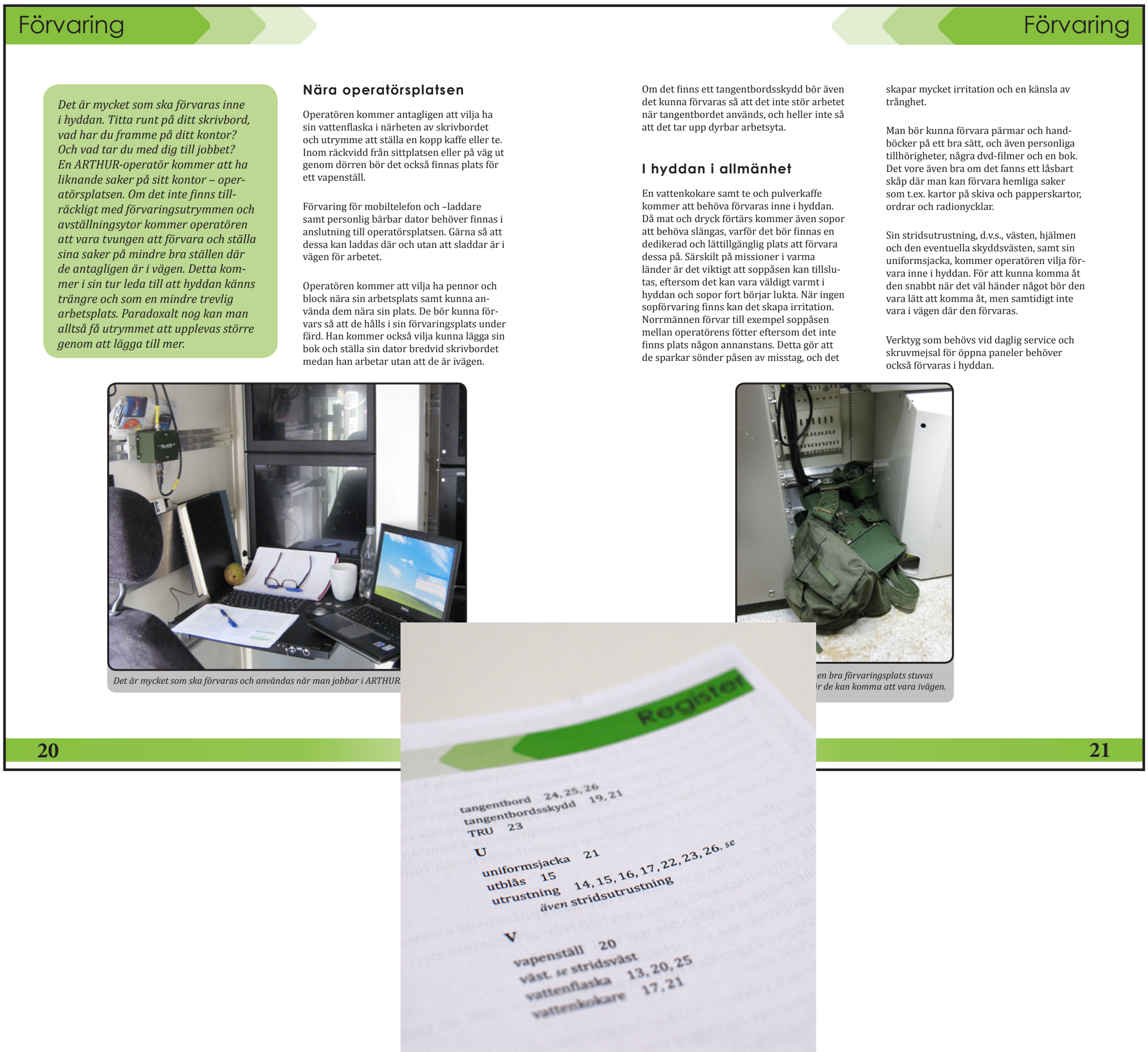
The booklet was given the title ”ARTHUR WLS´s User: - A Guide for Use Centered Product Development” and displays a picture of the two personas Radek and Else standing in front of the ARTHUR on its front page, see figure 21. The image is supposed to convey the theme of the booklet at a glance. The booklet is written in Swedish and starts off with an introduction that tells the reader what the document is about, its purpose and how the reader can find what he is looking for in it. The booklet is designed to be useful in many situations. The reader could read straight through all 30 pages at once and thereby get a thorough understanding of the ARTHUR operators´ working situation, or perhaps find a relevant article by searching the index page for a specific keyword, seen in figure 23. At the back there is a checklist that can be used to make sure that the most important things are not missed during design work, seen in figure 24. It can also be used as an of evaluation tool on an existing design. Each short bullet comes with references to pages where more detailed information can be found in the booklet. One could also check the table of contents for an interesting subject or just flip through the booklet and stop by a picture or headline that catches ones interest. The booklet is full of pictures and illustrations and the headlines stand out to support this behavior. The text is organized in rather short article-like bodies that can be read either individually or sequentially. All main chapters are introduced with a short description of what it is about and how the reader can use it. The introductions are put in green boxes in italics as seen in figure 23.

Figure 21. *The frontpage of the booklet.*

Contents

Figure 22. *The contents of the booklet.*

The booklet itself is company-restricted information, but below is a short description of the chapters that can be seen in the table of contents in figure 22. The scenario chapter presents the static and mobile scenarios as presented in this report. The personas are also the same as in the report. Behavior, Placement, Sound and Lighting and Storage are chapters that contain rewritten, short, article-sized texts based on the knowledge gathered in this project. The behavior chapter informs the reader about the user's behaviors that can be generalized to all users. It includes descriptions of what a soldier wears, what it feels like to walk around in the shelter, how the operators fill their needs of communication, food and beverage as well as what specific tasks an operator performs during a shift in ARTHUR. The placement chapter deals with how to place equipment with displays as well as specific components of ARTHUR such as the ladder, the navigation unit and power outlets. In the sound and lighting chapter there is information about what to think about concerning sound and ighting as well as consequences of poor sound insulation and lighting in addition to opinions from the surveys. The storage chapter, seen in figure 23, summarizes what equipment and utensils the operator needs to store inside the shelter and how the operators store them toady. The deployment chapter explains the steps and order of the deployment. The chapter work posture includes anthropometric measurements taken from DEF-STAN and interpretated and screened to fit the developers of ARTHUR as seen in figure 24. The chapter also includes guidelines and pointers of what to think about when designing the environment the user will be working in, such as reach and the design of the workstation. Finally, there is an infographic describing the respondants in the survey, which includes their age, height and operator experience, as seen on page 25.


Förvaring

Det är mycket som ska förvaras inne i hyddan. Titta runt på ditt skrivbord, vad har du framme på ditt kontor? Och vad tar du med dig till jobbet? En ARTHUR-operatör kommer att ha liknande saker på sitt kontor – operatörsplatsen. Om det inte finns tillräckligt med förvaringsutrymmen och avställningsytor kommer operatören att vara tvungen att förvara och ställa sina saker på mindre bra ställen där de antagligen är i vägen. Detta kommer i sin tur leda till att hyddan känns trängre och som en mindre trevlig arbetsplats. Paradoxalt nog kan man alltså få utrymmet att upplevas större genom att lägga till mer.

Nära operatörsplatsen

Operatören kommer antagligen att vilja ha sin vattenflaska i närheten av skrivbordet och utrymme att ställa en kopp kaffe eller te. Inom räckvidd från sittplatsen eller på väg ut genom dörren bör det också finnas plats för ett vapenställ.

Förvaring för mobiltelefon och –laddare samt personlig bärbar dator behöver finnas i anslutning till operatörsplatsen. Gärna så att dessa kan laddas där och utan att sladdar är i vägen för arbetet.

Operatören kommer att vilja ha pennor och block nära sin arbetsplats samt kunna använda dem nära sin plats. De bör kunna förvars så att de hålls i sin förvaringsplats under färd. Han kommer också vilja kunna lägga sin bok och ställa sin dator bredvid skrivbordet medan han arbetar utan att de är ivägen.

Det är mycket som ska förvaras och användas när man jobbar i ARTHUR

Förvaring

Om det finns ett tangentbordsskydd bör även det kunna förvaras så att det inte stör arbetet när tangentbordet används, och heller inte så att det tar upp dyrbar arbetsyta.

I hyddan i allmänhet

En vattenkokare samt te och pulverkaffe kommer att behöva förvaras inne i hyddan. Då mat och dryck förtärs kommer även sopor att behöva slängas, varför det bör finnas en dedikerad och lättillgänglig plats att förvara dessa på. Särskilt på missioner i varma länder är det viktigt att soppåsen kan tillslutas, eftersom det kan vara väldigt varmt i hyddan och sopor fort börjar lukta. När ingen sopförvaring finns kan det skapa irritation. Norrmännen förvar till exempel soppåsen mellan operatörens fötter eftersom det inte finns plats någon annanstans. Detta gör att de sparkar sönder påsen av misstag, och det skapar mycket irritation och en känsla av trånghet.

Man bör kunna förvara pärmar och handböcker på ett bra sätt, och även personliga tillhörigheter, några dvd-filmer och en bok. Det vore även bra om det fanns ett låsbart skåp där man kan förvara hemliga saker som t.ex. kartor på skiva och papperskartor, ordrar och radionycklar.

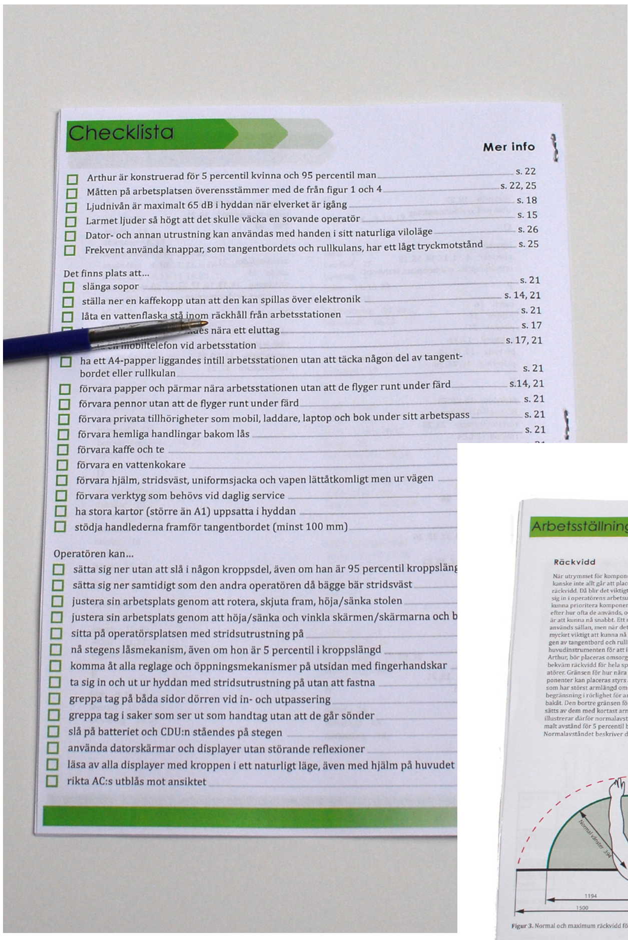
Sin stridsutrustning, d.v.s., västen, hjälmen och den eventuella skyddsvästen, samt sin uniformsjacka, kommer operatören vilja förvara inne i hyddan. För att kunna komma åt den snabbt när det väl händer något bör den vara lätt att komma åt, men samtidigt inte vara i vägen där den förvaras.

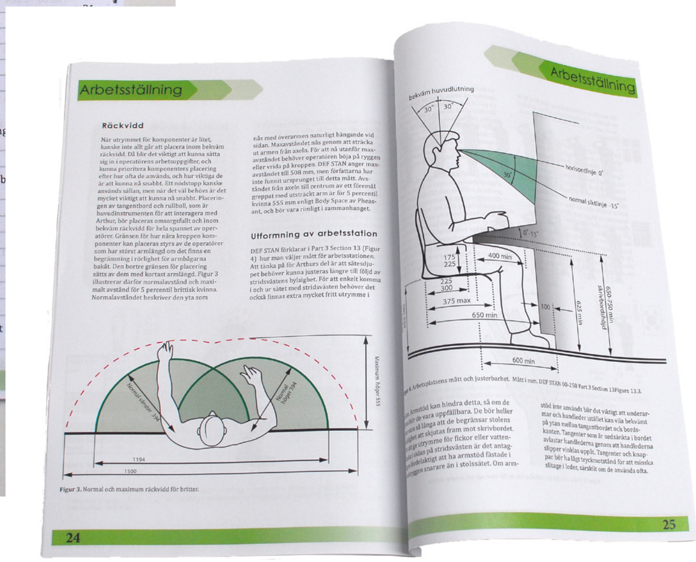
Verktyg som behövs vid daglig service och skruvmejsal för öppna paneler behöver också förvaras i hyddan.

20

21

Figure 23. *Pictures from the booklet. The top picture is a spread from the storage article in the booklet, showing the airy layout and the green box in the beginning. The lower picture is a snapshot of the extensive index.*





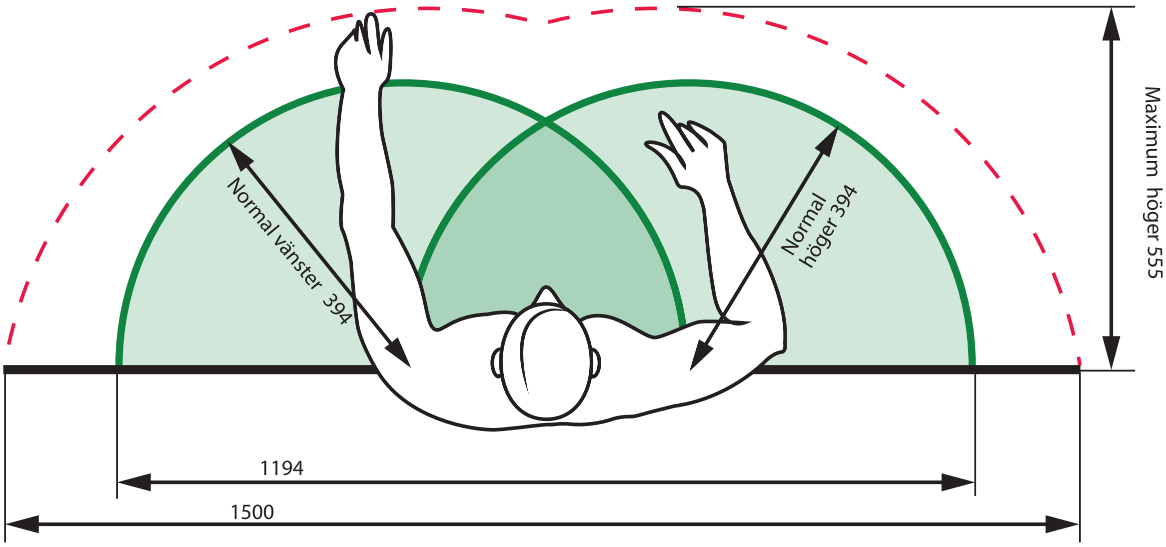


Figure 24. *Pictures from the booklet. Top left is a picture of the checklist on the back of the booklet. The middle right picture is a spread from the work posture chapter. The bottom picture can be seen on the spread as well and depicts the normal and maximum reach.*

8 EVALUATION

Before applying the results, it is important to evaluate the validity of the source material. The uncertainties in the data collection as well as the fulfillment of the requirements for the booklet are evaluated below.

8.1 Data Collection

The surveys have been one of the most valuable sources of information in this thesis. However, they do come with some degree of uncertainty. Since the situation in which they were filled out was not controlled there is no way of knowing whether they were filled out individually or with the help or influence of others. In the UK surveys five respondents had answered that radar theory was the most difficult thing to learn. Seven had answered that the keyboard should be sunken into the desk, and four also mentioned the need for a cover for the keys so the surface could be used as a desk surface as well. The fact that so many answered the same things could mean that they have cooperated, although it could just as well be that this was an issue that they have discussed previously, or it could simply be a coincidence. The implication of this is that when X respondents point out the same thing, it is not necessarily X times as important as an issue pointed out by just one person.

The fact that there can be misinterpretations due to the authors' limited Norwegian and Danish skills or the participants' limited English skills also contributes to the reliability of the result. For instance, when one Dane answered where the combat gear is stored and said that it "is kept on the cap on the truck or on other vehicles", the "cap of a truck" was interpreted as the ledge around the shelter. Misinterpretations and loss of nuances in the translation could also have occurred in the articles found at artilleriet.dk, which were in Danish. The authors do not speak Danish but understand it somewhat.

Many of the things mentioned as problematic in the surveys confirmed our suspicions, such as the lack of storage space and desk surface. But there were also things that we did not predict, such as garbage being a problem in the Norwegian ARTHUR. As always with user comments however, they cannot simply be strictly obeyed, but must be synthesized to what the underlying problem is. A perfect example of this is the Korean who mentioned that the track ball was hard to reach and that he would want it moved down the edge of the desk. This would be a bad thing, since he would lose the wrist support that the desk provides. The underlying problem might in fact be that the chair is not adjustable enough and that he therefore sits too far from the desk and finds it difficult to reach the track ball. The participants that gave a plausible cause for their headache all stated it was due to the noise. Even though it could be the case, it should be noted that headache can be caused by a number of factors such as insufficient lighting, dehydration, bad working posture especially for the neck, staying alert without anything happening for longer periods of time or a combination of several of these factors, that might be less obvious for the survey respondants. They should also be taken into account as possible causes for headache.

The Danish operators had a big variance in heights; they have two operators that are above the British 97th percentile, and one that belongs to the 5th percentile. Although it is not a sample large enough to draw any statistically correct assumptions, it is interesting to know that there are currently two operators in Denmark who are too large to comfortably operate the system.

The questions in the survey worked well with a few exceptions. In question 14 ("Have you or anyone around you come up with any small invention or solution to make your work easier?") could be answered yes or no, which should not be allowed in qualitative questions. One Dane answered the question with a yes without further explanation, which means that potentially useful information was lost. Further, that same question should have requested a picture of the solution to allow for an analysis of the real problem behind the solution.

The answers from the UK were returned to us after the first presentation at Saab was held and the booklet was already done. It did not pose any big problems however, since the surveys mostly confirmed the previous answers. The fact that no revolutionary discoveries were made through the British survey gave confidence in the fact that more answers to the same survey would not have given much more data. To meet the British, as it seemed at one point could be possible, would however have given important data, especially if given an opportunity to observe real users.

The military culture was feared to be an obstacle in the collection of data, since they might not be very prone to complain and acknowledge problems. The authors have not noticed any signs of that in the surveys, and since we did not get to meet any users we did not encounter that problem either. However, in the telephone interview with the Czech operator it turned out to be difficult to elicit complaints and problems in spite of the probing. Some problems were successfully elicited, but the operator repeated that the system is perfect many times. This could of course be an honest opinion, but since the probing worked in some cases, it is more likely that it was a sign of the military or Czech culture in general that shone through.

In the simulated user observation, the think aloud method did not work quite as well as anticipated. The space inside ARTHUR where the tasks were performed was too small to have an investigator present and the participant was not prompted to verbalize as much as wished. The participant only verbalized what he was doing, and not what he was thinking, and the data that resulted from the think aloud protocol was just an explanation of what is done during deployment. This was helpful as well of course, but it was not possible to capture the aspect of when the task gets too demanding since there was not that much verbalizing done.

8.2 Booklet

Requirements for the booklet were that it should:

1. Be able to be used as a checklist for making sure human factors has been considered in the design.
2. Be able to be used as a checklist to evaluate the usability aspects of the product.
3. The checklist should not be open for individual interpretations
4. Make the user present in the mind of the designer during the design process.
5. Contain background information for those who want the complete picture.
6. Not inhibit the engineer's own creativity in problem solving but guide him in the right direction.
7. Be easy to find the information needed for a specific part.
8. Be general enough to be applicable in several future projects.

In the authors' subjective opinions, all requirements for the booklet have been fulfilled. There is a checklist in the back that can be used for both making sure human factors has been considered and as a rough usability evaluation. The checklist is written without leaving room for different levels of fulfillment, in other words one can only check that the statement has been fulfilled. The statements are also written in a manner that eliminates interpretations, for instance "there is a place to dispose of garbage". Either there is a place or there is no place. This was done since theory suggests that designers usually prefer to get precise data instead of general guidelines (Fulton Suri and Marsh, 2000, cited in Högberg 2005). This is also supported by the meta-study at the company. The scenarios and personas are created so that they will be easy to remember, and the pictures in the booklet give the stories life and also make it easier to remember them. There are many different levels of information in the booklet so that readers can decide for themselves how much information they want. Each chapter starts with a summary of the chapter so that one could only read the summary or the whole article for more information. The booklet did not contain any direct solutions to problems so as to inhibit the creativity of the engineers. In some cases there were examples of possible solutions to steer the designers in the right line of thought. There is also a table of contents and an extensive index with key words and key areas to make it easy to look up specific inquiries in the booklet.

Whether the last requirement is fulfilled is hard to predict. If no major changes occur in the near future, the booklet should be general enough to be applicable in several projects. However, when the issues raised in the booklet have been taken into account in a project, there will probably be a need to raise the human factors awareness to the next level and therefore raising a need for revision of the booklet. In some cases there was a need to explain the cause of an issue by describing the current solution in order to understand the issue and make sure the same design mistake is not repeated. This was a trade-off between keeping it general or explaining enough about the issue, and making the issue clear enough was considered more important.

Verifying the results is important in any project. It can guide future work in the area in the right direction. The booklet was quickly spread among the engineers at the end of the project, and it was recieved with anticipation. Unfortunately, the project ended before the engineers had sufficient time to try the booklet out and see how it fitted to their work. However, the scarce and statistically insignificant feedback that was recieved was clearly positive.

The personas are well founded in facts about the users. This makes them reliable and useful for a long time at Saab. Despite that, they should probably not be used on any product other than ARTHUR, unless that products users have been studied as well, and turned out to match the current personas. To avoid confusion, other Saab products should have their own personas with separate images and names, rather than borrowing an existing one that does not fit entirely.

9 DISCUSSION

9.1 Purpose and Goal

The purpose of this thesis is to increase the understanding of the radar operator's working environment in ARTHUR and to increase the knowledge about human factors at the company. This has been done by analyzing the extensive amount of data that has been collected to find the issues, disturbances and preferences of the operator in his or her interaction with the system. The goal to collect relevant information about the users and how they use ARTHUR as well as to produce material that conveys knowledge about the user in an accessible way has also been fulfilled. The data collection consisting of interviews, surveys and articles about an artillery division working with ARTHUR in Afghanistan has resulted in relevant information about the user. The booklet conveys the information necessary in order to gain an understanding of the user and how this understanding can be used in the design process.

9.2 User Involvement

The ARTHUR user has not been as involved in the thesis as preferred. Since the military world contains a high degree of secrecy, restrictions and politics, it has been difficult to get a hold of the users and impossible to meet them in person within the timeframe of the project. Unfortunately, this fact is the biggest contributing factor for the accuracy and extent of the result of the thesis. It was not possible to arrange to meet any real end-users, even though the authors have done everything they could to try to make it happen. In spite of this, the data collection has resulted in new information about the users and the usage of ARTHUR. The collected information is reliable even though it does not come from personal contact with users. The surveys and telephone interview, which is the closest contact with users in the data collection, have generated valuable opinions about working with ARTHUR. These opinions have correlated with each other, verifying their reliability. Despite the earlier mentioned potential language misinterpretations and cooperation between respondents, there is no reason to believe that the facts are dubious. The articles from the Danish artillery are also considered reliable, since they come from a reliable source containing first-hand information. Both surveys and interviews were performed until reaching a saturation point, which shows that all information available has been gathered. Conclusively, the fact that the authors have not met the users in person probably only contributes to the extent of the result but not the reliability.

9.3 Human Factors

As mentioned in the theory chapter, Traub (1996) states that the barrier to human factors integration can be overcome in three ways, namely education, enforcement and end-user involvement. The thesis has only contributed in the part of education. Even though end-users have contributed to the research conducted, it is not correct to say that they have been involved in the thesis. Enforcement must come from the management level of a company, or even by laws and regulations. End-user involvement requires collaboration with the existing and future customers and the company. Politically this might not be very easy to accomplish, but it is nevertheless crucial for the success of both human factors integration and the product itself.

Although the thesis has resulted in guidelines in how to incorporate human factors in the product development process, guidelines are not enough for human factors to truly be applied on the product. Theory clearly states that it is paramount that human factors experts are involved. As mentioned in the HFI theory chapter, checklists cannot replace the technical judgment of people possessing the required formal education and on the job experience, and simply imposing constraints on the system developer cannot solve HFI issues (Booher 2003). The authors realize that giving the employees at Saab guidelines and a checklist is not in line with theory in the field, and does not by far have the same effect as to hire a human factors expert to be a part of the development team. However, it sure is better than not considering human factors at all. The guidelines can raise awareness of the human factors field and the issues its theory can foresee as well as provide a starting point for the complete integration of human factors in the product development process.

In the case study by Waterson and Kolose (2010), attempts by the human factors team themselves to actively push HF into design and raise awareness among other project members was seen as an important mechanism for success of HFI. The thesis has raised awareness by being carried out at the company and by the fact that the authors have had a chance to talk to different departments about human factors. The thesis project will also be featured in the Saab Group company magazine Tech Transfer. The fact that the thesis has received so much attention within the company can be seen as a step towards human factors integration. Having a human factors team working full time would further increase the effect.

In order to get the most out of the results from this thesis, the design engineers and the system mechanists, as well as management, should use the booklet in their daily work. Whenever designing something that is visible to the user, the designers should use personas to think about what the user would think of his solution, consider the scenarios to see how the usage would be affected by the solution and look through the booklet to find out more specific facts about users and how the solution can be made to fit the user better. The booklet should also be used when the mechanist interprets the system requirements and turn them into design requirements as well as when evaluating the level of human factors considerations in a system.

9.4 Process

The emphasis throughout the thesis has been to create an understanding for the operator rather than to find solutions for problems found. This was difficult at times, since as a product developer you are used to always try to find solutions for problems. As it was understood that the company needed help with finding the user problems and not solving them, the success of the thesis depended on finding the problems and not the solutions. This approach was a good experience in not trying to do everything yourself. Another delimitation that was set up was that neither the system software would be dealt with, nor the technical aspects of the system. The delimitation was set up to be able to get a scope that was manageable within the timeframe of the thesis. However, a similar evaluation of the system software will probably be necessary at some point to ensure a completely integrated system.

It has been very rewarding to carry out the thesis work at the company, and we have learned a lot about how a big company works. It has been an eye-opener to experience the inertia within such a big company when it comes to major changes in the design process. In theory it seems achievable to integrate human factors in the development process, but one realizes that in reality it can take years of hard work. It is also extremely important that the initiatives come from the right people and that the proposals gain support.

10 RECOMMENDATIONS

Since ARTHUR is a mobile workstation, it can be seen as both a vehicle and an office. At the moment, it seems as though Saab considers it to be something in between those two, while some users consider it to be a vehicle and others an office. For instance, one Dane answered in the survey that he would like to have seat warmers in the chairs. He clearly considers ARTHUR a vehicle, since not many would come up with the solution of seat warmers if it is too cold in an office. Likewise, another Dane suggests replacing the chairs to “Normal chairs which you can move around”. He must not see ARTHUR as a vehicle since no one would want chairs to move around in a vehicle.

It is important that the user and the developer have the same perception of what the product is, both because the user’s needs could be met more specifically and because the user will be happier with the performance of the product if it meets his expectations. If the user expects an office and gets a vehicle, he will be disappointed and feel that it is not a good office. However, if he expects a vehicle and gets one, he will judge it for what it is and probably be more content with the product. Therefore, it is vital to clearly convey what the user should expect out of a product and be consistent it that message to avoid misconceptions. A clear standpoint on this subject would aid design work, and in front of all benefit the ARTHUR operator. A consistent expression sheds doubt about what ARTHUR is and what is to be expected from it, and this minimizes any disappointment related to misunderstandings about its functionality.

The perhaps most important recommendation to succeed in human factors integration and in developing more usable products is to involve the end-user to a greater extent. Both theory and practice agree that this is crucial. The fact that Saab has user groups is a great start, and they should start using appropriate methods for eliciting user needs. This kind of first hand information is incredibly valuable to the product developing departments and offer insight in otherwise hard-to-reach areas. Another crucial factor for success is the involvement and enforcement from the top management.

To deal with the fact that the design department has little knowledge about what it is like to have ARTHUR as a work place, some practical experience would complement the information that can be gained in the booklet. The authors recommend arranging a workshop for designers to experience a working day in ARTHUR. By having experiences to relate to, the designers will better be able to imagine what the user would think of a solution. During the workshop the designers could for instance walk around in the shelter with combat gear to see where things are in the way and to experience how much it actually adds to a persons' dimensions. They could also learn how to deploy the system to understand what needs to be reached quickly and they could try placing all the things an operator needs during a shift to better grasp how the stowage should function and where there needs to be more space for placing equipment. A workshop like this could put the engineers in the shoes of the users, in a way that words and pictures cannot.

The information in the booklet is at its most useful when it is current. If the prerequisites change radically or if new and completely different conditions apply, there will be a need to update parts of or even the entire booklet. Someone with knowledge in the field of human factors should do this. The knowledge gained from the booklet should also be used in cooperation with the customer at an early stage in order to allocate funding for human factors improvements and as support for solutions that will be used in the design.

11 CONCLUSION

This thesis set out to investigate who the users of ARTHUR are and how they really use the system. The research carried out adds substantially to the knowledge of ARTHUR users and ARTHUR user behavior at the company.

The booklet that was produced presents the findings in an accessible format. It contains the personas, which present the user, and the scenarios, which show how he or she uses ARTHUR. The booklet, along with the two life size personas, convey the findings about the ARTHUR users to the people who develop the product in a way that makes it easy to remember and relate to. Together they serve as a common platform for discussions concerning the user of ARTHUR. Using the booklet in the product development process is a first step towards the implementation of human factors in ARTHUR. It gives some basic information on anthropometrical measurements and lists areas to take into considerations when designing for the user. It also contains a checklist of what needs to be taken into account.

To go further into adapting ARTHUR to its user, human factors specialists are required. The key to successful human factors integration lies in education, enforcement and end-user involvement. The first step in education has been taken through this thesis; enforcement and end-user involvement are initiatives that need to come from within Saab.

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APPENDIX I

Problem and Cause Matrix

Category	Observed Problem	Possible Cause	Consequences	Possible Action
Behavior	Operators eat by the working station.	They have no other place to eat.	They close the keyboard cover and place the plate there - unable to use the keyboard in emergencies. Food is spilled, gets messy, damages equipment.	Create a place where the operator can eat in a good way.
	The operator keeps the door open <	The operator has a need to see what is happening outside.	> Sand or dust enters the system, the cooling/heating stops having < an effect, intermittent errors. Light is emitted at night.	Add a window to the shelter. Camera to surveil the outside.
		The operator has a need to communicate with people outside while working.		Enable communication with closed door, such as wireless intercoms, some kind of filter in front of the door or loudspeaker and microphone on the outside. Stimulate operator. Use RCU.
	Grabs protruding objects and surfaces when entering the shelter.	Lack of handles to grab.	Grabs battery switch protection, night curtain, CDU and door post. Things break. Operator might fall.	Design things that look like handles so that they actually work like handles. Add handles inside the shelter. Add surfaces to push yourself forward from. Add a handle outside door, opposite side of door hinges.
	Places drinks where there is a temporary free spot.	No dedicated place to put drinks.	Drinks can spill out on sensitive equipment. Drinks can spill out and spoil paper and make the desk sticky. Blocks working surface. Breaks rules. People avoid drinking coffee/water and are more tired/dehydrated.	Dedicate a place to put drinks.
	Operator watches movies on personal laptop.	Job is boring. Too little to do. Wants to stay awake.	Operator might miss an alarm. Might miss other things (i.e. radio communication). Laptops placed on keyboard limits access to buttons. Can accidentally cause button pushes.	Incorporate movie watching into DPU and the screen interface. Enable DVDs to be played on the built in screen and make movie pause when an alarm goes off. Shift focus from movie to alarm window.
	Operator falls asleep.	Monotonous buzzing. Boring job. Long shifts. Lack of breaks. Lack of sleep. Comfortable chair. No one watches over you.	Does not wake up by alarms. Newly awakened, makes bad and slow decisions.	Insulate better for noise. Make outside sounds more audible inside. Better alarm sounds. Make system notice when operator gets drowsy.
Body size	**Observed Problem**	**Possible Cause**	**Consequences**	**Possible Action**
	Hard to reach buttons and equipment.	Short people. Awkwardly placed equipment.	Pain. Skips tasks that are not vital. Has to get help or aiding equipment.	Place equipment within reach of everyone.
	Hard to operate system with combat gear.	Small spaces, gear is bulky and gets stuck.	Gear can break. Gear gets taken off. Gets stuck when moving. Operator gets frustrated. Moving is time consuming.	No sharp or protruding corners. Place equipment with respect to the gear on operator. Less equipment.
	Too little leg room.	Bad disposition or too much equipment.	Operator gets frustrated, goes outside. Pain.	More leg room, less equipment.
	Cannot see power plant display.	Helmet hits ceiling and stops head from reaching sufficient eye-level. Lamp shines into display and limits the viewing angle.	Operator gets frustrated. Could bang his head in the ceiling. Removes helmet. Neglects to read display, might miss errors, power plant could break down. Pain in neck and shoulders. Squats to see display, works above shoulder height to press buttons.	Move lamp. Lower display. Removable display. Recieve errors on computer screen.
	Operator sits with lower body twisted.	Too tight to swing legs in under desk.	Pain. Reluctance to remain seated for longer periods. Performs tasks quickly and carelessly.	Make room for easy entrance to seat.
	Hard to reach ladder lock mechanism.	The lock mechanism is placed too high.	Some operators cannot get the ladder down or have to jump to reach it. Some have to ask for help to get ladder down which slows deployment time. Frustration. Embarrassment.	Move down lock mechanism or extend the pulling chord.
	Chair is uncomfortable for longer periods.	Limited adjustability. Chair is not adapted to situation. Combat gear is uncomfortable and gets in the way in chair.	Pain. Operator gets frustrated. Moves around. Takes off combat gear.	Use RCU. Replace chair with one adapted to situation. Make chair comfortable with combat gear.
	Both crew members cannot sit down or get up at the same time.	There is too little room between the chairs. The combat gear gets in the way.	Sitting down or standing up is time consuming. Crew members might collide. They could get frustrated. They might adjust their combat gear to compensate for this situation in an otherwise sub-optimal way.	Separate work stations by distance. Remote control Arthur. Allow chair entrance from right side of right chair.
	Stomach is pressed against desk.	Chair is positioned too close to desk.	Stomach hurts. Breathing is difficult. Uncomfortable working position. Reluctance to remain seated. Extra hard to get seated.	Allow chair to be slided back and forth. Use quick locks on rails. Position chair further away without impairing reach of controls.

APPENDIX I

Problem and Cause Matrix

Daily work

Observed Problem	Possible Cause	Consequences	Possible Action
No place to write.	Lack of dedicated area. Lack of space.	Writes on bad surfaces, such as keyboard, lap, walls, etc. Writes on smaller paper. Writes less. Operator gets frustrated.	Dedicate an area for writing.
Documents are placed where they get in the way.	No place to put documents when working.	Tasks take longer to perform. Operator gets frustrated. Documents have to be moved often.	Add surface close to the working station where documents can be placed.
Documents needed when working are placed out of comfortable reach.	No place to keep documents within reach when working.	Documents are hard to retrieve. Neglects double check of info, takes chances and relies on memory.	Add surface close to the working station where documents can be placed.
Hard to find a pen when needed.	Pens are not stored in specific places.	Pens get lost. Operator gets frustrated. Simple tasks take longer time.	Dedicate an area to keep pens, add pen holder.
No place to put up paper where they can easily be read (e.g. checklists).	Lack of dedicated area. Lack of space.	Papers are not put up and get lost. Things don't get done because the checklist is lost or hard to see.	Make room for putting up papers. Add holders on e.g walls.
No place to store documents, dvd:s, maps.	Lack of dedicated area.	Documents get lost or damaged. Documents are not secured during transport.	Add a closed space too keep documents etc.
Difficult to boil water.	Kettle has to be retrieved, maybe from far away. Lack of dedicated area near power outlet.	Operator drinks less coffee and tea and is tired. Boiling water takes more time than nessesary. Places kettle poorly which may cause accidents. Kettle is stored far away from shelter.	Install a kettle permanently. Add a dedicated space where a kettle can be placed, permanently or when needed. Add a place where a kettle can be stored when not used.
Coffee and tea is stored in bad places.	No place to store the packages.	Packages might be stuffed behind cables, cables get damaged. Packages open and leak.	Add storage for packages of coffee and tea.
Combat gear is placed where it limits access (e.g the floor, back of seat or in operators' lap).	No place to put gear where it is easy to reach and out of the way.	Gear is stepped on and gets damaged. In the way when sitting down and moving around. Operator gets frustrated, might be reluctant to move around. Moving around takes longer.	Add storage for gear that is easily accessible and out of the way.
Combat gear is put in hard-to-reach places (e.g stuffed away in corners).	No place to put gear where it does not limit access and is easy to reach.	Gear is lost and mixed up. Takes time to retrieve. Operator gets frustrated, might be reluctant to retrieve gear.	Add storage for gear that is easily accessible and out of the way.
Weapons are not placed in the weapon holder.	Weapon holders are too complicated. Weapon holders are placed off route between operator and door.	Weapons are placed on the floor or leaning against the wall, can break or get in the way.	Design for weapon holders at an early stage.
Sometimes difficult to read CDU display when door is open. (when placed to the right of the door when entering, close to the floor)	The sun shines on the display and impairs the contrast.	Reading errors. Makes mistakes. Takes more time to start CDU. Pulls the night curtain out a bit to help read the display.	Add sunprotection. Make display readable in bright sunlight.
Difficult to use the CDU. (when placed on the middle of the wall to the left of the door when entering, near floor)	Awkward placement in shelter: cannot read the CDU from the ladder which defeats the purpose of having it close to the floor.	Reading errors. Makes mistakes. Takes more time to start CDU. Reluctance to check the CDU. Frustration.	Place CDU so that it can be read from the ladder.
Garbage is stored in inconvenient places, such as between the operators legs.	No dedicated place to put garbage bags.	Operator gets frustrated. Garbage bag cannot be found when needed. Bag breaks if kicked/stepped on. Garbage bag falls/tips over and spills its contents over floor. Bag is in the way and impairs mobility.	Designate a place for a garbage bag. Introduce garbage bag holder.
Keyboard cover is stored on work station.	There is no better place to put it.	Keyboard cover obstructs fingers. Operator gets frustrated. Moves the cover. Cover is lost.	Replace keyboard cover with rollfront version. Add a stand/ rails to keep the cover in e.g. under the desk. Remove keyboard cover and add a switch for inactivating keyboard.
Uncomfortable to use the map holder.	Operator has to lie on floor to use it, or bend in strange positions to reach the lowest parts of the map.	Pain. Operator gets frustrated. Reluctance to use map holder, uses separate map. Neglect of tasks.	Place map so it can be used in a reasonable working position.

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Problem and Cause Matrix

	Observed Problem	Possible Cause	Consequences	Possible Action
Discomforts	Operator is not alert when action is required fast.	Operator is under-stimulated due to long periods of inactivity.	Makes wrong decicions. Makes decisions slowly.	Stimulate the operator. Keep the operator alert. Make the operator alert when alarm goes off.
	Pain in neck, back and thighs.	Working posture makes body hurt. Operator needs to reach and bend his body in order to reach and fit in by the work station. E.g. lowering the chair too much in order to fit knees under table, and thereby putting stress on thighs.	Demoralisation. Inability to perform work. Permanent injuries.	Redesign work station to integrate seat, screen, and desk and adapt them to relevant anthropometrics.
	The shelter is cold during winter.	Cold climate, open door, poorly insulated.	Unpleasant working environment. Loss of focus. Increased consumption of hot food and liquids. Decrease in fine motor ability.	Close door. Seat heating. More heating of shelter.
	The air in the shelter is dry	AC dries out the air.	Operator feels uncomfortable, needs to drink more.	Cool air with alternative technology that keeps humidity in air.
	Headache, dizziness and insomnia after a couple hours of working.	Noises in working environment from AC and TRU.	Tiredness and irritation. Less alert. Reluctance towards task. Alarms less audible. Tries to drown out the noise with sounds from personal laptop.	Insulate sources of noise better. Enforce use of headset or earprotection. Make alarm loudspeaker louder.
Maintenance	**Observed Problem**	**Possible Cause**	**Consequences**	**Possible Action**
	Hard to open cabinets with gloves.	Handling tools requires fine motor skills. Screws are hard to keep hold of.	Screws are lost. Opening takes more time. Reluctance to open cabinets when it is cold. Operator gets frustrated. Fingers freeze if gloves are taken off.	Quick locks. Big tools. Big screws. Few types of screws.
	Screws fall off.	Screws are not fastened enough when something is opened, and fall off due to vibration.	Screws are lost. Cabinets are not tight enough.	Quick locks. Screws that indicate when they are tight enough.
	Hard to find tools to access cabinets.	Tools are not stored in the shelter. Tools are lost or hard to find.	Takes unnessesarily long time. Cannot open cabinet. Reluctant to do routine maintenance. Operator gets frustrated.	Designated space for tools in shelter. Locks that do not need tools. Standardized locks.
	Screws break.	Screws are tightened too hard.	Cabinets are not tight enough. Screws need replacement.	Quick locks. Screws that indicate when they are tight enough.
	Hard to remove chair when performing system maintenance.	Chair is heavy. Tools are needed to unscrew it.	Reluctance to remove chair, maintainers work in bad working positions. Reluctance to repair less vital errors. Maintainance takes longer.	Wing nuts instead of screws. Quick locks. A less heavy chair. Chair that can be flipped forward and does not need to be removed. Roof mounted chair.
	Filters are difficult to change	Difficult to reach, awkward placement. Takes two men for one filter (on top of shelter)	Injuries on nails and fingers, frustration, reluctance to change filters. Fear of getting shot if changing filter without cover.	Self cleaning filters. Easy to reach placement of filters.
	Maintenance takes a long time.	Several different kinds of screws in the same rack. Equipment is hard to reach, placed in crammed spaces.	Reluctance to perform maintenance, reluctance to repair less vital errors. Shorter performance time for system.	Standardize the type of screw used. Use empty spaces better.
Computer interface	**Observed Problem**	**Possible Cause**	**Consequences**	**Possible Action**
	The track ball gets stuck and the cursor is slow or jumping.	Dirt is stuck around the track ball.	Operator makes errors. Operator gets frustrated. More likely to develop pain in forearm. Reluctant to change settings more than absolutely nessesary.	Other type of pointing device. Enable cleaning of track ball. Enable use of external mouse.
	Requires practise to handle the track ball configuration.	Track balls are not widely used. The use situation has not been considered when designing the track ball configuration.	Errors are made. Takes time to perform tasks. Pain due to improper working positions. Disables multi-tasking by demanding use of both hands. Reluctance to perform non-vital tasks.	Change the configuration of the track ball to fit the use situation. Replace track ball with alternative pointing device.
	Difficult to reach both track ball and keyboard in good posture.	Track ball and keyboard is not placed with consideration to the context of the rest of the workstation, e.g. the chair is too far from the desk or the operator aligns chair to fit with keyboard and has problems reaching track ball or vice versa.	Pain in shoulders and neck. Inefficient computer interaction. Frustration.	Holistic view of work station design. Make everything adjustable.

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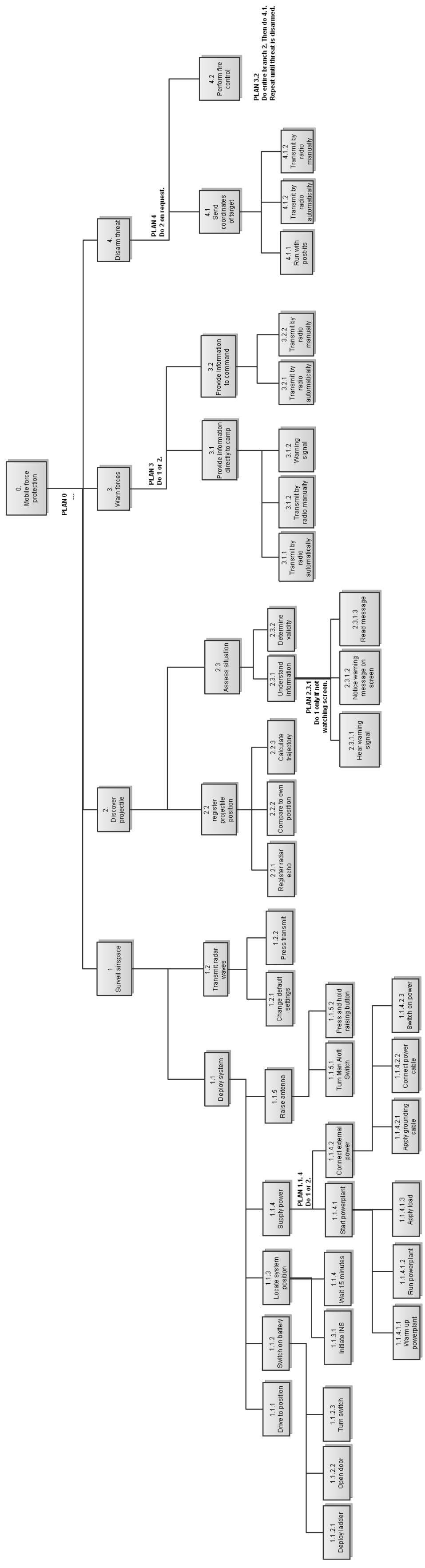
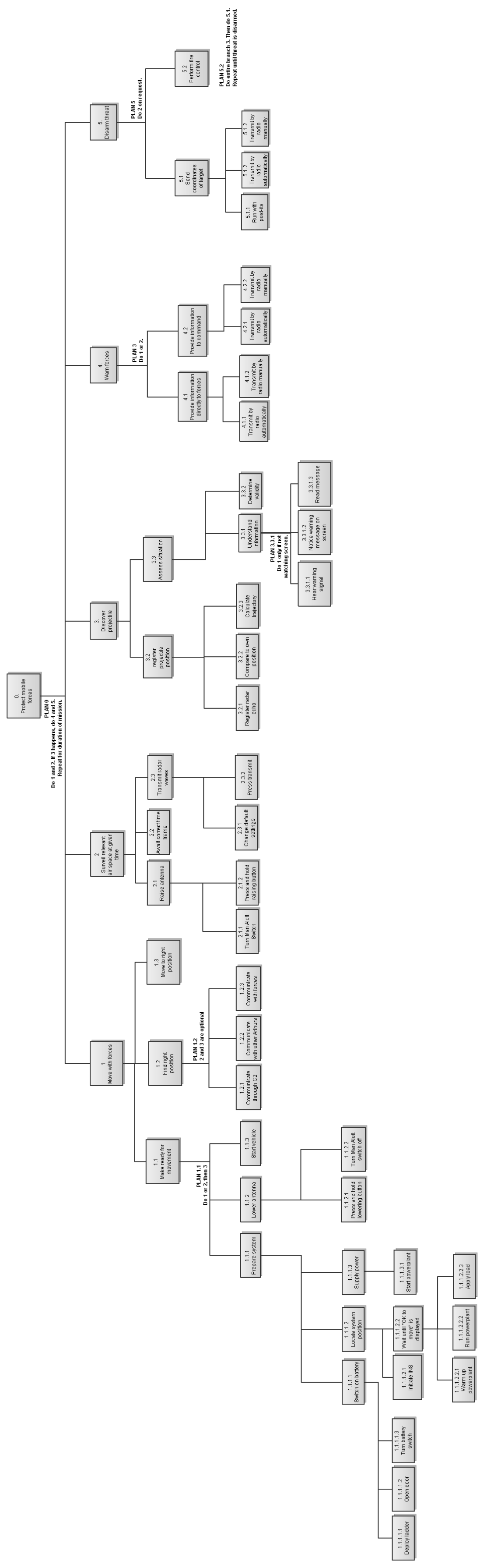
Problem and Cause Matrix

	Takes time to type numbers	Diffucult to use horizontal numbers or numpad integrated in qwerty keys.	Operator gets frustrated. Errors are made. Delayed reaction time.	Have keyboard with separate numpad. Have external numpad.
	It is difficult to find menu items in user interface.	Menus are not intuitive or self explanatory. Maybe even counter intuitive. Interface requires experience to memorize where	Using interface takes time, especially for beginners. Frustration. Makes mistakes. Takes longer to learn system.	Redesign interface to work better with todays mental models.
	Hard to distinguish between different types of system errors and targets.	Only one alarm sound to all alarm cases.	Operator reacts to alarms incorrectly. Longer reaction time. Cry wolf phenomena.	Audibly differentiate alarm cases. Visually distinguish between the cases.
	Difficult for the operator to separate ghost echoes from real targets.	Ghost echoes and targets are not distinguished by the system.	Valuable time is spent on deciding the validity of an alarm. Operator does not feel in complete control of the situation. Fear of making a wrong decision becasue consequences are severe.	Make system distinguish between ghost echoes and real targets. Make a system that verifies each target.
Handling of information	**Observed Problem**	**Possible Cause**	**Consequences**	**Possible Action**
	Might not have time to render the system useless for enemies during a take-over.	Takes too long to dismount the hard drives. There is no "self-destruct button" for the hard drives.	The enemy might get hold of sensitive information. The enemy could operate Arthur. Information is lost. Operator might not escape in time.	Introduce "self-destruct button". Ease dismounting of hard drives. Require password to access system.
	Cannot store confidential material safely.	No lockable storage.	Material is stored somewhere else. Material is stored unsafely. Material is hidden in shelter and lost.	Introduce lockable storage. Introduce good hiding place. Introduce secure digital storage.
	Impossible/difficult to export documents from the saab software to open formats	The system uses a closed format.	Information is not transferred to where it is needed. Information is transferred manually which takes time.	Enable exportation to common open formats.
	Operator performs the same tasks manually and digitally.	More difficult to visualize tactics digitally than on paper maps. Paper maps are easily accessible.	Takes time. Some information is not stored digitally. Unauthorized people might get a hold of the very visible information.	Enable easy digital presentation of and input on maps. Big screen/touch screen.
Safety	**Observed Problem**	**Possible Cause**	**Consequences**	**Possible Action**
	Light from screens can leak out when opening door in the dark	The screen is bright. Placed so it is visible when door is open.	Decreased night protection. Ruins night vision for people outside the shelter.	Connect screen brightness to door mechanism. Light sensor in screen brightness.
	There is no emergency exit.	Low priority. Not asked for by client.	People might die if exit is blocked during emergency. People might feel unsafe.	Make room for an emergency exit.
Miscellaneous	**Observed Problem**	**Possible Cause**	**Consequences**	**Possible Action**
	Antenna gets scratched.	Antenna cover is too soft. Arthur is used in the woods.	Needs repainting. Gets corroded. Looks worn.	Introduce a more protective cover.

APPENDIX II

Hierarchical Task Analysis





APPENDIX III

Personas with References

Else Poulsen

Else (1) Poulsen (2) is a sergeant in the Danish army. She is 29 years old (3) and work as an Arthur radar operator. Being 162 cm tall, this suits her well. She can almost stand upright inside the shelter. Else is engaged to Niels, who she met during conscription. He now works with human resources at the municipality in Ringsted, one hour from Copenhagen. Else and Niels got engaged just before Else went on a foreign mission to Afghanistan. This was partly to strengthen their relationship, and partly to be left alone from some of her male colleagues.

Before initiating her military career, Else studied to be a physical education teacher. She quit half way through when she realized that sitting down indoors and attending lectures was not her thing. Also, being a former soccer player, she missed the physical challenge that she was expecting from the education. Else recently decided to stop smoking (4), but out on a mission she finds it difficult. She often feels restless and uneasy during the long shifts in Arthur, when there is nothing to do. At those times it is hard to stay off the cigarettes. Other ways to pass the time is by reading books (5), texting her fiancé or other friends back in Denmark, or by talking to the other operator if he is there (5). If he is not in the shelter, Else opens up the door to be able to talk to her colleagues outside (6). She always looks forward to breakfast and dinner in the British cookhouse (7). The food is good and the British colleagues are very nice.

The toughest part of being an Arthur operator, from Else point of view, is that you need to sit down a lot and the fact that you need to investigate lots of "ghost targets", or false targets (8). Being away from Niels for a long time is off course also tough, but it feels good to have someone back home, waiting for her. She is always happy to receive books and films by mail from him.

Else likes being in the military. She especially appreciates the general positive view on physical exercise. She really likes the challenge of handling such a complex technical system as Arthur, and being the one who sits on important information. Else feels that she has an important task (9). After four years with Arthur she is starting to get a bit bored though. She knows this job inside and out, and it feels like she might have grown out of Arthurs´ small shelter eventually. Else is pondering if she should continue in the military and continue her career, or if she should quit and do something else.

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Quote, translated from Danish: “Purely professionally it is a very satisfactory job, and I can see that both our training and equipment is working properly, and it gives an a kick when things succeed”

Radek Novak

Radek (1) Novák (2) is a tall soldier in the Czech army, measuring 189 cm (3). After completing his conscription as a radio operator, 20-year-old Radek wanted to continue his career in the armed forces. Since he knew English the best in his platoon, his officers offered him to train to become a radar operator for the ARTHUR system (4). He thought this suited him very well, and he put his language skills to good use during the training course with the Swedes.

Now, after six months working with ARTHUR, Radek is looking forward to going on Foreign Service. He feels that it is a good way to see the world and experience some adventure. His older brother Damek has been to Iraq as an infantryman and he tells Radek fascinating stories of his times in Iraq. Radek’s mother is very proud to have two sons in the military, but his little sister worries about Radek leaving on a dangerous mission abroad.

Rumor has it that people watch a lot of movies during the downtime that they often have at missions abroad, and to Radek that sounds great. That is why he is saving up money for a new laptop that he can both watch movies on and play computer games (5). As kind of a computer geek, Radek gets annoyed with the fixation of paper maps in the military. He finds

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it a drag to transfer coordinates and targets by hand and he would like to get rid of that task (4). Once he tried complaining to an officer about this, but he got told off and has never brought it up since.

Radek has learned to handle ARTHUR quite well, but he is still worried that he will make a mistake when it really matters. He finds it difficult to navigate the menus under pressure (6). Since he is tall it is taxing to sit in ARTHUR for any longer period of time (7). The combat harness and helmet comes off as soon as he enters the shelter (8). Sometimes he even takes off his boots to get some extra legroom.

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8. Survey responses to question 13, Norwegian survey. *"When taking off clothes and equipment, where does it usually end up? Has it ever gotten in the way when put there?"*

APPENDIX IV

Static Scenario with References

Staying put, continuous monitoring, working shifts, fighting boredom.

It takes quite an operation to protect a huge camp like Camp Fernandez. The Arthur division is a part of this massive operation. It has been positioned in a Forward Operating Base (FOB) about 15 km away from Camp Fernandez, out in the desert in the middle of nowhere. The mission is to monitor the entrance of the camp to make sure allies and their own forces make it to and from Camp Fernandez safely [1]. It is known that the enemies are located in the mountains nearby, so the Arthur division knows that if a mortar attack would occur, it would probably be from somewhere in those mountains.

The division has been at this FOB for three weeks now [2], and the operator is getting a bit tired of the rough conditions here. He is longing for the luxury of Camp Fernandez [3]. He especially misses the cooked food in the mess hall and the shower blocks. Here at the FOB, the menu is field rations [4]. There is not even lighting here [4], so when night falls they usually hang out in the tents playing board games [5]. When they go to bed, it is in sleeping bags instead of mattresses here [5]. At the FOB, Arthur surveils the surroundings 24 hours a day [6]. They are six operators that take turns, so they have to sit for eight hour shifts inside Arthur.

The operator has done everything he needs to do during his shift. He has already checked all the instruments and ordered some spare filters and fuses from Camp Fernandez. Now he is thinking of putting on the movie that the previous shift operators left for him [7]. But then he remembers that it is Sunday, and that means that he needs to stay extra alert. Sundays are referred to as "holy shit Sundays" here since they have noticed that the enemy often attack on this day of the week [8]. The common belief is that the enemy does prayer on Fridays, plan its attacks on Saturdays and then carry them out on Sundays. So instead of watching a movie, he takes off his jacket and boosts the air-condition, to stay fresh and alert. Despite his attempts he almost falls asleep from the noise and lack of amusement. The system is performing well, everything looks as it should and all he can do now is wait for an alarm to sound. Fortunately, they have not attacked this close to Camp Fernandez in a long time [9], but that is no reason to doze off. He starts talking to the operator next to him and he is bored too [7]. Through the open door they can see the guard outside, and they engage him in the conversation too [10]. The guard gives up after a while; it is exhausting to shout over the loud buzzing of the radar.
The guard outside tells the operator that the daily shipment has arrived [5]. It is the highlight of the operators' day, especially if there is something in the mail for him. He cannot leave the shelter, but the co-operator can go outside and say hi to the driver.
The shipment comes from Camp Fernandez with supplies like fuel, food and water [5]. Today the shipment also contains the filters and fuses he ordered and toilet paper, but unfortunately no mail.

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APPENDIX V

The Survey

Survey of operator environment of Arthur radar system

This survey is a part of a master thesis at Saab in Sweden, investigating the operators working environment in the Arthur radar system. The purpose is to find areas of improvement that are related to the human using the system. We are looking into every task and thing that an operator can come across in using Arthur, not limited to the operator work station but including the entire interior and exterior of the shelter.

The answers will neither be connected to the individual who provided them, nor to the country from which they came. Even if you would think that the system as a whole is good and needs no improvement, please try to mention any details that are less than perfect. Also keep in mind that it is not you as an operator, but the system, that is under investigation.

1. Age

2. Gender

3. Height

4. Years of experience with Arthur

5. Position/post

6. What do you think are the most difficult things to learn or get used to, for a beginner? What is it about those things that could be tricky?

7. What do you think are the biggest differences between how an experienced operator and a beginner handles their tasks?

8. Are there differences in how the beginner and the experienced operator interact with the system?

9. Which tasks take significantly more time for beginners compared to experienced operators?

10. Which things are still tricky or time consuming for experienced operators?

11. Where on your body do you feel tense after a long working session? Is there anywhere that you have felt pain?

12. If you are wearing combat gear when working, where does it get in the way the most? What gets hard to reach?

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13. When taking off clothes and equipment, where does it usually end up? Has it ever gotten in the way when put there?

14. Have you or anyone around you come up with any small invention or solution to make your work easier? (like where to put things or a modification of an existing thing)

15. Have you ever gotten annoyed by the position or shape of a button or switch, or by the placement of any equipment?

16. How do you spend your time when there is nothing useful to do in front of the screen? And how about when there is nothing useful to do at all?

17. What would you like to change about the following things:

- keyboard

- trackball

- seat

- screen

- storage spaces

- lighting

- sounds

- maintenance

18. Do you have any other thoughts or points of improvement?

Thank you very much for taking time to give us your opinion!