MSc Thesis in Interaction Design

Guidelines for the Design of an Airline Crew Control Operations Monitor

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ABSTRACT

The purpose of this master thesis was to examine the usability of an Operations Monitor for crew controllers at an airline. The comprehensive question of issue was how the Operations Monitor should be designed in appearance, interaction and functionality to support the users in an airlines operations control room.

The background to the purpose is a EU-project called Descartes using development computerized optimisation techniques for the operation control. Within Descartes there is an interest in investigating in different visualization techniques, and in new methods of working for crew controllers. The thesis part in this project is to enlighten problems in designing for airline operation controllers, and to show what the consequences of the different design choices can have for the interaction.

Different phases of user centred system development has been used in the process, some of these are user analysis, task analysis and prototyping, all founded upon methodology from contextual design. Three visits have been paid to the users and a lot of the work has been performed in the users work context. Workshops have been held with expert groups, and four prototypes have been derived from this, three of which have been implemented. End users have evaluated these and the result was analysed in relation to previous research within this area. This resulted in design recommendations, formulated from a user perspective. The purpose of the design recommendations was to be the foundation for the next step in the iterative development process. The comprehensive questions for the thesis was finally answered derived from the design recommendations.

SAMMANFATTNING

Målet med denna magisteruppsats har varit att undersöka användbarheten av en Operations Monitor för besättningsövervakare på ett flygbolag. Den övergripande frågan har varit hur Operations Monitor borde utformas till utseende, interaktion och funktionalitet för att stödja användarna i ett flygbolags kontrollrum.

Bakgrunden till syftet är ett EU-projekt, Descartes, som använder utvecklade datoroptimeringstekniker för kontrollrumsmiljö. I Descartes finns ett intresse att undersöka olika visualiseringstekniker och nya arbetsmetoder för besättningsövervakare. I Descartes syftar denna magisteruppsats till att uppenbara problem i att designa för flygbolags verksamhetsövervakare och att visa vad konsekvenserna av de olika designvalen kan ha för interaktionen.

Olika faser av användarcentrerad systemutveckling har använts i processen, några av dessa är användaranalys, uppgiftsanalys och prototyper, vilka grundats på metodik från kontextbaserad design. Det har gjorts tre besök hos användarna och mycket av arbetet har utförts i användarnas kontext. Det har dessutom hållits workshops med expertgrupper. Fyra prototyper har härletts ur dessa faser, av vilka tre har implementerats. Slutanvändarna har utvärderat dessa och resultatet har analyserats i relation till tidigare forskning inom detta område. Detta har resulterat i designrekommendationer, formulerade ur ett användarperspektiv. Syftet med designrekommendationerna var att bli nästa steg i den iterativa utvecklingsprocessen. De övergripande frågorna för uppsatsen besvarades slutligen utifrån designrekommendationerna.

PREFACE

This paper is a master thesis report in Computer Human Interaction/Interaction Design, written for the IT-University of Gothenburg, being a part of Chalmers University of Technology. The master thesis was carried out by Eva Eriksson and Daniel Lindros at Carmen Systems AB, Gothenburg.

We would like to thank our supervisors for their support; at Carmen Systems Dan Ryrlén served as our supervisor and at the IT-University Maria Redström was assigned as our supervisor.

Thanks also to Carmen Systems for believing in us and giving us a chance to show what we could contribute to in the industry, and for giving us a place to sit.

We are most grateful to the Descartes team, for their support and patience, and especially the project manager Sergey Tiourine, for his attention and time spent to help us.

Throughout this work we have gained help, ideas and feedback from a lot of people worth mentioning, above all, our teachers at the IT-University; Staffan Björk, Christina von Dorrien, Lars Hallnäs, Peter Ljungstrand and Johan Redström. Our fellow classmates have also contributed with a lot of feedback, and showing a great deal of interest to our work, especially Charlotte Axelsson and Marie Mattsson, who have truly been there for us during our moments of despair.

This master thesis would not have been able to be completed if it wasn't for the friendly people at British Airways, especially Jamie Hobbs, as well as the people we met at KLM.

Thank you!

Eva & Daniel

TABLE OF CONTENTS

1 INTRODUCTION

Technology is deeply changing human work; increasing automation, integrated systems, devices inserted between collaborating individuals, advanced communication networks, small and large scale distributed systems, embedded and wireless technologies, and so forth. In the dynamic work areas where many people have to perform their tasks, there is a tremendous need for communication, collaboration, and problem solving. Large information spaces, variability, discretion, learning, and information seeking are common characteristics of contemporary work contexts. Under these circumstances, designers need to establish a complete understanding of the users context to design effective, efficient, and satisfying systems.

For several reasons, when introducing a new system into any context, the usability is not always considered. Developers often see the functionality of a system as separate from the user interface, with the user interface as an add-on. Users, however, do not make this distinction. The way the user interface is presented to the user is perceived as the actual system; to users the interface is the system. Consequently, if the interface is usable, they will see the entire system as usable.

User interfaces are often thought of as referring only to how the screen looks. But due to the fact that the users see the interface as the actual system, this definition is not adequate; it must include all aspects of the system design that influence the interaction between the user and the system and not merely the screens that the user sees (although these are certainly part of the interface). Ultimately, the user interface is made up of everything that the user experiences, sees and does with the computer system. This includes (Dray, 1995):

- The match with the tasks of the user
- The metaphor that is used
- The controls and their behaviours
- Navigation within and flow between screens
- Integration among different applications
- The visual design of the screens

Because of this, poorly designed user interfaces can set severe constraints on a system; if it is difficult to reach the systems functionality through the user interface, the entire system becomes unusable. The design of the user interface could have a great impact on the results of the use of a system, from attention to usability through user-centred design, including such things as improved efficiency, reduced training time, reduced system maintenance costs after implementation, fuller utilization of system functionality, and so forth.

At the same time, user’s expectations have changed. They have seen what is possible in commercial applications that are “user-friendly”, and they want similar kinds of software to make their jobs easier by reducing cognitive demands. Well-designed systems are useable, they work the way the user thinks they should and let the user focus on the task without having to pay attention to the technology tool itself. Usable systems are easy to learn, remember and use, efficient, and designed to minimize errors and to promote user satisfaction. The usability needs to be designed in. Being able to design useable user interfaces requires awareness, commitment, the application of appropriate user-centred tools and processes.

There are important benefits of usability interfaces for the business (Dray, 1995). These include:

- Reduced errors
- Lower support costs
- Lower initial training costs, and greatly reduced retraining
- Less productivity loss when the system is introduced, and more rapid recovery
- More focus on tasks to be done, rather than on the technology tool
- Lower turnover and better morale
- Reduced rework to meet user requirements
- High transfer of skills across applications, further reducing training needs
- Fuller utilization of system functionality
- Higher service quality
- Higher customer satisfaction

The purpose of having an interaction designer developing the user interface is to assure the usability and efficiency of the computer based system. The interaction designer is a systems architect on the user – and usability level, with a deep knowledge in design, and a wide knowledge in technique and systems.

The main focus of much HCI research has been gaining different kinds of contextual information necessary to design a suitable solution, as well on techniques for evaluating a proposed design, e.g. as part of an iterative design process. Turning all of the gained information into a concrete user interface, including deciding upon the demands on the system, selecting what information to be shown, what functionality to be, how to layout and present information and related interaction techniques, is the task.

This master thesis will consider how graphical tools should be designed to support the crew controllers in decision-making at an airline operation control.

At Carmen Systems the main business concept is that of developing systems that optimize transport operations in domains such as airlines and railway (airlines being the dominant domain) all over the world. Due to the size and complex nature of these domains, planning effective solutions and schedules is achieved with difficulty. It is mainly in this phase, i.e. the planning phase, which Carmen Systems focuses their work, developing software that optimizes solutions and makes resource planning easier, effectively cutting a great deal of expenses for the client.

Recently, Carmen Systems has taken the step from planning into the day of operation[1], a step that bears many new aspects. This step was taken in the year 2000 by the research and development department of Carmen Systems in a project named Descartes[2], which is collaboration between Carmen Systems, the Technical University of Denmark, British Airways and the European Union.

Descartes is primarily a research project intended to explore the possibilities of implementing an integrated operations control system at an airline.

[1] The day when planned schedules go live.

[2] Decision Support for Integrated Aircraft and Crew Recovery on the Day of Operations.

1.1 Research question

This thesis will deal mainly with one question, namely:

How should a graphical user interface for an airline crew control Operations Monitor be designed so that the user, the crew controllers at an airline company, is best supported in both their current work, and also their future work?

To be able to answer the research question, several other questions are identified:

- What is the purpose of the Operations Monitor?
- How will the incorporation of the Operations Monitor change the way the user works?
- What present ways of working must be taken into account?
- What is the users context and how are they organized?
- What visualization techniques are suitable for this type of work task and environment?
- How do different aspects in the work environment and user's tasks affect the use of an Operations Monitor?

The aim of the master thesis is to conduct design recommendations for a day of operations monitoring system for crew controllers at an airline, using methodology from HCI and CSCW as a method. The thesis will focus on the usability of the system from the users point of view, and based upon that propose a basic design of the components and the interaction between those in order to facilitate the users work.

The goal is to provide documentation on the analysis of the users' needs and tasks, a report on the method used, the workflow and finally provide the overall results. Also, design recommendations will be provided and a basic prototype designed and implemented.

1.1.1 Demarcations

There are three resource areas included into Descartes, aircraft control, crew control and passenger control, and these three are all supposed to have an Operations Monitor. A vision from the Descartes team is to create a monitor for top managers, or even further to information desks at airports and so on, all with a graphical user interface. The demarcations for this thesis were to create guidelines for one of these monitors, the crew controls; this was decided in collaboration with supervisors, our selves and the project manager of Descartes. The decision was based upon that the parts of Descartes most developed were the Crew Recovery Solver[3] and the Fleet Recovery Solver[4], meaning that the most help and information were to be found within these areas. Since the alarms for crew control are the most complex, it seemed to be the greatest challenge, and therefore chosen.

The Operations Monitor is to be company independent, meaning it is to be as general as possible, not focusing on the users that has been involved in the analysis, but users all over the world.

[3] Optimisation tool, described in chapter 2.5.1 The Solvers
[4] Optimisation tool, described in chapter 2.5.1 The Solvers

2 BACKGROUND

This chapter will present the nature of the complexity that the work of airline crew controllers is founded upon, what different stages has been gone through before problems end up in the control room from the initial crew scheduling process, and also what factors in the context affects their work. The Descartes project will be presented, since this is the background to the Operations Monitor concept.

2.1 Crew Scheduling

The crew scheduling process consists of several phases where the timeframe differs depending on the airline company and what tools are used. It is a heavily complex process, since the number of crewmembers might differ from thousands to tens of thousands, each with their own personal demands, regulations, conditions and wishes, which must be taken into consideration along the way.

2.1.1 Planning

Planning is when all the schedules are drawn, and it takes place a few weeks, or even a few months, before the day of operation. It is a complicated procedure where there are many laws and regulations, generally determined by the government and the union, which must be considered to achieve a permissible result. For instance, if the planning involves cabin crewmembers, such details as airplane-licenses[5], visas, worked hours, rest and days off must be taken into account. Because of the complexity of planning, it is often subdivided into two parts. The first stage of planning is to build a pairing[6], while the second part consists of assigning crew (in the case of cabin crew planning) to the pairings, effectively creating a crew roster[7], which is used as the crewmembers personal schedules.

2.1.2 Tracking

Naturally, because the rosters are created at such an early stage, it is inevitable that during the time between the publishing of the roster and when it goes live, something will occur that renders part of the roster invalid. For instance, a crewmember could resign or have a long-term illness. Therefore, all rosters produced by planning are handed to the tracking department, which primary objective is to keep the rosters intact by repairing the parts that become invalid.

2.1.3 Day of Operation

When the rosters go live on the day of operation, interferences, e.g. acute illness, weather or delays, will still occur even though the tracking department has kept the rosters intact. The day of operation controllers for crew therefore to some extent solves the same problems as tracking, i.e. roster repairing, although there is a much tighter time frame during the day of operation and fewer resources may be altered.

At present the airline companies way of handling and solving issues that arise during the day of operation is very outdated, ranging from old text based systems that administers crew information to the pen and paper method of solving problems. The

[5] Which aircraft types the crewmember is allowed to work on, e.g. 747, 767 etc.

[6] A chain of flights. Often starts and ends at the same place, e.g. LHR – MAD, MAD – GTW, GTW - LHR

[7] A work schedule for a crewmember containing pairings

way the people in operations control[8] work at the moment is due to the lack of support tools. Carmen Systems created Descartes to address this problem. Due to the complex nature of the operations control, designing a system that replaces or supports the current way of working is extremely difficult. Other companies that have failed have made several attempts.

2.2 Descartes

The goal of Descartes is to develop a tool for integrated disruption[9] management, Carmen Integrated Operations Control, making the handling of disruptions easier and partially automated. A disruption object includes the description of an actual or a simulated irregular operation. Descartes comprises a set of solvers, which can construct alternative options suggested to reduce the effect of irregularities. Descartes is a decision support system intended not to replace the current way of working, but rather supporting it.

Descartes is a component-based system, comprised of several different building blocks. At the lowest level, there exists a real time data storage called Flamenco, which communicates with the British Airways current information sources and keeps a local copy of all the data (such as timetable, aircraft and crew data); there is no intention to directly modify data or act as the airway's database. The data stored here is the information base for the remainder of the system. Parallel to the Flamenco database exists a rule server, which purpose is to maintain the operational alarm status in the database.

The Carmen Data Storage, Flamenco, is the part of Descartes that will be the integrator for the Carmen and the customer applications. It is designed to provide a fast, flexible and reliable data storage, and consists of the following information components:

- Timetable information
- Pairings
- Rosters
- Aircraft rotations
- Passenger Name Record
- Ground duties
- Crew information
- History track for stored information.

2.2.1 The Solvers

There is one solver for each resource area: the Fleet Recovery Solver, the Crew Recovery Solver and the Passenger Recovery Solver. The purpose of the solvers is to search for an optimized solution that minimizes the cost function, without breaking any of the legality rules imposed on it. The solvers are designed to construct several options, i.e. solutions, which may be structurally different. The user may select any of these options to implement or evaluate in other resource areas. The solver handles two different kinds of requests, option generation and option evaluation. An option is a suggested change to a schedule or changes to other resource areas that may resolve a disruption. When generating options, the solver will take a disruption as input. When evaluating options, the solver will take a disruption and a number of options as input. The solvers in different resource areas are supposed to cooperate. One solver is set to generate options,

[8] The place where people work on the day of operation
[9] One or several inconsistencies in the roster, defining one problem.

and the other ones are set to evaluate the options generated by the first solver. This way, an option can receive scores from different solvers, which can be very useful in the decision process.

The algorithm used within the solver iteratively improves the solution by trying small changes and selecting the ones that improves the schedule. This is repeated until no improving changes are found. When time is critical, a deadline could be set, and the solvers present the options generated so far.

2.2.2 The Disruption Manager

The goal of the integrated disruption management is to maintain a holistic view on airline operations and to avoid sub optimal decisions when managing irregular operations.
The problem solving cycle consists of the following phases:

- Monitor operations - monitor traffic program execution detect actual or potential problems and generate alarms.
- Define scope – receive alarms, evaluate them and define the scope of the problem; decide the time frame, severity and resources affected by the problem. Several alternative scenarios can be considered.
- Generate options – generate and review alternative options available to cope with the problem
- Evaluate options – evaluate proposed options with other resource areas affected.
- Make decision – review alternative problem scenarios and their corresponding options and select the best action to be implemented.
- Implement solution – communicate the changes to all relevant parties involved.

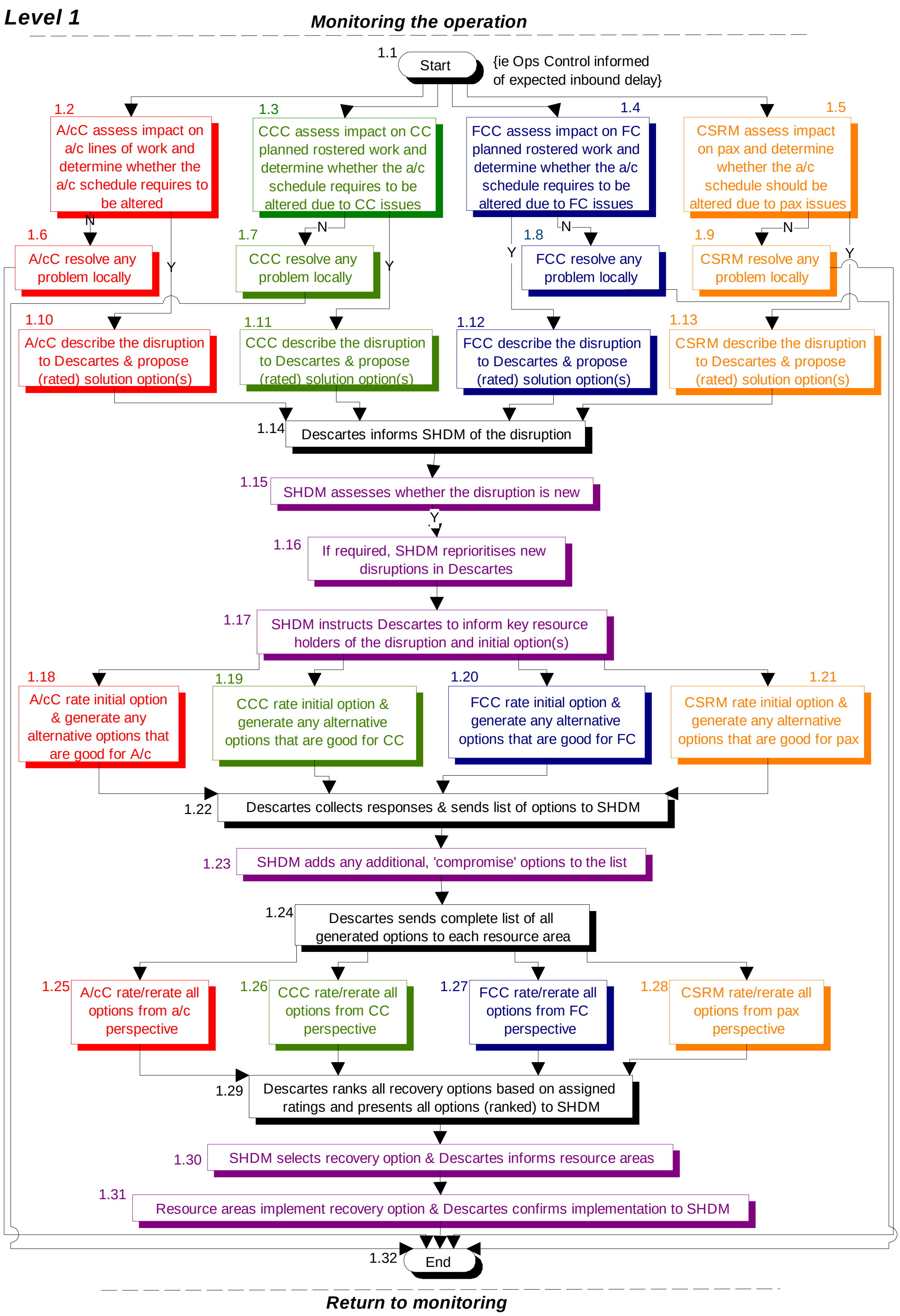

Figure 2-1 Graphical workflow diagram of the way of working with Descartes.

Ops Control – operations control	A/cC – Aircraft Control
A/c – Aircraft	CCC – Cabin Crew Control
CC – Cabin Crew	FCC – Flight Crew Control
FC – Flight Crew	CSRM – Customer Service (passenger)
Pax – passenger	SHDM – Short Haul Disruption Manager

The communication within Descartes is performed via sending XML-messages, and XML (e**X**tensible **M**arkup **L**anguage) is essentially a way of structuring and describing data, much like a database. A XML document is composed of data embedded within tags, which is self-definable. These tags define the structure of the data, based upon a DTD (**D**ocument **T**ype **D**efinition) containing rules that ensure that the structuring itself is unambiguous.

Since XML data is stored in plain text format, XML provides a software- and hardware-independent way of sharing data, which makes it much easier to create data that different applications can work with.

2.3 Introduction to the context

The work that takes place in control rooms challenges both humans and technology. The people working there, the controllers, have to be able to make quick decisions as well as be alarm during less busy times. In order to carry out their work, they need large amounts of data, both dynamic operational data, as well as static information. This information has to be presented in a form that makes it easy to access and assimilate. The work has to be coordinated within each resource area, as well as within the entire group, since the operators are much depending on each other's work and decisions. This places special demands on the technology; it should be fast, trustworthy and easy to manipulate so that the complexity of the work is reduced.

The work performed in an operations control room at an airline can to some extension be compared to the work situation in an air traffic control tower, although the safety issues are more considered in the control tower. Studies (Mackay 1999, Bentley et al 1992) have shown that the air traffic controllers divide their work between 40 years old computer systems and paper. To take away the paper strips they use and replace them with automated versions, which offer benefits in terms of increased efficiency, could also endanger the work with unknown risks through radical changes. We must take advantage of the uniquely human skills in the physical world, and let the interface support the most important part of the system, the controllers themselves.

Airlines operations control is a time–critical system involving quick decisions. Controllers hold the fate of thousands of crewmembers, thousands of passengers and hundreds of aircrafts in their hands, and mistakes that result in inconsistent schedules are just not accepted. The work is complex, collaborative, well established and successful and requires quick responses to the constantly changing conditions. The traffic has increased, but even so, the basic user interfaces and corresponding work practices have remained the same, with relatively minor variations concerning nationality, resource areas, control team and individual level.

Traditional operations monitor systems have no visualizations of alarms and there exists no alarms in them. The controller will monitor different changes (e.g. changes in aircraft schedules or crew check-in status) and from experience deduce that a certain change may cause a problem that he must act upon.

Improving the systems used today at the airlines operations control, presents an interesting challenge, since the existing systems are already extremely safe and the work involving these systems is founded on a strong routine basis. Creating a new tool, one must not only consider offering improvements, but also avoiding generating problems. A tool that increases the controllers' efficiency; making them come up with more cost considered solutions in less time, may not permit more errors and inconsistency. The system may not only support the controllers in crisis and in peak levels of the day, but also support their vigilance during slow periods.

Increase in air traffic density and complexity have led to a higher degree of demands on the mental workload of controllers. Very high workload can lower performance and set an upper limit on alarm handling capacity. Very low workload may result in boredom and reduced alertness, with negative consequences when handling emergencies. Factors increasing the controller's mental workload include display factors, work team dynamics, external communications and experience. The new system has to be introduced within the context of the existing environment and help the end users to find the optimal balance between alarm handling and the smooth flow of operations.

2.4 Human Factors

The work that the airline controllers perform can be compared to the work in different types of control rooms. In a study performed at the line control and passenger information on London underground (Heath, Luff, 1996), showing that individual and specialised work tasks are produced with respect to the actions of colleagues and rely upon individual's ability to participate, simultaneously, in multiple activities. Like airline controllers, their specialised actions and activities are produced, recognised and coordinated with the contributions of their colleagues. By continually monitoring and discriminating the work performed in the environment, and by judgement of years of practise and experience, the controllers coordinate particular actions with each other. This makes their mutual understanding of how to act in emergent events, and they can predict each other's activities and the movement of the influenced traffic. This systematically coordination is performed in real time, and the individual tasks and activities are embedded in and inseparable from ongoing and perhaps not obvious interaction with colleagues within the local room. The individual work is based upon socio-interactional foundations, a complex web of staff, management, experience, routines, and the collaborative ability to perceive the not obvious (Heath, Luff, 1996).

To avoid system failure, it is important to realise that one of the major causes for this is the mismatch between the functionalities of the system according to the designers view and its context of use. In an ethnographical study of air traffic control (Bentley et al. 1992), it is found that some conventional principles that are normally considered as good design may be inappropriate for cooperative systems. Manual actions and manipulation of information may be essential methods of communication and cooperation, and might therefore be kept. When new information is to be added to the system, the computer might not always perform the best sorting to maintain the sort order, the human operator has to be able to change the order the computer suggest, or to be completely responsible of these actions.

When automating the user interface of a database, the technical change must require minimal changes to working practices, to avoid the huge cost of retraining and because the user interface is only one part of the complex systems that is airline operations control (Bentley et al, 1992). Humans may distrust the automation because they fail to understand its complexities, and it is possible that reliance on automation may lead to a loss of human knowledge in the skills that the automation replaces.

Pressure to provide the capacity to handle a greater number of flights in the future and to maintain high levels of efficiency have led to proposals to provide more reliable and powerful equipment, and at the same time increase the level of automation in airline traffic control facilities, to use the advances in technology to replace tasks that are currently performed by humans. Automation may not compromise the safety or efficiency of the system by reducing the human controllers ability to provide necessary backup when disruptions occur. Systems to automate the similar area of the air traffic control have been undertaken primarily from a technical viewpoint, in the areas of sensing, warning, prediction and information exchange (Wickens et al 1997). The controllers have not adopted these previous experiments, since the experiments have not supported the working division of labour. This problem is described and identified by Hopkin in 1991 as follows:

> "One striking aspect of automation applied to air traffic control systems is that most of the forms of automation for the controller to use, as distinct from those which sense or process or compile data automatically, are for one controller at a human-machine interface. They are aids to an individual controller's decisions, problem solving or predictions, yet they are being introduced into contexts where many of these functions have previously been performed by teams"

To build an effective computer support for the activities in a control room, the designers have to understand the nature of the not obvious cooperation taking place there.

In a panel on human factors in air traffic control automation (Wickens et al 1997) recommendations for the design of a automated system for air traffic control are drawn, and since these environments are equal in some aspects, some of these guidelines can be projected as guidelines for an automated interface for airline traffic control. The system is to keep and use the controllers' cognitive strengths, but which also struggles to compensate for weaknesses. Such compensation includes making discrete and infrequent events more distinguished, providing obvious and reliable predictive displays whenever possible, providing communications and visual backup for working memory when errors can be costly, providing visible feedback for state changes, and using display techniques to improve individual and shared situation awareness, both among controllers within and outside the same resource area as external sources.

2.4.1 Stress

Stress is an important factor to take into consideration, when studying the work and the people working in a control room. This affects the performance and the result of the work, as well as the well being of the controllers themselves. The workplace environment, being a large noisy room, and the work tasks consisting of alarms and dynamic data, increase the level of stress.

Stress is associated with four major kinds of effects: emotional, physiological, cognitive and behavioural (Eysenck, 1999). The level of stress is depending on the interaction between an individual and the environment. Stress could be caused by noise and by the feeling of lack of privacy, a syndrome that could easily appear in an office landscape. The feeling of being in control of the situation is also an important factor to consider, especially since no day or problem is another alike in a control room. Any stressor is likely to have more severe effects on us when we feel unable to control it.

Increased heart rate, increased blood pressure, higher levels of adrenaline and noradrenaline are some physiological effects that tend to increase in line with the intensity of noise (Eysenck, 1999). Some people might find that carrying out a fairly complex task in loud noise find it hard to maintain their concentration on the task, while others find themselves being able to benefit from the noise in order to increase the perception of the environment. There are of course benefits in working together in a large office environment, since there is an increased closeness to co-workers serving friendship opportunities, reduced role conflict and role ambiguity. The open-plan office might not only reduce the ability to concentrate, but there is also an almost total lack of privacy since everyone can see and hear everything everybody else is doing. All of these factors influence on the satisfaction with the work, and therefore the level of stress.

Measuring performance in relation to stress is difficult, since a person who is very stressed might try harder than a non-stressed person (Eysenck, 1999). If there is a lot of time pressure and a high level of stress, it might be easier to make errors and mistakes. Since there are periods of time when there are no problems to deal with in the controllers task, then the focus, concentration and stress might just decrease, reducing their performance. The performance and the stress are both also depending on the motivation, the experience and the level of relevant knowledge.

There are three strategies for how to deal with a stressful situation in solving a time-critical problem (Eysenck, 1999). These are:

- The task-oriented strategy, involving obtaining information about the stressful situation and about alternative courses of action and their probable outcome; it also involves deciding priorities and acting so as to deal directly with the stressful situation.
- The emotion-oriented strategy, involving efforts to maintain hope and to control one's emotions; it can also involve venting feelings of anger and frustration, or deciding that nothing can be done to change things.
- The avoidance-oriented strategy involving denying or minimizing the seriousness of the situation. It also involves consciousness suppression of stressful thoughts and their replacement by self-protective thoughts.

The cognitive effects of stress are important to take into consideration when creating a tool in a control room, since the level of stress affects the concentration, increases the controllers' distractibility, and reduces the short-term memory capacity.

2.4.2 Attention

Attention consists of focalisation, concentration and consciousness, and implies withdrawal from some things in order to deal effectively with others (Eysenck, Keane, 1998). Why we attend to some things rather than others is that we choose to attend to sources of information that are relevant in the context of our present activities and goals. Sometimes our attention is involuntarily captured by certain stimuli.

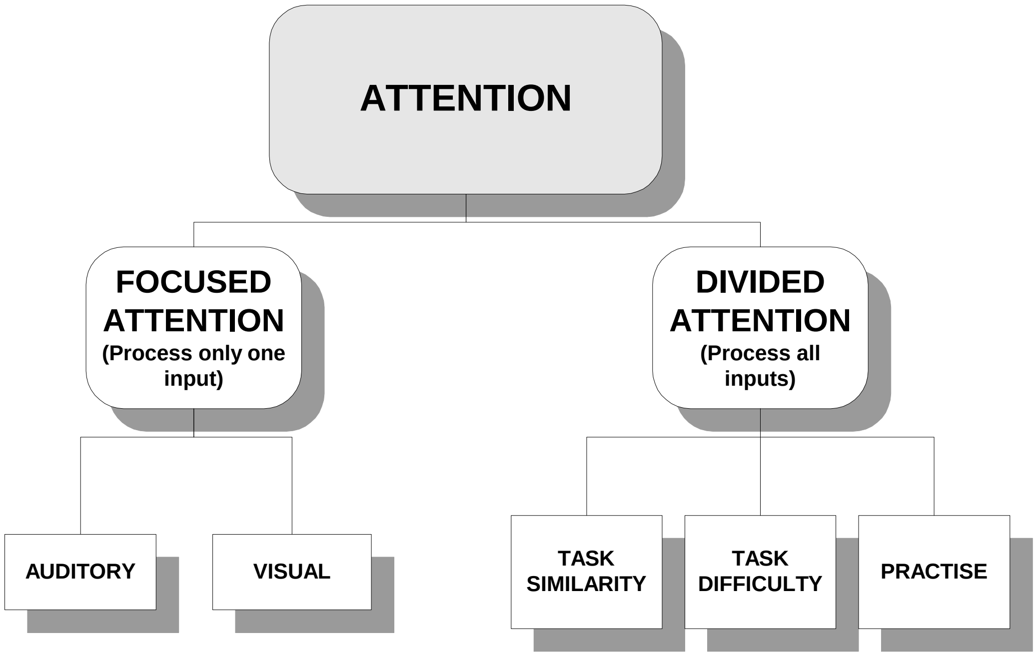

Figure 2-2 A visualization of attention derived from Eysenck, M., Keane, M., "*Cognitive Psychology - A students handbook*" 1998

Focused attention is when several inputs are received at the same time but focusing and responding to only one (Eysenck, Keane, 1998). In the area of focused attention, a huge selection process is taking place, where one message is going through the filter to be processed immediately, while the unattended message is memorised for later processing. Processes with focused attention are of limited capacity, but they can be used flexibly in changing circumstances in a dynamic environment.

Divided attention is when several inputs are not only received, but also attended to and responded to (Eysenck, Keane, 1998). There is of course a limit of how many inputs can be processed at the same time, before the attention mechanism is overloaded. The attention is depending on the external as well as the internal environment (i.e. our own thoughts), and the nature of the input. In order of performance, two dissimilar tasks can be performed well together, if they are easy and well practised. In contrast, if two tasks are very similar, difficult and with little practise, the worst levels of performance will occur.

Practise strongly influences the improvement on performance, converting processing activities automatic. Automatic processes are fast, they do not reduce the capacity for performing other tasks simultaneously, they are unavailable to consciousness, and they are unavoidable. They do not require attention, but they are difficult to modify once they have been learned.

2.4.3 Internal Models

In critical situations, as in the work of the controllers, it is important that decisions can be made and executed quickly. Being able to work efficiently depends to a large extent on the user's inner representation of the system, i.e. how efficient his or her internal model is. In effect, visualizing information is analogous to forming an internal, or conceptual, model of the data. Striving to create a good internal model is an important part of designing the user interface; by facilitating the creation of the user's mental model and efficiently supporting time-critical decision processes, it will be easier for the user to understand the system, and will also ease the learning time. "Users always have mental models and will always develop and modify them, regardless of the particular design of a system. Our goal as user interface designers is to design so as to facilitate the process of developing an effective mental model" (Shanbhag, 2002).

Although it is widely accepted that mental models do exist, and that they are an important part of the interaction between the user and system, they are often vague and hard to define. The importance of mental models when designing has been stressed over and over again, but there is scarce information and suggestions on how to go about doing this, much due to the fact that so little is known and evidence surrounding actual mental models is hard to find.

Mental models (Eysenck, Keane, 1998):

- Mental models constitute a person's causal understanding of a physical system, and are used to understand and make predictions about that system's behaviour.
- They are incomplete, unstable, and may be even partly ad hoc.
- These models can simulate the behaviour of a physical system and may be accompanied by visual imagery.
- They are unscientific; people maintain "superstitious" behaviour patterns even though they are known to be unnecessary, because they may cost little physical effort and save mental effort.
- They are usually characterised in prepositional terms.

2.4.4 Optimal and Satisficing Decision Making

Boer, Hildreth and Goodrich discuss in their article "Satisficing Decision Making with Dynamic Mental Models", the possibility of supporting different kinds of mental models. They suggest the existence of two types of mental models, namely the optimal control model and the satisficing model. The optimal control model describes the highly trained and motivated individuals, where optimal decisions and solutions are desired. During this phase of decision-making a set of criteria are evaluated for all possible actions, which are combined into one utility function from which the single extremizing decision is chosen as the most optimal. The satisficing decision-making the set of criteria is divided into several motivational criteria, i.e. the reasons for making the decision, and constraining criteria, i.e. the reasons why a decision should *not* be taken. These criteria are evaluated, resulting in a set of decisions and if the motivational exceeds the constraining, the decision is considered acceptable. Further, the satisficing approach to decision-making does not require an extensive search across all different decisions as each decision is evaluated independently.

In natural settings, human decision-making is more prone towards a satisficing model than an optimal one. The overall role of the controller is to assure that one or more tasks are carried out satisfactory by monitoring the status, and intervening when necessary. The mental models associated with the current tasks provide the information that shows the controller where to focus his/her attention next, and what tasks are to be performed next.

Assuming that this hypothesis is accurate, the question arises of which category, optimal or satisficing, the controllers belong to. It can be argued that controllers are highly trained individuals, not necessarily in the act of computer-usage, but rather in their field of work, which is the result of a great deal of experience. Although highly trained, their current way of working suggests that the controllers make their decisions from a satisficing point of view, much due to the fact that the current problems that arise within their work-tasks are very complex, and the current tools do not support the possibility of making optimal decisions, much less doing it alone. With the debut of *Descartes*¸ this is likely to change, as the controllers will have much more support to make decisions of an optimal nature. Even so, optimality is difficult to define, and under time-critical conditions, there may not be enough resources to obtain an optimal solution or decision. We can make the assumption that under slow periods the controllers will be using an optimal control model, trying to establish the optimal solution, while during peak periods with a high work-load and time constraints, this may shift towards a more satisficing type of decision-making.

2.4.5 Structural and Functional Models

Parallel to the theory of optimal and satisficing models of decision-making exists another, more conventional and accepted, where it is suggested that mental models can be categorized into two main types, namely structural and functional (Preece, 1994). The fundamental difference is that the structural model assumes that the user has an internal representation of how the system works in memory (how-it-works), while the functional model assumes that the user has an internal model of a procedural type (how-to-use it).

A structural model is used to form an understanding about a device or system in terms of its internal structure, i.e. its components (Preece, 1994). The creation of a structural model requires great effort from the user, but after successfully acquiring one it allows the user to predict the effects of any possible sequence of actions. However, this is very uncommon, and even highly experienced users get by without using one, as they are content with using the functional equivalent. The functional model is, unlike the structural, obtained by using similar past knowledge, and while the structural model allows predictions, the functional is centered on tasks. For example, when using a mobile telephone, one seldom understands what is happening inside the telephone when making a call or setting the alarm, which in effect means that there exists no (or exists vaguely) structural model of the mobile phone. Even without this model, we can use the telephone with a great deal of skill, because we rely on our functional model of the telephone to guide us.

2.4.6 Mental workload

Over the past thirty years, the difficult tasks that have had to be performed of the operators in different areas have drawn the attention to the area of mental workload. Questions concerning the operators work has arisen; how busy they are, how many tasks they can handle safely simultaneously, and if they have to struggle to maintain an adequate level of performance.

A definition of workload is that it is a demand placed upon humans, an experienced load not only task-specific but it is also person-specific (de Waard, 1996). Individual capabilities, motivations to perform a task, strategies applied in task performance as well as mood and operator state affect the experienced load. Workload is the specification of the amount of information processing capacity that is used for task performance. In the concept of mental workload how the goal is reached and individual restrictions imposed upon performance are included. Therefore workload depends upon the individual, and owing to the interaction between operator and task structure, the same task demands do not result in an equal level of workload for all individuals.

Directly related to demand is complexity, since complexity increases with an increase in the number of stages of processing that are required to perform a task. Task demand and complexity are mainly external but both depend upon goals set for task performance. Difficulty of a task is related to the processing effort that is required by the individual for task performance, and is dependent upon context, state, capacity and strategy or policy of allocation of resources.

3 METHOD

In the area of Interaction Design a lot of things are to be included, from the technique within a physical IT-artefact to cognitive psychology, but the most important factor that all aspects of this area has in common, is the user centred design process. In this thesis the development of a graphical user interface is in focus, but from an Interaction Design point of view, that is just one part of a much larger perspective, including everything from the interaction within the system to how it will affect the users in their social identity in the environment it will be used.

Interaction design is founded upon several research areas and two of those are Human Computer Interaction (HCI) and Computer Supported Cooperative Work (CSCW), which claim the need for understanding the context in which new technologies are introduced and recommend a strong focus on the users needs. Design for dynamic work contexts cannot be based only on analyses of the current task situation.

The primary problem is how we can understand and model work that changes dynamically and define lists of procedures, tasks, and goals. Methods, such as site observation, task analysis, and ethnographies, provide researchers and designers with a work-oriented understanding of the use situation. A field study is an analytic process that leads to a general understanding of a work problem, while design is a creative activity that requires specific, worked-out solutions. A field-study is not bound by technology, while design creativity is limited by the users needs as well as the available technologies. HCI research has shown that theoretical concepts can be very useful, but they must be completed by studies of work based on experience as well as by experimental design of prototypes.

The term usability is constantly repeated in the research of Interaction Design, an expression not quite obvious by definition. The international standard ISO 9241-11[10] defines usability as follows:

> "Usability: the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use".

The used product in Interaction Design is the computerised system, and the three factors mentioned in the definition; effectiveness, efficiency and satisfaction, are essential to measure and predict. To achieve this, the goals set up in the beginning and the work throughout the entire design process has to be founded upon profound methodology.

[10] www.usability.serco.com/trump/resources/standards.htm#9241-11

3.1 Design methods for user centred system development

The user is always in focus in all types of user centred system development, but how much the user is involved in the process varies extensively (Preece, 1994). There are a lot of different and well-defined methods for this, and some of them are presented in the following diagram:

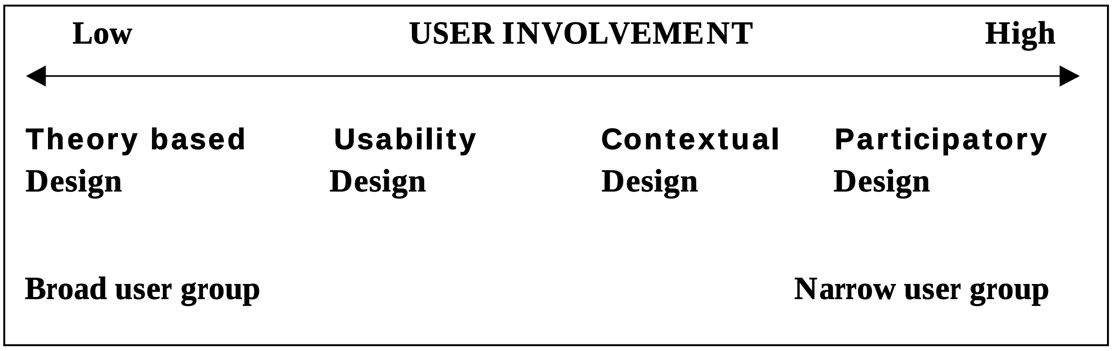

Figure 3-1 Diagram of user-involvement in different user-centred design methods.

If it is a wide target group, like in public systems, then the process can be founded upon theories about human skills and behaviour like perception, cognition and so on; this is preferably used when there is a low user involvement. The next step is usability design, where the designer is to specify the users, the task and demands, meaning the target group is smaller and the user is more involved. The following step is contextual design, where the designer is to understand the context of the user and a greater involvement of the user is required. All observations and studies will be performed in the right context. If the target group is narrow and homogenous, then participatory design is preferable, where the user is active in the entire design process being a member of the design team and the designer has to be taught the users task.

3.1.1 Contextual Design

The method used in this thesis is contextual design (Beyer et al 1998), where the designer is to understand the users situation and work. All operations and observations take place in the right context, at the place of work. The focus is at the work and workplaces, task, situation and environment, since the system is to fit into everyday life, and support the users in the way they want to work. The work of the interaction designer is founded at gathered data, team and design thinking. Since the collected data can have a huge impact on the design, it is most important to decide what data is needed and how it is going to be collected, since data is collected for a reason.

In a collaborative workplace, where individuals work in teams, several different competences are to be found. These types of organizations are highly complex, consisting of multiple interacting factors. The people in the organization are each having different roles, expectations and motivations and the technology used today, and the technology to come, has different functions and reliabilities. The structure of the organization and of the work, the different partitions within the groups, and the culture of history, rituals, habits, ways of behaving, codes of practise and ways of talking, all have a fundamental role in the overall organization.

The design is depending on the knowledge and interests of this group of individuals. To design a tool for such a dynamic and complex organization, are even more complex, since the users find themselves as part of an ever-changing environment. To gain knowledge of the group and the individual members that it consists of, we use contextual inquiry, described here.

3.1.2 Contextual inquiry:

Contextual inquiry aims to understand the users, their needs, their desires and their approach to heir work on a day-today basis, to reveal the hidden work structures.
There are four foundation principles for the contextual inquiry (Beyer, Holtzblatt, 1998):

Context:
The interviews and observations are conducted in the right context, at the place of work. By being where the work takes place, makes details available and the work structure becomes recognizable. It is important to try to avoid simplified summarising information from the users or the management; it is preferable to see “with your own eyes” to gain the correct information. Avoid abstract data, information and explanations; force the users to be concrete. It is very human to abstract, combining similar events and avoiding details in one specific case. A system is designed to fit several users, abstracting upon each individuals experience. Therefore the system will not be useful to real people if the design is based upon abstractions instead of details and concrete data.

Partnership:
The designer and the user have to collaborate to understand the work, there has to be a balance between them, for shared inquiry and discovery of the work. Assist the user to express her/himself, make her/him aware of actions, see structures, and articulate silent knowledge. Let the user affect your understanding. The designer is not there to answer questions or not to receive answers.

Interpretation:
The collected data is just to get started and demands an interpretation. Design is founded at interpretation; it has to be correct. Discuss the interpretation from a design perspective with the users to control, adjust and gain feedback, it ensures that the work is understood correctly. The designing ideas that are taking shape are the final product evolving from a chain of discussions and analysis. Summarised, the interpretation phase evolves as follows: Facts-hypothesis- implication-design idea.

Focus:
During the inquiries, while collecting data, the designer has to keep focus, what is relevant for the design-process and concentrate on that. A focus gives the designer a framework for making sense of work. The focus is depending on the starting point and makes several more details visible.

3.1.3 User studies

The purpose of user studies in HCI and Interaction Design is to find out what exactly what the customer or client requires from the system (Preece et al, 1994), and they can be conducted all through the design process. Depending on when user studies are performed, the result differ; if it is done in beforehand to require information and background knowledge, during the development process to evaluate and gain feedback to design proposals, or afterwards for evaluation and to see if the goals have been achieved. There are several methods to perform user studies all varying in the amount of preparation required, some of these methods will be presented here:

- ***Interviews***
  This is a method that requires a huge amount of preparation, to set up questions and goals, to fully understand the purpose of every question. The designer is to ask one user or a small group of users their opinions, needs and wishes, and the users are not able to be anonymous. It is very important that the designer puts effort into creating a relaxed atmosphere, trying to make the user comfortable to establish a good contact. It is always difficult to make the user describe their problems with a system, they might think they find it hard to use because of their stupidity and not because of the systems poor design, or they might be frightened of criticizing their employers choice. It is important for the interviewer not to ask leading questions, to beg for a particular answer based on the interviewers own expectations or personal attitude.

  There are two main types of interviews, structured and unstructured (Preece et al 1994). Structured interviews have predetermined questions, and the focus is not on individual differences and nuances, but the goal is more often to use the answers for statistic comparisons. Unstructured, or flexible, interviews are less formal and work very well in an early stage of the design process. The purpose is to investigate the users individual attitude, and the interviewer is free to follow the users replies in a new direction. Even though it is less important with predetermined questions, it is very important to set up goals for the purpose of the interview, to prevent completely loosing the subject.

- ***User observation***
  (Preece et al 1994) This is used to observe the user interacting with a system. Depending on the purpose of the observation, the user could be asked to perform a specific task or to do their normal work. The result from any kind of user observation can be affected by the fact that they know they are being watched and might therefore become nervous and eager to do everything perfect and right, even though the effort is to see the user perform their work in an environment totally uninfluenced by the observer. The observations can be recorded by video to gain the most informative facts, by audio also known as a verbal protocol with spoken observations, or by notes that will be the most incomplete ones.

- ***Expert groups***
  (Preece et al 1994) This is a method where a group of experts are involved in the design process. Since the experts are specialists then there is a risk to loose the common user, but the method is perfect when designing for a small group of users. It is a quite expensive method, but since the experts have extensive knowledge of the environment where the design is to be used and about the problems to be solved, then the development process could benefit greatly from this. The method is necessary when the context is unknown for the design team, but can be useful in any design process.

3.1.4 Prototypes

The design process is to communicate different ideas and design choices, and to be able to evaluate them, there has to be a prototyping step in between where the design is to take shape. Depending on in what phase the design process is, the prototyping tool differs a lot (Preece et al 1994). At an early stage it is important with rapid prototyping, where the tool could be pen and paper or animations; prototypes that might be thrown away and not implemented. With this method it is possible to create a great number of prototypes to a low cost, and to evaluate according to the requirements. With evolutionary prototyping the first prototype is to be kept and developed continuously until it is fully implemented. Incremental prototyping is used in huge systems, to build a system in different phases, founded upon the basic skeleton adding extra functionality.

Three important terms (Preece et al 1994) when discussing prototyping are full-, horizontal- and vertical prototypes. A full prototype contains full functionality but with lower performance. A horizontal prototype shows the user interface, but the functionality behind the buttons is not implemented. A vertical prototype contains complete functionality for one part of a system.

3.2 The design process

The design process has several different levels from concept to prototype, but all include planning, analysis, design and evaluation. The user centred design work an iterative process where these four activities are constantly performed. It is important to alternate between designing and reflection, between details and context. The users help out with realistic examples and tasks, so that the design is not built upon fantasy-models. The essential principles of user-centred design are to make user issues central in the design process, to perform early testing and evaluation with users and to design iteratively. The process is as follows (Schneiderman, 1998):

1. The first step is the planning phase; where the problem is to be identified, develop the concept, define the challenges and opportunities, understanding the background and the need for a new system. Identifying the users and the technical and environmental issues at the workplace does this. From this, a schedule and a time plan are drawn.

2. The second step is to perform research and needs analysis. Focusing on the users, they are to be divided into related groups, and their work activities are divided into task units. Through construction of scenarios, shadowing at the place of work and contextual design, a needs analysis is conducted. The sequences of tasks that the users perform everyday are sketched into a process flow diagram. Major objects and structures that will be used or considered in the software interface are to be identified in this phase. Technical issues and other constraints are to be resolved.

3. In the third phase, the design concepts and prototype design are to be considered. Based on the user analysis, their needs and their tasks, specific usability objectives are created. Guidelines and style guide are initiated. A navigational model and a design metaphor are selected. A first prototype of the most important views or screens is created using a rapid prototyping tool. Based on this prototype, interviews and usability tests are conducted.

4. In the last phase, iterative design and refinement are conducted. The main view prototype is to be expanded, to create a realistic example of how it should be in the future, in an implemented full system. When the full system is implemented, then expert reviews are conducted, as well as full-scale usability tests. The last thing to do in the design process is to deliver the prototype and the specification of the complete system.

Since this is an iterative process, these four design phases will continue to be repeated.

3.3 Methods used

The methods used in the different design phases are to be presented in this chapter, as well as motivations for why these methods have been chosen.

Phase 1: Planning

The work started out in the beginning of August, initially listening to presentations to get to know Carmen and their systems. Since there is no literature written about the work in operation control rooms, there was no time spent on finding literature in the traditional way.

To identify the problem, several informal interviews were conducted with the employers at Carmen; the project manager, the supervisor and the rest of the Descartes team. In cooperation the research purpose for the thesis was formulated, and most important of all deciding upon the demarcations. When the planning was done, it was decided to use contextual design as the work method, since opportunities were given to visit the users at their place of work.

The purpose of this phase was also to understand the background and gain basic knowledge of the area. Available literature was collected, mostly internal documents from Carmen Systems, and published literature upon human factors and the work in different types of control rooms. Similar systems from other companies and a former master thesis project[11] (Armini, Wallenburg, 2000) were presented. Demonstrations were performed of the existing parts of the Descartes system, and the requirements of this.

This information was the background given to prepare for the first meeting with the users, the crew controllers of British Airways. The first phase resulted in a problem analysis, which was the foundation throughout the rest of the design process.

Phase 2: Analysis

Interview questions[12] and purpose for a visit to British Airways were carried out, in cooperation with the tutor at Chalmers as well as with a controller at British Airways. The questions were brought along with a recordable mini disc player, to gather verbal protocols.

At first there was a structured interview with a former controller who is now deeply involved in the Descartes project. Then there was an invitation to perform a user study of a planner, who explained his work and his tasks. Examples of how it was performed were showed, but it was unfortunately not really the kind of information that was looked for. After that there was time for the operations control, where the real users actually do their job. The people spoken to at British Airways were all very nice and very open to speak about their work. The invitation was to shadow the controllers while they were working, but unfortunately there was a very quiet day, and few incidents happened. The persons were interviewed with a combination of structured and unstructured interviews were a duty manager who was used to computers, and an older crew controller with a lot of experience but who was not that used to computers.

All the information from this first meeting with the users were brought together, and resulted in the user and task analysis.

[11] This thesis differed from ours in the sense that it focused more on the concept of visualizing crew alerts with an enhanced Gantt chart view. Furthermore, it was not a component in a larger system, as the operations monitor is in Descartes, but designed to function as stand-alone tool.

[12] See chapter 12 Appendix 12.1

Phase 3: Design

The main purpose of this phase is to communicate ideas and concepts. The choice of method to communicate this has to be based upon what the goals are, how the results are supposed to be evaluated. The purpose of the thesis is to conduct guidelines for an Operations Monitor for crew controllers, and the method to evaluate if the goals are achieved is to perform prototype tests on future users, even though the entire system will not be completed. Final usability tests were to be performed later on with contextual inquiries, and in between there would be one more possibility to meet with the users, giving the opportunity to choose contextual design as a method in an iterative design process.

Based upon the user need and analysis, and methodology for human factors in control room working environments, usability objectives were created. Guidelines for the concept and the design of the graphical user interface were initiated, and the basic monitor metaphor was developed. Basic interviews and tests were performed with a colour-blind person, to decide recommendations on colours.

The first step was to have a brainstorming workshop with a group of experts in Interaction design. Using a rapid prototyping protocol, pen and paper a first prototype was tested to a small expert group, the Descartes team. To decide upon the functionality within the interface, post-it notes were used. On each note every function that had ever been thought of was written, and while moving them around on a wall, decisions were finally taken upon main functions and sub functions.

Testing the prototypes in the right context with experienced users at a regular basis, increases the opportunities to communicate with the users, and to study users perform tasks in the scenarios.

Phase 4 – Evaluation

Later on the design work continued according to the iterative design process, where the method brainstorming was chosen to come up with even more paper prototypes. One of them was chosen to be developed into another rapid prototyping tool, a Photoshop picture as a horizontal prototype. Some basic functionality was added, to make it even more vertical to demonstrate a scenario. New tests were performed to the Descartes expert group, and to expert controllers at KLM using contextual inquiry. A third and to some extent full prototype was created for the final evaluation, with experienced controllers at British Airways. The fourth and final prototype is a full prototype.

The last part of the evaluation phase was to gather an analysis of the test results, and derive design recommendations from this. The initial questions were to be answered, and this master thesis report was finalised.

4 REQUIREMENTS GATHERING

A fundamental part of designing user interfaces such as to facilitate the users and their demand is to understand them and the context that they work in. The requirements gathering phase focuses on acquiring a deep knowledge of the users, the users' tasks and also their context.

4.1 User Analysis

The user analysis is the result of observations and interviews carried out, in accordance to the context design method described earlier in the method chapter, with crew controllers located in operation control centers at British Airways and KLM. It describes the user and their situation.

4.1.1 Target Group

The target group for the Operations Monitor are the crew controllers who work at an arbitrary airline company's operations control. As the Operations Monitor is not intended to be specific to a single airline's needs, but ultimately be possible to implement at any given airline, the Operations Monitor will be made as company-independent as possible, focusing not only on the crew controllers at British Airways and KLM, but on crew controllers in general.

4.1.2 Users

Crew controllers are common at all ages around 25 and up to retirement age, and nearly equally divided between the sexes. At different airlines, several crew controllers work together in a team, each responsible for a certain part of the roster maintenance, e.g. short haul and long haul. A crew controller duty manager is also present, for supervision. The team communicates orally between each other.

Often, the crew controllers have had other employments, e.g. as part of the cabin crew or luggage handling, at the airline company for which they work, prior to them being appointed the job as a crew controller. This means that the employee already has experience and understanding about working at an airline. If the employee is formerly a cabin crewmember, which is often the case, he will have a wide experience of the work and resources that will be administered in the tasks of the crew controller.

No actual education is provided for newly drafted crew controllers. Instead, the newly employed learns by shadowing and working closely with existing crew controllers, enabling them to become accustomed to their new work-tasks. During this learning period, a lot of experience and competence, which would have been lost due to retiring crew controllers, is preserved in the company.

Due to the nature of the work, a crew controller is a person with high stress tolerance, the ability to work with multiple information sources and problems simultaneously. Also, the crew controller must often phone crewmembers and handle sensitive issues, e.g. persuade crewmembers on leave to work extra. Therefore, the crew controllers must often act as negotiators.

4.1.3 Environment

The crew controllers are situated in the operations control section of the control center, which in turn is usually located in the immediate vicinity of the airlines home base airport. The operations control is essentially one large room, divided and distributed among the different resource areas of which it consists. Because of this, even on calm days, a constant murmur of voices can be heard throughout the premises. Furthermore, equipment such as computers, telephones and telex add to the noisy ambience, which is ever present in the operations control.

Figure 4-1 Parts of the KLM Operations Control Room

However, the disturbances are not all auditory. Due to the fact that no walls are present to effectively segregate the employees, a lot of the activity that takes place there is visible to others located in the same room. If the crew controller is focusing his attention on his current tasks, using for instance the computer, in the periphery of his vision he will constantly be aware of other peoples' movements and actions. Consequently, this leads to a certain degree of stress in the crew controllers work environment.

This kind of work environment does not need to be considered a disadvantage in all cases; if the crew controller is aware of what other people are doing and saying, it is easier to obtain an overview of current event, overhear important information etc. Since information is received by the controllers through external sources, like VHF, telephone, telex, and so on, they must handle auditory, visual and even tactile input, and instantly shift their attention whenever is required. These are not the only sources from where a controller picks up information. In the noisy control room, several noise patterns can be detected and a trained ear can perceive what is happening. The general level of noise tells the controller how much activity there is, in slow periods both people and machines does not make much noise. When the problems rise to appear, the noise level rises, since the controllers start talking and machines start making sounds. In peak periods it is a bit less noisy, since people are working and there is only room for essential conversations.

Controllers also learn to recognize specific noises, i.e. if there is a lot of activity in the AC-control (aircraft control), then there will most probably soon be a lot to do for Crew control. The controllers also rely on overhearing each other's conversations and phone calls, some phrases or even single words serve to produce and prepare particular actions and activities for colleagues within the control room.

4.1.4 Work Related

As the crew controllers work on the day of operation, they must often carry out their work within a tight time constraint. Solving problems that occur during daily aircraft traffic control rapidly is of the essence, in order to minimize financial losses and keep the passengers happy. The longer a problem is unattended, the more likely it is to impact later scheduled flights. However, the amount of work and stress experienced by the crew controller varies greatly; they could have a minimal amount of work for several days or weeks, when an extremely busy day suddenly emerges. Typically, the workload reaches its peak levels early in the morning and late in the afternoon. During the time in between, things are relatively calm.

During the day of operation, constant surveillance is necessary to address any issues that may arise in the air traffic situation. Therefore, there must always be one or several crew controllers present at all times, including at night time, although night shifts are usually not as long as the day shifts. The workload is usually low during the late hours.

4.1.5 Level of Competence

The crew controllers are highly experienced and specialized users who are very familiar with their tasks. They all use workstations as a part of their daily work and are therefore assumed to have basic to good knowledge in the usage of computers.

4.1.6 Relation to the System

British Airways currently utilizes Carmen Systems planning software in the early planning stages. Other employees have been involved in the design process of Descartes with Carmen since the early stages of development. Many people at British Airways are therefore familiar with the company name Carmen Systems.

At KLM, the crew control section expressed scepticism towards optimisation tools in general, as they had been given the opportunity to test and evaluate other optimisation tools, but with unsatisfactory results.

The crew controllers themselves, however, have no experience with the Operations Monitor, and in general do not even recognize the name Descartes.

4.1.7 Systems Used Today

The systems presently used in operations control are company dependent. However, they are all typically old and outdated, and it is common that text based systems are used in their work. Some crew controllers totally lack the aid of computer-based systems; instead, their work is carried out manually. The absence of up to date computer based support in operations control is much due to the fact that the airline companies are extremely complex organizations, making it difficult to replace current systems and tools without a great deal of effort and costs. Many attempts have been made just to fail because of the sheer complexity.

Certain cabin crew control groups use an 18-year-old system called Tracie, which is an entirely textual-driven tool. It is based on a large number of textual commands, with which the crew control performs actions. Tracie is extremely outdated and complex and also has serious limitations. Other systems in use include FICO, which is a 30-year-old flight information system, which produces textual information about weather, aircraft maintenance, flight conditions, and airport specifications.

Figure 4-2 FICO: Text based system at KLM

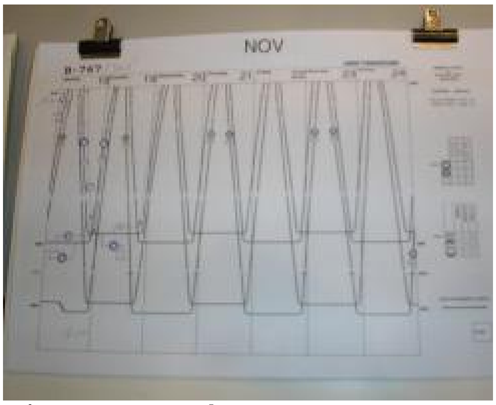

Figure 4-3 Paper chart in use at KLM

4.1.8 Expectations

The users are positive towards a new system as they think that the current system is out of date. Their current way of working is perceived as messy and complicated and they hope that an implementation of a new system will help the communication between the different areas.

The users hope that other areas (e.g. flight crew and cabin crew) can be integrated to increase the efficiency. Replacing the text-based system with a graphical one (with mouse input) is an expectation. Other wishes are to be able to sort out the information that is not relevant to the user.

Users are unwilling to act as input devices for a computer system of unknown benefit, or benefit only for the management not for their own work, particularly if data entry tasks distracts them or slows them down.

4.2 Task analysis

The task analysis, as with the user analysis, is the result of observation and interviews conducted in accordance to the context design method described earlier in the method chapter. It describes the tasks and actions of the crew controller.

4.2.1 What is the goal of the task / activity?

The ultimate goal of the crew controllers' work is to maintain the consistency of the current roster, which is passed down from roster maintenance. The crew controller handles the inconsistencies that are crew related.

4.2.2 What does the task / activity consist of?

On the day of operation, the roster is handed down from roster maintenance. Although the roster at this stage is intact and free of errors, there is still the possibility of disturbances. Crewmembers might still call in sick, flights can be delayed, and aircraft maintenance might be prolonged. The crew controllers' task is to monitor for disturbances in the roster that affect the crew, and repair them if and when they occur.

The disturbances encountered are often due to weather conditions, technical aircraft issues, crewmembers calling in sick and timetable changes. When repairing the effects of a disturbance, the crewmembers must create a solution. When creating a solution, a sense of backward thinking is required. At present, small disturbances mean a low degree of cognitive workload making it easy for the user to solve the disruption in his mind, without the aid of tools. When larger disturbances occur, pen and paper is used to keep track of facts. At some airlines, crew controllers have the aid of certain software tools, e.g. to help them compare the rosters of on-duty crewmembers and standbys, easily look up a crewmembers personal facts

To reduce the impact of necessary late changes, the crew controllers try to keep the start and end of a rotation as intact as possible. Also, when replacing crewmembers they try to use crewmembers that are already out in the field. Often, however, standby personnel are required; when a stand-by crewmember is used, he or she is ticked off from a list, making other controllers using the list aware of the fact that that crewmember has already been used.

When replacing a defect crewmember, standby crew is used. The crewmembers in standby have different states, with different readiness levels; they could be at home, staying at a hotel or at the home base control centre. The crew controller has the authority to change the schedule of a crewmember, assuming it does not violate any rules or laws. On some occasions, the crew rules can be violated at captain's responsibility; the captain will make the final decision. The flying program of a duty crew can only be changed in emergency situations. A routine morning problem for a flight crew controller is to tackle the morning aircraft availability info, with no time to react on the aircraft type substitutions.

Their main concern is to keep the flight-schedule, but they are also responsible for keeping the rules of each crewmember and each aircraft unbroken. They are under continuous pressure to find solutions, but also to find the cheapest solutions as possible and ensure that there will be no gaps. To perform their work they often have to break rules, and therefore the human judgement must be incorporated into the system.

Finding correct information and over viewing changes are the most fundamental part of the controllers' tasks. If a new interface would present too much information about an alarm or inconsistent flight, reading time and interpretation difficulty will increase. If too little information is presented, time will be spent finding that information from other sources, which increases the controllers' mental load to retain the necessary details.

4.2.3 Cognitive Workload

The crew controllers' work consists of several tasks and subtasks. These tasks are tackled by using different methods and techniques, which all have different cognitive aspects to take into consideration.

Activity	Surveying the current situation - Receiving information	Handling one or several disruptions	Communicating information to/from other parties	Implementatio n
Method	Communicate with other resource areas. Monitor for inconsistencies in the roster. Receive telex/telephone calls and sorting them.	Prioritize problems. Estimate to what extent the disruption will affect the crew. Solve the disruption.	Overhear co-workers discussion. Handle crew by telephone. Scream across the tables. Walk up and talk to/deliver a paper. Verbally update changes between shifts.	Transfer solution(s) from paper or mind to system. Inform the co-workers of the solution.
Cognitive aspects	Find the correct information. Sort out the information that is relevant. Handle multiple information sources. See both focus and context.	Be able to imagine different scenarios. Relating the problems to prior experiences.	Have in mind all the changes that can affect the next shift. Communicate across resource areas.	Determine which co-workers the solution will affect.

Figure 4-4 Cognitive aspects of the user's tasks

Scenarios

This section describes a typical scenario in which disruptions appear, quoted from Jamie Hobbs, a cabin crew duty manager at British Airways. The three letter abbreviations are IATA-codes for airports.

> "A crew are planned on the following itinerary:
>
> 1. LHR - MAD - LHR - GLA and night stop.
> 2. GLA - LHR - FRA night stop.
> 3. FRA - LHR - GOT night stop.
> 4. GOT - LHR - GLA - LHR and finish.
>
> Before the LHR - MAD sector the aircraft goes tech (broken) and we have to change to a new aircraft with a 2hrs 30min delay. What typically happens here is we work out the crew hours and find that they are still OK to operate LHR - MAD - LHR - GLA with a 2h 30min delay, so we leave them on the itinerary. Later in the day we work out that we have a spare aircraft / flight crew / and enough cabin crew on standby to re-crew the GLA flight and get an on time departure. When we do this the standby crew then take over the complete itinerary and the other crew are re-planned with whatever work is uncovered.
>
> The problems arise when the itinerary includes different aircraft variants (757, 767, A320 etc). The initial crew held all of these licenses but the standby crew probably hold some different licenses (757, 767 and 737, max 3 by law) or the standby crew are going into days off / leave and can only do part of the trip. This means that we have to start to break the trip into smaller trips, which uses more crew and other resources such as drivers to get the crew to and from the aircraft. Every time we break a trip there is a cost, the above itinerary cost 4 manpower days for each crewmember. However, if each night stop and the first and last legs were operated by different crewmembers it would require 5 crews using 8 manpower days."

4.2.4 Current problems

Following is some of the problems with how the crew controllers currently work. They are not listed in any specific order.

1. After having created a solution, the crew controller does not, to any large extent, consider the quality of it. This is mainly due to lack of tools, and the fact that there is limited time for creating different solutions and evaluating them. Currently, the crew controllers use their experience and intuition to find a more or less effective solution, and stick to it.

2. One of the largest problems and also one of the most essential parts of the work is to receive correct and up-to-date information. Currently, the crew controller receives the information he needs from many different sources. Another controller could give it to him orally, by phone, by telex etc. Getting information to people involved in a problem is extremely important, and at present the only way to achieve this is to physically speak to them, as the system does not support any means of communication. The problems concerning gathering the correct information in time has some impact on how satisfied the controllers are with their decisions and overall work. Since information concerning the problem at hand is not always received on time, it affects how the problem is handled and

increases the amount of stress.

3. There is a lack of communication between the cabin crew controllers, flight crew controllers and aircraft control. The reason for this is that they each have their own goals. Cabin and flight crew also have different unions, resulting in different industrial rules – different legalities. Also, the decisions made are too fragmented; i.e. typically flight crew, cabin crew and aircraft make their own decisions.

4. Because of the way the information is communicated, it is difficult for the controllers to make proactive decisions. Currently, the crew controller reacts to disturbances as they are reported, disregarding disturbances later in time while he solves the current one, even if the latter may be of higher priority. The decisions made are often a result of events that have recently transpired, and are therefore reactive in character. Working more proactively might lead to better solutions, and fewer resources being used.

5. By the time the roster made by the planners have reached the day of operations it has changed an estimated amount of 80%. This leads to the crew getting split up etc. and also adds to the complexity.

4.2.5 New ways of working

The integration of the Descartes system in the crew controllers' work will, needless to say, change the way they currently work. To which extent depends on how they decide to use the system in their daily work, as the crew controller is able to choose to what degree he or she wishes to incorporate the support of Descartes. Being alerted of one consistency via telephone, the crew controller might decide that it can be solved easily without involving Descartes. In this case, his course of work is unchanged, and can be conducted in the traditional fashion. In some cases, the crew controller might choose to use Descartes for monitoring purposes only, in which the information retrieval procedures change, but not the remaining tasks. Further, the entire Descartes workflow might be used when finding and repairing an inconsistency in the roster; using the Operations Monitor for information retrieval, the solvers for generating solutions and ratings and the Disruption Manager for evaluating the different options and communicating them to the different resource areas.

However, since this thesis focuses solely on the Operations Monitor, assessing the impact on the crew controllers way of working must be made from the basis of how the Operations Monitor, and not the remaining components of Descartes, will affect it.

As with the entire Descartes system, the crew controller can choose to which degree he wishes to use the Operations Monitor. The current way of receiving notice of an inconsistency, defining its scope and retrieving information concerning it and the effects will be, not necessarily entirely replaced, but complemented by the Operations Monitor and the possibilities which it provides. The Operations Monitor could in many cases replace the crew controller's many information sources as a single alternative, and instead of actively searching for relevant information; this could be obtained by simply consulting the Operations Monitor.

Also, the fact that the Operations Monitor can present alarms which happen in a wide time range, the users scope of the disturbances that have and will occur during the time of work will be much broadened. Consequently, there is a much better possibility of working proactively.

4.3 Usability requirements

The requirements placed on the usage of the system are derived from the user analysis.

4.3.1 Learnability

1. A crew controller should be able to identify, examine and understand the scope of an alarm and its consequences, to the degree that he or she would be able to solve the alarm the traditional way, within one day of using the Operations Monitor.

2. The crew controller should be able to create a disruption and send it to the solvers within two days of using the Operations Monitor.

4.3.2 Flexibility

1. The crew controller should be able to use the Operations Monitor as a tool to work in the traditional fashion (without solvers or a Disruption Manager) as well as use it as an integrated part of the entire Descartes system.

4.3.3 Throughput

1. The usage of the system should reduce the time it takes for the crew controllers to see the scope of an alarm, and what areas are affected.

2. The system should support the user so that he may be allowed to choose which alarm to handle next.

4.3.4 Attitude

1. 80% of the users should answer YES to the question: “In your opinion, do you consider your work easier with the Operations Monitor?”

2. 80% of the users should answer YES to the question: “In your opinion, do you consider it easier to retrieve information about the effects of an inconsistency in the roster?”

3. 80% of the users should answer YES to the question: “In your opinion, has the usage of the Operations Monitor affected your decision-making in a more proactive way?”

4.4 Functional requirements

The requirements placed on what functionality the system should offer is derived from the task analysis.

1. The Operations Monitor should be able to visualize alarms.
2. The Operations Monitor should be able to visualize the details of alarms
3. The Operations Monitor should be able to visualize data from the airline’s databases, i.e. crew schedules, flight schedules, aircraft information, standby lists etc.
4. The data visualized in the Operations Monitor should be updated in real-time.

5. The Operations Monitor should be able to show a history of events.
6. The Operations Monitor should be able to create a disruption, based on the information of the alarm, and send it to the Disruption Manager.

The functions which should be a part of the Operations Monitor is listed below (no specific order):

- **Assign alarm to self**
  Tag an alarm with the crew controller's name.
- **Create disruption from alarm**
  Create a disruption that can be sent to the Disruption Manager
- **Sort alarms after attribute**
  Sort the alarms after optional attribute, e.g. type, reason, time etc.
- **Aircraft schedules**
  Provide Gantt view[13] of aircraft schedules.
- **Key indicators**
  Provide key indicators for important resources, e.g. number of crewmembers currently "in the air", number of standbys, number of standbys used etc.
- **Change time scope**
  Changeable time span for viewing alarms, e.g. 24h time span, 5h time span etc.
- **Weather report**
  Predictions of the current and future weather conditions.
- **Shift-change report**
  A report of transpired events; problems and their solutions.
- **Standby list**
  A list of standbys available, and their status.
- **Check-in status**
  Status of crewmembers. Have they checked in or not.
- **Messages**
  Send messages to other controllers, in the same or another resource area
- **Disruption Manager**
  Open the Disruption Manager
- **Clear screen**
  Clear the screen where several processes might be running, to start something else, when a problem is handled.
- **Split screen**
  Split the screen into several parts, so that if working with several alarms, they can be compared
- **Search**
  Search for database information. Crew schedules, aircraft schedules, standbys etc.
- **Current GMT Time**
  Show the current time in GMT.
- Information about crew hours and related points.

[13] A Gantt chart is a horizontal bar chart developed as a production control tool in 1917 by Henry L. Gantt. Frequently used in project management, a Gantt chart provides a graphical illustration of a schedule that helps to plan, coordinate, and track specific tasks in a project. Gantt charts may be simple versions created on graph paper or more complex automated versions. A Gantt chart is constructed with a horizontal axis representing the total time span of the project, broken down into increments (for example, days, weeks, or months) and a vertical axis representing the tasks that make up the project. Horizontal bars of varying lengths represent the sequences, timing, and time span for each task. http://whatis.techtarget.com/definition/0,,sid9_gci331397,00.html

5 INFORMATION VISUALIZATION

The Operations Monitor is the component in *Descartes* where the controllers will attain the information they need to carry out their work. The controller works with a significant amount of data, both dynamic and static, and the Operations Monitor must therefore be able to visualize a considerable amount of information to support the controllers. It is important that this information is readily available to be accessed at any given time, as quick decisions require fast information retrieval. Still, caution must be wielded to prevent creating a large cognitive strain due to an overload of information, which would consequently degrade the quality of the controller's work and influence it in a negative manner.

All this huge amount of data, which is available to the controllers to work with, would be easy to present to the user, although it is not certain that this would bring understanding, i.e. information. It is important to make a clear distinction between data and information, as it is the derivation of information from the data that is difficult, which we attempt to ease by means of visualization tools (Spence, 2001).

The controller's work varies in the sense that it sometimes requires attention to detail, and other times it calls upon an overview of the situation, and analogously, information, which is relevant in one situation, might be dismissible in another. The demands on the Operations Monitor are bound to change depending on the nature of the work the controller is performing at the time, and the Operations Monitor must therefore take this into consideration and be flexible enough to support such work. These conditions introduce a situation where a great deal of consideration must be taken to what information is presented to the controller, and how/when it is visualized. The Operations Monitor must therefore strive to be able to present relevant information for the situation at hand.

A problem arises, however, which is how relevance is defined, and how to effectively suppress irrelevant information, because the relevance of presented information is based on the situation at hand. Another concern is the fact that currently, the controllers work in an environment with many information sources, ranging from textual feedback from their current computer systems to overhearing oral conversations between other controllers in the room. The Operations Monitor has the intention of being able to present situation-relevant information to the controller, but it would be naive to assume that the system could totally replace the current ways of gathering information, and the ideal system would take this into consideration.

The field of information visualization deals with these issues by investigating methods to graphically represent important and relevant information. These methods have however been mostly focused on situations where the user's work is centred solely on the visualization, i.e. his/her work task is to monitor and interact with the information that the system visualizes (Somervell et al, 2002). In the controllers' case (and in most other professions) this is not true, and it is therefore important to understand how to convey the intended information in a way that has minimal impact on the user's other tasks. Given that the user's work tasks do not always demand immediate interaction with the Operations Monitor, it is conceivable that it could also serve as a form of secondary display, i.e. peripheral visualization, during these times.

5.1 Focus and context

A common problem when attempting to visualize a large amount of data on a screen is that of showing detailed information concerning an object while at the same time providing an overview. For example, when reading a printed document, one is able to spread the different sheets of paper across a table, effectively obtaining an overview of the entire document (e.g. number of pages, different chapters and titles etc.), or if the document is bundled this overview can be obtained by flipping through the pages. Focusing on and reading a single page conveys the detailed and actual information. In this situation, the focus+context collaboration increases our overall comprehension of the document, and prevents us from "getting lost" (Spence, 2001). Because the common document viewers on computers are able to display only one page at a time, i.e. present only the focus and ignoring the context, reading for instance a manual on a screen is more difficult than reading the same manual as a book. Although, on a screen, a rudimentary overview might be obtained by glancing at the position of the scrollbar to see one's current position relative to the entire document.

In the event of a complication, to effectively solve the situation at hand, a controller needs not only see the details, such as which flight or crew the complication affects, but also surrounding information such as how it will impact the schedule for the rest of the day. The focus+context field addresses these issues by attempting to retain both context and detail.

5.1.1 Different techniques

Similar fields of information visualization include the detail+overview technique, which also address the problem of attaining both a detailed view and an overview. This technique, however, breaks down the information into different views, in contrast to the focus+context technique, resulting in degraded performance due to cognitive load which the visual searching and higher use of memory causes (Card et al, 1998).

The focus+context technique is based on three assumptions (Card et al, 1998): First, the user needs overview and detailed information simultaneously. Second, the information needed in the detail and overview may differ. Third, these two types of information can be combined within a single display. The technique is founded on the principle that more screen space is available for the detailed view, while at the same time retaining the relevant peripheral context, giving the user a pointer of where to go from there.

The need of having context information co-existing with details of the focus (hence the name focus+context) has attained a great deal of attention the last decades, and a multitude of techniques have been developed to address this requirement (Spence, 2001). One technique that has evolved into numerous others is the *Bifocal Display*. Its concept is to treat the information as a long horizontal strip of paper, which is bent around two posts so that the entire strip is still visible, although the sections of the strip from the posts and outward will be distorted and provide the context, while the center between the posts will serve as the focus (Spence, 2001).

The *Bifocal Display* implements information distortion in a single dimension, namely the X-dimension, but it is also easily possible to distort across the Y-dimension. Combining the distortions in both the X and Y-dimension renders yet another alternative, which can be very useful in other fields of application, for instance when visualizing maps.

5.2 Visual Output

The graphical user interface for the Operations Monitor will, as most other applications, be presented visually (the most common source of output) on a computer screen, as no other output (such as tactility) is conceivably an alternative for our purposes. The decision of using a computer screen for the output source imposes a number of considerations to take into account, such as how adequate the lighting in the room is and how strained the perceiving eyes are.

Other more hardware-dependent issues are the update frequency and resolution of the monitor, which for example influences how difficult it will be to distinguish graphical objects or characters from each other. Reading from a screen also lays the foundation for other disadvantages, some of these are (Preece, et al., 1999):

- Low contrast between the characters and background
- The emitted light from displays is harder to read than the reflected light from a paper. Glare also reduces readability
- There is a reduced hand and body motion compared to paper, which might be fatiguing.
- Being unfamiliar of displays can increase stress.

User's needs in terms of visual displays bears three important aspects, namely the physical aspects for perception (e.g. brightness and the selection of colors with regard to color-blindness), the way the information is displayed (e.g. size of objects and order of items) and the way the information is used (Preece, et al., 1999).

5.2.1 Color-blindness

Considering the fact that 1/12 of the male population has some kind of color-vision deficiency (Rigden, 1999), it is imperative that, if color is chosen to be an informationcarrier, great consideration of the colors chosen is taken into account during the design process. There are basically two types of color-deficiencies that dominate color-blindness (Rigden, 1999); *dichromatic* vision, in which one of the three color-receiving pigments is missing (usually red or green), and *anomalous trichromatic vision*, where all pigments are present, but shifted in color (red shifted towards green or green shifted

Figure 5-1 The photograph on the left is how a person with no color-deficiencies would perceive the fence and sign, on the right is how a anomalous trichromat would see it.

towards red). The anomalous trichromatic deficiency does not only affect the way red and green is perceived, it also affects how one perceives all colors which vary from each other by the amount of red or green. An easy approach is to design for the people with dichromatic vision, as this is the "worst" case of color-blindness. Consequently, the lesser degrees of color deficiency will also be well accommodated (Rigden, 1999).

5.3 Cultural aspects

Making a user interface globally approved, as the Operations Monitor is intended to be, requires the designer to be aware of the implications that his or her design choices will have on different cultures. The interface design and interactivity reflects a cultural sensitivity and understanding of the target audience (Barber and Badre, 1998). Colors, for instance, have a dramatically different impact depending on which culture the users are a part of. In the article, *Cultureability: The Merging of Culture and Usability*, Barber and Badre present a color-culture chart, which illustrates what meaning different colors could have in different cultures:

Colour	China	Japan	Egypt	France	United States
Red	Happiness	Anger Danger	Death	Aristocracy	Danger Stop
Blue	Heavens Clouds	Villainy	Virtue Faith Truth	Freedom Peace	Masculine
Green	Ming Dynasty Heavens	Future Youth Energy	Fertility Strength	Criminality	Safety Go
Yellow	Birth Wealth Power	Grace Nobility	Happiness Prosperity	Temporary	Cowardice Temporary
White	Death Purity	Death	Joy	Neutrality	Purity

Table 5-1 Colours' meaning in different countries.

Looking, for instance, at the colour red, which for most westerners implies something dangerous, is in China in fact associated with the feeling of happiness (Barber and Badre, 1998). Consequently, making an object in the user interface red to symbolize some kind of danger or warning would, in China, have a different effect on the user than desired.

The cultural difference in user interface perception is by no means only restricted to the effect of colours. Another significant influence is in which manner different cultures would read a book, as certain cultures, e.g. Arabian countries, read from right to left. In others, for example China, they read from the top of the page to the bottom. It is easy to imagine the importance of the placing of the different building blocks, which the user interface is composed of, to avoid confusion. It must be mentioned, however, that due to the dominance of western software and their user interfaces, a lot of cultures have accepted that specific way of perception. For instance, Arabians would traditionally read calendars from right to left, but due to them using the western equivalence, they are now used to reading them from left to right.

Icons, too, can pose to be a contradiction; an icon can imply two very different things in depending on the culture, as a metaphor may not be consistent in two different countries. They are often misunderstood, or not understood at all, by users in certain countries. Some of these icons are listed here (Henning, 2001):

- The yellow file folder does not look like the file folder used in many other parts of the world.
- The mailbox icon is not understood in many countries.
- The upheld hand, meaning “Stop” in many countries, is considered a rude gesture in Mediterranean countries.

Icons and their metaphors are used to facilitate the user’s experience of an interface, but if misused, they can cause more harm than good.

Usability must be redefined in terms of a cultural context, as what is “user friendly” for one culture can be vastly different for another culture (Barber and Badre, 1998).

6 PROTOTYPE DEVELOPMENT

In this chapter a description of the development of the prototypes will be given, starting with an overview of all the phases. The exact changes in each step as well as the design proposals and user tests will be described in chronological order.

6.1 The development process

In the beginning, the background research and analysis was performed. In this early stage, one of the most important aspects that came up was to change the definition of the crew controllers work task; the task is to solve alarms, not spending time detecting them. This became the basis for the entire design, through all of the prototypes.

At an initial visit at British Airways, the following information in a system that would support the work from the users personal point of view were revealed to us:

- To what destination are the flight / cabin crew and aircraft designated to a service at any point during the day. The system would be real time and would take into account any delays affecting these resources (aircraft presently elsewhere with a slot delay or flight crew elsewhere on a tech aircraft). This would be useful on the example as there is no point re-crewing the night stop if it will be operated on the same aircraft and will be late anyway.

- It would be useful if all of this information were available through clicking on a flight number on the screen.

- What standbys is there that could operate the itineraries with the licenses required; there is no need to see other licensed crew but to have the facility to do this if required.

- Where delays are in the system and to be able to easily identify the nature of the delay while dealing with tech aircraft in a different way to slot delays.

- Crew hours are often an issue so if it would be possibly to see what crew hours are without the need to make calculations, both legal and industrial.

After creating the analysis, and considered the users personal opinions and wishes, there was a workshop with a group of experts in Interaction Design, where findings from the user and task analysis were presented. The purpose of the workshop was to discuss the initial design, but in the end it became a very useful discussion on the controllers new role using the system, and what new ways of working there would be. From this discussion, where new aspects were brought up, ideas to guidelines for the initial design were derived.

The following table shows the prototype development phase:

Proto-type #	Design Material	Purpose of development	Purpose of testing	Test Group
1.0	Paper	To attain a quick visualization of the new work flow/tasks of the crew controller To give a concrete form to our definition of alarms	Check the technical possibilities of alarm handling	Descartes Team
2.0	Paper	To decide the relation between the alarms and their specifics.	Check the interaction	Ourselves
2.1	Photoshop Image	To digitalize prototype 2.0 Before software implementation be able to decide upon graphical issues	Check the functionality of the interaction	Ourselves
2.2	Visual Basic Software	Be able to run a scenario by solving a problem the traditional way	Check the usability and functional requirements that do not involve Descartes	Descartes Team Crew Controllers KLM
3.0	Visual Basic Software	Be able to run a scenario using only the Operations Monitor, but also with the interaction of the rest of Descartes	Check all requirements	Crew Controllers, British Airways
4.0	Visual Basic Software	To enhance the overall graphical look and the interaction	---	---

The following chapters will describe in detail the different stages of the prototype development, the tests and results.

6.2 First prototype

The purpose of the first prototype was to visualize ideas, to give a concrete form to the definitions of alarms, which we had decided upon. We wanted to be able to discuss in what direction the work process was heading for, and explore with the Descartes team if the basic ideas of the concept was actually technically possibly. The purpose of the prototype was also to be a tool to visualize the new role of the controller; to deal with alarms not spending time detecting them.

The first prototype was initial sketches in paper form. The design ideas were based upon the wish to explore new ways of visualizing large amounts of data, as well as sorting out information for the user. It was experimented with, at least within this business area, unconventional methods, with shapes, dynamical sizes of graphical objects and colors. The first and most inspiring example looks like this:

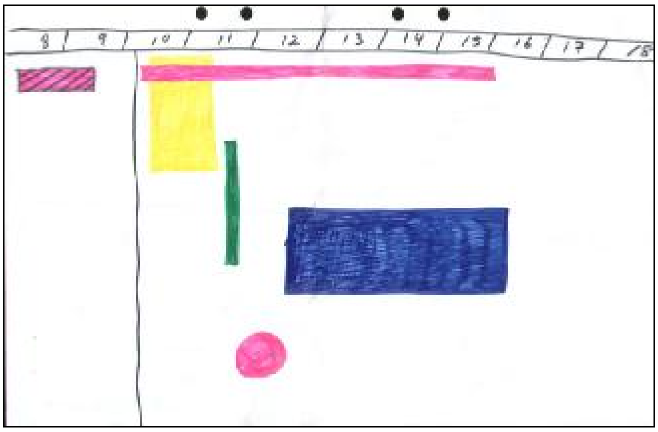

Figure 6-1 The first prototype

- The upper bar is a timeline, where each box is one hour, from 8 am to 6 pm. The vertical black line deriving from the bar indicates the present time, meaning the time is 10.15 am. Since the work is heavily time critical, it was decided to let the alarms being sorted in order of when to occur in time. The time bar and the present time is the consistent frame of the alarm information.
- The space at the left of the vertical present time line is past time, and the space on the right side is time to come.
- The colorful boxes are alarms. The color represents the type of alarm; pink, yellow, blue and green represents delays, cancellations, defects and massive. The colors are chosen just to separate the different types, and are not considered from a design perspective.
- The shape reveals if it is an alarm; presented as a box, or a Disruption Manager message from another resource area; presented as a circle. The size of the objects indicates the impact of the alarms. The horizontal length of the object represents for how long time the alarm will have an impact on the operation, and the vertical depth reveals how many crewmembers are affected by the alarm.
- The striped object to the left is an alarm that has been taken cared of; the problems triggered by that alarm are solved.
- The diagonally positioning of the objects indicates when they are to happen in time.
- The idea is that when an object is highlighted, by moving the cursor over it, more detailed information will be shown in a pop-up menu, meaning the type, the flight number, number of crewmembers, the crew id and so on. All this information would be clickable links, leading to new pop-up windows with even more additional information.
- The tool provided for the interaction is the mouse.

The purpose was to give the user an instant idea of what there is to deal with and when the alarm will occur. By immediately visualizing the impact and the type of the alarm, it would reduce the cognitive load for the user to decide in what order to handle the different alarms. This would basically be an overview, and at the same time provide the user the opportunity to find the necessary details of the alarms to be able to create disruptions and solve them.

6.2.1 Workshop with expert group

The aim of the workshop was to receive feedback on the concept and the new way of thinking concerning the controller's role; to check the technical possibilities of alarm handling. The ideas and findings were presented verbally, and to demonstrate an example the first prototype was drawn on the white board. The workshop took place in a meeting room at Carmen Systems, and present were members of the Descartes team, well known with the Descartes concept. The workshop was not recorded, but notes were written during the discussions.

When the prototype idea was demonstrated to the Descartes team, a lot of positive feedback was given for experimenting, but there was also a bit of resistance for dropping the Gantt view of the aircraft rotations; the traditional way of visualizing information in this business area. They thought that the view could have a purpose, if it was a complement to a Gantt view of the take offs. It was found that we were on the right track when changing the definition of the controllers' task within Descartes, from over viewing and detecting alarms to concentrating on solving them.

A discussion was started, about how the alarm server and rule server does detect alarms, what information is within them, and what the possibilities to detect patterns for grouping alarms are. Since these servers do not yet exist, we presented our assumptions based upon the requirements for the servers available at SAS (SAS, *Request for Proposal Regarding Traffic Control Systems for SAS Traffic Control*, 2001), information retrieved from interviews conducted with the responsible of those (Appendix 12.2), and there was a greater understanding for the problems connected to this when we left the meeting.

6.3 Second prototype

Based on the discussions from the Descartes workshop, the prototype was developed even further. Concentration was put on brainstorming creating sketches on paper, again and again, creating both large and small changes to the original idea, still keeping the new role of the controller in mind. The main reason that the prototype was developed was to decide the relation between alarms and their detailed information.

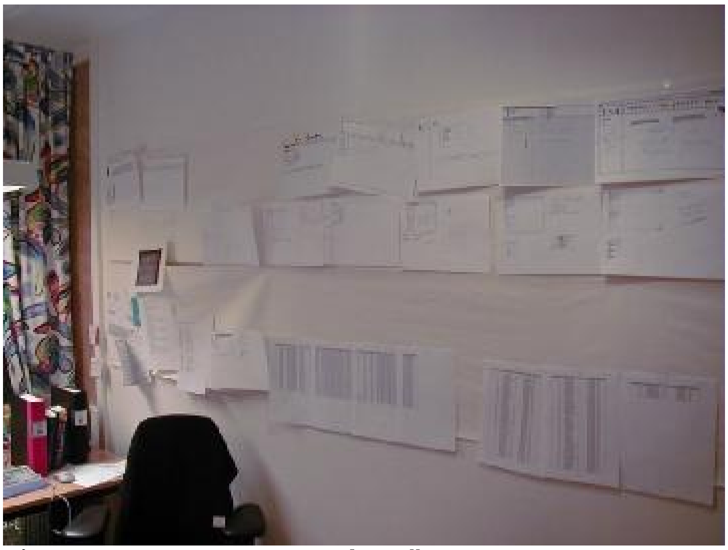

Figure 6-2 Paper prototypes on the wall

When an idea came up that was agreed on, it was put aside and new ideas were tried.
The focus of the tests was to experiment with the interaction of the prototype. Finally the office walls were covered in sketches. In the end, on the table there was one single

sketch left, which was agreed to implement since it was satisfying in accordance of the requirements.

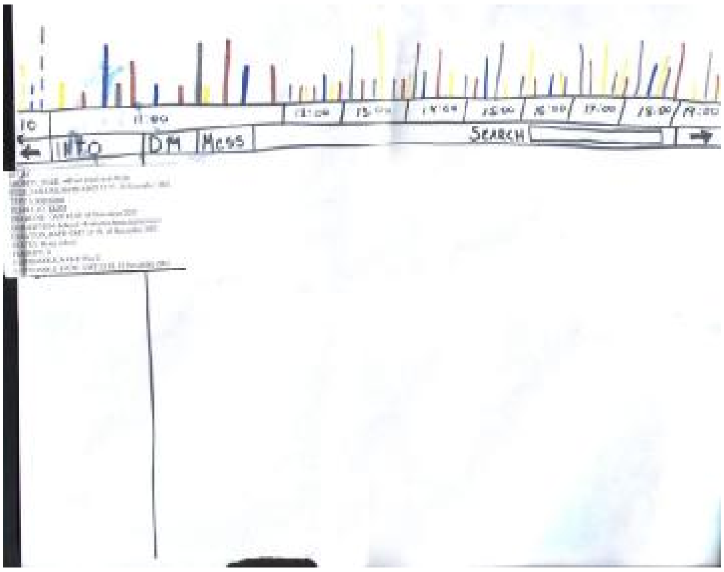

Figure 6-3 Prototype 2.0, paper version

To be able to start designing the prototype, a few assumptions about alarms must be made. Since alarms and the specifics surrounding them are yet to be determined, these assumptions may turn out as impossible to implement.

6.3.1 Alarm Creation

The following assumptions about creation of alarms are decided upon for the continuing of the design work, based upon specifications for the alarm handling servers and interview with Bo Vaaben[14]; responsible for a similar server at SAS.

- Alarms can be created manually or generated by the alarm server. Ultimately, we assume that the alarms are created in a "black box", regardless of from where it came or how it was created.
- An alarm will not propagate to an infinite number of additional alarms, i.e. the alarm at hand deals with itself and not the consequences it has.
- An alarm of larger type, i.e. airport closure and weather, will contain information about what its impact will be on flights etc.
- Alarms are presented on the correct resource area's Operations Monitor.
- When creating a disruption from the Operations Monitor, the information required is that which is stated under the info block in the "DTD for a disruption".

The purpose of development of the prototype was mainly to get a digitized version of the previous paper prototype. Also, this digitized prototype would be useful to be able to decide upon graphical issues, before implementing it as a functional prototype in a

[14] See chapter 12 Appendix: *12.2 Interview questions with Bo Vaaben*

programming language.

In this prototype we were more focused on what functions there should be, how it should communicate with the rest of Descartes, and we tried different scenarios. The sketch looked like this:

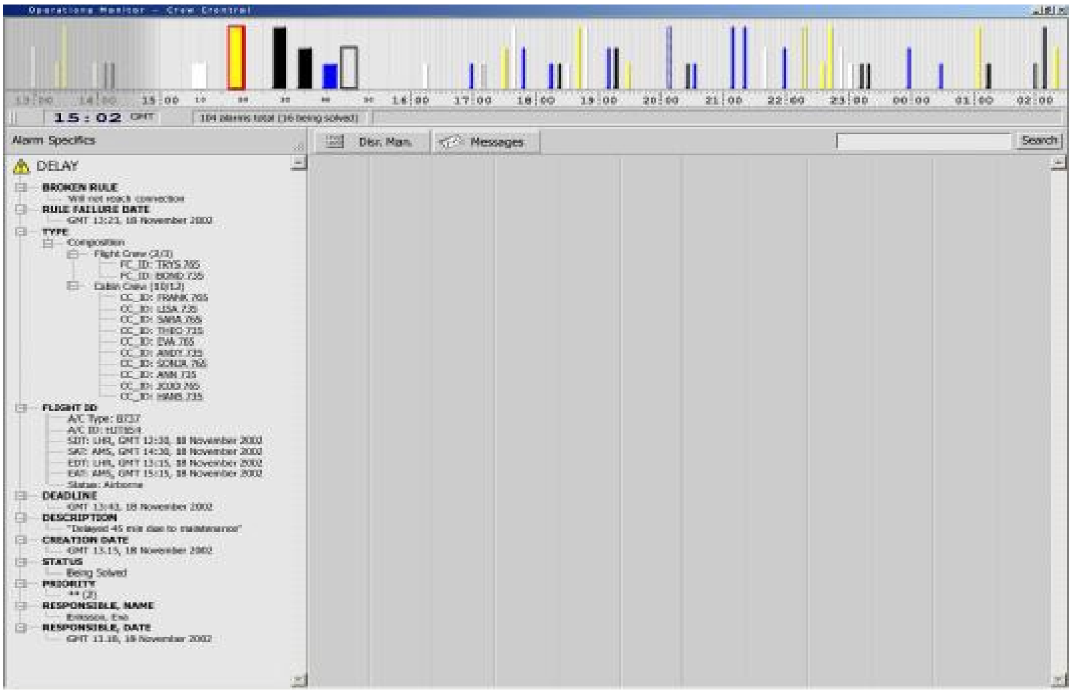

Figure 6-4 Prototype 2.1, made in Adobe Photoshop

The prototype consists of three different areas; the alarm overview (on top), the detailed alarm overview (to the left), the desktop area and the menu bar (to the right). The appearance of the Operations Monitor is based upon a static frame consisting of dynamic data surrounding a workspace area. To always have the frame visible, meaning the alarm view and alarm specifications, is to never let the user loose the overview of the alarms and what problems there are to solve, even if the users focus is involved in a certain detail solving a problem.

The alarm overview

On the top there are vertical bars of different length. These bars represent the alarms; this is the alarm overview, where the color is depending on what type of alarm it is. The possible types of alarms are as follows:

- CASUALTIES – maintenance, crew sick
- DELAY
- CANCELLATION
- WEATHER
- CLOSURE – Airport
- OPERATIONS-DEFECT – partly invalid crew or AC

In the design, the numbers of types are reduced to support the users cognitive load. Casualties and OP-Defects are considered to be related types, they are different in the sense that they are treated differently, but they are related in the sense that something or someone is not fully operational. Weather and closures are also related, in the sense that they affect a great number of flights and crewmembers, they have a heavy impact on the operations and are highly prioritised. The types of alarms visible in the interface overview are:

- DELAY
  CANCELLATION
  DEFECTS – casualties or OP-defects
  MASSIVE – Airport closure or bad weather

- These four types of alarms are to be presented as a vertical line in four different colours, to support the overview of what types of alarms are to happen, meaning what work tasks there is.

- The lengths of the objects represent the scope of the problem

- When implementing, it started off with creating a picture in Photoshop, to decide upon sizes, colors and so on. A color scheme was created based upon the ISO rules, and performed an interview and a test with a colorblind person. It is always a risk to present information through colors, and the general design guidelines are to present information with a maximum of four basic colors, and finally colors that worked well with colorblindness as well as with the ISO standard was found; yellow, white, blue and black.

- The positioning of the graphical objects in the x-axis indicates when the problem will occur, according to a timeline, which is divided into partitions of one hour. If there are a lot of objects within the same period of time, the time line can be stretched out to minutes, to provide a clearer view. The time line is scroll-able, presenting information about what alarms there are in the next 24 hours, as well as what alarms have been handled the last 24 hours. In the main view, 12 hours will be presented automatically.

- The present hour is automatically enlarged, and the objects within it are therefore wider then the others.

- The status of the alarms is unsolved, being solved and solved. While unsolved, the objects are filled with the color presenting its type. When being solved, the object will become empty keeping the color in just the frame, to let everybody know that somebody is handling it. Finally, when the problem is solved, then the shape will be striped, in the original color. The purpose of keeping solved problems within the view is for the user to be able to understand why things are the way they are now, to understand how the flow of the operations has been affected by a prior solution.

The desktop area

Below the menu bar, on the right side of the detailed desktop view, a large blank area appears. This is meant to be a work area, where additional information can be presented and other programs, i.e. the Disruption Manager, can be started. In this way, the controller never looses the overview of the alarms while solving a specific problem or working with something else. The alarm overview and the detailed desktop view becomes the static frame around the changing work area.

The detailed desktop view

Below the strictly time based overview, there is a desktop and an alarm specification window. When marking an object in the overview, by dragging the mouse above it, more detailed information about the alarm will appear in the alarm specification window. If the user decides to handle that alarm immediately, one click with the mouse will make the information stay there. If the mouse instead is dragged on to another object, then the detailed information about the new alarm will appear instead. The detailed information to appear is:

Alarm Attributes

- BROKEN_RULE – name of the broken rule
- RULE_FAILURE_DATE – date and time where the rule fails
- CREW_ID – id of the affected crew member
- FLIGHT_ID – id of the affected flight

- TYPE – the type can be: crew legality or composition
- PRIORITY – priority of the alarm
- STATUS – unsolved, being solved, solved
- CREATION_DATE – date and time of creation
- LAST_UPDATE – date and time of last update
- DEADLINE – after this date and time, the alarm is not possible to attend to

- DESCRIPTION – remark from the rave rules or additional information from the person who created the alarm manually

The following will be filled automatically by the system, as soon as a controller has started handling the problem.

- RESPONSIBLE_NAME – name of the person who is dealing with the alarm
- RESPONSIBLE_DATE – specifies the date and time when the responsible person was assigned to solve the alarm

The crew ID and the flight ID will appear as links, and if a link is activated, that schedule will be visible in a graphical presentation in the desktop view. To keep the view of the roster, click the mouse once. To view another roster, scroll the mouse to that link.

The menu view

Above the desktop view, there is a menu bar. The menu bar has a link to the Disruption Manager, a clock presenting date and GMT-time, a chat link and a search function.

- If the Disruption Manager button is activated, the Disruption Manager will appear in the Desktop view.
- The purpose of the search function is for the user to find information about something that is not presented as an alarm, and the result of the search will be presented in the desktop. This function provides the user to look up database information about a crewmember, flight, aircraft, airport, etc.
- The possibility to chat and send messages within the network is an additional function, perhaps not necessary for the controllers' task, but it supports the

communication within this large work place.

6.4 Prototype 2.3

Once we had seen the prototype as a Photoshop document, we started to further develop and implement the interaction in Visual Basic. The purpose of this prototype was to be able to provide the means of actual interaction, so that a scenario could be conducted, where the user could solve a problem in the traditional way of working.

Based upon our experience from British Airways as well as information about the content of an alarm, decisions were taken upon what information should be visual in the different interaction steps.

The design changed in some details:

- § A stand by button is added since there seemed to be a need for a stand by list with quick access
- § There is no longer a red frame around the object that is being handled since the color red is associated with danger and alarms and all of the objects are alarms. The colors of the alarms; white, black, blue and yellow was decided upon since they does not change in appearance when having a defected color vision[15].

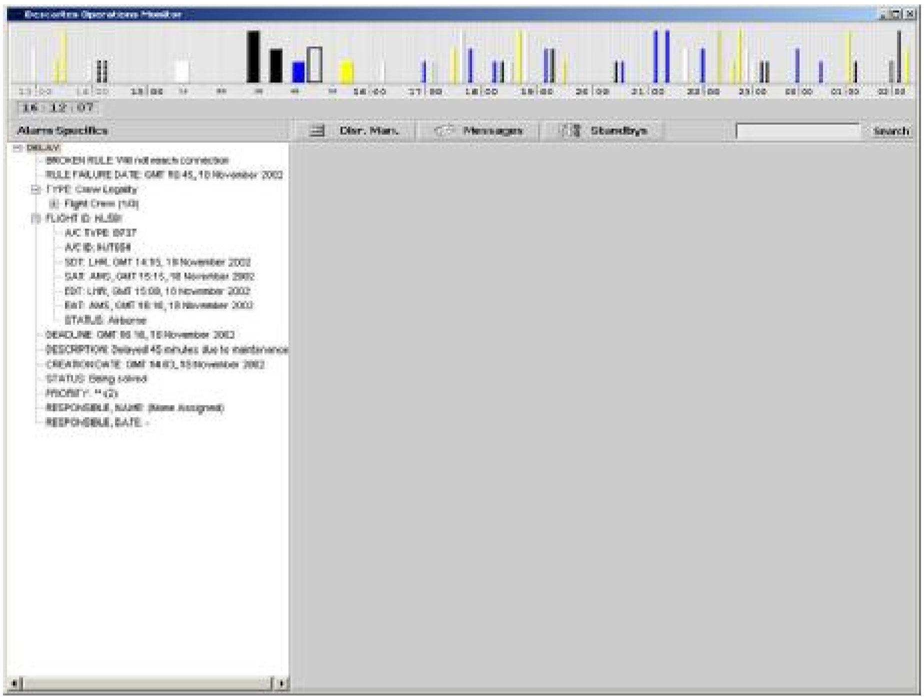

Figure 6-5 Prototype 2.2, made in Microsoft Visual Basic

- § The background colors have been changed, to make an even more distinct separation to the three different areas of the view.

A scenario was created, with two different possibilities to solve it, using the traditional way or the Disruption Manager. Finally there was a prototype with possible interaction in six steps, containing static and pre-determined information.

[15] Tests have been performed by applying colour palettes of different dichromatic types of colour deficiencies (Rigden, 1999). http://www.labs.bt.com/people/rigdence/colours

6.4.1 Workshop with expert group

The aim of this second workshop was to further discuss the ideas from the previous workshop, now graphically presented in prototype 2.3. The workshop took place in a conference room at Carmen Systems, and was recorded with a mini disc player. Present were members of the Descartes team and some other interests.
The background of the prototype was presented, and then there was a demonstration of the design and all the details within it, and finally a scenario showing how to solve a problem the traditionally way and with Descartes. The scenario was a delayed flight affecting connecting flights for twelve members of the crew.

This meeting went very well, there were no expectations on an interactive implemented prototype. New ideas came up to discussion, mostly concerning the technical possibilities of alarm handling. The following functions were discussed too:

§ The ability to sort the alarms in different ways; i.e. geographically or by type.
§ A list of key indicators, meaning the number of available aircrafts, stand by's, crew on leave and so on.
§ Individual bids[16] should appear in the crew in the personal crew information.
§ A map presenting where all the flights are.
§ A Gantt chart of the aircraft rotations.
§ Scenario possibilities.
§ Weather report.

In the end an invitation to join in with the other parts of Descartes for the final presentation at British Airways in London came up. Even though this suggestion would mean a lot more work, this was accepted since it was a great opportunity to perform final tests and to continue developing.

6.4.2 Testing second prototype at KLM

The prototype was brought to KLM for demonstration and to perform some tests, the aim of this trip was also to require additional information to the analysis, just to be certain that it would be company independent. Also, the testing of the prototype was focused on checking the consistency of the usability and functional requirements. Only the requirements that did not involve the rest of the Descartes system would be tested.

The controllers at KLM handles problem concerning the following resources ("The airline business", 2001):

§ Fleet size: 97
§ Employees: 30 253
§ Passengers: 16 million

Before leaving for KLM, goal of the tests were prepared and questions to achieve these goals. The questions to be answered were:

q Is it valuable to always be able to monitor all problems?
q Is it valuable to have graphical presentations of the alarms?
q Is it possible to solve tasks in the traditional way, not using solvers?
q What functionality is missing?

[16] Wishes from the crew, e.g. not work on Sundays, or a night stop at a special location on a certain date.

- What information is missing?

The tests were performed three times at the controllers' desks in the very large and noisy room that is the KLM Operations Control at Schipol Airport in Holland; one sales representative at Carmen and one from KLM arranged the visit. The three test persons consisted of one manager of crew control (former crew controller), one crew controller and one roster maintenance person. The tests were performed from laptops placed on the table in front of the test persons.

When the tests were performed, two different designs were shown, to give the test persons a referential system. Initially a brief explanation of the concept of Descartes was given, and then the old master thesis project (Armini, Wallenburg, 2000) was shown, where a problem was demonstrated and solved. The concept was explained fairly quickly, but still ensured that it was understood. Then the Operations Monitor concept was explained, and the prototype was presented in detail. Questions came up, and the answers were to be found by letting the test person try pushing a button to find out what function it was, and by letting the test person explain what he think it should be. Finally a scenario was explained verbally, and the test person explained how he would solve the problem with his existing tools. Then the scenario was demonstrated visually, showing how a typical problem could be solved in the old way, using the test persons own terms and definitions to increase the understanding, and then in the new way using Descartes. The scenario was a delayed flight that involved crew legality, and affected 12 members of the crew that would miss their connecting flight, an every day problem.

Results

- The controllers find it valuable to be able to monitor the alarms, as long as it is the problems that concerns them, that they do not have to sort out which are relevant or not. It would ease the work a lot, if all information about an alarm were to be found in a click.

- Graphical presentations are mostly valuable when working with scenarios, being able to move the objects with drag and drop. Since there seems to be a possibility to include vital information into the graphical objects presenting alarms, like in the prototype, then it will fulfill its purpose, and even be very satisfying.

- It is possible to solve problems in the traditional way, since all the information needed, and the functions to support that work is available or possible to add.

- Suggestions to information and functions missing:

  - A shift change report was asked for, to know what has been done during the previous shift.
  - Information about crew hours and the complicated system of points connected to these has to be presented in the personal stand by and crew information.
  - The Gantt chart of the aircraft rotations was used to a minimum extent today, meaning this could be a sub function to look for during the rare times when it could be useful.
  - A check in list was considered as vital, which is an updated status report on the crews, with alarms generated if they are late.

- All of the test persons asked for the possibility to work with possible scenarios.
- A complete stand by list containing information about the licenses, competences and location of the crew.

The tests were affected by the fact that it is complicated to separate the Operations Monitor from the rest of the Descartes concept, as well as separating the user interface from the underlying system. Difficulties came up when explaining Descartes in total since this was not the purpose of the tests and there was no interest in knowing the test persons opinions about that, but it became easier when focusing on one detail, solving problems the traditional way using the Operations Monitor.

Another aspect that have affected the result was the fact that it was impossible to run the prototype and demonstrate the scenario on the computers used by the controllers, but on laptops meaning much smaller screens and an environment not known to the users. There was also a lack in that there were no screen dumps from their own systems within the prototype, which would have made them more confident with the system since they would recognize the environment.

The attitude towards the concept of the Operations Monitor was mostly positive, and when the controllers got used to the prototype, they came up with constructive feedback, helping us to judge what functions are fundamental and which are not, and what was missing.

Home again, the results from the workshop as well as from the KLM visit was immediately discussed. All possible functions were written down on small post-it notes, and according to the studies, tests, interviews and workshops, the functions were grouped and classified as main functions or sub functions.

Figure 6-6 Post-it notes for evaluating functions

6.5 Third prototype

It was decided to try a new design again, in experimental purpose, to be able to have something to compare to. The purpose was to learn more about how these new types of designs actually were accepted by the controllers as well as the managers. The purpose of this prototype was to focus on the concept and the functionality, not graphical details. It was important that a scenario could be conducted, where the users would be able to solve problems by using the traditional way of working, as well as use the rest of

Descartes for problem solving. The fundamental ideas are still the same, but the appearance changes, as well as some terms. At British Airways the term “alarm” is not used, leading to a change to alert. The Operations Monitor now consists of a menu bar on the top, the vertical alert list on the left side, an alert specification below it and the workspace on the right.

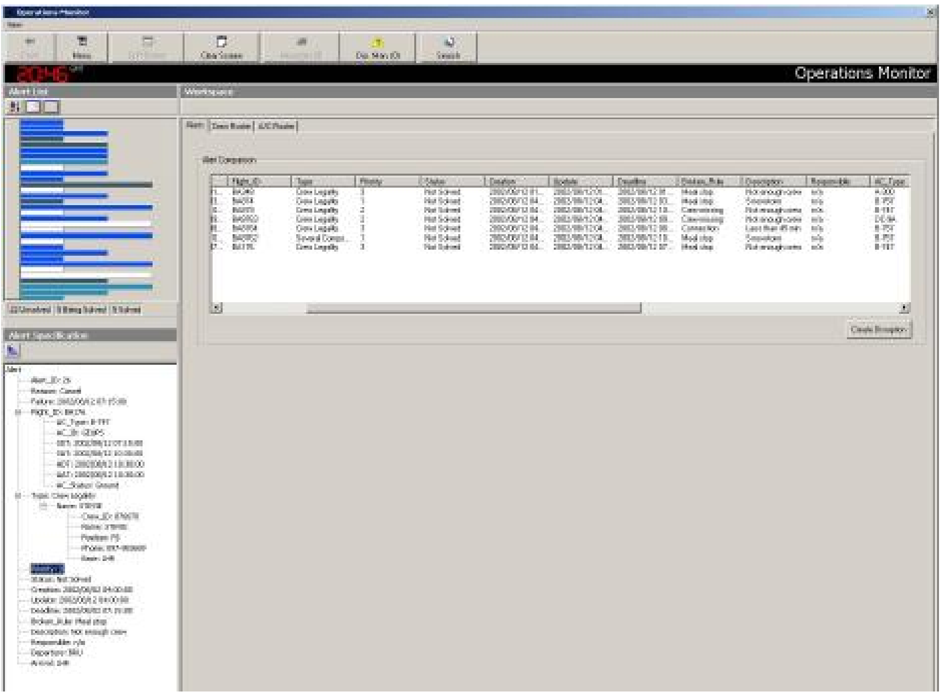

Figure 6-7 Prototype 3.0, made in Microsoft Visual Basic

One large change was that the information was now retrieved from a database, from real scenarios. This change led to that the prototype became more dynamic and realistic. The Operations Monitor was now able to communicate with the Disruption Manager, through sending XML-messages; a truly realistic scenario could be performed at the visit to British Airways.

Unfortunately the time was not enough to complete the graphical part of the user interface, so the focus was to test the interaction and the functions.

The menu bar

On the top there is a menu bar, containing seven buttons with some main functions:

- The back button is for going back one step in your actions, to see the previous picture or regretting a choice.
- When the menu button is pressed, a drop-down menu appears, containing sub functions. From here you can choose to open the stand by list, a view with AC-rotations, a weather forecast, a table with check-in status of the crew members, a shift change report, a history view, a table of key indicators, the timetable or a ring list with telephone numbers. When one of these alternatives is pressed, the choice will be started in the desktop area.
- The split screen button is used for splitting up the desktop area into several views, to be able to work with several programs or lists at the same time.
- The clear screen button is for clearing up all the windows that has been started in the desktop area.

- The message button opens the message function, a small window that will appear in the desktop area, where you can read or send messages to co-workers. When a new message is received, it will appear on the button, meaning you can see how many unread messages there is in your message box.
- The link for opening the Disruption Manager in the desktop area also contains a number. This number indicates how many Disruption Manager messages you have, meaning disruptions there are to evaluate from other resource areas.
- When the search button is pressed, a small window is opened in the desktop view, containing an empty box. Anything can be printed within this box; crew number, tail number, the name of an airport, and so on, when the results of the search are to be presented, it is shown in the desktop view. The purpose of this is quick access to crew rosters, airport information, aircraft status and so on.
- Below the menu bar, the GMT time is presented.

The alert list

The placing of the alert list has changed, it is found at the left side in the monitor, and has become smaller in size. There should be a vertical timeline to the left, but there was no time to implement it. The alerts are still presented as color filled bars, but as thin horizontal bars, in three different lengths.

- The length indicates the impact of the alert; the shortest is just affecting one crewmember, the medium several members in a composition, and the longest is several compositions, several flights.
- Above the alert view, there are three buttons. The left button is a sort button; when it is pressed a drop down menu appears with different sorting opportunities. The alerts are automatically sorted in when they will occur in time, along a timeline. Other alternatives to sort the alerts could be geographically, according to type of alert, when to occur in date, according to the size of the impact, when the alert was created, and so on. The sort function is important when working with several alerts, to be able to detect patterns or reason of occurrence that the alarm server has not discovered. The two buttons next to the sort button were added for demonstration purpose, and not yet decided upon. The left one selects all of the alerts, and the right button deselects all the alerts. What could be useful is perhaps an add-button, meaning one can select one alert to appear in the workspace, and add another one to it, without using drag and drop. This is function that is implemented; being able to select some alerts with specifications to be visualized in the workspace above each other, so that they can be compared to each other.
- Below the alert list, a bar with facts is seen. The facts are data about the alerts in the alert list, the number of alerts being solved, has been solved and are unsolved.

The alert specification

When the mouse is moved over an alert in the alert list, then the specifications about that alert is presented in the alert specification. When the mouse moves to another alert, then that information will be visible here instead. But if an alert is selected, then the specifications stay within the view. The list of data is expandable, meaning when selecting the flight ID then specifications about the aircraft will appear. This is possible to do with any data that is underlined, like a link. The reason to why all facts are not presented at once, is because it is not always necessary, and will then just become irritating and increase the mental load on the user, having to sort out information. The specifications that automatically appear are the data that are needed for creating a disruption, and to get a quick overview over the problem.

There is a button above the list of specifications, a submit button. The user can submit oneself as responsible for handling an alert, visible to all co-workers.

The workspace

The workspace has become a little bit larger. Besides that there is just one more change; when several windows and processes are running simultaneously in the workspace, then they will be placed on top of each other, with a bookmark sticking up at the top. By selecting a bookmark, that window will appear at the top and be visible. The purpose of this is for the user to know how many windows are open at the same time, and using the bookmarks provides quick access and an overview.

6.5.1 Testing third prototype at British Airways

The controllers at British Airways handles problem concerning the following resources ("The airline business", 2001):

- Fleet size: 263
- Employees: 62 844
- Passengers: 36 million

Before performing the test, new questions and goals were prepared:

- Is it possible to solve problems in the traditional way, not using the crew recovery solver?
- What functionality is missing?
- Is the division on main and sub functions correct?
- What information is most critical?

The testing focused on checking all the usability and functional requirements, as this was possible now that the Operations Monitor could communicate with the rest of Descartes, which could therefore be incorporated into the scenario.

This test was performed in a meeting room at British Airways Compass Center at Heathrow in London, and was arranged by responsible for Descartes. Present were three representatives from British Airways; one former crew controller, one manager, one from Operations Management, and a representative from Carmen; the responsible person for the crew recovery solver. The meeting lasted for almost two hours, and a mini disc player recorded all audio with a small microphone placed on the table, to not forget any of the valuable comments.

The technique consisted of two laptops connected through a network, with one screen projected on the wall. Unfortunately the laptop containing the crew recovery solver experienced technical problems, it accidentally turned off now and then. This affected the demonstration to some extent, since the scenario was interrupted and could not be shown in one interval. Time had to be spent waiting for the computer to restart, and this contributed to irritation and anxiety among all persons, but also it also contributed to laughs and jokes.

At first the background, the ideas and the concept were presented, the user interface was shown in details, and then a full demonstration of the scenario was shown. We performed the demonstration of the scenario and the responsible for the crew recovery solver demonstrated the Disruption Manager and the XML-handling. During the presentation, questions were asked and discussions came up.

Unfortunately there was no time for putting the graphical design in focus when we were to present this prototype at British Airways in London, and therefore the appearance is not very satisfying. This prototype was instead more technically advanced, since the alerts and the information presented about the alerts were drawn from a database that we had created. The communication with the Disruption Manager was implemented, meaning we could communicate through sending XML-messages, creating disruptions.

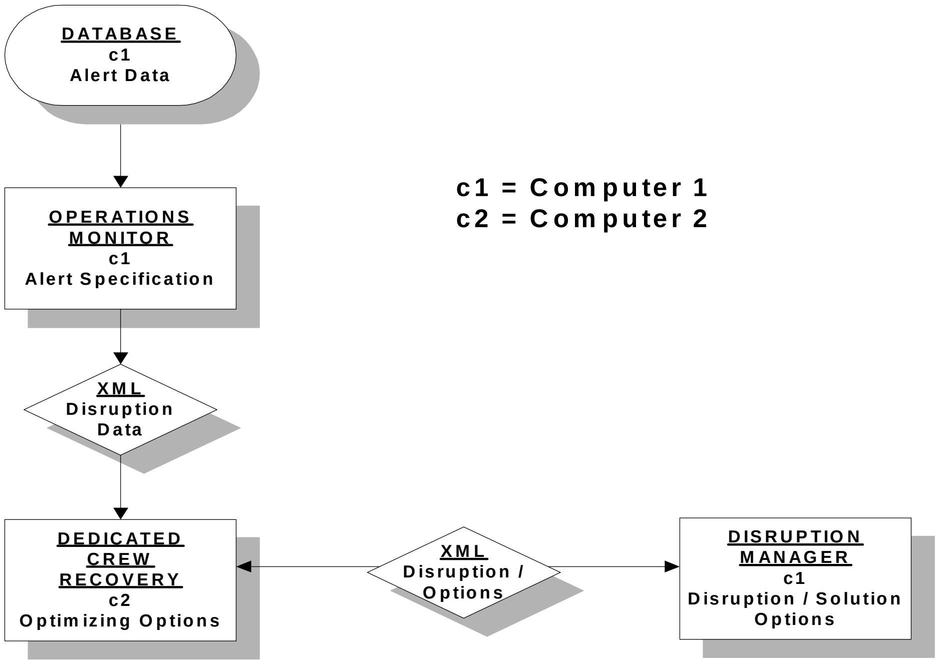

Figure 6-8 Flow chart of the demonstrated scenario

The demonstrated scenario, where a flight was delayed 60 minutes, affected three crewmembers since their connecting flights were to be missed. The new way of solving the problem, using Descartes, was demonstrated; to create a disruption and send it to the solvers. The traditional way of solving the problem was demonstrated; presenting information about each affected crewmember, their rosters and personal information, and compared it to a stand by list with rosters. When finding three stand bys, they were signed to the flights, and the original crewmembers schedules were changed.

Results

The test persons were very familiar with the Descartes concept and development, and had no problems respecting the fact that it was just a prototype, not fully implemented. It was rather an advantage that the prototype was not graphically completed, since the focus were not towards the graphical appearance but to the concept and the functionality.

- *Is it possible to solve problems in the traditional way, not using the crew recovery solver?* Consideration was taken to the fact that problems could be solved without the solvers, leading to conviction that the information presented in the interface was enough, and satisfaction among the test persons with the fact that this had been considered at all in the design. They were also satisfied with the way a disruption was created, and how alerts could be compared with each other.

- *What information is most critical?*
  The most critical information is always depending on the nature of the problem, but in general they are: the route, the time and the knock on effect.

- *Is the division on main and sub functions correct? What functionality is missing?*
  The division of main and sub functions were satisfying, even though suggestions for added functionality came up presented here:

  - To be able to work with scenarios, being able to move around flights or crewmembers presented as graphical objects in a Gantt view. When crew rosters are displayed in a Gantt format then overlaps of disruptions can be seen physically; when trips are displayed as graphical objects they could be repaired on screen. One of the test persons used an excellent metaphor as an argument: "It is like an analogue or a digital watch; you look at the problem, you don't read the numbers. Overlap or not, you can see the picture of the time; you don't read the numbers to work out what the time is. It is exactly the same with a Tracie screen where you have to read the screen, and a Gantt chart where you assess the gaps between."

  - Having suitable stand bys appearing as graphical objects in the crew roster, so that it would be able to sign a stand by immediately. The destinations are usually of no matter when working with roster maintenance, just to fill the gaps with available crew.

  - To be able to appreciate the nature of the problems, the most important factors to appear are the route, the time and the knock on effect. The easiest way would be to show this as graphical objects, not having to read them It is almost irrelevant what the route is, more if one object collides with another, if they are night stops or not, and just being able to move and replace them. The objects have to be comparable, and moveable by drag and drop or point and place.

  - In the alert view, sometimes the most relevant fact to see quickly is when to take action rather then when an alert actually occurs. In the cases when there will be just one opportunity to take action, then this is very important.

  - Navigation in and interaction with the interface should be configurable by keystrokes or be mouse driven, preferably mouse driven, from the test person's personal experience it is a disaster to mix the two due to the consequences of added confusion and time-loss.

  - The timeframe and expansion has to be deeply considered. The timeline in the alert view has to be expandable, since there is a personalization in peoples time view, one person would prefer to see the whole day, another prefers to see what will happen the next hour, and so forth, so something in between is the optimum.

§ In the detailed alert view, it is not a good idea to separate the route from the arrival/departure times, since the term used is “the six thirty from Paris”, meaning it is preferable to support that in the visualization, based upon the terms used in the operations control.

§ In the detailed alert view, all relevant information should be displayed without requiring scrolling.

§ When comparing several alerts with each other, moving them from the detailed alert view to the workspace, then the lines of information will be too long, meaning that the cognitive load on the user will increase trying not to loose the lines while scrolling them.

§ The optimum solution to the visualization of the alert would be to have one object saying this is the possible problem, and one object next to it saying this is the possible solution.

Findings showed that when the way the controllers work today can be supported as well as derive advantages from other graphical tools, closing in on the gap from the graphically more advanced tools used in planning to the tools used at day of operations, then the concept is actually satisfying.

6.6 Fourth prototype

Since the third prototype was not graphically completed, it was decided to use the conceptual and technical feedback from that, to implement the fourth and final prototype. This prototype is not implemented for the purpose of being tested upon the users, since there were no possibilities given to do that, but rather to enhance the overall graphical look of the prototype, as well as the interaction. The design is founded upon everything learnt during the entire development process; the design and interaction strives to take consideration to all aspects possible.

The alert view was decided to be horizontal again, due to the fact that several types of Gantt charts, with a horizontal timeline, will be presented in the workspace, and the cognitive load on the user would ease if the visualization views are to be consistent, that the time is always read from the left to the right.

Derived from cultural aspects, it has been found that it will not cause any problems having the timeline from left to right, since all cultures have adapted the western way of “reading” when using a timeline, regardless of which way they traditionally read. The timeline chosen in this design is therefore satisfying in a company independent perspective.

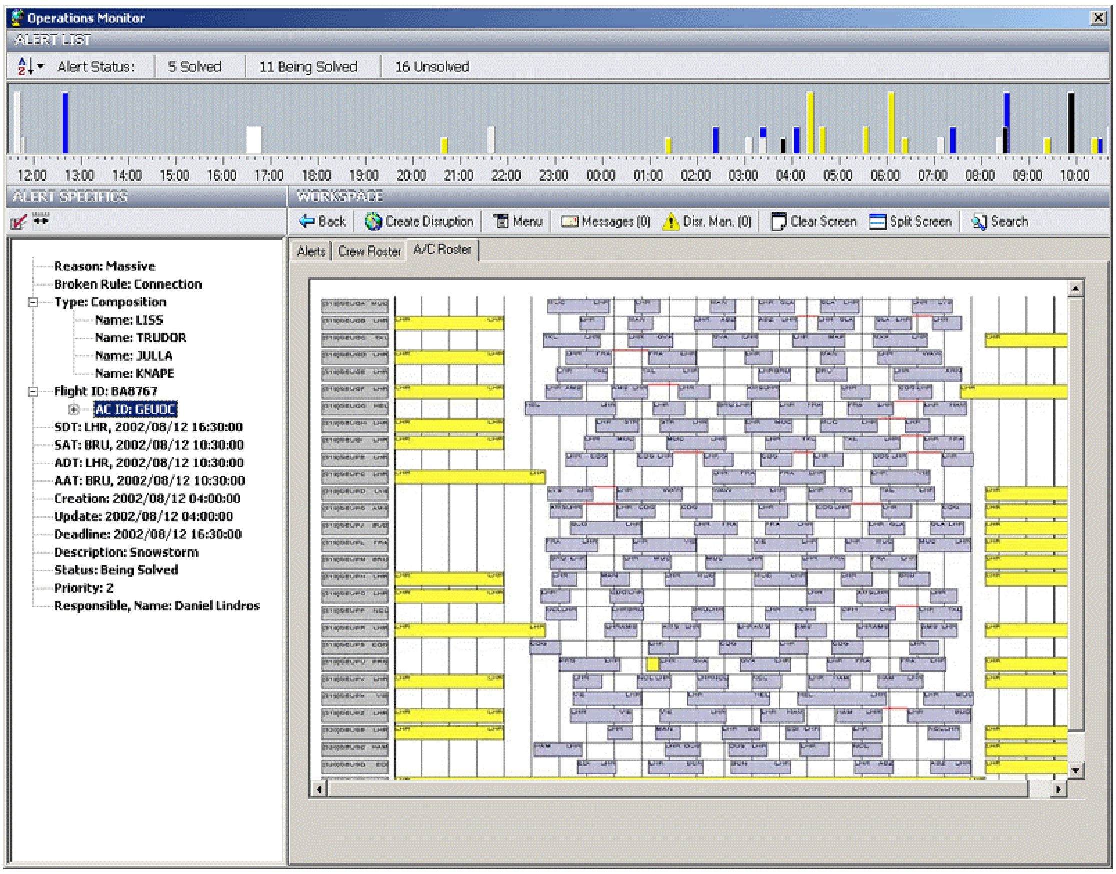

Figure 6-9 Prototype 4.1, made in Microsoft Visual Basic

Alert overview

- The alert overview is positioned at the very top. It contains a menu bar, consisting of a sort button to sort the alerts in different manners, i.e. geographically, according to types or impacts, and so forth. There is also statistics of how many alerts has been solved, are being solved or are still unsolved.
- In the alert view, the vertical objects represent alerts. The length of the of the objects represent the scope of the problem, crew legality is the shortest representing a single crew member, composition is the middle sizes representing several crew members on the same flight and several compositions is the tallest representing several flights affected by the same problem.
- The graphical presentations of the alerts are dynamic, meaning the alerts will be enlarged when marked.
- The timeline is dynamic, meaning it could be justified according to the users personal settings, according to how many hours will be visible at once.
- The colors represent the type of the alert, meaning cancellation, delay, massive (airport closure or bad weather) or defects (partly or completely defect crew or aircraft).

Alert specifics

- The detailed alert list is enlarged, to present all relevant information without scrolling.
- The information displayed is information retrieved from a database, according

the requirements for the alarm server.

- On the top there is a bar with two buttons, one for signing the controller to an alert, and the right one moves the alert to the workspace.

Workspace

- In the desktop view, the bookmarks remain when several windows are open at the same time, providing quick access to an underlying document.
- On top there is a menu bar, containing:
    - The back button, to go back one step
    - The menu button, containing functions in a roll down menu. When a function is chosen, then it will be opened in the workspace. The functions are:
        - Aircraft rotations – Gantt representation of take offs and landings
        - Weather report
        - Check in status – status of the crew
        - Stand by list
        - Shift change report – description of a shifts events
        - History events
        - Key indicators – available and unavailable aircrafts and crew
        - Timetable
        - Ring list – list of telephone numbers of crew
    - The split screen button, splitting up the workspace in several windows.
    - The clear screen button, clearing the work space
    - The message button, opening the message function inside the workspace. The number next to it indicates the number of unread messages there are.
    - The Disruption Manager button, which opens the Disruption Manager within the workspace. The number indicates the number of not handled Disruption Manager messages there are.
    - The search button, which opens a search function in the workspace, where it is possible to seek for any kind of database information, like crew roster, crew information, aircraft information, rules, and so forth.

Not implemented but intended to be so:

- Clock presenting the accurate GMT time.

Alert overview

- Status of the alerts, meaning solved unsolved and being solved.
- Solved alerts staying within the alert view.
- When the mouse is above an alert, and the alert is enlarged, then the timeline should be expanded as well.

Workspace

- When choosing several alerts to put the detailed alert information in a comparable list in the workspace, then it should be able to compare the alerts without scrolling. Reducing the number of columns presented from the database should do this.

6.6.1 Brief technical description of the prototype

The Operations Monitor prototypes were implemented using Microsoft Visual Basic 6.0, as it was determined that considering the time constraint, we could achieve visual and functional results faster with this tool than with other, more conventional, development platforms. The program basically consists of a form, which is the graphical representation of its components (the window and its buttons, captions etc), five code modules, which contain various code different functions, and a class module, which describes the alert objects (the coloured rectangles in the timeline).

The prototype receives information on the alerts from a Microsoft Access Database. Storing the data in a database, and not hard-coding it, significantly simplifies the accessing and manipulation of data in the program. This data is also used when the user chooses to create a disruption in the program. The data is then read from the database and structured into a XML document, which is then outputted as a file.

In addition to the standard GUI components provided with the Microsoft Visual Basic 6.0 package, user developed components were also used, to provide greater flexibility.

6.7 Results from the design phase

Usability Requirements

The learnabilty requirements are, summarized, that a controller should be able to judge the nature of a problem to solve it the traditional within one day, and two days to solve it using Descartes.

Because the time available for workshops with users was not enough to test this requirement, and the fact that no actual database information could be retrieved from the systems in use today, the learnability requirements were not possible to test satisfactory. The results of the tests depended on the users opinions in this matter as well as our judgment of how well understood the concept was. This way of measuring learnability goals is not preferable, but in this case necessary. Therefore the learnability requirements are more recommendations for future tests, and for successfully introducing this tool into the controllers context.

The flexibility requirement was that the Operations Monitor is to be used as a tool still working in the traditional way, but also to use it with Descartes. The different qualities of the prototypes, meaning the different levels of technicality and graphics, made it possible to test this requirement with the real users. Also the scenarios being presented in two different ways, traditionally and the new way of Descartes, contributed to this. It was found that the flexibility requirement was fulfilled.

One of the throughput requirements was that the time finding information about the scope should be reduced compared to today. This had to be tested upon what the test persons estimated, since there was no connection to real live databases. From the data base information presented in the Operations Monitor and the functionality within it, this would most probably reduce the time, and the requirement was therefore fulfilled.
The second throughput requirement was to support the user to choose which alarm to handle next. The concept of the Operations Monitor as it is presented in this thesis fulfils this requirement, according to test results.

The attitude requirements were that 80 % of the users should answer yes to that the work would become easier with the Operations Monitor, that it would be easier to retrieve information about the effects of an inconsistency in the roster, and that the decision-making process would become more proactive.

The users were convinced that the use of the Operations would definitely make their work easier; they expressed enthusiasm towards having all information within the same view. They also thought that working more proactively would be possible due to the fact that they, which is a consequence of the second throughput requirement, could actually choose themselves which problem they wanted to handle next.

Functional Requirements

The functional requirements are that the Operations Monitor should visualize alarms, details of alarms, data from the airlines databases, history of events, the data should be updated in real time, it should be possible to create a disruption and send it to the Disruption Manager.

That the data should be updated in real time is a technical requirement that was not possible to test with the prototypes available, but it is the most necessary requirement of them all, the requirement is the basis for the alarm generation defined in the Operations monitor. The rest of the functional requirements have been possible to test with the prototypes, and the users have considered them as the most relevant aspects of the Operations Monitor and also considered them as fulfilled. Testing has also shown that the main list of functions described in the functional requirements chapter 4.4, are directly dependent on the succeeding list of functions.

7 DESIGN RECOMMENDATIONS

In this chapter, recommendations on the design of the Operations Monitor are presented. They are the result of our studies of the crew controllers and their work environment, as well as the background information on human factors and information visualization, and are meant to give a pointer to which direction to take when designing the Operations Monitor.

7.1.1 Minimize the mental constraint on the user

Generally, one of the most important aspects to take under consideration while designing a graphical user interface, is to lower the users cognitive load, not having to remember a high level of details. This is especially important since the crew controller works with a large amount of data in a stressful environment, which affects the user's level of concentration, increases the distractibility and reduces the short-term memory capacity. This helps provide the user with a mental model of the system, which is coherent with the design model. A correct mapping of the user model and the design model is the goal.

Even though too much information can be cognitively straining, the same effect is achieved when providing the user with too little information; if important information is suppressed then the user will spend time looking for it. Humans have a natural talent for selecting which information to process, which should be taken advantage of.

Keeping the number of components of which the Operations Monitor consist to a minimum means the crew controller will have less to keep in mind at any given time. These components should also be placed in and aligned to a static frame. Also, the Operations Monitor should be kept in one window. If the user opens another process, it should be presented somewhere in the Operations Monitor. If the user must switch often between several windows or views, his or her cognitive strain will increase, inducing the feeling of "getting lost".

If the user wishes to handle several alerts at the same time, use the split-screen method, splitting the screen space into several parts, homogeneous in appearance, and placing each alert in a separate part. This way, the alerts are comparable by the user and the user avoids "getting lost" in different windows. Provide the user with the alternative to clear the entire screen if required, instead of manually having to shut down the different "information containers" that may be open.

7.1.2 Be consistent

Another important aspect is to strive for consistency. This is considered using the appropriate metaphors; use identical terminology in prompts, menus and help screens. The abbreviations and terminology used should be standardized and controlled. The interface should have consistent layout, fonts and colors. It is preferable to use up to four standard colors, and additional colors reserved for occasional use. This aspect is important for the user to be able to predict what will happen, to recognize the environment and to categorize objects that belong together.

Use the same font for the captions of title bars and buttons. Also, make the title bar's backgrounds different than the other background colors; this way it makes it more apparent which screen space is designated to which container. Also, as explained above, the different components of the Operations Monitor should be aligned to a reference frame. It is important that the Operations Monitor takes advantage of the screen space, to minimize the need of scrolling when displaying information.

7.1.3 Provide feedback

Always provide the user with informative feedback. Some sort of system feedback should follow every user action. If the actions are frequent and small, the feedback can be discreet, while if the actions are more extensive then more substantial feedback should be provided. The icons on the toolbars should be flat in appearance when no interaction is performed with them.

When the user hovers the mouse over an icon, the borders of the button should appear, making it "stand out" from the toolbar, effectively making it apparent that that particular button is currently in focus. When the user presses the button, the usual button reaction, i.e. the appearance of it being pressed, should be utilized. This behavior provides the feedback the user needs to know that the toolbar button is responding to his or her actions. After pressing a button, the resulting actions performed by the system should be visually obvious.

When a specific alert is clicked in the alert list, the color of the alert should change, so that it is apparent that it is in fact chosen. Hovering the mouse cursor over an alert should immediately bring up the information coupled to that specific alert. This way, the user can quickly attain relevant information about an alert.

Additional information should be possible to access through clicking on the alert specifics. The user may want to find out more about a certain crewmember that has been affected by an alert, and by clicking this, more in-depth information should be presented, i.e. personal data, roster etc.

Avoid using sound feedback. Because the crew controllers work in an open environment, the sounds will add to the already noisy background ambience. Furthermore, the sounds may refrain the crew controller from overhearing conversations between other crew controllers, which is an important information channel.

Take into account the fact that a substantial percentage of the male population is color blind, and to choose colors that people with and without color-deficiencies can easily distinguish, especially if color is chosen to be an information-carrier. Red and green should be avoided if possible. For example, the colors blue, yellow, black and white are preferably chosen as the different alert types (if alerts are chosen to be visualized as graphical objects), as color-blind people do not perceive these much differently. Because the users can be of virtually any nationality, choose icons and metaphors that are understandable by people with different cultural backgrounds and take notice of which colors mean what in different countries. Because of the latter reason, it would be beneficial to provide the user with the means of selecting a specific a country and/or culture, and the operations monitor would thereafter change the color-scheme accordingly; it is hard, if not impossible, to derive a certain number of static colors which would signify the same thing in all cultures and it would be better to have pre-defined color-schemes for different cultures which could be chosen on request.

7.1.4 Minimize the input actions

Using fewer input actions provides greater productivity and fewer chances for error. It is preferable to make a choice by a single keystroke, mouse selection or a single finger press, rather then to type in a string of characters. Since the users competence regarding computers varies, and a wish for more mouse input actions has come up during the interviews, this is an important aspect.

As a lot of the user's interaction with the Operations Monitor will be dealing with the retrieval of information, and because of the relatively low amount of user input through keyboard, it is preferable to use the mouse as the main source of input. Keyboard shortcuts can be provided as a complement, if an advanced user wishes to use the Operations Monitor in a quicker fashion. Keyboard entry will naturally still exist, for example when the user enters information into the database. There should also be the possibility for the user to customize own macros.

Make it possible for the user to regret action by providing an "undo" or "back" button. The Operations Monitor should strive to make it impossible, or at the very least difficult, to make mistakes. Having the possibility to undo actions will greatly increase the trust the users have for the system.

7.1.5 Support the user's current way of working

Take into account that the Operations Monitor will fundamentally change how the user works. Consequently, the incorporation of the Operations Monitor might make the user feel as if he or she is being replaced by an automated system. To counteract this, allow the crew controller to decide to what degree he or she wants to use the Operations Monitor, and provide support for the way they work today. It is important that the Operations Monitor truly supports the essential part of the system, namely the crew controllers themselves. This can be done by providing them to use it as:

a. **A monitoring source**.
Provide the crew controller with a view of alerts, so that he or she can monitor the current status of operations, and react to problems. If he wishes to handle an alert, let the user assign himself or herself to it. This lets the user, and other controllers, know that he or she is handling the alert. Also, provide the function of being able to create a disruption from the alert, so that the user may send it to the Disruption Manager.

A shortcut to the Disruption Manager should be available in the Operations Monitor, so that the user may quickly open it. It should be apparent also, if a disruption has been sent to the user from another controller, for evaluation. This can be done by, for example, placing incoming disruptions as graphical objects in the container where the alerts are located. In this case, the Disruption Manager messages should be distinguishable from the alerts. Another alternative would be to have a status bar for the Disruption Manager, showing information on incoming and outgoing disruptions.

b. **An information source**.
Let the user use the Operations Monitor for information retrieval, and determine whether or not he wants to solve the issue in his or her old way, or with the Descartes system. Provide the crew controllers with the means of looking up detailed information on:

- Crewmember schedules and their personal information, e.g. name, telephone number, address, crew id, etc.
- Aircraft schedules.
- Weather predictions.
- Current standby status. Total number of standbys and their current status, e.g. at home, at base etc.
- Check-in status of the crewmembers.

This information should naturally be derived from the airline's own databases, and updated in real-time, so that the user is always presented with up-to-date and current data.

Another basic, but very important piece of information is the current time. This should be shown in GMT (Greenwich Main Time), as the operations control always works according to this time zone.

A search function should be available, letting the user search for information in the database. There should be a possibility of searching for everything that is currently in the database.

c. **A scenario tool**.
Provide a scenario function that lets the user manually create a new, or modify a by Descartes created, solution. This can be done by graphically presenting, e.g. with a Gantt view, the crewmembers schedules and making them alterable.

Crew controllers often depend on the communication with other crew controllers and other resource areas, and including a complement to this oral communication, a message system allowing the controllers to communicate via the Operations Monitor through the use of message, would be beneficial. There should be some indication if new messages have been received.

7.1.6 Support both a focus and an overview over the current status of operations

The alerts should be presented in a way that the crew controller can easily obtain an overview of the situation, as well as get a detailed view when required. Visualizing the alerts as graphical objects, rather than text can achieve this. As the most important information, for the crew-controller to decide which alert to handle first is the impact, i.e. alert type and how many crewmembers it affects, this is could be mapped (if alerts are chosen to be visualized as graphical objects) to the alert's height. Color could be used and be mapped to the reason of the alert, i.e. if it is a delay, massive etc. This way, it is easier at a glance to attain an impression of the alert's characteristics and it also has the advantage, in contrary to textual equivalents, of being much more likely to draw attention from the crew controller during periods when the work-load is low, and the crew controllers focus might be elsewhere.

To attain focus without loosing the context, a focus+context technique can be applied, such as the bifocal lens. The user could then get an impression of the context, i.e. overall situation, by merely glancing at the alerts, while at the same time focusing on a single alert and its details.

The Operations Monitor should generate a shift-change report when the crew controller is finishing his shift. This is used by the next crew controller to get an overview of transpired events, and what actions where taken.

Provide the user with the means to see the status of important resources, i.e. key indicators. Important resources to be monitored are for example, number of crewmembers currently flying, currently on the ground, number of standbys etc. It is also beneficial for the user to see the current status of alerts, i.e. how many are solved, not solved and being solved.

7.1.7 Make the users feel in control

It is important that the users feel that they are in control of the situation; part of this means that they should have a correct mental model of the system, as described previously, but also that they should be able to incorporate their own judgments and experience into the system. For instance, the breaking of certain rules, perhaps not allowed by the system, may become necessary. If this is possible, the user will feel that he is more able to do his work correctly and easily.

Other ways to achieve this is to allow customization of the alerts. Enable the user to sort the alerts. One situation might call for the alerts to be sorted chronologically (this is preferably set as the “default” way of sorting). In other situations the user might find it appropriate to sort the alerts by their priority, or destination airport.

Also allow the user to customize what time scope he wishes to work with, i.e. let him or her choose for example 12h view, 24h view etc. The timeline should effectively be as dynamic as possible, easily manipulated by the user.

7.1.8 Support usage in both time critical and time uncritical conditions

When the user is under time pressure, a satisficing decision-making process takes place, suppressing the importance of making optimal decisions and solutions. When time is less of the essence, the focus will shift towards making these more optimal, resulting in two different ways of using the system. When under time pressure, it is important that the Operations Monitor responds to the user’s interactions in a quick manner.

If the Operations Monitor is carrying out work, it should show the work process by displaying for example a progress bar, and preferably the estimated time of when it will be finished. Also, information and actions should never be “far away” from the user, i.e. no further than a few clicks. Keep relevant information close at hand. Toolbars are a way of achieving this, providing easy access to often-used functions by clicking a toolbar button. It is also important that the crew controller can quickly get the information of an alert.

When the user has more time, more attention can be paid to creating more optimal solutions, using optimal decision-making. In this phase, the operations monitor should support the user by providing, for instance, a scenario tool as stated in 7.1.5c, so that the user can focus on creating and comparing different solutions.

8 ANSWERING THE QUESTION STATEMENT

From the extensive research conducted we are now able to address the questions that were formulated in the introduction chapter of this master thesis.

What is the purpose of the Operations Monitor?
The purpose of the Operations Monitor is basically to provide the crew controller with a tool that can present information about problems involving crewmembers. As our user and task analysis proved, the crew controller currently spends a substantial amount of time searching for information on problems and their effects, when they should be using that time resolving it instead. The Operations Monitor supports the crew controller in this manner by facilitating the process of discovering, and retrieving information about, a problem so that he or she can instead focus on the process of solution generation.

How will the incorporation of the Operations Monitor change the way the user works?
The answer to the previous question has somewhat already answered this. Due to the fact that the user's work will be more focused on solving problems than detecting them, his or her way of working has consequently been subject to change. The crew controller will spend less time searching for problems and surrounding information, using the Operations Monitor for the primary source of information. However, in the task analysis chapter, under new ways of working, and also in the guidelines, we have established that to what extent it will change is dependent on to which degree and what purpose the crew controller chooses to use the Operations Monitor.

The Operations Monitor is flexible in the sense that it allows usage in different degrees. The crew controller can use it as simply a monitoring source, becoming aware of potential problems. Another possibility is to use it for the purpose of information retrieval, looking up details on specific crewmembers, flights etc. Finally, he may also use the Operations Monitor in it's full capacity, utilizing both of the functions just mentioned and also the function of creating a disruption from the information provided by the Operations Monitor and sending it to the Disruption Manager, using the rest of the Descartes system for solution generation.

What present ways of working must be taken into account?
The user and task analysis has provided us with the conclusion that the crew controller is very familiar with his domain and relies heavily on experience gained throughout his working period. Furthermore, our tests and evaluations have concluded that this experience is of great importance in their day-to-day work, and that experience cannot be totally replaced by a system like the Operations Monitor and Descartes.

It has also given us the conclusion that if we provide the means of effectively making the crew controller aware of an alert and its scope, and providing quick access to information on resources that are affected by it, this will greatly relieve the crew controller in the phase of gathering information. His current experience in for instance seeing which problems, i.e. the alerts in the Operations Monitor, are related, which method of attacking the problem and generating a solution should be used, which rules can effectively be broken etc must be preserved. This knowledge is, as stated above, the result of the experiences of working as a crew controller and is very difficult to duplicate in automated systems.

What is the users context and how are they organized?
The user analysis has shown that the environment in which the crew controller works, i.e. the operations control room, is highly dynamic, containing both auditory and visual disturbances. They are situated near other resource areas, which they currently rely on for information and that affect their own work.

What visualization techniques are suitable for this type of work task and environment?
On the day of operation, many problems can occur at any given time, as stated by the task analysis. The crew controller may be forced to work with several related or unrelated problems at the same time, and parallel to this keep an eye on the overall situation for any new problems that may occur. In the guidelines, we conclude that a suitable alternative to allow the crew controller to both work with a detailed view of an alert and at the same time perceiving the overall situation is by implementing a focus+context visualization technique.

How do different aspects in the work environment and the user's tasks affect the use of an Operations Monitor?
In the background chapter we conclude that the priority of a problem and the time constraint placed on the crew controller greatly influences in what manner he or she uses the Operations Monitor. If the crew controller under a tight time frame handles a problem of high priority and great impact, he or she will most likely be using satisficing decision-making, concentrating on quickly solving the issue instead of creating good solutions. Given time, however, this will probably shift towards optimal decision-making, where the user can focus on creating an effective solution to the problem. This affects how the crew controller will use the Operations Monitor; as a quick source of information, or as a tool for, with Descartes, creating optimal solutions.

9 DISCUSSION

In this chapter the results will be discussed, as well as the method used, and the over all work. What factors have affected the results will be discussed, what could have been done differently, what could have been made better, what have been learnt from this and what have the Interaction Designer perspective contributed with.

9.1 The method

The method used in this master thesis has been satisfying. There were several aspects contributing to choosing what method to use, but the most important was the opportunity to perform a lot of work in the users right context, at their place of work, and the contextual design method was therefore naturally given. One aspect contributing to the choice of creating prototypes was that there is no similar system with an Operations Monitor existing today, and to reduce the cognitive load of the users, trying to imagine one, it had to be visualized. It was also the best way to communicate the ideas to the people at Carmen, the members of the Descartes team. The greatest benefit from creating prototypes as a design method is that it facilitates the cooperation between designer and user, creating a greater understanding for each other's problems and assets.

It was important to be able to create and to demonstrate scenarios, for the designers to understand the type of tasks there is and for the users to recognize their work. Discussions concerning what functions are needed to solve a problem came up during tests, and without these discussions important aspects related to reality would probably not have been considered. It is important to discuss how the result will be used, since it is difficult to predict how the future users will actually use the system and how it will be experienced.

A certain degree of criticism has been involved when evaluating the results from tests and workshops in accordance with literature and previous work, since the prototypes and recommendations evolved from these are nothing but guidelines and experiments. A weakness with this method is that the scenarios are typical and realistic problems, but never enough since each task for a controller is always unique, and this complexity affects the result. The time constraint is always an important factor, and that is also a weakness to this method, it is difficult to perform realistic tests in the right context with all the complexity concerning the work in the operations control of an airline company.

In the design of the prototype, the users have been involved for test purpose. The designers have decided all decisions concerning the design, but the users have been consulted along the way. It would of course have been optimal to have crew controllers cooperating in all stages of the design process according to participatory design, ensuring all details to be optimal. Since this was not possible, the design process became iterative, with tests performed along the way. Users were involved when creating the foundation for the work, demonstrating their way of working today, as well as in testing our general ideas, the information presented and the interaction. The creation of all the graphical details was entirely the designers' choice; there was no possibility to focus on this too during the tests.

It is a great advantage of having a prototype to communicate concept and ideas, but one has to be aware of that it can also limit the tests. The focus tends to be directed to the details of the appearance, making it harder for the test person to see what is missing and what to change. When testing the third prototype, letting the test persons be aware of that it was not graphically completed, the focus were more directed towards the functionality, interaction, concept and what was missing.

User studies have been conducted to study how the users interact with the systems or prototypes available in different stages of the design process. At first the purpose was to study how the controllers use the available systems today, to gather requirements and information. Later on user studies was conducted to evaluate the work, the reactions, the ideas, and to investigate whether the prototype was enough for achieving the goals we had set up in advance.

The contextual inquiry worked very well for observations as well as for testing. Problems with conducting this kind of interviews became very obvious, since the users are all experts on what they do, it is their every day tasks, and they summarize their performance down to nothing. This is why the observations are important, while studying when the work is actually performed; the complexity of the problems as well as of the work procedure becomes obvious. Details, problems and hidden structures would not have come to our knowledge if we were not to observe the work in the right context. Performing the interviews in the control room while they were working, gave us a lot of useful information about to what extent they take advantage of divided attention within the entire room, while focusing on a task. The fact that these interviews and observations were performed at two different airline companies contributed to even more concrete and detailed information. Unfortunately the days for the visits have been really calm days, without any major disturbances. This provided more time to discuss and interview, but less knowledge of how the work is performed, how problems are actually solved, which has been a great lack throughout the work.

Sometimes problems occurred with keeping focus during the interviews, even though there was a pre-decided goal. To keep focus turned out to be difficult, since the environment and the problems were totally unfamiliar, especially in the beginning. As soon as we started to collect the information, it was realized that the unfocused parts of the interviews contributed with a lot of important facts too, since this was the controllers' personal opinions and stories.

The number of performed tests was satisfying, even though more tests would have contributed to even more aspects and opinions to consider. The selection of test persons was satisfying in one sense; they were a great difference in ages and therefore experience. To become as company independent as possible, tests would have to have been performed in several cultures, meaning in other parts of the world. More aspects would probably have come up if all test persons were crew controllers, even though this actual variation in professions contributed to a wider range of subjects were to be discussed.

Is it possible to test and evaluate a graphical user interface separated from the rest of the system? This question has been vital during the entire design process, and several answers are to be found. It is possible when performing tests with test persons that are familiar with the Descartes concept; the focus is much more on just the Operations Monitor, its concept and functions. When performing tests with users that have not heard of the type of decision support system that is Descartes, then it is almost impossible to separate them. In that case, it is preferable to test only the traditional way of solving problems, not involving the solvers or the new way of working. This way, the purpose of the monitor would be to support the users in their existing systems and just be an add on, which is not quite correct, and still the trap of the general idea of an user interface. When using a system, the user does not make a distinction between the interface and the underlying functionality. How is it possible to measure the usability of a system if that underlying interaction is not satisfying, or even existing?

How the results in this thesis could be used in the future has to be discussed. The analysis is a good basis for future work concerning the crew controllers, as well as the recommendations. Specific details in the design should not be considered as optimal in any sense, since this was not the main purpose of the thesis. Since this concept of an Operations Monitor has been abstracted from the rest of the Descartes in many levels, then it is recommended to create new analysis based upon how the work will change the routines for the users, what reorganizations are meant to be, and so forth, if the Operations Monitor is to be a part of a larger system.

It was good practice to really have to understand the users work in detail, since it provided the possibility to practice our capability to make them express exactly what they are doing, every single step, even though it might be totally obvious and natural to them. It is not easy to make someone aware of actions that they have in their backbone, to make them verbally express their silent knowledge, especially when you are not familiar with the environment yourself. This might be complicated, but never the less necessary.

9.2 The prototypes

Several aspects have been taken into account when designing the prototypes. The most significant has been for the design to reduce and sort out the information, in order to reduce the cognitive workload on the user. This is to minimize the errors and the time to collect relevant information when it is time critical and very stressful. Sounds and animations have not been considered as options at all, since that would move the users attention and be disturbing in this noisy stressful environment, where the users are already using the sounds of the environment using divided attention while working focused on one task.

In order of cultural aspects, it might seem as if the designs are completely western, even though it was a requirement that it would be company independent. According to the information retrieved on different cultural aspects in interface design, the design is satisfying in any part of the world. The timeline being read from left to right is not the most common in all parts of the world, but even so, the use of western computerized systems has made this visualization of time generally accepted.

The choice of colors has been decided in accordance to be carriers of information, meaning they have the same meaning and does not change in appearance even though the user might be colorblind. The cultural aspects of colors have also contributed to the decisions, since some colors might have different meaning in different cultures. The color red has been avoided, since this is connected to danger in some parts of the world, and all the graphical objects carrying information with colors are alarms, meaning the color should not affect the priority or draw attention from the others.

The icons has been decided upon from different aspects too, like the most commonly used trying to match the users internal model with the underlying functions reducing the cognitive workload, and the cultural aspects of the meaning if the icons. The icons are not to appear alone, there is also a describing text to what function it is, this to reduce the possible confusion of what it is presenting.

9.3 The work process

When going to British Airways the first time the preparational work was not enough, and some of the information available was not up to date. Everybody at Carmen was very nice, and they told everything they knew, if they were asked. The problem was that we did not know what to ask for, since we had so little knowledge of the aircraft business and no experience at all. The preparations were founded upon contextual design methodology, as well as experience from previous work. The results of the interviews were satisfying, even though there were some problems to keep focus, to stick to the subject, this because our inexperience of performing interviews in combination with the unfamiliar and new environment. When returning from the trip, the performance was considered to be not satisfactory, but now when looking back we have another opinion. This was actually the day when we were taught the most, and collected the most fundamental information that has been the basis for the thesis.

One important aspect that has been very helpful is the fact that we got several contacts at British Airways, and this lead to that we were able to complement the information with questions via e-mail. Our understanding for the users situation, as well as our own task became more obvious as time went by and the more we worked with the information we had. We kept on choosing between ten different thesis subjects, and needed help from the tutors to be able to narrow it down to just one. Not until then, when the period of despair was over, we were able to focus on the design and what type of tool that actually would be helpful to the users. New energy and a lot of experimental ideas came up. At this point we started to work more and more with the rest of the Descartes team, there were several workshops, and since we now had more knowledge about the business in general and the Descartes project in particular, more relevant questions were to be asked and give more qualified answers to their questions.

The fact that the system Descartes, in which the concept Operations Monitor is just one part, is a research project and therefore not yet developed and completely implemented, has had a great impact on our work. Some things have changed along the way, definitions has not been decided upon nor unified. This has forced us to make assumptions, based upon a mix of wishes and requirements, both for our point as well as from the developers point. In the early stages of the work, there were a lot of worries for the technical requirements of the Operations Monitor, it was first decided to be a thin client, meaning no room for almost any graphical visualization, but after a while when discussions upon software contracts came up, it was decided that we would just not care about this. A lot of things will probably change again, both technical issues and requirements, especially when things will be more developed and customers are to take part in the decision process too. Of course it has also been a great advantage to have the possibility to take part of a research project, since there is great opportunity to experiment with ideas and techniques, and to actually be able to effect the development process, by starting discussions or finding factors there has not been thought of.

One factor that have had a great impact on this thesis, and as it will have on future work concerning this concept, is how the alarm generation will be handled, as this is not yet decided upon today. The existence of our version of the concept Operations Monitor is actually depending upon this.

The questions set up in the beginning has been answered by design recommendations, and partly by the development of a prototype. It would have been preferred that the recommendations were more detailed, describing exactly what functions are vital and exactly how the design and interactions would be. This has not been possible, since there is a great lack in our knowledge of how the future users think while prioritizing and solving problems, how they use their experience, and also because of the complexity of the context and the problems within it. It would have been preferably if the context in which the crew controllers work had been analyzed in its total, meaning a user analysis and a task analysis including all resource areas. This would probably provide a great deal of aspects to the understanding of the complexity in the control room, to detect the hidden patterns that has to be supported for the success by the introduction of a new system.

9.4 Future work

It would be recommendable to investigate how Descartes will change the organization in a control room, what new routines there would be, what the controllers new tasks would consist of, an so on.

To create more correct analysis and recommendations in order of the complex nature of the context that is the operations control, it is recommended to perform research including all resource areas within it. When this is done, then it is possible to abstract the different parts of it to adjust the tools for a specific user target group in a much more correct way.

The next step in the iterative design process would be to implement a prototype of all the parts that Descartes consists of, to perform more realistic tests with the entire concept. The prototype should be developed in accordance to the design recommendations compiled in this thesis. Since there is a great difference in how the controllers are used to computers, then it is recommended for the prototype to support the possibility to create macros for the users to personalize their input work.

When designing the Operations Monitors for other resource areas, then a new user and task analysis should be performed, since their work differs a lot from the crew controllers, even though it is in the same context. This thesis could be used in preparation for such a user study, but the design recommendations are not valid.

One very exciting project suggestion is to investigate how it would be to add virtual reality technique into the day of operation, by using gloves or similar be able to physically move around boxes and blocks presenting routes in crew rosters or flights.

10 CONCLUSIONS

This master thesis explores what are the most important factors in the work performed in the context of an operations control at an airline, and what tool can best support the controllers work. The research question has been narrowed down to; *"How should a graphical user interface for an airline crew control Operations Monitor be designed so that the user, the crew controllers at an airline company, is best supported in both their current work, and also their future work?"* To be able to answer this question, several methods have been used. A user and a task analysis have been created, resulting in four prototypes, which have been tested upon real users and expert groups.

From the results of the user tests, the usability and functional requirements were measured for consistency, and the results were satisfying considering the means that were available. The following design recommendations were derived from these results:

Minimize the mental constraint on the user

Striving for consistency using static windows for presenting dynamic data
Minimize the number of components that the Operations Monitor consists of
Allow several processes run simultaneously inside the Operations Monitor
By using split-screen several windows can be open simultaneously
The Operations Monitor should be kept in one window

Be consistent

Same font for title bars and buttons
The title bars backgrounds different than other background colors
The different components should be aligned to a reference frame
Minimize the need of scrolling when displaying information

Provide feedback

Make the borders of the buttons stand out when marked
When choosing a button, let it be "pressed"
The alarms should change in appearance in accordance to status
No sound feedback
Consider the choice of icons and colors from an intercultural perspective
Limit the number of colors as information carriers due to color blindness

Minimize the input actions

Use the mouse as a main input
Allow keyboard shortcuts and macros as a complement
Allow regretting actions by providing a "back button"

Support the user's current way of working

Allow the user to decide to what degree the monitor should be used:
As a monitoring source
As an information source.
As a scenario tool
Create an internal instant message system

Support both a focus and an overview over the current status of operations

Visualize the alarms as graphical objects

Visualize the time of occurrence, the impact, status, and type
Visualize by using a focus+context technique

Make the users feel in control

Allow users to incorporate their own judgement, allowing them for instance to deliberately break certain rules
Allow customization of the alerts by sorting them in preferred priority
Create the timeline as dynamic, to be customized

Support usage in both time critical and time uncritical conditions

Toolbars are preferably used for quick access to often-used functions
Progress bar displaying the status of the process

These design recommendations were the basis for answering the questions set up in the beginning of the work, and for the concept and design of the final prototype. Since the crew controller's task will most probably change using the Operations Monitor, from detecting alarms to solely solving them, it is important supporting them in the traditional way of working. The concept of the Operations Monitor is built upon the definition of alarms generated from an alarm server, and the purpose is therefore to present the appearance of alarms and details of them. This data presented is both static and dynamic, meaning the design of the Operations Monitor can be described as a focus + context visualization task.

The most important role of the Operations Monitor would be to reduce the information available, to act as a filter sorting out alarms and sorting out information. The knowledge and experience of a controller can never be replaced by automation, and it is therefore important to support that the system can be justified according to the unique nature of each problem in combination with the users individual preferences. Founded upon a user analysis and a task analysis, general design recommendations and human factors affecting the controllers, their work and their environment, suggestions for an interface design of the concept Operations Monitor has been concluded.

Three prototypes have been implemented and even more ideas have been experimented with. Evaluated from real user tests, the judgment has been done of what tool to be useful, deciding what functions are to be main functions and which are to be sub functions. The prototypes are the results derived from the recommendations and analyses, being the physical proof of our knowledge and hard work.

The results of this thesis have been affected by the difficulties of separating the concept of one module of a larger system in order to evaluate it, especially a system that is still under development. The context in which the system is to be is very specific, the user group is narrowed and specialized, and this master thesis can be used as a foundation when designing for this environment since it describes what factors are important considering and what the problems may be.

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12 APPENDIX

12.1 Questions to British Airways

12.1.1 Pre-Questions

What is the total number of controllers?

How are they divided? (e.g. crew (3), AC(2), pax(2), long-haul, short-haul, fleet-division?)

Education? What is the most common way of becoming a controller?

How often does new employees come? How are they being trained?
For how long does a controller work? (e.g. 6h a day, 5 days a week)

How large is the time-window handling schedules? (e.g. 72h?)

How long before and after real time? (e.g. 48 h before 24 h after?)

How are alarms and real-time information received? (e.g. telephone, telex, data-link, VHF)

Are confirmations required?

How large part of the crew members are in operations/stand by at the same time? (e.g totally 75%, 3000 in cock-pit and 8000 cabin?)

How many members of the crew are each crew-controller responsible for?

In short range, how many changes a (normal) day? (e.g. 50-200?)

To what extent are the different types of alarms divided into different controllers?

How are solutions displayed?

Are costs for the solutions displayed or analysed?

What is the work-flow priority when a problem occurs?

12.1.2 Interview Questions

1. Describe your background.

2. What is your relation to the profession?

3. Why have you changed profession?

Describe a typical day.

4. How long time does it take to become an accomplished controller?

5. Describe how you perform the profession?

6. Describe some tasks / problems.

7. To what extent does stress and time-pressure impact on the decisions made during work?

8. What tasks are the most difficult?

9. What is the best / worst working as a controller?

10. Are there any individual differences between how different controllers solve tasks?

11. What factors decide in which priority order a task / problem should be solved?

12. What information is considered relevant? Are there any individual differences?

13. How relevant is the overall overview of all of the information?

14. Does the cost impact on decisions?

15. How far before real time do you need to visualize information? After? (Recommended time window)

16. Are decisions made routinely? (By habit)

17. Does conflicts appear when two controllers work to solve the same task? (Could this happen? Are the tasks divided some how from the beginning?)

18.How does the organisation behind the controllers work? (Impact from managers.)

19. What do you know of the Descartes project?

20. Is there a motivation among the controllers to improve the systems?

21. Are there any improvements you could think of now?

22. Expectations and risks with a new co-ordinated system?

12.2 Interview questions to Bo Vaaben

1. What are the requirements for an alarm server?

2. To what extent is it possible to group alarms in categories, i.e. "cancelled", "delayed" and so on?

3. One alarm could generate 100 other alarms, how does the server handle this? Is it possible to distinguish the original alarm from all the generated alarms?
Example: One flight is delayed 50 min. Effect: The AC and 14 crew will miss their next flight, meaning 14 crew pairings and one AC rotation will be disturbed. In a worst case scenario, could this generate alarms for all the affected flights, say 100 of them? For how long time, or to what extent will the alarms create this chain reaction? Is it possible to stop it by the original alarm? Is it possible to have an automatically generated start and stop time for the alarm?

4. How is an alarm generated?

5. Is there a template for what an alarm should contain? What information is possible to show?

6. Is it possible to prioritize alarms, can they be sorted by how critical they are?

7. How is cost considered?

8. Are you involved in the design of the alarm server in Descartes? Have you any information about requirements and specifications for this? What are the differences between the SAS alarm server and the Descartes one?

9. Where, in the Descartes architecture, will the alarm server be?