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Use of large screen displays in nuclear control room

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Abstract

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Technical industries have been growing in size and complexity the last decades, and the monitoring task has been facing new challenges. The influence of human factors in technical systems is critical for the safety, and a well-designed human-system interface (HSI) is of great importance. To support operators in control rooms, the HSI needs to be designed considering the cognitive functions and its possibilities and constraints. Modernised HSIs have resulted in more computer-based control rooms in order to meet the new demands in controlling systems in a safe and effective way. The intentions and appliances of large screen displays, as a part of the digital HSI, are somewhat still unclear.

This thesis includes a literature study and a case study that aim to describe how the situation looks today for large screens implemented in nuclear control rooms, in research and empirically. The study covers the intentions of the large screens, how they are implemented and used, and the interface design of the large screens.

The literature and empirical results agree that an overview function is the most important for large screens in control rooms. A large screen provides shared information, is viewable for every one in the control room and should be a permanent information source for the operators. In addition, it enhances teamwork. However there is still a lack of specific designs for large screens. If todays shortages of large screen implementions were better considered, more of their possible benefits could be utilized in control room work. Introducing new technology into a system implies a risk for new problems to arise and should therefore be carefully considered.

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Populärvetenskaplig sammanfattning

De senaste decennierna har stora tekniska system (industrier, kraftverk etc.) vuxit i storlek och komplexitet, och uppgiften att övervaka dessa innebär nu nya utmaningar. Påverkan av människan, *human factors*, i sådana system är viktig för säkerhetsfrågan, och därför är designen av *människa-maskingränssnittet* (human-system interface - HSI) av stor betydelse. För att kunna stödja operatörer i kontrollrumsarbetet måste ett HSI designas med tanke på människans kognitiva funktioner, samt möjligheterna och begränsningarna dessa medför. De uppdaterade och moderniserade HSI som finns i bland annat kärnkraftverkens kontrollrum har mer och mer gått från analoga till digitala och datorbaserade, för att lättare uppfylla de nya kraven när det gäller att kontrollera systemen (kraftverken) på ett säkert och effektivt sätt. Vad intentionerna och användningsområdena bör vara för de så kallade *storbildsskärmarna* (large screen displays - LSD), som ingår i digitala HSI, är fortfarande osäkert.

Examensarbetet innehåller en litteraturstudie och en fallstudie som båda syftar till att beskriva hur situationen ser ut i dag för LSD i kärnkraftverkens kontrollrum, ur en teoretisk och empirisk synvinkel. Uppsatsen tar upp avsikterna med LSD, hur de tillämpas och används, och hur gränssnittsdesignen av dessa ser ut.

Både forskning och fallstudien visar på att det viktigaste för LSD i kontrollrum är att ge en översiktsbild över systemet. En LSD ger gemensam information till alla operatörerna samtidigt och bör vara en permanent informationskälla i kontrollrummet. Den hjälper dessutom till att öka interaktionen mellan operatörerna. Men det finns fortfarande brister, till exempel saknas särskilt utformade riktlinjer för design och utformning av LSD. Om dessa problem kunde lösas med hänsyn till de specifika förutsättningar som LSD har, skulle de också kunna utnyttjas bättre i kontrollrumsarbetet. Man bör komma ihåg att införandet av ny teknik i ett befintligt system innebär alltid en risk för att nya problem ska uppstå. Därför bör sådana implementeringar och dess konsekvenser noga planeras och övervägas.

Content

1. Introduction

The complexity and size of technical industries has been growing in recent years. One result of this is that operators monitoring and controlling technical processes are facing new challenges. In nuclear power plants, which include complex processes with high safety demands, the control rooms are currently undergoing modernisations to include more advanced technology and computer-based systems. One of the main reasons for upgrading is that the main part of instrument and control (I&C) equipment in nuclear power plants today is analogue. The decreasing availability of replacement parts causes the cost in the operation and maintenance to increase. I&C modernisation with digital equipment has been accelerating as plants have been ageing, and as more plants receive license renewals, and as features that digital technology offer are needed to increase cost-effective electricity production. The introduction of computer-based systems has resulted in an increased attention to the importance of the *human-system interface* (HSI) design.

In modernised nuclear control rooms, humans work with several types of HSI tools to monitor and control the power plant process. In some control rooms, also *large screen displays* have been introduced. This master thesis will give a contemporary sketch of the role, intentions and use of those screens. Large screens have been used as an information source for a long time already, but becomes more and more common and important in control rooms. Yet, many applications of large screen displays are not always optimal in making the best use of the potential benefits this technology brings. The intentions of implementing large screens in a control room may not always agree with the final appliance. What could be a complement that improves the control room work, safety and productivity of the plant, sometimes misses its goal. The influence of *human factor* is important when machines, systems and interfaces are to be designed. We have to understand how to get the machine to fit the human, and not the other way around. An MTO perspective (*man-technology-organisation*) implies a holistic view on safety in systems and considers the combination and interplay of the three factors when accidents occur.

This thesis has been performed with support from Institute of Energy Technology (IFE), Norway and the Department of Information Technology at Uppsala University. In addition to a literature review and a case study performed at a nuclear power plant, other sources of inspiration have been personal communication with large screen designers and a nuclear power process expert at IFE, attendance to two large screen workshops, and a visit at a nuclear power plant simulator.

1.1 Aim and scope

The aim of this thesis has been to sort out the most important and generally accepted ideas and applications of large screen displays. Another aim is to investigate the core characteristics and the most optimal appliance of the large screens. To do this, I have been asking myself some questions as guidance. These are as follows:

– what is the unique value and purpose of large screen displays in control rooms?

– how do guidelines and the design of large screen design look today?

– how are large screen displays applied and used in control room work?

A literature review and a case study of a nuclear power plant control room has been performed to collect data. The input of both theoretical and empirical character aims to complement each other. The objective of the literature review is to evaluate and give an overview of some of the most important and relevant articles and books that concern the topic of interest. The outcome of it should then help to draw some conclusions of the subject, in combination with the case study. The question about the application of large screens will be answered mostly by the case study chapter, which contributes with information from a real nuclear power plant. This was made to confirm, or reject, the findings from literature, and to bring further light on the problems set up for this thesis.

Within the scope of this thesis lies the interaction between humans in the control room and the HSI, particulary large screen displays, in the work of controlling and monitoring the process of a nuclear power plant. The different technical solutions of screens are also of importance for the work performance, but in this thesis focus will be on the cognitive part of the work within a control room. The "design" discussed here includes therefore only the design displayed on the screen, and not any parts of the hardware.

Control room activities include much more than the examples and issues discussed in this thesis. For example, automation and alarm issues have been excluded because of their complexity, and could in themselves have been the topics of separate theses.

1.2 Concepts and definitions

Some fundamental and central concepts will be explained in this section. Some of them are specific for the area of large screens, while some occurs also in other contexts but need to be defined especially for this thesis.

The interaction between operators and large screen displays is central in this text, and the physical domain is the *nuclear power plant control room*. When I refer to the people inside this domain whose work task is to control the plant process by directly working with large screens and other parts of the HSI, I will name them *operators*. Literature used in this thesis name them differently, e.g., workers, users, persons, etc. depending on the text. When referring to crew performance issues, *crew members* are assumed to be the same operators earlier described.

A *screen* is a physical device for displaying information. The definition here of the closely related *display* has a somewhat less physical touch than a screen. I.e., a *screen* is a physical artifact, while a *display* is a screen but with a content; it *displays* something. The *device* (technical/physical equipment) for this can vary, as well as the size of it. The central term in this thesis, *large screen*, actually does not have any generally accepted size standards. It could yet be said that it should be larger than ordinary VDUs (*visual display units*) (Noyes & Bransby, 2001). The *large screen display* is, because of its size and purpose, often placed at a distance from the operators' *work stations*, which distinguishes it from the ordinary *desk top displays* at the desks.

The interface is *designed* by constructing and structuring the information on the screens, and giving it an appropriate form and character. The design could include both practical and esthetical values, and include colors, shapes, and ways of representing or arrange information.

The *human factor* area describes the human performance in interaction with the surrounding world, and the capabilities and functions of this. It is closely coupled to the term *ergonomics* which can be defined as the sience of human in work, and the interaction between the man and his tools. (Nationalencyklopedin, 2008-02-07) Wickens and Hollands' (2000) definition of human factors is the way in which "human accomplish work-related tasks in the context of man-machine system operation, and how non-behavioral and behavioral variables affect that accomplishment". (Wickens & Hollands, 2000, p. 2) Human factors is an important variable to consider in HSI design work. (Wickens & Hollands, 2000)

1.3 Outline

The next chapter presents the theoretical frame of reference used in this thesis. Background information about control room work and some central terms about the human cognitive capabilities and constraints, which are important in the human-system interaction work, will be provided. The chapter's purpose is mainly to guide those who lack any previous experience of the subject. Chapter 3 continues with the literature review, where different aspects and opinions in large screen research and its usage are presented. Chapter 4 presents the method used for performing the case study, and presents the procedure of it. The case study has been performed at a nuclear power plant. The interviews and observation of the operators have brought additional information to the work in an attempt to empirically anchor the questions raised in the literature review. The fifth chapter presents the results from the interviews, and the sixth chapter discusses these results. The last chapter, 7, contains an analysis of the research and the case study, discusses the whole material together, and gives some brief conclusions.

2. Background

This chapter aims to introduce and describe the background and related theory for the theme of this thesis. It will describe the conditions on which the theories and problems are based, and introduce readers who are not familiar with the field. The broad field of human-computer interaction stretches from human behaviour, socio-technical perspective to design philosophies. For those who work with or have been in contact with the theoretical concepts of control room work, human factors or interface design etc. earlier, this chapter might bring some redundant information, and can continue reading at chapter 3.

2.1 Control room work

Control room work can be a very complex task with many affecting factors. In recent years the task demands of operators have grown as the technical systems become larger and more complex. Increased effectiveness combined with the increasing complexity are noticed in a higher level of stress for the operators when making decisions. Problems they are facing are for example conflicting goals, severe consequences, pressure from management and society etc. Not surprisingly, the organizational structure influences even the control room work. The communication, both between workers (horizontal) and between workers and management (vertical) is crucial for a good work environment. (Wickens & Hollands, 2000)

The development towards larger industrial processes over the last years has also resulted in requirements for a higher level of automation in the processes. Automation replaces human work in situations where humans are limited because of physical or cognitive constraints (e.g. lack ability to work with dangerous chemicals, too high complexity of process). (Wickens & Hollands, 2000)

2.1.1 HSI – human-system interface

To handle the monitoring of the technical systems, the interest of *human-system interface* has increased and the importance of it has attracted more and more attention. The HSI is closely coupled with the area of human performance and the possibilities and constraints it implies. It is therefore a crucial area of knowledge when choosing or designing new HSI tools and equipment, for example large screen displays. How can they contribute to control room work? They, and other HSI tools, need to be designed with the psychology of humans in mind. The HSI can include both the "the function of providing information to crew members" and "the devices used to present this information". (Stubler & O'Hara, 1996, p.27) A computer-based interface consists of displays and controls (e.g., handles and buttons). Through the interface a two-way interaction is possible: the operators both receive information about the process state, and can control it. (Vicente, 1999)

The information displays in a control room are a central work tool in the HSI for the operators. The displays constitute an important link of information between the process being controlled and the operator controlling it. In a closed-loop system, e.g., a nuclear power plant, the operator's only ability to monitor and control the process is to rely on the variables shown in the displays. The most successful display design would be a design that helps the operator in his or her work by providing a reliable interface model of the system. Short time constants, future information and system response are helpful elements that can make decision making faster and more efficient. (Wickens & Hollands, 2000)

Displays in control rooms can have different characteristics. Some provide information to one operator (e.g., at the workstation) and some concern several operators (a crew) at the same time. When aiming to reach multiple operators a so called *group-view display* is used. The hardware for the group-view display could be a large screen, often wall mounted and available for the operators directly from their workstations, or the more traditional (and smaller) desktop screens. In the latter case, the display could only be available for operators in a delimited part of the control room, a so called *walk-up display* for which operators need to leave their workstations to use. (Stubler & O'Hara, 1996)

A large screen display also places within the scope of serving multiple operators with information. It is a public display in the control room, often with information concerning several operators with different tasks. The area of use decides the location of the display device in the room, wich is an important consideration. A display can also have the mission to give overview state information. Requirements for *overview displays* are to present data that quick and easy can inform the operators about the overall conditions of the plant on a relatively high abstraction level. An overview can be available for one or more operators. The operators should be able to maintain the awareness of process status on the whole, with important and useful data concentrated in one place. This reduces the time consuming process of gathering and integrating data for the operators. With more data points presented in a smaller area the display gets denser, and the process can be presented in its whole. (Stubler & O'Hara, 1996)

2.1.2 Traditional vs. modern control rooms

Control rooms, in nuclear power plants as well as other industries, have experienced a development. From the conventional hardwired controls and analogue panel displays, the interior and devices have developed towards a more and more computer-based feature. (Stubler & O'Hara, 1996) Comparisons indicate advantages and disadvantages in both newer and older solutions. Several researchers on the subject claim that the benefits of the conventional control room are the openness and sharing of controls and panels, while modern computer-based environment tends to isolate the operators at their own desktops and work stations. The result is a decrease of the communication and interaction between the operators. The critic maintain also that the computer-based interfaces bring new and heavier demands on human performance, which lead to increased cognitive workload. Therefore, it is important trying to maintain the advantages of the conventional solutions when designing and introducing computer-based control rooms. (Stubler & O'Hara, 1996; Wickens & Hollands, 2000)

2.1.3 Human cognitive possibilities and constraints

In modern display systems the number of displayable data points has increased, and with this more difficult challenges for the human operators. More and more developed display units are being used to a greater extent in the control room interior to meet the increase of cognitive work load and handle the amounts of information. Complex information presented in the "wrong" way would increase the chances of misunderstandings and human errors to occur, because of the somewhat unclear communication between the system and the operator. Therefore, it has become more and more important of choosing *what* information to display, and *how* to display it. Different ways of representation might be suitable at different times, depending on the system and the information requirements. For example, for the specific intentions of large screen displays some representations are more suitable than others. This will be further discussed belove, and through the examples of literature and case study findings some examples about best representations can be found out. (Wilson & Corlett, 1990)

Operation, normal or with incidents, should be run according to certain priorities. In some situations, priorities between safety, economy and efficiency may be conflicting. In these situations, the differences between an *expert* and a *novice* occur. Wickens and Hollands (2000) name some of the abilities of the expert operator that makes it easier for him or her to cope, naturally, better with events like this. These are, among others; to predict the future, that they possess a better mental model, have a broader attention and an ability to handle a multitask environment. (Wickens & Hollands, 2000)

Experienced operators are very attentive to the patterns in their work domain and also to detect anomalies. Design for expert users and novices could ideally differ to some extent. Fundamental information (such as lines and symbols that mimics the physical appearance of pipes, valves, pumps, and the relation between them) is not as necessary to experts as to new users, but can instead be seen as useless and "cluttery" to experts. Wickens and Hollands (2000) maintain the importance of the implicit knowledge and experience of an operator who is well familiar with the work domain. These skills of an operator improve the co-ordination and control work performance. (Noyes & Bransby, 2001; Wickens & Hollands, 2000)

Expert users are able to extrapolate the technology when needed, i.e. *finishing the design*, and they also possess a great tacit knowledge of the context to do this. The intention of finishing the design is typically to reduce the workload, by making their own solutions that suites the individuals better and work as "innovative" tools. An example is manipulation of alarm set points, which will make the alarms act as "reminders" for specific actions. In a field study by Vicente and Burns (1995) these types of redesign and manipulations are in some situations welcomed, because of their enhancement of work. Yet, some critic alarms should be respected to not being modified, a question that needs careful consideration and thorough knowledge about the system. Designers can not predict all events in a system, but thanks to the field experience of the operators some deficiencies of the design can be corrected. It is even claimed that corrections like these make the system more reliable than without the operator's involvement. (Vicente & Burns, 1995)

Mental models are internal representations of the system and process that are helpful when carrying out a task, and increase the understanding of the process and the situation. A mental model may have inaccuracies or be incomplete, because the form of it depends on the experiences of the operators. A good mental model gives a better comprehension of the system, and guarantees a higher safety level. To give a definition of a 'good' mental model, one can say a model with correct relations between the system components, which represent the reality in the most realistic way and is able to support the operator even in abnormal situations. A well performed and worked through interface design should support the mental model of the operator. (Wilson & Corlett, 1990)

Some difficulties for the operators controlling large systems could be, e.g., long and slow time constants, which aggravate the control task. System interfaces often present discrete variables instead of the more realistic continuous ones. This does not match the operator's mental model of the (continuous) process he or she works with. Better and more accurate interface design makes the controlling and monitoring more correct and safe. (Wickens & Hollands, 2000)

A definition of situation awareness in Roth et al.'s article says it is "the perception of the elements in the environment within a volume of time and space, the comprehension of the meaning, and the projection of their status in the near future" (1998, p. 245). In a nuclear power plant it implies awareness of the current plant and task state, and to have access to relevant displays. Control room work often also implies teamwork, with demands on good collaboration and coordination between operators. As part of the interaction activities it is also important to understand each other and the situation, and *shared situation awareness* could make it easier. By sharing displays (e.g., large screens), environment and other information (e.g., verbal) also the shared understanding increases. This will in addition also enhance tasks performance. Yet, a study by Bolstad and Endsley (1999) suggests that shared displays to some extent would slow down the performance for teams because of the distraction. The "internal" help that a mental model gives was at the same time found to improve team performance. Shared displays only contribute *indirectly* to the mental model. (Bolstad & Endsley, 1999; Roth, Lin, Thomas, Kerch, Kenney & Sugibayashi, 1998)

A condition for the use of language and other communication channels is *common ground*, which also affects shared situation awareness. A definition of common ground is "*p* is only common ground if: all people conversing know *p*; and they all know that they all know *p*" (Monk, 2003, p.270), i.e. the operators have the same viewpoint and a shared understanding of the plant status. Common ground could be developed by common education, training or other history of joint actions for the operators. The assumptions we can make from a common ground make our communication easier and more effective, and therefore even our work. (Monk, 2003)

Good communication within the crew and awareness of the other's work are essential to control room work. Crew performance can be improved by several means in the HSI, e.g., a common and coherent representation of goals, shared visualization of activities, shared understanding and a shared mental model of the process. Common education and training within the work domain will also help the operators create a shared mental model and common ground.

2.2 Interface and display design

This chapter will present the field of design, and what designers should think of when designing for humans, both on a higher and lower abstraction level. Methods in the design process requires a holistic approach on the conditions, and some guidelines and tips for elements, colors etc.

2.2.1 Design philosophies

Ecological interface design (EID) is an approach to display design which focus on the actual environment (e.g., programs, control rooms) and its physical constraints. A high compatibility will be supportive to the operator, both in normal and abnormal situations, also in unanticipated events. By displaying the *natural* environment, including its constraints and a consistent representation of levels and used variables, the mental models of the operators are supported. The operators can more easily detect and diagnose faults, when being aware of the system's different abstraction levels. (Wickens & Hollands, 2000)

In his book, Vicente (1999) maintains that the EID is very useful when a work analysis is carried through. If the interface designer only takes the cognitive constraints into consideration, which would practically be the opposite of the ecological approach, there will be gaps in the design. Designers can not anticipate all situations in their design, and not even the expert users can predict good enough to fill these gaps. In cases where expert users and their mental models have been the centre of the design process, the results are not universal and reliable enough. By identifying the knowledge and information that operators need to deal with events and faults, even the unanticipated, the goal can be reached of an interface design wich meets the requirements for a safe operation and ability for the operators to cope with all kinds of work tasks. The EID approach is vital because the environment influences the behavior, but the behavior does not influence the environment. (Vicente, 1999)

Display design should make the display area more effective and the monitoring easier. The information could be condensed by providing visual images that contain more data point per area unit.. The *information rich design* (IRD) philosophy is not afraid of displaying too much information to the operators. Good design principles make it possible. The "key-hole" effect (only a fraction of the total system is viewable) is reduced, and the increase of information gives the operator a better overview and awareness of the system. The design principles in IRD support the cognitive skills on a low level and thus enables an easier monitoring. By using analogue elements, visual patterns and cues, the operator obtains more information at the same time than with, e.g., numbers, text or cluttered design. Visual information does not require to be processed or interpreted, only directly "perceived" by the operator. (Welch, Braseth, Veland, no date)

2.2.2 Design elements and representations

How the information is structured and represented on the display affects the human performance. This is why design choices are crucial for safety and productivity in industries. Cognitive workload can be reduced, and the interface works supportively to the operator. How the information is going to be *used* also determines the display design. For example, values should be presented in a form in which it is usable to avoid calculations, which are cognitive demanding. Process information might be easier to read from an analogue display, which supports *pattern recognition*. The formats to display information are numerous, and have, of course, both advantages and disadvantages. (Brown & O'Hara, 2004)

A handful of them are, figure 1 a-e:

- *Analogue/digital:* figuratively (graphic) or numerically information representation.

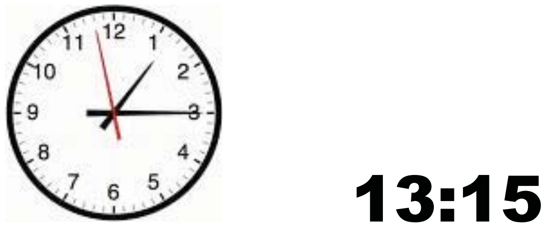

Figure 1a) Analogue and digital representation of the same information.

- *Alphanumeric:* characters of both letters and digits. Besides speaking for themselves, alphanumericals can also be included in graphical displays.

- *Trend graph:* graphic representation of a parameter's development over time. Trend pictures can provide both historic information and prediction. Trends support comparisons (when more trends are overlaid) and locate deviations from the normal values (reference values).

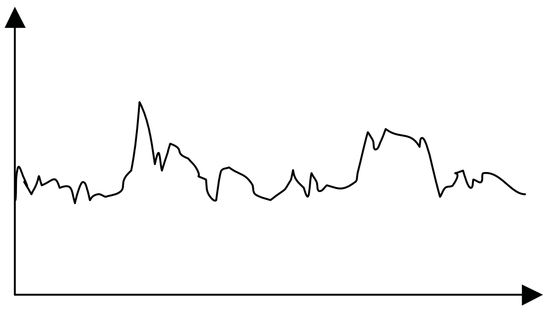

Figure 1b) Trend graph plotting one variable as a function of another

- *Mimic:* a static, graphic representation of the system, which "imitates" its physical geography. Includes both graphic and alphanumerics.

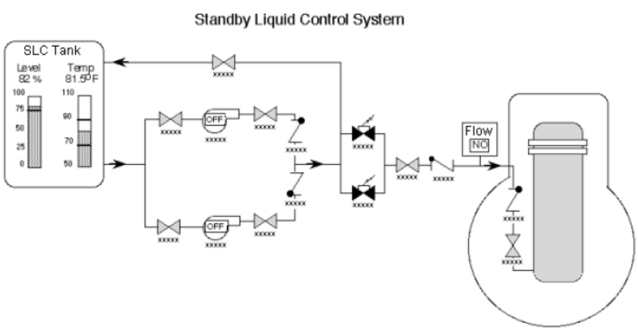

Figure 1c) Mimic of a system (NUREG-0700)

- *Bar chart:* graphic represenation of numeric quantities. Sometimes a type of *deviation display*, which provides effective monitoring and fault detection. The bars show both positive and negative deviations (from the reference point). Analogue.

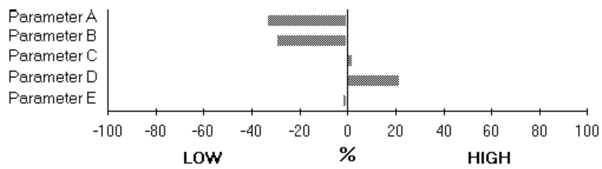

Figure 1d) Bar chart, including both positive and negative deviations (NUREG-0700)

- *Pie chart:* (circle diagram) analogue displaying of the relative fraction of the parameter value.

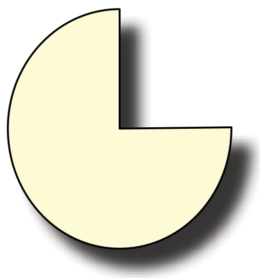

Figure 1e) Pie chart

(Brown & O'Hara, 2004; Wilson & Corlett, 1990; www.ne.se)

3. Theory – literature review on large screen displays

This chapter reviews literature on large screen display research. The purpose of the review is to describe as thoroughly as possible the role of the large screens in a control room context and the intentions of using them. The chapter is divided in three sections that each discusses and structures information about the questions adressed in this thesis.

3.1 What is so specific about large screens?

More and more large screen displays have been included in industrial control rooms. Because of the increased complexity of technical systems, it has become even more crucial to have an effective and safe monitoring of these systems. Large screens appear as a part of the upgrade and modernization of industries' HSIs to compensate for the weaknesses. But, the implementation of large screen displays is relatively new, which itself, in some extent, requires new work practices and investment of time and money.

3.1.1 Overview or detailed information?

To start, the main part of the literature about large screens agrees with the application which aims to give a status or process overview. Large and complex systems make it crucial for the operators to get overview information. Groot and Pikaar (2006) suggest that overview information should be displayed permanently so that the operators always have access to it. Yet, they say, the overview should only be available at the "secondary vision" of the operators, to not intrude on the actual work tasks. But because they are frequently looked at, they should have a good accessibility. Large screens are a good way of realizing this because of their physical size and position in the control room. They are often placed at a height and a distance from the control panels which makes them viewable for all operators, even if not in the "primary vision". Collier (2005) also means that it is important that critical information is permanently displayed, and that the accessibility of the modification of such information should be restricted. (Collier, 2005; Groot & Pikaar, 2006) The nature of "critical" information in this case could represent more than just the overview, but in many cases it constitutes the core information to an operator team with monitor tasks. Human errors have sometimes proved to be the reason for incidents caused by hidden information; a file that unfortunately hides important desktop displays or surfaces have caused several more or less serious incidents, like the accident at Three Mile Island, Harrisburg in 1979.

Stubler and O'Hara's (1996) compilation of a great amount of group-view display literature provides useful opinions of this area. A group-view display is convenient to apply when several operators need to access the same information. This should support the operators' awareness of the system status, and provide an overview of the process by a quick glance. An overview, provided by any type of hardware, should be able to warn the personnel even in early stages of an incident rising by providing the essential parameters of plant status, and be of good help in the monitoring work. (Stubler & O'Hara, 1996)

Simultaneously, detailed information is needed for operations on definite parts of the system. During normal operation a status overview will be considered enough, with its fields of application such as monitoring and detecting abnormal situations. But, when abnormal events occur (e.g., faults) the operators need some more detailed and specific information on the desktop displays. This is because every operator still needs their specific information to handle the task in situations like this. Davey's (2005) advices for displaying specific task information agree that it should normally be displayed at the consoles and workstations of the operators. The wall display should on the contrary display information that supports coordination among several workers, their tasks and shift staff. (Davey, 2005; Groot & Pikaar, 2006)

A historical review of large screens is given by Davey (2005) in his report. The earliest implementations of large screens gave an overview by mimic diagrams of both process and equipment status. As mentioned above, an important purpose of the large format displays was, among others, to provide an overview of the plant organization and its internal relationships. (Davey, 2005)

3.1.2 Sharing and its contributions to control room work

How could a large screen display affect the control room work? With shared information the operators are able to create shared mental models, shared situation awareness and therefore a shared understanding for the process and status, which in turn enhances work performance. A permanently displayed large screen provides a great aid when shifting displays at workstations; it helps the operators maintaining their awareness. (Davey, 2005) A study by Dudfield et al. (2001) agrees with this. Both improved situation awareness and shared mental models were noted at workers sharing a large screen display, in this case a panoramic display. The importance of shared mental models has been discussed in this text, and it gives further weight to the type of results just mentioned. (Dudfield, Macklin, Fearnley, Simpson & Hall, 2001)

In the case of including large screen displays in the HSI in control rooms, one function is to provide the same information to every operator, *shared information*. The content of group-view displays, which for example appear as large screen displays, should be information required for more than one concerned operator and their respective tasks. (Stubler & O’Hara, 1996)

The awareness of other’s work, which is provided by a group-view display, may increase the coordination of the different work tasks in the control room. Help and support can be exchanged between the operators in a team and create a synergy effect to the control room work. The presence of a group-view display with common information could also reduce the negative effect of isolated workstations. Crew coordination can also be achieved with a greater “openness of tools” and interaction brought by a shared display. This means the operators are not bound to their workstations or work tasks, but freely can contribute to other ongoing tasks. The interaction seems to be enhanced by shared information even when the collaboration is within the same task. This could be a good help when there is spatial or physical hindrance for collaboration, or many operators are contributing to the same task at same time. (Stubler & O’Hara, 1996; Collier, 2005)

When implementing a large screen display in a work area (e.g., a control room) the purpose is often to improve the work performance in several and different manners. Even without an explicit purpose, the large screen can increase the frequency of interaction and teamwork between workers. This is because of the public character of the display and its providing of common information for the operators. The right choices of display design and information could create an encouraging effect on the operators to interact more with colleagues. Several studies claim that utilizing large displays will improve the social interaction between workers. Social interaction like this will in addition also decrease the risk of events in the system being undetected by the operators, when providing "more eyes" to monitor. Interaction can also enrich the creativity in the control room work. (Tan, 2004)

The more communication and openness there are between operators in a control room, the better team performance. O'Hara and Roth (2006) claim in their chapter, that the conventional control room and its equipment have a number of advantages over the modern, computer-based control room. For example, in older control rooms there was a more frequent verbal interaction between operators which increased the shared situation awareness of the plant status and ongoing activities. As mentioned before, the physical workplace and the physical placement of the large screen, also have impact on the team interaction. Hutchins (1995) mentioned *horizon of observation* and *openness of tools* as factors which affect teamwork. Both can be said to be provided by a large screen, because of the shared information between many operators at the same time. (O'Hara & Roth, 2006; Hutchins, 1995)

3.1.3 How the size of displays influences work performance

In their study, Groot and Pikaar (2006) mention, among other things, the psychological factor of overview displays. The contribution of it is an, by the operators, experienced feeling of enhancement in their control work, which further improves the work performance of the operators. (Groot & Pikaar, 2006)

In his dissertation, *Exploiting the Cognitive and Social Benefits of Physically Large Displays*, Tan (2004) summarizes results about psychological and physical effects given by the use of large screen displays, and the benefits to gain. For example, several studies tell that the user's sense of presence improves, and in addition performs better and more efficient at tasks. While we are learning, the environment around us influences how much information we remember. It is shown that display size affects the memory when it comes to learning; the larger display, the faster and better memory performance. This, in turn, comes of a greater sense of presence. It is tempting to think there would be a direct effect between the use of large displays and a greater sense of presence, even though Tan's (2004) study does not explicitly mention the relation between those two factors. (Tan, 2004)

More studies in the same area also show the advantages in using larger displays, for example by its wider fields of view, which improves the productivity and performance of the users. The results also say, in line with the one above, that the peripheral awareness and memory improves when using large screens. But, there are also some issues about the use of this technology. Some examples are problems connected to the management activity of the screen. In larger displays the cursor more easily disappear and in case of activity of windows opening or closing on the screen (use of so-called multipel monitors) it gets more difficult to keep the control when the screen size increases. (Czerwinski, Robertson, Meyers, Smith, Robbins & Tan, 2006)

The results above are supported by a recent (commercial) study at the University of Utah supported by NEC Display Solutions (2008). By comparing participants performing tasks on traditionally sized screens with performance on widescreens, it was found that a larger screen size increases the productivity. For example, participants using a 24” widescreen were more productive and time-saving than persons using a 18” desktop screen. The time saved was in the region of 30%. Also the use of dual monitors increases the work performance, according to the study. (NEC Displays Solutions, 2008)

Collier’s (2005) proposal for large screen displays providing links to additional useful information to support task work, adds another purpose for the large screen. Finally, three important specific functions could be summarized as; *direct operators to additional information, support crew coordination*, and *support personnel communication and collaboration*. (Stubler & O’Hara, 1996; Collier, 2005)

3.2 How do the design guidelines of large screen displays look?

Different tasks need different information. For large screens in control rooms, as well as for every part of the HSI, there are also specific needs of *how* the information should be displayed. This section will present some of the most common and important suggested guidelines for design of large screens. Considering the information requirements of a work domain or tasks, an analysis may be necessary in the beginning of the design process. The design and content of a display is of course depending on what the operators and tasks require.

3.2.1 Shortages of large screen display design

Traditional, and not always optimal working, HSI principles used in industry are still frequently applied when designing new screens for process control. Sometimes the traditional screens are just copied to the large screen. This holds back the potential benefits of large screen that could meet the challenges in industry. Larger screens could afford greater situation awareness, better state overviews etc. But instead, large screen displays often are used just to scale up traditional screen pictures. (Veland & Eikås, no date) Vicente and Burns (1995) discuss these problems with control room design as “the remains from the traditional interface design”. It is a problem when a system’s technical processes *per se* have been modernized, but the interface design has not followed the development in a sufficient extent. (Vicente & Burns, 1995)

The overall consideration of the HSI design is important when a large screen display is introduced, according to Davey (2005). Sometimes the control room is not considered in its entirety, which is important to make the HSI parts work well together. The layout of the workstations, consoles, placement of desktops etc. should be *reconsidered* so that the large screen display becomes functional and appear to advantage, for example, is viewable from all work locations. (Davey, 2005)

Veland maintains that even though large screen displays have been used for several years the outcome has not been as great as hoped for. The reason he gives is the lack of relevant design guidelines and specific knowledge of the area of large screens. The large screen display investments in industry are not seldom undirected without any specific function or purpose in mind. Correctly designed and used, the large screen display should provide a surplus value to the control room work and the HSI. Because of its complementary function in the control room, it is important that the same design is not being used for the other parts of the HSI as for the large screen. (Veland, no date)

The need for more specific developed and adapted guidelines for large screens is also asked for by Collier (2005). He lists three main shortcomings of the guidelines available today: *lack of adaptation* of the traditional display guidelines (to today's newer and different conditions for large screens), *bad interpretations* of existing guidelines (when they could be interpreted to new conditions), and *not following the adjustments when the weighting of importance changes* (other issues in the HSI becomes more important beacause of new conditions). (Collier, 2005)

3.2.2 Support human cognitive functions

As mentioned earlier, human cognitive capabilities are functions which, when used in the right way, can be of great help in the controlling or monitoring work. A great asset is for example *pattern recognition* which works on a low cognitive level; the *skill-* or *rule-based behavior* levels (from the *SRK taxonomy* by Rasmussen in Vicente, 1999). The skill-based level represents the lowest of the cognitive control levels, at which our most basic actions happens. Actions on this level do not require any real effort or even conscious attention from the operator. Instead these actions are parts of automated and integrated patterns of behavior. Patterns in design, for example displaying the time-space behavior of a system, can be registered by the operators on a basic cognitive level and because of the little amount of workload this requires, the task could be carried through parallel with other tasks. (Vicente, 1999)

Some of the most important factors in interface design are elements and design that supports human cognitive functions. Knowledge about this area is useful to make monitoring effective, safe and easy. As systems grow larger, and processes become more complex and the amount of information to monitor will increase. It is then valuable to have an effective scanning process of the system. Information which is easy scanned and consistently presented so that the operator is supported to recognize and easily locate and understand the information quickly. A well established and often appreciated way of dealing with this is by supporting human capabilities for pattern recognition. When meters or controls are displayed randomly they do not form a uniform view for quick scanning (see figure 2 a-b). Instead, information arranged in patterns, e.g., by arranged by their "reference values", would be more supportive and the pattern recognition could be employed by the operators. (Vicente & Burns, 1995)

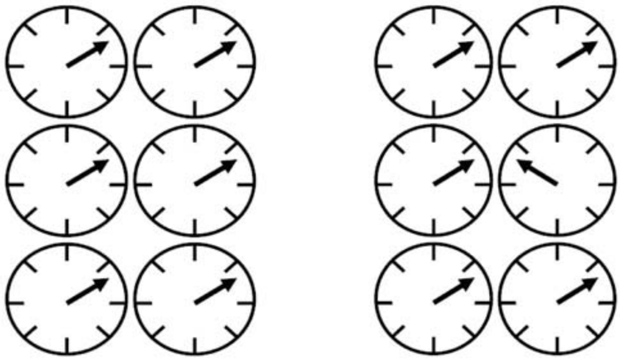

Figure 2a) Uniformed information where deviations easily detects...

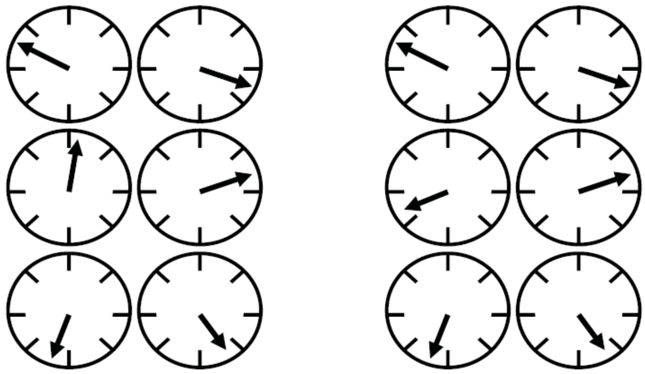

Figure 2b) ...instead of values with no uniformed set points, which do not support pattern recognition.

Some interfaces do not show reference values or constraints, which would have made it easier to detect abnormal values at a glance. Instead, it requires work; memory load and knowledge, to establish a fault value that could be used in the monitoring. By choosing and work through the design choices thoroughly, including feedback from operators, this can be avoided. (Collier, 2005; Groot & Pikaar, 2006; Vicente & Burns, 1995)

In frequently examined pictures, which large screen is a good example of, the amount of static information should, and can, be reduced to a minimum. Collier (2005) claims that experienced users, who frequently use the interface, will quickly learn the display and be familiar with the location of labels etc., and these could thus be removed in favor for dynamic information. It is a waste of space to display lines, self-evident information etc. instead of more useful information that will actually improve work. This is especially important for large screen displays, as Collier (2005) remarks, because elements on a larger screen tend to be larger (because of the screen size itself, and to be viewable at distance). By removing useless "clutter", the display will be denser and save display space. Veland points out that high density of information is not a problem when designed for experienced users as long as it supports the cognitive possibilities and constraints, and one should not be worried about information overload. The space in the display should instead be used effectively with an objective to maximize the data points per unit area, with information units of the most important data combined. This type of condensed information with many data points correspond with the theories about designing for the experienced user. To make the display even quicker to scan, information of a more important nature, e.g., alarms and abnormal values, should be made easily distinguishable. This could be achieved by placement, use of colors etc. Displays with permanent information are easier to scan. (Collier, 2005; Groot & Pikaar, 2006; Veland)

To develop the overview display function further, and as an addition to the line of argument above, Stubler and O'Hara (1996) mean that the dynamics of the plant should be displayed. Static values do not show the behaviour of the system, while dynamics supports the pattern recognition ability and give more information to the operators. Stubler and O'Hara (1996) are therefore maintaining the need of a plant mimic in the display. The different opinions about mimics will be discussed further in section 3.2.4, *Representation display styles*. (Stubler & O'Hara, 1996)

O'Hara et al. (2003) suggest some ideas for displays for collocated collaborative work. The ideas are for example; to support natural interpersonal interaction, smooth transitions between different tasks (individual/collaborative), and provide shared access to displayed objects. (O'Hara, Perry, Churchill & Russell, 2003) Also, NUREG-0700 (*US Nuclear Regulatory Comission Regulation*) provides guidelines for large screen displays. These guidelines cover viewing distances, viewing angels, illumination for best viewing conditions, and text and labels restrictions. This guidance is also dependent on the conditions in the control room and sources of light in question. (Stubler & O'Hara, 1996)

3.2.3 To select information

The selection of information is one part of the design process which is of crucial importance. There are several things to review. For example, there must be a good knowledge of the tasks that will be performed in the domain. This requires a good and solid understanding from the designers of the domain and process. The EID approach recommends that the end users must be known, defined and taken into account during the design process to be able to select the required information content. (Veland; Veland & Eikås)

As mentioned before, the group-/overview displays are types of large screen and these two share several design guidelines. As an overview display, it should provide a quick scanned status overview by providing just a few familiar landmarks, and the amount of information should be tried to be kept down. The choice of parameters and values are because of this a crucial part of the design. (Stubler & O'Hara, 1996)

Defining the *information needs* and making the right selection of information can work as guidance to improve the control room work. Observations made by Davey (2005) include for example context representation (to help operators to create a mental model and understanding of plant context); visibility of status (prioritized information especially important for shift personnel); a permanently common view (available from several positions in the control room to support task coordination); and workplace oversight (a need for the supervisor to monitor ongoing work tasks). (Davey, 2005)

3.2.4 Representation display styles

The graphical representation of a system called a *mimic* provides an overview of the relationships between the system parts (e.g., pipelines, pumps, flows). Such a representation is helpful to the operators, supporting their mental model of the system. Displays that have this impact on the mental models should be designed carefully considering the safety matter. In many processes, for example in the nuclear industry, the mimic displays are commonly used, and is actually required by EPRI (Electric Power Research Institute). A mimic gives a good representation of the functional relationships in the system and helps the operators to detect alarms e.g. (Stubler & O'Hara, 1996)

Nevertheless, the value of the mimic is discussed among researchers. The format could be helpful, but is yet not the most important information for experienced operators. For example, the mimic does not say as much about the plant function as it does about the plant structure which the operators already should be familiar with, and this fact does not make the mimic format very useful in a control room environment. (Wilson & Corlett, 1990)

The critic towards the mimic about not being a sufficient information source among experienced operators comes from the fact that it provides information the operators already know. For example, static pictures, lines and other "learnable" information that is the content of a mimic do not give any new important information such as the system status. This might be one reason to why mimic is not seen as very useful, although it is implemented in many large screens' design today. For example, trends in display present the actual system status, and how the system is changing over time. For experienced operators, who already know the morphology of the system, trends and quantitative information over time convey more. (Stubler & O'Hara, 1996)

To improve and develop the traditional solutions, Veland and Eikås suggest to use the concept of IRD to develop a more supportive and effective interface, and the EID can be of good help when forming mental models for the users. EID also provides information derived from different levels of abstraction in the system. By using the IRD principles, perceptual capabilities and visual design, the lower stages in the SRK taxonomy are supported, but not the knowledge-based. This works well as the large screen should serve as an easily scanned overview. (Veland & Eikås)

3.3 How are the large screens applied?

An overview display should have a consistence design, also in relation to other interfaces used in the HSI. An overview display, and its purpose, is not only reserved for large screens. The application on a large screen is yet an effective one, especially when several operators operate in the control room. A large screen display, providing a status overview, should be viewable from everywhere in the control room at the same time. This will in addition encourage interaction and teamwork between operators in the control room. Even when an operator is constrained to perform tasks from a different work area than his/her console area, the public positioned large screen is helpful. (Groot & Pikaar, 2006)

As larger displays become more and more common in control rooms, the vendors and users still do not know very well how to use them in an optimal way, Davey (2005) says. In his paper he gives evidence of a couple of questions which addresses the uncertainty about this. For example, when information becomes shared and public, who in the work team has the responsibility and access to select what to display? And how should the information be prioritized when there are several, and maybe conflicting, purposes of the large and shared display? Often a supervisor or head of the control room crew has this responsibility, but has to take the individual operators and their ongoing activities into consideration, which sometimes can be a difficult thing to decide. As the large screen displays are a complement to the common desktop displays, there is also a coherence in which the new type of information should be incorporated. (Davey, 2005) The possibilities to interact with a group-view display bring further issues that need to be dealt with, which Stubler and O'Hara (1996) also mention. For example, the complex issues about how the input information should be controlled, who should have authority and access to the display, identification needs of the users, and the question of the responsibility. (Stubler & O'Hara, 1996)

Yet, there are no clear answers to these questions. The issues are also domain dependent, which calls for cutomized solutions in every application, with unique individuals and conditions. The central question of use of large screen displays will be further concerned by the case study presented in the next chapter. Opinions and views of only a small sample of operators will be presented, but yet it is valuable information and might be comparable to other similar cases.

4. Method

This chapter describes the method of the case study performed in this thesis. Also, the participants, control room layout and HSI, and procedure (e.g., interview questions) are described in the following sections.

4.1 Case study

A case study was chosen to complement the literature review and to contribute to the understanding of how large screen displays are used when implemented in an existing control room. In the scope and range for this case study, three control room operators in a nuclear power plant have been interviewed and observed during work.

4.2 Field method

The goal of the data gathering was to enhance and complement the literature review by exploring the research questions empirically. Therefore, a case study was carried out. The inductive nature of a small study like this could include some sources of error. It is therefore important to evaluate the sources and keep in mind that the selection of respondents is only a fraction of the reality and all the opinions about the subject, and also that different control rooms have different solutions.

Methods used to conduct the case study are gathered from theories such as the ethnographic method, naturalistic method and customer-centered design (Beyer & Holtzblatt, 1998; Genzuk, 2003; Noyes & Bransby, 2001; Rose, Shneiderman, Plaisant, 1995), all further described below. These methods contain information about data gathering in empirical milieus. Focus on cognitive workload in control room work has increased in the research area, and is nowadays a more and more important matter in control rooms. Therefore, the data gathering should be done with methods suited to the human work. Methods as interviews, direct observations, verbal protocols and walkthroughs/talkthroughs are therefore appropriate for this aim. (Wilson & Corlett, 1990) In this case study, interviews and observations have been the main source of empirical data.

For this thesis, which to a large extent is descriptive, an ethnographic approach has been suitable. The result of an *ethnographic method* is a narrative description of the object of interest. The gathering of data can be done through both interviews and observation. In the article by Genzuk (2003) the method is described as an intensive study of a restricted domain where the observer is more or less involved in the activities observed. The case study only includes a shorter visit in the environment of control room work and large screen use, and therefore not correspond to the ethnographic studies described in the literature. It has although influenced the performance of the case study in this thesis, for example by the naturalistic belief that says that events must be explained in relation to their context. (Genzuk, 2003) An ethnographic study (or the kind that this thesis presents) gives information and insights about the physical work environment and other conditions that influence the operators' work. It is important to make the interview and observation situation as authentic as possible, including observations of the operators in action. Even the everyday work tasks include important and crucial aspects for the understanding. (Rose et al., 1995)

The intention of the *naturalistic* analysis is to describe the work environment, task and conditions as they appear, in their natural environment, instead of in a controlled, experimental environment. The settings are highly realistic possible and the analysis gives a realistic picture of the work practices and working conditions of the operators. (Noyes & Bransby, 2001) The *contextual design* is desribed by Beyer and Holtzblatt (1998) as a customer-centered method suitable for learning about a system and its users' needs when (re)designing a system. The method follows the line of the ones above; by collecting data from the system in question the understanding and knowledge of the system increase. The theory emphasizes the importance of work practice in a design process. Factors as communication, roles and relationships, values and standards, and physical conditions are affecting the work practices and performance. To understand the users and their work tasks, it is considered necessary to understand also their working environment (e.g., tools and arrangement of spaces in the work domain). (Beyer & Holtzblatt, 1998)

4.3 Participants

The interview participants consisted of licensed nuclear operators; one reactor operator, one turbine operator and one shift leader. They all have long experience of control room work in nuclear power plant operation; up to 31 years each. All three operators have worked in the control room in question both before and after the renovation and upgrading of the power plant and the control room (finished in early 2000). The participants are in the age between 45 and 65.

4.4 Control room layout

In the nuclear control room used in this case study there are workstations for three operators in the shift team (see figure 3). They all have 5-6 desktop screens each. In front of the desks of the reactor operator and the turbine operator the wall panels are placed, in a 90 degrees angle. On the left-hand side (close to the reactor operator) is the *security panel* (4 m wall panel, analogue display of mimics over the security system), and the right-hand side (in front of the turbine operator) containing the traditional *wall panel* over the turbine side of the process. The wall panel remains from the original control room, built in the early 70's. Since then, the HSI has been partly upgraded, for example with a security panel and the computer-based parts such as the desktop screens and the large screen display.

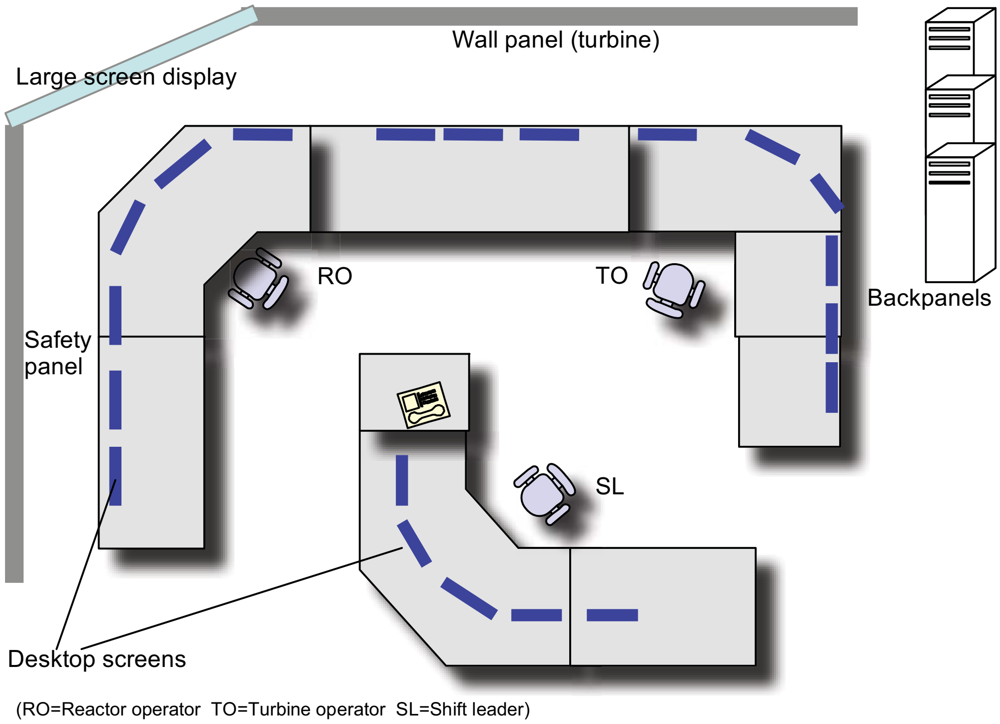

Figure 3. The layout of the case study nuclear control room (all measures not exactly to scale).

4.5 The large screen display

The *large screen display*, added in the upgrade project, is placed in the angle where the two wall panels meet. This is the only large screen display in the control room, and its size is approximately 2.5 m wide and 2 m high. (see figure 4)

Figure 4. The large screen display in the nuclear control room, fitted in between the security panel (left) and the turbine wall panel (right).

4.6 Procedure

During one day and with one shift team, three interviews at 30 minutes each were performed. All participants were interviewed separately one by one. Before the interviews, I observed the operators working and randomly asked questions to become more familiar with and better understand the environment and the activity in the control room.

My interview questions were structured by themes, and covered the issues I was interested in. They were put together from the themes formed by the literature review. In line with the problems for this thesis, I wanted to know more about how and when they use the large screen display, and their views about the contributions of it. The themes in my interview guide therefore covered the areas *aim and intentions of this large screen display*, *the unique role and value of it in the control room work* and *opinions about its design* (see appendix A for the interview guide). The interviews were semi structured, because of the more open-ended questions and possibility to more detailed information from the operators. The topic of the interview was explained to the participants by a short introduction. I took notes and recorded the interviews, after asking the participants for their permission. They were also promised anonymity.

5. Result – case study

In this section the data from the case study and the interviews will be presented. It will be further discussed in *6 Discussion – case study*. Swedish-English translations of quotes are my own. I have chosen to exclude notations of narrations and statements from the operators because they are anonymous. In cases where the role of them makes a difference in the context, e.g., when the shift leader gives an opinion related to his head position, the role is explained.

5.1 Purpose of the large screen

A modernization project of the control room and the plant was performed 5-6 years ago. This was the latest upgrade of the control room. Among other things, a large screen display was added as a part of the upgraded HSI. The aim was to change the traditional wall panels and analogue pointers, with large screen displays and smaller desktop screens to make a fully computer-based control room. For various reasons all of those goals were not achieved, and the result was a hybrid control room with one large screen display in addition to computer-based workstations. A new safety panel was designed (with a traditional appearance: wall panel with static mimic feature), and some of the wall panels (turbine side) and the back panels (in an adjoining room to the control room) still remain as parts of the HSI. Some operators expressed that there would be some possible advantages to the control room if more large screens had been included, but yet the operators seemed content with the present control room layout.

The clearest opinions about what is the purpose of the large screen seemed to be an *overview display* with *shared information*. By its size and position as a viewable source from almost every location in the room, it constitutes an effective tool for monitoring. For the most part of the time trends of some critical parameters are displayed on the large screen, and the reactor operator has a central role of monitoring those. The operators were of the opinion that all of the operators can support and contribute to the monitoring task because of the large screen display. This would not have been possible if the overview were displayed on a smaller and less viewable desktop display, they said.

The operators expressed that a typical large screen appliance was to display information that is of interest to everybody in the shift team. The information relevant to everyone is, according to the operators, the important and general parameters in the process. These parameters are not representing only one part of the process, but are collected from different ones. Examples of such parameters are: produced effect, reactor and water temperatures, and reactor containment pressure (see figure 2). The selection of parameters has been made by the operators in the shift teams, and the same picture (i.e. the same selection of parameters) seemed to be preferred by all shift teams. The selection provides a general representation, which covers the overall status of the process, and is therefore interesting to the whole crew.

5.2 Fields of application

During abnormal operation or incidents, the team prefers to have the specific crucial information at the large screen as shared task information. One operator said that “the large screen is used when you want more persons to see”, for example in abnormal operation to increase the situation awareness. Sometimes, the shift team chooses to display specific pictures and parameters at the large screen. This possibility is mostly used during more intense and crucial operation, such as incidents or normal process changes (e.g., start or closing operation). By displaying specific status information of crucial process parts on the large screen it is put in focus and can increase the operators’ focus.

The shared visual perspective the large screen provides, and the continuous updating of it, keeps the operators updated even during normal operation about the process status if or when any anomaly occurs. The special feature of the large screen is the size, which contributes to make it viewable from the most locations in the control room (depending on its placement). The large screen provides a shared information source and increases the operator’s awareness not only on the overall status but also of each others’ ongoing work. Even though the reactor operator has the most use of the large screen, the parameters displayed concern the process as a whole. In a complex system, like a nuclear power plant, no part is isolated from the others.

The operators meant that they sometimes, with help from the common information, support and give input to each other. The reactor operator has the primary role of monitoring the large screen. But, the operators said, the “viewability” of the screen makes it possible for the operators to contribute to the monitoring task. All three operators maintained that the reactor operator was supported in this task by the others, especially in situations where he was occupied with other tasks or was not present at his workstation. When something abnormal occurs in the process “then, everybody see it and can attract attention to it”, the reactor operator said.

Except from these inputs now and then from the other operators, which work as reminders for the reactor operator, he says himself that not much additional conversation is exchanged between the operators concerning the large screen display. And according to all the operators, the way of working, solving tasks etc. has also not been influenced by the large screen.

Restrictions for access to modify the large screen display are limited. The turbine operator, who seldom uses the large screen directly, claims he do not have hardly any access of this kind. He thinks it is good that not anyone is permitted to modify the large screen picture, or it would be “a jumble”. The reactor operator says that he has the responsibility of what should be displayed on the large screen and understands it as a somewhat “informal agreement” within the control room team. This may be because of his physical position in the control room, just in front of and closest to the large screen and within reach of the keyboard and mouse to the large screen. This position could in turn have been determined by his role as reactor operator, and the importance of that.

5.3 The large screen display design

The intention when the large screen was implemented, was to display a system overview (mimic). Today the shift teams nearly always chose to display trends of the most important parameters (approx. 8 parameters), because it gives them best support in their monitor work. One operator says "it just turned out that way" about the choice of screen picture, and that no more strategic or thoroughly discussions preceded. These trends represent the most important parameters for the primary side of the process, and describe the process at a relative high abstraction level. When incidents occur in for example a subsystem it first shows in the general trends, but to solve the situation the operators switch picture (in case of time) to proceed at a more detailed level. This supports the information given on desktop screens, and provides shared information for the crew. In normal operation, having general parameters displayed in trends provides the opportunity to quickly scan for changes in the process. All the operators think this is an easy way to monitor trend picture.

During most operation a trend picture is displayed on the large screen. According to the operators it was a natural choice, and gives them good support for supervising the process. Advantages of trends compared to system overviews (mimics) are in this process for example: the quick-scanned picture, the parameters are put in a context, and deviations from normal operation (or previous values) are easy to detect. Most of the smaller desktop screens in the control room display, in contrast to the large screen, mimic pictures of different parts of the process. Regarding the large screen display, all three operators stated there is an advantage of the trend picture. They experienced more difficulties monitoring a mimic than monitoring a trend. A mimic is static and parameters are shown by numeric values. They say that a deviation in a mimic picture does not draw their attention like a deviation in a trend does.

The large screen display in the control room somewhat follows the guidelines for design to support human cognitive functions. Considering consistency, one operator says the colors used for specific parameters for the trend curves also recur in other, similar parts of the HSI when representing the same parameters. There are although some differences between pictures used in the HSI. For example, the trend pictures (for example the large screen) have black background while the mimics have grey background.

The analogue viewing in the large screen trend picture provides easy- and quick-scanned information. Below the trends is more detailed information about the parameters, e.g., present value. This information is presented in text and digital numbers, and complements the analogue trend picture which does not present digital information. The colors are black text on grey background. The operators regularly look also at this information to be updated, but still the trends give most information "just by a glance" and clearly show process changes. The dynamic in the trend information keep the operators aware of not only the momentary status, but also the changes, activity and history of the process. The reactor operator can at an early stage see if there is "any trend that is about to slip away". By continuous seeing the changes in the process, the operators can be alerted on events *going* to happen and even prevent some of the alarms.

Limits for the parameters are not displayed in the lareg screen picture. These are crucial factors for the operation, when the main task in control room work aims at keeping the parameters between those limits. As a result the operators are obliged to know all the values by heart. At the moment this seems not to be a large problem for the operators, because of the relatively long experience they hold. That type of information, one operator claims, is something essential to know in the control room (see figure 3. The digitals in the margin just show scale values). At the same time, another operator finds it almost impossible to remember limits for the momentary, digital values shown in mimics at the desktop screens, and he will not be able to decide whether it is a correct value or not. If a deviation occurs in such a picture, it would not draw your attention, according to him. He therefore thinks trends are preferable, because of its clearer presentation.

Overall the operators give the impression of being satisfied with the large screen display. Yet, they express thoughts of the advantage of having more large screen displays that would have covered a larger part of the plant's systems. This would bring more possibilities and conveniences to work. With the analogue wall panels, which still represent the turbine side, the turbine operator has to leave his workstation to adjust (start or stop) some of the objects at the wall panel, with physical handles and buttons. He expresses interest to convert also the turbine side into computer-based interface displayed on large screens. For him it would mean he could operate objects in the process from his keyboard and mouse at his workstation.

Regarding the physical device one operator mentions the problems when the screen is put out, because of broken source of light. There is no redundant system to avoid situations like this, and when it is being repaired the screen is (partly) black and can not be used. The shift leader states that there is a shortage of the access and usability of the large screen. Because the keyboard and mouse that interact with it are placed at an individual position, more closely to the reactor operator, it is not reachable for the shift leader. To avoid leaving the workstations, he suggests a switch function to make it possible for every keyboard to include access to the large screen display.

6. Discussion – case study

This section discusses the results from the case study; the purpose and use of the large screen display. It treats the subjects of the thesis: purpose, appliance and design issues.

6.1 Purpose of the large screen

The main purpose of the large screen display in question seems to be to provide overview information to the monitoring work, mostly during normal operation. The large screen is constantly available, and, to some extent, it gives background information to the operators.

During the interviews the operators gave their overall content impression of the large screen and its present role in the particular nuclear control room. This information might not say that much, since they often have no experience of other control room environments, and their own control room then becomes "incomparable". This fact makes it difficult to draw any objective conclusions from this kind of user statements in situations like this.

The modernization project had in the very beginning plans to uniform the HSI into a computer-based control room with several large screen displays. Some modifications were done, and the final version contained some preserved parts of the HSI and one large screen display. It is difficult to make any contra-factive statement about how the control room work would have been influenced by several large screens, but some ideas from the operators came out of the interviews. The idea of the implemented large screen, one operator says, was to display a system overview picture, but this gradually changed more and more to a constant use of the trend picture.

So, how should a sudden change of use affect the information content? Should the structure or role of the large screen be updated? It is not necessarily a problem; the operator teams appear to have found their own fruitful field of application, even if not the anticipated, and it makes a complement to the monitoring in the control room. Interestingly, even if this example shows a lack of well defined application, it does not necessarily have to result in a useless large screen display.

6.2 Fields of application

As mentioned above, the main purpose of this large screen appears to be providing an overview status of the process. The screen provides, by its position in the room, an easy access and presents deviations in a clear way. Since it was implemented in the control room it seems as though the communication has not increased significantly, and there is no direct interaction with the screen in task solving, individual or in teamwork. Direct process operation with the large screen is not possible, and it appears to be used mostly in normal operation. One operator tells that the large screen is used for "nothing specific" or concrete, but is at the same time a frequently used part of the HSI as an important background source of information. Through the large screen the operators' awareness of the process activity retains. It provides a passive, yet valuable, source of information in monitor work. To not forget: most control room work is passive monitoring. Effective and reliable overview tools are therefore especially important in this area.

6.3 The large screen display design

To continue the overview theme, trend pictures appear to meet several design guidelines for good and supportive design. The case study trend display, for example, has an analogue feature, and includes little "clutter" such as digital numbers, labels etc., except for the parameter information below the trends, and digitals in the margin. There are although some shortages in the design. Limits for trend parameters are missing, which could be a problem for new and less experienced operators, who have to keep this information in their head. Of course this is not an issue for experienced crews, to whom it may seem as "unnecessary information". This is a matter of discretion. On one hand, information forced to be remembered implies increased cognitive work- and memory load, on the other, for frequently used and viewed pictures it is not recommended to have too much, seemingly unnecessary, information.

Trends show in a clear way any deviation from the normal values and the history of the parameters, which makes it easy for the operators to discover any anomalies. A single, digital number can only display momentary information and requires interpretation by the operator, while the history of a parameter sets the parameter value in a context. In the trend picture the operators can, by just glancing at the screen, see the process development and detect changes (wanted or unwanted). It supports pattern recognition, unlike digital numbers by which it is harder to detect any deviations. Analogue displays support pattern recognition in a larger extent by displaying information in a more effective way, which humans easier can process, for example by quick-scan the picture. This type of processing can be done at a lower cognitive level, and should be supported.

The choice of displaying trends on the large screen was quite natural and not a discussed topic. The trend diagrams although appear as a good alternative and it suites the operators and the shift teams in their work. Most of the desktop screens are filled with system overviews in mimic format, which makes the trend picture a good complement. By selecting and gathering trend parameters in one picture, the status overview is both condensated and customized at the same time. Condensated, because of the reduction of information which is not directly interesting, and customized, because of the focus of the most crucial and necessary parts of the process. This would not have been achievable in the same extent for a mimic, where the placement of elements in the picture is determined by their topological context. Instead, in the trend picture all the parameters of interest are gathered in one picture.

Dynamic information, provided by the continuous updated trends, keeps the operators "in-the-loop" and maintains the situation awareness. In the interviews all operators express positive judgments about having trends displayed at the large screen display, and refer to the maintained awareness during operation, and them being able to detect deviations at an early stage.

The attitudes toward the large screen display appear to be good. Based on this the operators seem curious about a situation with more large screens in the control room HSI and the possibilities it implies. A further expansion of the computer-based HSI could in addition have made the interaction with the system (possibilities to through keyboards etc. operate directly with the large screen) easier and more available.

7. General discussion and conclusions

After two chapters (Chap. 3 and 4) that present research about large screen displays and the screen in the case study, this final chapter will summarize and discuss the results. The comments about the case study screen's design in the end of the chapter will not be detailed, but just guidance and broad suggestions to how it could be changed and improved.

7.1 The overall purpose of large screen displays

The intention with the large screen displays is to bring complementary support to the operators that is valuable to the control and monitor work. From the literature review, and the case study performed in this thesis, it seems pretty clear that the most important function and intention of large screen displays in nuclear control rooms is to provide a process state overview. Researchers seem to agree on this point.

The overview implies many different functions at the same time, because there is many ways to provide an overview. Something common for most researchers is the opinion that large screen displays should provide information that is not too detailed but instead display information at a higher abstraction level. By displaying a system overview at the large screen, the operators should use other information sources when looking for more detailed information. The role of the large screen is thus being kept as a "secondary" vision, according to Groot and Pikaar (2006). Nevertheless it should be permanently displayed. When not displaying any detailed information, other sources are of course needed to complement the picture of the process. The lack of details is not a shortage of a large screen. Instead, it meets the demands of facilitating monitoring and presenting an overview, which was said to be its purpose. At the same time it also complements the rest of the HSI in the control room, e.g., the desktop screens, where the detailed information can be found.

Since the large screen should provide an overview it does not have to, or should, display too much information. The most essential information is enough, and will guide the operators to further, more specific information. The lack of details in the case study large screen does therefore not seem to be a problem for the operator crews; deviations in the trends will give them the information they need.

The overview also implies that a large screen and its information should be viewable for every operator in the control room. This is to a large extent also applicable for the case study large screen. The location of it is central, both in relation to the rest of the HSI, and in the visual field for almost every person staying in the control room. The parameters displayed by trends was made with the intention to cover the key functions of the nuclear power plant. Those parameters should be sufficient to monitor and maintain the overall awareness of the process. For the monitor task some overall information at quite a high abstraction level is considered enough.

The literature emphasizes the importance of maintaining situation awareness in the control room, both individual and collectively. Shared information, like the one on large screen displays, enhances the interaction, openness and coordination between operators. In the case study control room the large screen offers possibilities to monitor the process by trends, that directly or indirectly concerns everyone in the control room. Everyone in the staff, even visitors with work tasks outside the control room, can see the large screen, comment it and make the reactor operator (or any other responsible) aware of occurances he has not yet noticed himself. The crew can thus by this received shared awareness of the process status also have awareness of other's ongoing work. Overall, these functions are positive for a better performance. For example, O'Hara and Roth mean that traditional control rooms "force" operators to interact more verbally. Similar characteristics can be found in control rooms with large screen displays, and somewhat "bring back" older work practice. The increased interaction within the crew is one of the greatest advantages of large screens.

To which extent the screen size affect the operators in the case study is hard to determine in the range of this thesis. But, an example could be the handling of the constraint values for the trend parameters. This information the operators have to know by heart. The screen's size (in this case 1.5x2 m) and the central location of the screen could be factors which help and support this type of learning. The placement of it probably makes it more frequently used as an information source, which also is positive for the learning effect. But the question of the lack of supportive values in the picture still remains. The question about displaying parameter limits or not can maybe be compared to comments about reducing clutter in displays, but here I would say the parameter limits imply useful information. Without those, it means an extra factor of work load, especially for less experienced operators.

7.2 Design choices and issues

Which are the guidelines to take into consideration regarding large screens in general? And for the case study screen in particulary? The role of the large screen in a control room is mostly to provide an overview to maintain the awareness of the overall process status. To give an overview, not much details need to be displayed. The display should show the system at a higher abstraction level and direct the operator to further information when needed. A picture which just requires a quick glance to give a status report, for example trend pictures, works well to give the operators an overview. But more information could very well be added to the display with a good result, and a more effectively used screen area. To support quick scanning analogue design is recommended. Large screen design requires special consideration when chosing elements, labels, lights and dissolution etc. because of the larger distance from the operators' work stations. Also here would analogue pictures be more appropriate, because it is more difficult to make letters readable from a distance.

The problem with non-updated, "old" design for large screen displays is mentioned in several of the research articles. It says it does not sufficiently enough take into consideration that large screens is a *new* tool in the HSI, and can therefore not have the same design solutions as the other HSI parts (the desktop screens or wall panels, i.e.). Direct translation of previous (and old) design elements does not bring any additional point or advantage to the HSI or work performance. Without special and relevant design, the surplus of large screen displays is being missed. The knowledge about large screen displays and its fields of application now seems to be more solid and explored than before. But still large screen implementations have a somewhat unclear purpose. Could this be a contributory cause to the lack of relevant design guidelines? This leads to even more uncertainty about the large screens and more failures of using them in the most optimal way. Installations with an undefined goal, as described here, are liable to miss the role as a contribution and opportunity for the control room and its work practice. Then the large screen displays are reduced to being just another screen in the control room HSI. Clearly adjusted and specific guidelines for the large screen displays would therefore be a start to help to clear out the role of the screens and make it more effective in the control room.

7.3 Better utilization of screen surface?

Man-machine interaction, for example in control room HSI, requires a carefully planned design that can, by supporting humans, also improve the operation safety. Analogue displaying of parameters etc. has advantages over the digital. As the olding saying says: "One picture says more than thousand words," - and it is also quicker to interpret. Therefore, to a large extent information overload is not a problem. It is just a matter of design choices and presenting the information in the right way, for example using pattern recognition.

The IRD is an example of a concept, which tries to maximize the ratio of data per area unit. Regarding the case study large screen, it does not really follow the concept of IRD. Although the screen is displaying trends, an analogue representation which gives a rather blanket status overview, the screen picture does not provide any dense information and thus not optimize the use of screen area. An impression is still that the choice of displaying trend graphs on the large screen in question includes many positive features. In addition to those already mentioned here, it offers permanently displayed dynamic information which is easy-monitored information. To the operators, the interface dynamics seem to be useful by providing basic data, suitable and reliable to facilitate the monitoring of the power plant process.

In earlier chapters mimic pictures and trends were compared. This is two common styles of representation in control room HSI. The critic towards mimics is about the static information it provide, which is not helpful and contributing to experienced operators. Even though every operator has a learning period, a large part of the information a mimic present is basic knowledge, e.g., about the domain or the physical processes. It supports the mental model for the plant, but still it is not necessary in the every day work. The *status* of the process is more crucial for monitoring the process and overall status is easier to interpret by trend pictures. In this case the choice of the shift teams in the case study seems succesful. Still, the screen surface can be used differently and more effective

Also, the digital presentation in mimics demands interpretation of the information before it can be used, which increases the cognitive demands for the users. To detect a deviation among digital numbers the operator needs to know information about the parameter he is looking at, and actively determine about a potential deviation. It requires work at a higher cognitive level (rules or knowledge levels in the SRK taxonomy), whereas monitoring a trend display can be carried through at a lower level with much less cognitive demands. A trend contains also historical information, and shows slow and long-term changes, which is appreciated and helpful to the operators.

But, there are definitely opportunities for using it more effectively. The choice of displaying trends, and only trends, on the large screen has developed from the needs and work practices of the shift teams. Access to historical information and the possibility to predict future events is a great advantage in monitor work. But still the present design could be made denser, which also would provide more information gathered in the same place instead of direct operators to several other information sources.

Possible solutions to this problem could be to include more information elements. This could for example be some information elements that the operator crews use with the same frequency as the information at the large screen. To include more large screen displays in the control room would also be a contribution, both according to the operators and in order to further uniform the HSI.

To summarize, the most important purpose of large screens is to provide overview information and share it among multiple, or all, operators. Design guidelines for large screens does not differ remarkably from the ones for other parts of the HSI. Its focus is on support the cognitive functions who are specific for the large screen purpose (quick-scanning etc.). The use and application of them are mostly to give the operators shared information, which in addition increases the interaction within a shift team.

The appliance of large screen displays in nuclear control rooms, as well as in other industries, needs to be considered to not become a waste of money. The desire for and investments in newer technology is only worth something if it can add value for the operators. Introducing new technology into a system implies a risk for new problems to arise. The consequences of a large screen for plant safety and control room work should therefore be carefully considered.

7.4 Recommendations for future research

The large screen displays as a part of the HSI in highly complex industries, such as nuclear, have many advantages. However, many possibilities and aspects remain to be investigated further. I have deliberately excluded some, for example the automation problem which will include the large screens more and more, and the use of them in this aspect. Another large and crucial issue is about the alarm system. Today the large screen in some cases provides alarm information, but the advantages and disadvantages can be further explored and discussed.

References

Beyer, H, Holtzblatt, K, (1998) *Contextual design*. Academic press, USA

Bolstad, C. A, Endsley, M. R, (1999) *Shared mental models and shared displays: an empirical evaluation of team performance.* Proceedings of the 43rd Meeting of the Human Factors & Ergonomics Society, USA

Brown, W, O'Hara, J. M, (2004) *The development of detailed human factors engineering guidelines for digital control room upgrades.* Ohio, USA, Brookhaven National Laboratory

Collier, S, (2005) *Human factors guidelines for large screen displays* (HWR-796). Halden, Norway: Institute for Energy Technology

Czerwinski, M, Robertson, G, Meyers, B, Smith, G, Robbins, D, Tan, D, (2006) *Large display research overview*. In *Proceeding of CHI 2006 - Conference on Human Factors in Computing Systems* (pp. 69-74)

Davey, E, (2005) *A task-based usage strategy for control centre wall displays.* Canadian Nuclear Society Conference, Toronto, Canada

Dudfield, H.J, Macklin, C, Fearnley, R, Simpson, A, & Hall, P (2001). *Big is better? Human factors issues of large screen displays with military command teams*. In Tan, D.S, (2004) *Exploiting the cognitive and social benefits of physically large displays.* School of Computer Science, Pittsburgh, USA

Genzuk, M, (2003) *A synthesis of ethnographic research*. Los Angeles, USA, Center for multilingual, multicultural research

Groot, de N, Pikaar, R. N, (2006) *Videowall information design: useless and useful applications.* In *IEA2006 Congress Proceedings "Meeting diversity in ergonomics".* R.N. Pikaar (Ed) Enschede, Netherlands, ErgoS Engineering & Ergonomics

Hutchins, E, (1995) *Cognition in the wild*. Cambridge, MA: MIT Press

Monk, A, Common ground in electronically mediated communication: Clark's theory of language use. In Carroll, J. M, (2003) *HCI models, theories and frameworks: Toward a multidisciplinary science.* Morgan Kaufmann

NEC Display Solutions & University of Utah, (2008) *Increasing monitor size translates to higher productivity*.
http://necdisplay.com/gowide/NEC_Productivity_Study_0208.pdf

Noyes, J, Bransby, M, (2001) *People in control. Human factors in control room design.* Cornwall, England, MPG Books

O'Hara, K, Perry, M, Churchill, E, Russel, D, (2003) *Public and Situated Displays: Social and interactional aspects of shared display technologies.* Dordrecht, The Netherlands, Kluwer Academic Publishers

O'Hara, J.M, Roth, E.M, (2006) Operational concepts, teamwork, and technology in commercials in nuclear power stations. In *Creating high-tech teams: Practical guidance on work performance and technology*. Bowers, E et al. (Eds) Washington DC, American Psychological Association (pp 139-59)

Rose, A, Shneiderman, B, Plaisant, C, (1995) *An applied ethnographic method for redesigning user interfaces.* University of Maryland, USA

Roth, E.M, Lin, L, Thomas, V.M, Kerch, S, Kenney, S.J, Sugibayashi, N, (1998) *Supporting situation awareness of individuals and teams using group view displays.* Proceedings of the Human factors and ergonomics society 42nd annual meeting (pp 244-48)

Stubler, W.F, O'Hara, J.M, (1995) *Group-view displays for enhancing crew performance.* Proceedings of the Human factors and Ergonomics society 39th annual meeting, New York, USA, Brookhaven National Laboratory

Stubler, W.F, O’Hara, J.M, (1996) *Group-view display system: Functional characteristics and review criteria.* NUREG 0-700, Washington DC: U.S. Nuclear Regulatory Commission

Tan, D.S, (2004) *Exploiting the cognitive and social benefits of physically large displays.* School of Computer Science, Pittsburgh, USA

Veland, Ø, (no date) *Designing effective large screen displays for control rooms*. Halden, Norway: Institute for Energy Technology

Veland, Ø, Eikås, M, (no date) *A novel design for an ultra-large screen display for industrial process control*. Halden, Norway: Institute for Energy Technology

Vicente, K.J, Burns, C.M, (1995) *A field study of operator cognitive monitoring at Pickering Nuclear Generating Station – B.* Prepared for the Cognitive Engineering Laboratory, Toronto, Canada

Vicente, K.J, (1999) *Cognitive work analysis. Toward safe, productive, and healthy computer-based work.* New Jersey, Lawrence Erlbaum Associates

Welch, R, Braseth, A.O, Veland, Ø, (no date) *Information Rich Display Design*. Halden, Norway: Institute for Energy Technology

Wickens, C.D, Hollands, J.G, (2000) *Engineering psychology and human performance.* New Jersey, Prentice Hall

Wilson, J.R, Corlett, E.N (Eds), (1990) *Evaluation of human work. A practical ergonomics methodology.* Basingstoke, G.B, Burgess Science Press

Internet sources

Nationalencyklopedin (English dictonary) (2008), www.ne.se (2008.04.12)

Appendix A: Interview guide

Nuclear power plant Case study, Feb 13, 2008

1. Syfte och intentioner med storskärm:

Vad var syftet och intentionerna med denna storskärm, och stämmer dessa med hur skärmen används idag?

Följdfrågor:
Förväntningar och tankar om storskärmen innan? Stämmer det med den uppfattningen ni har nu?
Vilka arbetsuppgifter i kontrollrummet skulle påverkas/förbättras med hjälp av storskärmen?

På vilket sätt är storskärmen nyttig i/påverkar arbetet? (t.ex. ger översikt, korrekt mental modell, teamwork, stödjer problemlösning, m.m.)

Samarbete och interaktion: har storskärmen ökat interaktionen operatörerna emellan, eller ändrat sättet ni samarbetar på? Hur? (t.ex. arbetar över gränserna till varandras uppgifter/områden, mer muntlig kommunikation)

Användningens utsträckning i onormala situationer? (fel, uppstart, m.m.)

2. Storskärmens roll och unika värde:

Vad är storskärmens unika värde i kontrollrumsarbetet? (Dvs. vilka uppgifter skulle inte kunna klaras av (lika bra) utan den) Finns det något sådant?

Följdfrågor:
Konkreta exempel på sådana arbetsuppgifter? Till vilka uppgifter är den speciellt nyttig/bra? (t.ex. gemensamma/ individuella moment, skiftövergång, normaldrift...)
Hur väl fungerar den med andra delar av kontrollrummet? Anpassat gränssnitt etc.

3. Design:

Tankar och idéer bakom storskärmens design?

Följdfrågor:
Vem har gjort designen? Vad är idéerna/tankarna bakom val av visningssätt m.m.? Finns det några?

Vilka delar av designen är unika för storskärmen i kontrollrummet? (dvs. information som finns inte på andra skärmar i rummet)

Nöjd/mindre nöjd med? (t.ex. svårt att tolka/avläsa vissa element)

På vilket sätt skulle man kunna ändra designen? Önskemål? T.ex. vilken annan information vore bra att ha gemensamt?

Är informationen på storskärmen pålitlig? Händer det att den är dåligt uppdaterad? (t.ex. larmgränser, värden, m.m.)

Går det att byta bild/information på skärmen? I så fall; vems ansvar är det?