

**Master's Thesis Human-Computer Interaction**

**Videoconference in Field**

*A User Oriented Development of a Video Communication Tool for Field Use*

**Videokonferens i fält**

*En användarorienterad utveckling av ett videokommunikationsverktyg för fältbruk*

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## **Abstract**

### **Videoconference in Field – a User Oriented Development of a Video Communication Tool for Field Use**

Vattenfall Utveckling AB has earlier made a demonstration system showing the possibilities to improve service by using wearable computers and interfaces while working in field. At the demonstrations of the system in a lab environment to the business units at Vattenfall, the function “video communication with expert” was the most popular. The goal of this Master’s project was to test the videoconference function in field together with Vattenfall’s service personnel and to analyse the user requirements regarding quality, transfer, terminal and interface design of the videoconference system.

To achieve the goal an introductory field study was performed to create an understanding for the service technicians’ work situation. Second, an implementation of a test system was performed in Söderfors hydro power plant. Finally, an evaluation of the test system, including follow-up interviews, was carried out, using the constructive interaction method. The evaluation resulted in recommendations for a future implementation of a videoconference function.

We discovered that the governing quality parameter is the coverage from the radio local network, since if the coverage is poor, it will affect the remaining quality factors of the videoconference. None of the participants thought that video in both directions was necessary. According to the service technicians, a suitable videoconference terminal must be small, so it will not disturb their work. Moreover, the evaluation showed that the user interface could be designed straightforward, as the service personnel barely interact with the videoconference system.

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## Sammanfattning

### **Videokonferens i fält – en användarorienterad utveckling av ett videokommunikationsverktyg för fältbruk**

Vattenfall Utveckling har tidigare utvecklat ett demonstrationssystem för att visa vilka möjligheter det finns att förbättra servicen genom att använda bärbara datorer när man arbetar i fält. När man demonstrerade systemet i labbmiljö för affärsenheterna på Vattenfall, visade sig funktionen ”videokommunikation med expert” vara mest populär. Målet med detta examensarbete är att testa funktionen i fält tillsammans med Vattenfalls servicepersonal och utreda vilka krav som ställs på videokonferenssystemets kvalitet, överföring, terminal och gränssnitt.

För att uppnå målet utfördes först en introducerande fältstudie för att få en förståelse för servicepersonalens arbetssituation. Därefter implementerades ett testsystem i Söderfors vattenkraftverk. Slutligen genomfördes en utvärdering av systemet genom att använda metoden konstruktiv interaktion och genom att göra uppföljande intervjuer. Utvärderingen ledde till rekommendationer för en framtida implementering av en videokonferensfunktion.

Vi kom bl.a. fram till att den styrande kvalitetsparametern var täckningen på det lokala radionätverket. Om täckningen är bristfällig kommer det att påverka videokonferensens resterande kvalitetsfaktorer. När det gäller överföringen av audio och video ansåg ingen av deltagarna att video i båda riktningarna var nödvändigt. Servicepersonalen fann att en passande videokonferensterminal bör vara så liten att den inte stör dem i deras arbete. Dessutom visade utvärderingen att användargränssnittet med fördel kan utformas på ett sparsmakat sätt, eftersom servicepersonalen knappt behöver interagera med systemet.

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## 1 Introduction

This Master's thesis is a summary of a Master's project at the Department of Numerical Analysis and Computer Science (NADA) at the Royal Institute of Technology, in Stockholm, Sweden. The Master's project was performed during fall 2002 and winter 2003 and is a part of a Master of Science, degree in Electrical Engineering. The assigner was Vattenfall AB, a Swedish energy company. The supervisor at NADA was Ann Lantz and the supervisors at Vattenfall Utveckling AB were Mikael Svensson and Veronica Åberg.

### 1.1 Background

During 2001 Vattenfall Utveckling AB has demonstrated a system, which shows the possibilities to improve service by using wearable computers and interfaces while working in field. The functions demonstrated in the project "Mobile Internet in Plant" were measurement values from the technical status monitoring system and access to documentation depending on position (Norström, 2001). At the demonstrations of the system to the business units at Vattenfall, the function "video communication with expert" was the most popular. The function enables a service technician to get online help from experts when working in field, since the expert can see the same things as the service technician via a mobile web camera. The aim of this Master's project was to test the videoconference function in field together with Vattenfall's service personnel and to make an evaluation of the users requirements regarding quality, transfer, terminal and interface design of the videoconference system.

### 1.2 Definition of Videoconferencing in Field

The word videoconference derives its origin from the two Latin words *videre*, which means "I see", and *conferre*, which means "to bring together". Moreover, the combination of the words *videre* and *audio* results in the word *video*, which can be defined as a system that records and transmits visual and audio information using electrical signals (Wilcox, 2000).

If combining the above a videoconference can be defined as a meeting between people who are physically separated from each other, achieved by electronic communication techniques. In addition, a videoconference in field is defined similarly, adding that the conference is performed with at least one of the participants using a wearable terminal and stationed outside an ordinary office environment.

### 1.3 Problem Definition

The goal is to develop a proposal for a videoconference function, which can be used to solve specific assignments in field with support from a remote expert. The proposal will include user requirements regarding quality,

transfer, terminal and interface design for the videoconference system. The videoconference function can be useful in several vocational fields, but in this thesis hydropower service technicians will be used as example. To obtain the project goal the following questions will be answered:

**1. Which quality is required for the videoconference function to solve the specific assignment in field?**

Related sub questions:

- a. Is the bandwidth acceptable for this function?
- b. Is the available light intensity sufficient or does it need further improvement?
- c. Is the current resolution satisfying?
- d. Is the delay of the video and audio channels accurately equalized?
- e. Is the application time delay tolerable?
- f. How does the acoustic characteristics, in this specific environment, affect the audio quality?
- g. Which frame rate is acceptable?
- h. Is the error rate acceptable?
- i. How does the equipment affect the hydro power plant?
- j. How does the hydro power plant affect the equipment?
- k. Which coverage is desirable (the whole plant or specific places)?

**2. Which are the usability demands for videoconferencing in field?**

- a. Which kind of terminal and display is suitable for videoconferencing in field?
- b. How does the user wish to interact with the system?
- c. What are the user interface demands?
- d. Is sound and video required at both connections (service technician and expert) or is there any alternative that is suitable?

To fulfil the goal the following activities have been carried out:

1. A field study, with complementary interviews, was performed to investigate the service technician's work situation.
2. The market was analysed to identify useful pieces of technology.
3. An implementation of a test system was performed in Söderfors hydro power plant, Sweden.

4. A usability evaluation of the test system, including follow-up interviews, was executed using the constructive interaction method.
5. The results from the evaluation were analysed together with data from the interviews to capture the user aspect of the videoconference function.

#### **1.4 Vattenfall AB**

Vattenfall generates and supplies power and energy solutions to customers across Europe. This Master's project was a part of the research and development program "IT for efficient production and distribution", which was launched in spring 2001 by the Vattenfall Group. The main goals of the program was to provide propositions for solutions that could result in either increased cost-effectiveness of existing operations, a better cash flow, better use of capital, or new products/services that aim for higher profits.



## 2 Classification of Videoconferencing in Field

What is videoconferencing? In the introduction section of this report it was defined as a meeting between people who are physically separated from each other, achieved by electronic communication techniques. But videoconferencing is probably more complex than defined above. This section is an attempt to classify the area of videoconferencing in field.

### 2.1 Computer-Supported Cooperative Work

People cooperate and communicate for a number of emotional and productive reasons and the intended use for a videoconference system is to facilitate this cooperation. The expanding access to computers and the possibilities to interact and communicate with each other has lead to the development of a scientific area called computer supported cooperative work (CSCW). The aim for CSCW is to focus on groups of user, how the system should be designed to support group work and how these systems affect the group dynamics (Dix et al. 1997).

### 2.2 Groupware

An essential part of CSCW research is development of products, which support group work. These products are often called groupware (Dix et al. 1997). To separate different groupware they can be classified dependent on where and when the participants perform the cooperative work. To simplify the classification cooperative work is traditionally decomposed into a time-space matrix (Shneiderman, 1998), see table 2.1. The time-space matrix serves as a guide to which type of cooperative support that is needed in a specific situation.

**Table 2.1 Time-space matrix**

	Same time	Different times
Same place	Face to face, ex. classrooms and meeting rooms	Asynchronous interaction, ex. project scheduling
Different places	Synchronous distributed, ex. videoconference	Asynchronous distributed, ex. e-mail

#### **Face to face**

In a face to face situation the participants meet in reality and can interact with eye contact, gestures, non-verbal cues etc. An example of an application used in such situations is computers with large screen projectors used by lecturers.

#### **Asynchronous interaction**

Asynchronous interaction appears when colleagues leave messages at the same place but at different times, for example post-it notes.

### Asynchronous distributed

Email programs and conferences on the Internet are examples of applications used in an asynchronous distributed situation, which allow the users to communicate and cooperate at different times and different locations.

### Synchronous distributed

Synchronous distributed situations emerge when the users cooperate in real-time but at different locations. This type of cooperation is generally supported by telephone and videoconference.

Systems for cooperative work can also be classified by the function they primarily supports (Dix et al. 1997):

- **Shared applications and artefacts** supporting the participants' interaction with shared work objects
- **Meeting and decision support systems** capturing common understanding with help from computers during face-to-face meetings
- **Computer-mediated communication** supporting the direct communication between participants

## 2.3 Symmetries in Video-Mediated Communication

Video-mediated communication is the part of CSCW and groupware, which supports direct communication. Traditional videoconferencing is an example of symmetric communication. Symmetric communication implies that all participants have the same opportunity to see and hear each other, i.e. participant A can see and hear participant B and vice versa, see figure 2.1.

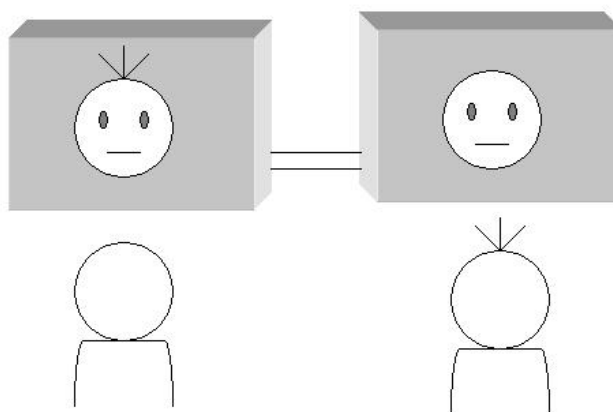
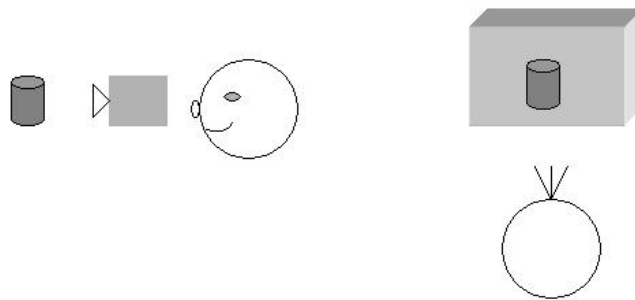


Figure 2.1 Symmetric videoconference

Conversely, videoconferencing in field is often, but not always, an example of asymmetric communication, i.e. when a user in field, with a wearable terminal, broadcasts image and audio from the task space in return to the

remote expert, while the remote expert sends back either video of their face or no video at all, see figure 3.2.



**Figure 2.2 Asymmetric videoconference**

One can ask if asymmetries affect the way people cooperate with a videoconference system. Billinghurst et al. (1999) present two studies with somewhat contradictive results: The first study, the Kuzuoka's Shared View project, implies that collaboration was most effective when instructor and student could share a common viewpoint and both the instructor and student could use gesture with speech i.e. that symmetric videoconferencing improves the collaboration. However, a bicycle repair project found that there were no differences in performance if asymmetric communication was used. To deeply enter the matter Billinghurst et al. (1999) performed further experiments, and came to the conclusion that half duplex high bandwidth may be sufficient for collaboration between a wearable user and a remote expert. Moreover, they found that the remote expert was more disturbed by poor video quality than the wearable user.

## 2.4 Summary

The goal of this section was to classify videoconferencing in field. Videoconferencing in field first and foremost belongs to the scientific area of computer-supported cooperative work. Moreover, since the users cooperate in real-time but at different locations the communication is synchronously distributed and since the communication involves moving images it is also video-mediated. Videoconferencing in field is often, unlike ordinary videoconferencing, asymmetric i.e. only one participant can see the moving images. Consequently, the conclusion of the above is that videoconferencing in field is asymmetric, video-mediated, synchronous distributed, computer-supported cooperative work.

### 3 Area of Application for Videoconferencing in Field

Studies have shown that even when people have a choice between different communication technologies, such as email, phone and videoconference, they still prefer face-to-face meetings (Whittaker, 1999). Nevertheless, even if interpersonal communication is important, the trend towards mobile work and globalisation of businesses are separating worker, which leads to reduction of face-to-face meetings. Using videoconference, which supports personal conversation between geographical remote co-workers, can relieve this reduction i.e. any organisation that relies upon geographically separated resources can benefit from videoconferencing. More specifically, videoconference in field can be useful in the following situations (Hestenes et al. 2001):

- **Decision support**

Sometimes a field worker has to make complex and time critical decisions that may have great economical importance. This situation represents expert-expert communication. An example can be when cracks or other irregularities are discovered in turbines at a hydro power plant, there is a need to communicate with experts to decide further actions. Since the turbine plays an important role and is a limited resource it is crucial to make an accurate decision as soon as possible. By a videoconference system it is possible to reach a remote expert or colleague fast, and together make a decision.

- **Guidance and demonstration**

Sometimes a fieldworker requires assistance from a remote expert to perform specific assignments. This type of situation involves someone less experienced communicating with someone more experienced. An example is when a service technician needs guidance on how to handle a new and not fully understood assignment or how to assemble new equipment.

- **Work planning**

The situation can also be the reversed, i.e. a field worker is able to assist a remote expert with support from a wearable videoconference system. For example, an engineer in charge of a new project, who inspects the work area with help from a field worker located at that area.

The above described situations are similar to the area of use described by Kortuem et al. (1999), who developed a collaborative wearable computer system, whose goal was to refine the collaboration between field and office-based service technicians. Furthermore, according to Najjar et al. (1999)

videoconferencing through wearable computers facilitates learning and support situations. This statement is also supported by Kortuem et al. (1999), who say that videoconferencing is more effective than phone conversation when an expert has to provide a technician with step-by-step directions.

## 4 The Technologies behind Videoconferencing in Field

When performing a videoconference a collection of technology is needed to support the application. This section gives a brief description to these technologies and how they are used. The main part of this section is gathered from Gulliksson & Lindström (2000).

### 4.1 From Transmitter to Receiver

To the ordinary user, a videoconference system can be seen as a black box i.e. the user knows what goes in and what comes out, but not what happens in between. However, to understand how different factors affect the quality of the videoconference a brief overview of the way from transmitter to receiver will help.

The first step is to establish a connection between the participants of the videoconference, which is done by dialling up the counterpart. When the connection is established it is time for the camera and microphone to collect the image and the sound, i.e. the data. Large quantity of data occupies a considerable part of bandwidth and can cause overload to the computer. This can be avoided by compressing and coding of the data to a small share of the original amount, which is achieved by cutting off everything we do not apprehend and by using the redundancy within and between the images in a video sequence.

When the compression and coding is executed the data is sent over a data link, for example Internet. Internet consists of a number of networks, which are connected by hubs, switches and routers. To get access to the Internet, which is a core net, the data must first travel through the access net, see figure 4.1. The access node controls, sends and forwards the data to the core net. Examples of access nets are LAN, mobile telephone nets and satellite nets. When the data arrives to the receiver it must be reconverted to images and sound in order to be apprehended by the remote videoconference participant.

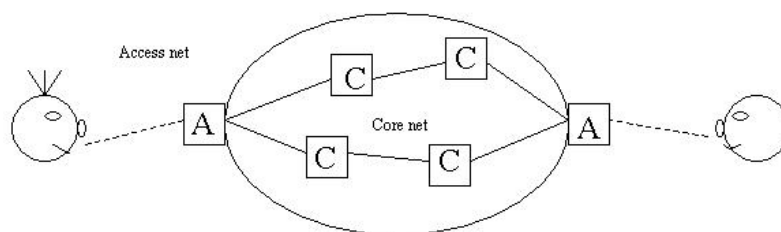


Figure 4.1 Network model for multimedia distribution

## 4.2 A Model of a Videoconference System

A videoconference system, i.e. network based multimedia system, can be represented as a stack of layers, see figure 4.2.

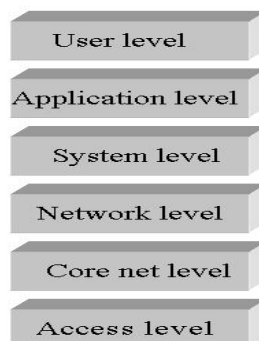


Figure 4.2 Model of a videoconference system

### 4.2.1 The User Level

The most important part of a videoconference is the persons using it. These persons are represented by the user level and can be described as the most important layer, since without the user the videoconference system would be unnecessary. Furthermore, the human has important physiological characteristics, which should be considered when designing a videoconference system. These characteristics are described later in this report, see section 7.

### 4.2.2 The Application Level

The next layer is the application level and represents the user interface of the system. The measure of this level is how the user experiences a specific service. A typical quality measure is subjective video and audio quality or lack of synchronization between sound and image.

When comparing different video applications, there are a number of quality parameters, which could be investigated. Some examples are frame rate, colour resolution, degree of compression.

The sound can also have varying quality and the main sound classes are telephone-quality and CD-quality. Telephone-quality can be comprehended differently dependent on which kind of digital coding and compression that are used. The most common standard is G.711, which means that a 3,4 kHz bandwidth is used. Frequencies outside that area are filtrated or subdued. CD-quality implies two channels (stereo) with one frequency area at 20 kHz.

### 4.2.3 The System Level

The system level consists of the hardware and software components, which handle the data, for example microphones, cameras and displays. The

system level can give the application the conditions for good quality, e.g. increase the speed of the application.

The quality of the system is among other things dependent on what resources, for example transport capacities, storing capacities and processor capacities that are chosen. Examples of resources are hardware and software for video compression, operating system, graphic card etc. By choosing the right components and by dividing the work correctly between them, the system layer contributes to an optimal system quality.

A videoconference system is an example of a real time system, which is a system that guarantees a certain capability within a specified time constraint. In what is usually called a "hard" real-time system, if the calculation could not be performed for making the object available at the designated time, the operating system would terminate with a failure. However, most real time systems are soft. In a "soft" real-time system the assembly line would continue to function, but the production output might be lower as objects failed to appear at their designated time. Videoconference is an example of a soft real-time system

#### 4.2.4 The Network level

The main task for a network is to create a connection between one or more end user systems. Moreover, the network must in our case support multimedia applications, which puts high pressure on the network.

Multimedia applications have much in common with other applications, but there are some characteristics that put extra pressure on the network:

- Continuous information streams with real-time demand
- Large quantities of data that should be transported and exchanged
- Distribution orientated applications are common

Additionally, there are five criteria which describe how well a network supports real-time transmission of a continuous information stream:

- **Throughput**, or **bandwidth**, is the number of binary digits, which the network is capable of transmitting and receiving per time unit
- **Transmit delay**, the time consumed for the first bit in a data block, which is sent by the transmitting terminal, until it arrives to the receiving terminal
- **Delay variation**, the variation over time of the delay that the network adds to the information sent
- **Error rate**, is a measure of how well the network respects the integrity of the transported data
- **Set-up time**, time usage in the network for an application to complete the whole application session.

Videoconferencing in field consists of mobile computers and wireless networks, which leads to some problems for the network. Some examples are:

- The bandwidth of the radio link and the error characteristics vary



- Mobile apparatus is capacity rationed
- Security problems increase when the signal is easy to reach
- The apparatus's physical position and network surroundings vary

The most interesting network for videoconference in field is perhaps the Internet. The Internet is sometimes very time-consuming and it can be problematic to send video. There are several reasons for this and it is not trivial to investigate the exact cause since numerous components, both software and hardware, are involved. The demand on the Internet is low and as a result several different networks can coexist. Moreover, the Internet can easily be upgraded. On the contrary, it is difficult to guarantee the service for video and audio transfer, which means that one has to be satisfied with a, sometimes, low quality, dependent on the load on the network.

#### **4.2.5 The Core Net Level**

The core net distributes data between the access nets. The most widely used techniques are asynchronous transfer mode, ATM, and synchronous digital hierarchy, SDH. ATM is a standard, which integrates different types of services over a fibre-based network and has special transportation characteristics for sound and video. SDH is foremost intended for static data flow between switches and not adapted for video and audio. The interested reader can find more information in the literature, for example *Multimedia över nätverk* by Gulliksson & Lindström.

#### **4.2.6 The Access Level**

The last layer in the stack is the access level, the last piece of the network, which connects the user to the Internet. There are many different types of access nets. One example is twisted pair, which is inexpensive and therefore one of the most commonly used. Another example is fibre, which is more costly but on the other hand provides a superior transmission capacity. Videoconferencing in field demands mobility and consequently a radio-based access net is needed.

A radio net must send the signals by air and must therefore share limited resources, which are the accessible frequencies. High frequencies demand free sight (> 30 GHz). A radio link, which demands frequencies about 2 GHz is limited to a distance of less than 70 km while for 11 GHz the corresponding distance is 40 km. Other "radio net problems" are fading, which occurs when the receiving signal is varying, which can be caused by the Doppler effect, scattering etc.

## 5 Quality Demands

As mentioned earlier the most essential component in a videoconference is the individuals using the service. Hence, the system must provide a satisfactory sound and image experience in order to please the user. This section will discuss the user requirements regarding audio and video quality.

### 5.1 Audio Quality

The ear can be described as differentiator i.e. the human ear is able to discern very small variations. Conversely, the eye can be described as an integrator, which denotes that it cannot detect the small variations between and within images in a video sequence. Hence, humans are more sensitive to sound changes than to image changes and, therefore, sound should have higher priority than video (Gulliksson & Lindström , 2000).

An important issue is synchronisation of sound and image, which is usually accomplished by delaying the audio until the more computationally demanding video is produced. The reason for this is that humans find it disturbing not to be able to connect the sound with e.g. the movements of the face. To achieve synchronisation between sound and image the time deviation cannot be more than +/- 80 ms. If the sound comes before the video the value is a little lower (20 ms). If the video comes before the sound the value is 120 ms (Gulliksson & Lindström , 2000).

A videoconference is an interactive application, which means that two-way communication is required. The human being is sensitive to time delays in interactive applications and to accomplish the feeling of talking to each other in real-time, the delay between receiver and transmitter cannot be higher than 400 ms. Furthermore, if one wants to be heard and hear at the same time the demands increase. According to Isaacs et al. (1993) small audio delays can disrupt participants' ability to reach mutual understanding and reduce the satisfaction with the conversation. Therefore, the user feels more dissatisfied about audio delay than with lack of synchronisation.

Another phenomenon is delayed echo, which means that one can hear one's own voice reflecting towards the receiver. This can be experienced as uncomfortable and interrupting and can be reduced with special hardware, echo-cancellation.

### 5.2 Video Quality

The vision is adapted to our natural environment. Consequently, the human vision has better resolution in the horizontal plane than in the vertical plane, since we are used to be more threatened by dangers moving on the ground than from the sky. It is therefore better, when for example designing a screen on a computer, to use a wide field of vision instead of a high field of vision.

As mentioned before the human vision is not very sensitive to very rapid and very slow changes between two images in a video, which means that it is not necessary to send more than 25 frames/second. Moreover, the human vision is also more sensitive to black and white than to colour. Some researchers claim that there is no connection between video quality and effectiveness of collaboration.

Kortuem et al. (1999) are of the opinion that poor video quality may deteriorate the collaboration between the service technicians in field and the person located at the office. The reasons why the video quality is perceived as poor are often related to frame rate and light conditions. In the NETMAN study (Kortuem et al, 1999) a frame rate up to 2 frames/second for a 200 x 200 pixel image was used, which resulted in visible delay and jerky motion of the remote video image whenever the mobile user moved the camera. Moreover, the study found that insufficient light conditions inside buildings contributed to the poor impression of the video quality, since the picture looked too dark. The effect of motion blur and light conditions was that the remote expert had difficulties to see what was shown on the image, for example shapes and labels.

The above is confirmed by Billinghamurst et al. (1999), whose study showed that the remote expert felt that high frame rate (30 frames/second) improved the collaboration if compared with low frame rate (1 frame/second). By contrast, the mobile user felt that the high frame rate did not improve the quality of collaboration significantly. According to Schaphorst (1999) 30 frames/second produces a perfectly smooth picture but this rate is more suitable for TV broadcasting and might be unnecessary for videoconferencing. Instead, he claims that 15 frames/second is suitable for videoconferencing and also that frame rates as low as 10 frames/second is acceptable. However, one must consider that a low value may look like a series of still pictures rather than continuous motion.

## **6 Advantages and Disadvantages of Videoconferencing**

Most of the research concerning videoconferencing has been done in office environments and conference rooms, which are somewhat different from videoconferencing in field. However, both videoconference in an office room and in field imply collaboration between people who are physically separated from each other. Videoconferencing can be beneficial in many situations but the function also has its limitations. The following section will briefly discuss the advantages and disadvantages of videoconferencing.

### **6.1 Advantages of Video over Audio Only**

According to Isaacs and Tang (1993) meetings over video has many benefits in comparison to audio only. First, by watching the remote participant it is easier to express agreement by nodding the head and understanding by e.g. leaning forward; the meeting participants are provided with continuous feedback from each other. Second, the meeting participants can enhance verbal descriptions with gestures, which may increase the participants' common understanding without extra effort. Third, the meeting participants can express different feelings with their facial expression such as surprise, scepticism and confusion. Furthermore, according to Veinott and Fu (1999) video matters both in formal negotiation tasks and normal conversations. The advantages regarding asymmetric communication are, according to Billingham (1999), that the presence of a remote expert through video-conference via a wearable terminal enables the subject to work more efficient and with fewer errors.

### **6.2 Advantages of Video over Face to Face**

According to Isaacs and Tang (1993) there is evidence of advantages of videoconference over face-to-face meetings. One example is that there seems to be less pressure on the participants to carry out social practice, such as social conversations, which make the meetings less efficient. This can be compared to e-mail when one wants to handle practical matters without the social interaction. Moreover, the participants, or participant, can remain at the office with all their resources at disposal.

Since a videoconference can be established more easily than ordinary meetings, people separated by miles can come together and share ideas, information etc. and there is no need to delay a decision until the participants have time to travel (Schaphorst, 1999).

### **6.3 Disadvantages of Video**

Despite that videoconference has many benefits it certainly has its limitations. One example is managing of turn taking. During videoconferencing there has to be more silence between the turns for participants to notice when the remote participant is finished speaking. This complicates the part-

icipants' ability to coordinate their utterances and, therefore, it is more difficult for the participants to reach mutual understanding (Isaacs and Tang, 1993). Furthermore, during meetings participants express different things with their body language, eye and head position etc. These cues can easily be missed during a videoconference (Isaacs and Tang, 1993). A further disadvantage connected with videoconferencing in field might be pointing. For example, when a remote expert instructs a service technician how to perform a repair, through videoconference, it might help to be able to point at a specific object in order to magnify the instructions.

## 7 Ergonomics of Wearable Computers

A wearable videoconferencing system must be functional and usable enough to convince the target group to adopt the technology. Thus, extra effort must be put into the design so that the system simplifies the user's work instead of making the work more difficult. This section will discuss the special terminal and interface requirements for videoconference in field described in previous research and also how to successfully implement the function.

### 7.1 Terminal Requirements

When designing a terminal for mobile use one must consider that size, weight and position will affect the human working with the system. Moreover, since the service technicians often has to perform manual activities, which requires full use of both hands, a wearable computer worn by hand might not be the best option (Kortuem et al. 1999). Consequently, one can ask which is the ultimate position for the wearable terminal.

According to Baber et al. (1996) a wearable computer worn on the wrist would require great muscle force to abduct, flex and extend the arm. On the contrary, the advantage with a wrist worn terminal is that the terminal can easily be brought in to the user's field of vision. More heavy loads can be worn with a belt around the trunk or hips. However, it is important to have in mind that it can cause tilting and pressure on the body.

Finally, the terminal or display can be worn on the head, which is the most frequent used position in connection with videoconferencing in field. A head worn terminal release the hands and arms but due to the weight it still can not be worn at this position over a longer period of time (Kortuem et al. 1999). Furthermore, wearing something on your head and in front of your face in public can feel socially disturbing (Kortuem et al. 1999). To sum up, the ultimate position is dependent on the type of work and the size and weight of the terminal.

The robustness of the terminal is also an important issue. During videoconferencing in field the terminal must manage cold, dirty surroundings, splashing liquids and working situations where the terminal may be dropped (Hestnes et al. 2001). Furthermore, to support collaboration effectively the system must be reliable enough to sustain a whole workday without major breakdown, (Kortuem et al. 1999, Perry et al. 2001, Pankoke-Babatz et al. 1997).

### 7.2 User Interface Requirements

According to Kortuem et al. (1999) interface concepts, such as the desktop metaphor, is not suitable for wearable computers with limited screen space and restricted input device. Therefore, is it important to keep the system as simple as possible, which means that the terminal should be simple for

making calls, with the functionality restricted only to features that really support the field worker (Hestnes et al. 2001).

As mentioned earlier the service technicians often need use of both hands and therefore, speech input could be an alternative to button input. According to Barber et al (1999) speech input tended to increase performance although with recognition errors, the time was longer than with button input.

### **7.3 Camera Requirements**

The camera is an essential part of videoconferencing in field. Since the equipment must be simple to use the camera should, if possible, have auto-iris and auto-focus (Hestnes et al. 2001). Furthermore, wearing the camera on the shoulder, instead of the head, hand and chest, keeps the image more steady (Hestnes et al. 2001).

### **7.4 Successful Implementation of a Videoconference System**

Previous research has shown that the success of a videoconference system is much more dependent on the nature of the application for which it is introduced than on system details and features (Egidio, 1998). Moreover, according to Shneiderman (1998) a successful videoconference system must be beneficial to the one who does the work, be accessible to a sufficient critical mass of user, not violate social taboos, and not counter common practice or prevention of exception handling. Therefore, when designing a collaborative system, or any system for that matter, there are three essential aspects to have in mind: the human, the context and the activity (Rubin, 1994).

Traditionally, designers and engineers have been focused on the activity, and very often neglected the human and the context (Rubin, 1994). According to Isaacs and Tang (1993) a collaborative system must be designed so that it is functional and usable enough to convince the target group to adopt the technology. Furthermore, when incorporating multimedia in a collaborative computer system the designer must put extra effort into the design since there is more than just include video and onto the front and end of the system. Therefore, it is essential to determine the strengths and limitations of each kind of communication system. This information can be used to make sensible choices among communication systems based on the requirements of the tasks and user. Moreover, it can be required to improve our understanding of how the mix of communication technology used by a group influences the way in which groups interact, develop and perform a variety of tasks.

## 8 Method Description

To extract data regarding the use of the videoconference function, qualitative methods were used. First, the study started with an observation to get a general picture of the service technicians' work and work environment. Second, the constructive interaction technique was used while the service technicians tested the videoconference system in field. Third, the service technicians were interviewed to get further information regarding the tests and videoconferencing in general. Finally, the extracted data was coded and analysed. These methods are described more pervading in the following section. The main part of content in this section is gathered from Repstad (1999).

### 8.1 Qualitative Methods

A qualitative method is about content rather than occurrence. A qualitative method is used when characteristic and features are more important than numbers and statistics. In quantitative methods numbers are used to describe how customary a phenomenon is, to compare different phenomenon and to express statistical connections and correlations. Conversely, in qualitative methods the text is in focus, i.e. the researcher writes notes, which are used as foundation for further analysis.

In qualitative research, one tries to reach depths instead of width, which means that one chooses one or few environment studies instead of many and also that the researcher tries to obtain a closeness to that environment. Furthermore, a qualitative method is flexible since the researcher can for example change the interview questions if necessary, which probably would not be appropriate during quantitative studies.

### 8.2 Observation

The purpose with an observation is to study human beings in their natural environment, investigate different situations that may appear and see how they behave in these situations. An observation gives the researcher knowledge of the social ensemble and processes, which can be difficult to capture in traditional interviews and questionnaires. Moreover, prior experience has shown that the test subject often says one thing and does something else. There are several reasons for this, for example test subjects, who answer interview questions or an questionnaire are not as problem orientated as they would be if they where to solve the problem in an authentic situation. Another reason could be that the test subject wants to maintain a desired self-image.

If the researcher wants access to e.g. a company she generally needs approval from the management. This can be a problem since the employees might see the researcher as a "controller", which is common in an environment with conflicts. Furthermore, the researcher should not socialize with the management more than necessary, and also remember to equally share



the attention to all actors in the current field of interest. The researcher must also have a humble attitude towards the actors and the observation field to avoid conflicts.

An observation is often dependent on a good informant. The informant should be cooperative, impartial, a good storyteller and a person, who possess the right information. Repstad (1999) also believes that an interesting informant could be someone, who soon will withdraw or already has withdrawn from the field, because she often can speak more freely. Furthermore, one should concentrate on open, positive, and helpful persons instead of wasting time on the negative, ignorant and suspicious ones.

It can be difficult for the researcher to remember the observation without some kind of documentation. However, it can be complicated to take notes or to use a tape recorder, dependent on which type of field one is about to observe. Therefore, an observation should only last for maximum a couple of hour without a break and it is important reserve time for documentation after the observation.

### **8.3 Constructive Interaction**

Merely asking people whether they are satisfied with a system is not enough, because the reasons they give might not illustrate their actual views or behaviour (Kahler, 2000). To avoid this, the thinking aloud technique can be used to capture what the participants are thinking while working. In a standard thinking aloud session the participant provide a running commentary of their thoughts while working on a pre-defined task (Rubin, 1994). The thinking aloud session results in qualitative data, which show how a person views a system and also the usability of the system.

However, this technique has its disadvantages. First, interaction is limited because the user mainly reports her experiences to the researcher (Kahler, 2000). Second, some participants find the situation unnatural and distracting and they therefore feel uncomfortable (Rubin, 1994). Third, the researcher might interact too much with the person tested and influence the results (Kahler, 2000). To evade these problems connected with the thinking aloud technique, constructive interaction can be used. The technique involves two users, who perform a task together. Consequently, this often leads to argument about what to do next and explanation to each other what to do next and how to do it and explanations to each other of why they did what the did (Kahler, 2000). According to Kahler (2000), this type of interaction is more natural than the thinking aloud technique. Moreover, the interaction between the researcher and test subjects is minimal and, therefore, the results are trustworthier.

Like the thinking aloud technique, the main benefits of constructive interaction is that it yield a set of qualitative data that provide valuable insight of how people perceive situations, how they solve problems and how they apprehend the usability of a given system (Kahler, 2000). The weakness is that it might be difficult to evaluate the data quantitatively. Thus, if

one wants to go beyond purely qualitative statement and perform detailed errors analyses or compare different pairings, the data must be carefully transcribed and analysed (Kahler, 2000).

## 8.4 Qualitative Interviews

User interviews alone are often not enough to reveal the problems of the system. Thereby, it is important to observe users doing work in their natural settings and to gather and document examples of that work (Wood, 1997). However, while a performance test unveils and exposes problems, it is often the interview afterwards, i.e. the debriefing session, that explain why these problems have occurred (Rubin, 1994).

The questions during a quantitative interview or inquiry are often too narrow and regular to depict a human's shade of experience and thoughts. Qualitative interviews also have their goal, but the interviewer does not follow a strict form, instead she uses an interview guide, which is not followed servile. Thus, the guide must be adjustable and variable.

## 8.5 Analysis of Qualitative Data

Qualitative data do not speak for themselves, they must be analysed and interpreted. During the analysis phase the data is arranged to a structure, which is easier to survey during the interpretation phase. The interpretation is a well thought valuation of the data in relationship to the content of the study and the theories, which puts the results into a greater context.

The phase begins with an overarching reading of the field notes collected during the interview. The reading will hopefully give ideas and themes to further analyses and it is important to make notes to remember them. The analysis phase ideally should continue for a longer period of time if one wants to process the material minutely. After the overarching reading the material must be analysed in detail and if the interview is audiotaped the next step is to transcribe the data. The transcript is then split in what seems to be essential scenes, which are sorted into themes and topics (Sapsford, R. Jupp, 1996). Below are two example scenes, which are sorted under sound respectively image problems.

### Scene 1

E: You have a pump... no, on your right  
 You have a pump on the floor down there  
 N: I can barely hear you  
 E: Go to the right of the stairs  
 N: To the right?  
 E: Right, right, right

### Topic

Sound problem

**Scene 2**

N: Can you see how many degrees it is?

S: No

L: Now?

Are you blind?

S: No, it is too blurry.

Is it forty degrees or what do we think? We guess that.

**Topic**

Image problems

These themes and topics are then interpreted and finally transformed into findings and recommendations.

## 9 The Study

To investigate the function “Videoconference in field” a study was performed. The study consisted of two parts: An introductory field study and a final evaluation.

### 9.1 Part One: The Introductory Field Study

To better understand the service technicians’ work and work environment an introductory field study was performed at Älvkarleby hydro power plant.

#### 9.1.1 Accomplishments

To document the observation a notebook and a digital camera was used. The digital camera was used as a complementary tool to remember certain situations. The observation started with a presentation of the reason for the observation. Afterwards, the personnel showed the control room and explained some of the functionalities and equipment. Since a hydropower plant control room is a highly complex environment, see figure 9.1, the goal was not to learn how the system worked, but to get an insight how the personnel worked in this specific environment.



**Figure 9.1** The control room in Älvkarleby hydro power plant

Next, two members of the personnel was followed while they performed the assignment of the day, which was an overhaul of transformer two. The observation lasted for five hours including coffee and lunch break with the personnel. During the observation notes was taken when opportunity was given, i.e. when the personnel was occupied with the same assignment for a longer period of time.

According to the plan, the observation was calculated to last for the whole day. However, in the afternoon the service technicians were supposed to perform the same measures as earlier, but in the reverse order and since the goal was to investigate the environment and how the service technicians worked in that environment, and not the exact work assignments, the observation was ended earlier than planned.

### **9.1.2 Observation Results**

The service personnel, who are responsible for the assignment, manage the work from the control room. The service personnel used an operation order when performing an assignment at the plant. An operation order is a list of measurements, printed on paper or on a display of a wearable computer, which needs to be carried out to perform the main assignment, e.g. an overhaul of the transformer. The operation order cannot be changed without permission from the author. When a measure is performed the executive personnel confirms this to the control room by using a stationary phone or mobile phone. The measure is then registered in Conwide, a state control system. To perform an overhaul of the transformer, the transformer and the belonging equipment must be turned of and meanwhile a “Work in progress”-signboard is attached to the equipment for safety reasons.

During the observation something was wrong with one part of the equipment. The service technician then consulted the blueprint of that specific part. The blueprints were filed and collected in the control room.

During the observation an opportunity was given to ask one of the personnel about his thoughts and feelings regarding a videoconference system and function. He felt that the system must be small and robust i.e. it must bear water, hits etc. Moreover, the system cannot take up too much space since it could prevent the personnel from performing their work, see figure 9.2, and the application must be fast and easy to use. He also felt that video might be unnecessary and that a picture, taken with a digital camera, could be enough if he wanted to consult an expert. Furthermore, the system could consist of a number of detachable modules so the user could choose which part of the equipment he wants to use.



Figure 9.2 A typical work environment for a service technician in a hydro power plant

### 9.1.3 Follow-up Meeting

The following day a follow-up meeting was held with two service technicians, the supervisor and technological responsible at Vattenfall Utveckling AB. During the meeting we discussed how a well-adapted field terminal should be designed and which functions that should be included. The service personnel had the following thoughts and ideas:

- The terminal must be small and easy to bring. Since the work at a hydro power plant includes narrow spaces, climbing etc. the terminal cannot prevent the flexibility of the service technicians
- The service technicians do not want to carry more equipment than they already do i.e. a mobile phone or a walkie-talkie and sometime a small, wearable computer
- The service technicians believe that there might not be a need for video i.e. moving images. Instead, they think that still image would be more sufficient
- The terminal could also be used to view blue prints, operation orders, information about executed and ongoing work etc.

### 9.1.4 Conclusions

The observation gave an understanding and knowledge of the service technicians' work and work environment and resulted in a scenario, see appendix 1, which describes a possible future field of applications for a videoconference function. Moreover, the observation was a chance to get to know the persons, who was going to perform the tests in the final evaluation. During the observation and the follow-up meeting the service technicians showed little interest in a videoconference function and they said that still pictures might be enough. There can be several reasons for this. First, a function including still images might be more concrete than

moving images, as this function already exists in certain mobile phones. A function with moving images is more abstract and therefore more difficult to appreciate. Second, the service technicians might expect that they will be forced to carry clumsy and heavy equipment if a videoconference system is installed. Finally, it is not unusual that new technology meets resistance from novice users. Hence, the videoconference function was investigated anyway to show the service technicians alternative solutions. Moreover, the results can be useful in future projects.

## 9.2 Part Two: The Final Evaluation

The design of the evaluation was inspired of a study of a wearable system for aircraft technicians performed by Siegel and Bauer (1997). The final evaluation was performed in February 2003 at Söderfors hydro power plant.

### 9.2.1 Equipment

As terminal the Walkabout HH3 was used. Moreover, a web camera was mounted on a helmet, which the service personnel occasionally use during their work, see figure 9.3, and the equipment list, see appendix 2. During the first test session we realized that the person at the hydropower plant was not able to hear what the remote expert was saying. To lock out the surrounding noise from the hydro power plant, a headset with a microphone and headphones was used during the following test sessions.



**Figure 9.3** One of the service personnel using the videoconference system

The programme NetMeeting was also utilized, which is an Internet conferencing solution for all Windows users with multi-point data conferencing, text chat, whiteboard, and file transfer, as well as point-to-point audio and video, see figure 9.4. During the evaluation only the video and audio function was used.



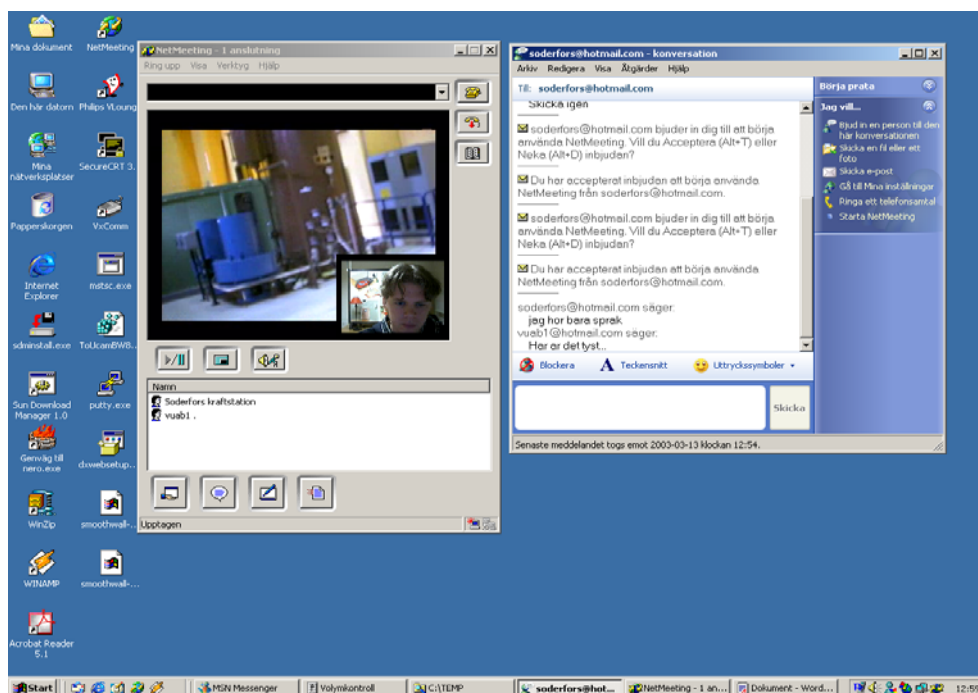


Figure 9.4 The videoconference seen from the remote expert's point of view

## 9.2.2 Accomplishments

The evaluation consisted of five test sessions. During the first test session we discovered that the test subject wearing the equipment was not able to hear what the remote expert was saying since the only loudspeaker available was fixed on to the computer and the machinery hall in a hydro power plant is a noisy environment. As a result we had to adjust the test session to the present conditions and decided to let one of the test monitors carry the terminal against the ear to be able to reproduce what the remote expert was saying.

During the second test we let an inexperienced person perform an inspection of the hydro power plant with guidance from a remote expert located at the office. The bearer of the videoconference terminal used the same equipment as in the first test but also a headset with a microphone and headphones, which partly locked out the surrounding noise from the hydro power plant.

The third test session had the same arrangement as the first test session, i.e. the two participants were both experienced service technicians and the task was to perform an inspection. However, during this test session the service technician at the hydro power plant used the same headset as in the second test session and also carried the terminal by himself. During this test we focused specially on if the remote expert could see details.

During the fourth test the service technicians performed a filter change of the hydraulic oil construction. The same equipment and qualitative techniques was used as in the previous two tests. The reason for this test was to investigate how the service technicians experienced the videoconference system while working with a complex task.

During the last test session we focused on the bandwidth. The bandwidth was gradually decreased and afterwards the effect of the video quality were evaluated.

All test sessions started with participant greetings and orientation, where the test monitor and the rest of the personnel involved in the evaluation greeted each participant. Next, the participants received a short, verbal, scripted introduction and orientation to the evaluation, see appendix 3, which explains the purpose and objective of the evaluation and additional information about what is expected from them. Then the actual performance test was carried out, where each test session task is described earlier in this section. Since a videoconference is collaborative, the constructive interaction-method was used. This method involves two people in the solution of a common task and therefore discusses what they are doing. By observing and listening to the participants solving a common problem, the researcher can discover important problems etc. After the performance test was completed the participants was interviewed. The interviewer used a topic guide as support during the interviews, see appendix 4. The conversation during the test and the interview where audiotaped and later analysed, see appendix 5, 6, and 7, and finally translated into recommendations, see section 11.

### 9.2.3 Evaluation Results

During the tests and the following interviews a number of opinions were collected from the participants, which are sorted in alphabetical order and described below (The quotes are freely translated from Swedish):

#### Appreciation

The service technicians believed that the videoconference function could be useful in the future, when communicating with each other, external personnel and experts. However, the function must be further improved to be useful for them.

#### Audio

As mentioned above, we soon realized that the sound from the terminal's loudspeaker was absorbed by the ambient noise from the hydro power plant and, therefore, the person in the field was not able to hear what the remote expert was saying. To eliminate the problem a headset was procured, which increased the sound quality considerably. However, the sound quality was still varying significantly during the test sessions. Occasionally the sound was almost perfect and the next moment the participants could not hear each other or the sound was distorted.

*(Outside the hydro power plant)*

*N: Can you go downstream? Lennart! He can't hear me. Lennart!*

*E: I hear so bad that I can't catch what you are saying*

*E: I can't hear*

*N: The thermometer or I mean the pressure meter*

*E: The sound is distorted. It is distorted*

This phenomenon could be derived to the distance to the radio LAN or that the radio waves was suppressed by solid walls. Moreover, the sound had a poorer quality during the afternoon.

One of the participants suggested that a mobile phone would be used instead of audio via the Internet.

*E: If one cannot get a satisfactory sound an alternative could be to use a mobile phone instead and only send the images via the Internet.*

The remote expert was not, comparative to the person in the field, particularly disturbed by the ambient noise level from and found the sound quality sufficient even despite that the speech sometimes got distorted.

*E: The sound is a little bit distorted but it doesn't really matter*

Because of the headset the person in the field was able to hear the remote expert despite the ambient noise level of the hydro power plant. However it was difficult to apprehend what the remote expert was saying in very noisy areas as for example in the turbine.

*N: ...*

*E: I can't hear what you are saying*

*N: The sound is very bad. The sound is a little bit higher in here. I think I'll go up again*

*E: Are you on your way up?*

*N: It was such a bad sound down there*

As mentioned before the headset increased the sound quality significantly. However, the wearer of the headset also heard an echo of her voice, which felt uncomfortable for some of the participants.

*N: I can hear my own voice. It feels uncomfortable*

During the test session, especially during the first, it was obvious that the participants could not perform the task if the sound was poor. However, if the image was poor they just used their voice instead.

*N: The problem is if we cannot hear each other, I cannot say that I do not have reception since you cannot hear me. If you had a phone, the communication would be more secure and the sound wouldn't be cut*

The remote expert found the sound acceptable.

The remote experts often asked the person in the field, about things, which they were able to see at the screen.

*E: Have you collected the bucket and the other things?*

*N: Yes, the bucket and the adjustable spanner...*

*E: Filters?*

*N: No, no filters.*

None of the participant complained over poorly equalized video and audio channels and we assumed that it was not a problem, and we therefore assume that the lie within the acceptable values, see section 5.1.1. This was confirmed by the interviews.

**Bandwidth**

Bandwidth has a general meaning of how much information can be carried in a given time period over a wired or wireless communications link. During the fifth test session the theoretical bandwidth was gradually reduced. The original theoretical bandwidth was 2Mbit/s, which we used during the previous four test sessions. First, the bandwidth was reduced to 1024Kbit/s, which still gave a satisfactory result. Nevertheless, when we reduced the bandwidth further, to 512Kbit/s, the video quality became considerable deteriorated and it was difficult to see the remote side. The “real” bandwidth was never measured and one should have in mind that the “real” bandwidth, which, among other things, depends on the momentary load of the network, might differ from the theoretical bandwidth, since the “real” bandwidth can be difficult to control.

**Camera**

The most common camera complaint was that the cameras field of vision was too narrow. The person in the field sometimes had to bow their head, bend their knees etc. to enable the remote expert to see the objects.

*N: There it is. Do you see it? Where I am pointing*

*E: Yes, if you lower your head I can see your finger*

*N: The camera is not at the same place as my eyes*

*E: No, it is not. You have to bow a little.*

It is difficult for the person in the field to understand what the remote expert is seeing and therefore had to watch the terminal to adjust the camera right. One of the participants suggested that the camera should be mounted on a pair of glasses to avoid this problem.

*E: It is difficult to direct the camera?*

*N: Yes*

*E: Because you cannot see the picture you are sending?*

*N: I can see it now*

One of the participants suggested that there should be a large camera mounted on the ceiling since it was more important to see where the person in the field where in the power plant rather than to see small details.

*E: The most important is to have a picture, which shows where you are*

Wearing the camera attached to helmet is experienced as clumsy. One of the participants suggested that the camera would be able to fasten on to the chest pocket

*N: The camera was disturbing when I rose*

Moreover, it was also swinging when the person in the field move, which sometimes was experienced as disturbing.

*E: When he walks the camera swings a lot. To see, you must stand still in front of something*

**Coverage**

Throughout the first four test sessions the radio local network covered the machine hall, the turbine room, and a small part of the floor below the

machine hall. Moreover, the radio local network also covered a small part of the control room and approximately six meters outside the hydro power plant. During the last test we used an extra antenna, which resulted in approximately twenty extra meters coverage. However, the coverage in the control room did not increase considerably.

During the fourth test the service technician received an alarm, and therefore had to leave the machine hall and go into the uncovered part of the control room. The service technicians had little experience of this specific type of alarm and needed assistance. However the connection was cut of and he had to use his mobile phone to be able to talk to the remote expert, which interrupted his work. This situation had, if the communication had worked, been a typical case when videoconference in field would be useful.

### **Reliance**

Reliance can be divided into two areas: reliance in the technology i.e. for the equipment and the communication set up, and reliance in the very videoconference function, i.e. how the user experiences the function. Reliable technology must be robust, i.e. the equipment and the communication channel must work whenever the user wants to use the product. Throughout the test sessions the videoconference system worked almost as planned and therefore the system can be considered relatively robust. However, the coverage from the radio local network caused some connection problems, which are discussed in the section below.

During the second test session the person in the field expressed that she felt comfortable performing the inspection with support from the remote expert even though she never had performed such a task before. The remote expert said that he trusted her while performing the inspection.

### **Resolution**

Resolution is the number of pixels contained on a display monitor, expressed in terms of the number of pixels on the horizontal axis and the number on the vertical axis. The camera used in the study had a maximum resolution of 640×480, which was satisfying during optimum conditions, i.e. when the person wearing the camera stood still and when the terminal had a good connection with the radio-LAN.

### **Social factors**

The person at the field had the possibility to see the remote expert i.e. symmetric communication. However, this possibility was almost never used and instead the participants used asymmetric communication, see section 3.3. As a result, the participants never experienced the social advantage and disadvantage with symmetric communication, described in section 7.1 and 7.3.

### **Terminal**

As mentioned in the introductory field study the service technicians do not want to carry more equipment than they already do. Since the work at a

hydro power plant requires mobility and use of both hands the terminal, used in the evaluation, is considered to clumsy.

*N: The terminal shouldn't be larger than a phone*

By observing the service personnel working with the terminal, we also discovered that the cord between the terminal and camera disturbed the service technicians while performing their work.

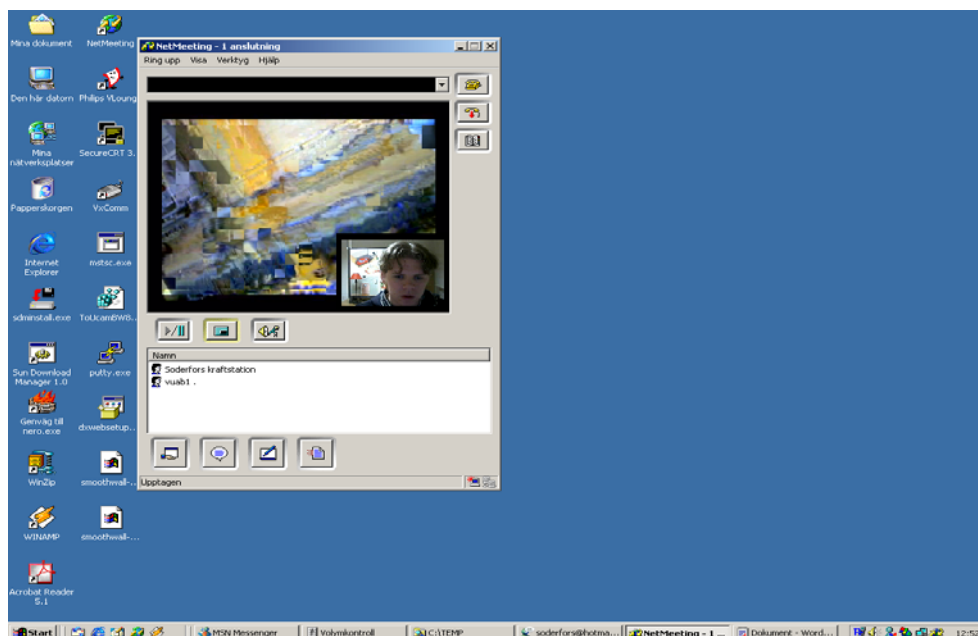
### Transfer

During the test the person in the field had the opportunity to see both the remote expert and an image, which represented what the remote expert was seeing. According to the persons in the field, they did not watch the remote expert at all and both the persons in the field and the remote experts believed that one directional video was enough, i.e. asynchronous communication. However, since the camera was difficult to direct, they found the camera image useful.

### Video

A common complaint was regarding the unsharpness of the images. When the person wearing the equipment moved the image appeared “blurry” to the remote expert, which made it difficult to see details. Therefore, the person in the field had to be still for a few seconds to stabilise the image, see figure 9.5.

*N: I can see everything satisfactory, but if you move the camera to fast it gets blurry, so you have to slow down*



**Figure 9.5 Distorted image**

Moreover, the same problem appeared when the person in the field was operating to far from the radio local network or solid walls

*E: I can see pretty well now. Actually, I can see better than I thought. Now I can only see squares, big squares. It is bad now. He is deep down, three to four meters under the floor. There is no sharpness*

During the test the remote expert was able to see details as manometer levels, but it was often difficult to see exact numerical values and, therefore, needed to ask the person in the field for the precise number.

*E: Is it on twenty-eight?*

*N: Yes*

None of the participant complained over poor light conditions in the hydro power plant and we assumed that it was not a problem. This was also confirmed by the interviews.

### 9.3 Method Discussion

Throughout the introductory field study and the final evaluation we used qualitative methods, which means that we restricted the area of interest to hydropower service technicians and their vocational field. Moreover, we used qualitative methods since we were more interested in characteristic and features rather than numbers and statistics. With the qualitative methods used during the study we could relatively simple extract from the participants concerning the equipment, how they experienced the video and audio quality, which type of video transfer they wanted etc. However, questions regarding error rate, frame rate, resolution etc. was more complicated to answer, since these parameters are more abstract. Hence, to answer questions regarding these aspects of the videoconference, the material regarding the audio and video quality had to be interpreted, which answered the questions about acceptable error rate, frame rate, resolution etc, see section 11. To extract data regarding *exact* limit values of acceptable error rate, frame rate, resolution etc, a quantitative evaluation in a lab environment might have been more suitable since a lab probably could supply more suitable tools for such measurements and by performing a qualitative evaluation one can achieve statistical ensured data.

The test sessions was completed by interviewing the participants. A qualitative performed interview demands an experienced interviewer, who asks the right questions. Since the interviewer in this study had little experience of performing interviews, the questions can be experienced as leading. As a result, some of the answers might be of debatable quality.

The main purpose for the videoconference function is to be used as a communication tool when the service personnel need expertise help. Nonetheless, it was difficult to simulate complex tasks to perform during the evaluation, which might have affected the test results.

During the introductory field study only one, relatively short, observation was made and it is possible that more and longer observations had given a more apparent picture of the service personnel's work situation.

## 10 Conclusions

In the section describing the problem definition of this study a number of questions were presented. The following section is an attempt to answer these questions with help from the results from the study and the previous research presented in the report.

### 1. Which quality is required for the videoconference function to solve the specific assignment in field?

#### a) Is the bandwidth acceptable for this function?

The used bandwidth, 2Mbit/second, is acceptable for videoconference in field and even when we reduced the bandwidth to 1024Kbit/ second we got an acceptable video and audio quality. However, as mentioned before one should have in mind that we never measured the “real” bandwidth. The most part of the problems with imperfect audio and video quality can be derived to unsatisfactory coverage rather than to low bandwidth. However, we got a poorer quality during the afternoon, which disturbed the communication, than during the morning, which perhaps depends on an increased load on the network.

#### b) Is the available light intensity sufficient or does it need further improvement?

The available light intensity is sufficient for videoconference and does not need further improvement. The light intensity in the machine hall caused no problem to the test participant and the darker areas, for example the turbine room, already have extra light.

#### c) Is the current camera resolution satisfying?

The current camera resolution (640×480) is satisfying during ideal conditions since the remote expert did not have to watch especially small details. Nonetheless, the person in field had to stand still to enable the remote expert to see the objects clearly. Moreover, if the remote expert should examine small details, for example small cracks, a higher resolution might be necessary.

#### d) Is the delay of the video and audio channels accurately equalized?

Since videoconference in field is asynchronous, the participants did not see each other’s faces and, therefore, we did not notice any synchronization problems. Likewise, we did not discover any audio delays, which disrupted the participants.

#### e) Is the application time delay tolerable?

The human being is sensitive to time delays in interactive applications, e.g. when pushing a button. The participants in this study only interacted with the system once, when dialling up the remote expert, which never led to any irritation regarding application time delay.



**f) How does the acoustic characteristics, in this specific environment, affect the audio quality?**

The acoustic characteristics of the hydro power plant affected the audio quality of the videoconference. As mentioned before a hydro power plant is a very noisy environment and the service technicians generally wear earplugs and ear defenders. Because of the noise it is almost impossible for the person in the field to hear the remote expert without the loudspeaker close to the ear, for example in a headset

**g) Which frame rate is acceptable?**

According to previous research a frame rate corresponding to 15 frames/sec is sufficient for a videoconference. According to the camera specification, the frame rate was 25 frames/sec, which can be considered to be TV-quality. The quality obtained during the evaluation was presumably lower, approximately 15 frames/sec, which the remote experts found acceptable. However, sometimes the frame rate decreased to approximately 1-2 frames/sec, which was experienced as disturbing.

**h) Is the error rate acceptable?**

During the test we had no tools for measurement of error rate. Nevertheless, the voice from the person at the plant got distorted, which is a type of error, during the transfer from the plant to the office. Still, the remote experts never expressed any irritation over this phenomenon.

**i) How does the equipment affect the hydro power plant?**

During the test sessions we got no indication that the equipment affected the hydro power plant. Nonetheless, this was never exhaustively investigated.

**j) How does the hydro power plant affect the equipment?**

The hydro power plant especially affected the coverage of the radio local network since the solid walls and floor, which sometimes negatively affected the quality of videoconference, subdued the radio waves.

**k) Which coverage is desirable (the whole plant or specific places)?**

The radio local network must cover the whole plant and the adjacent areas outside the plant. During the test sessions we used a radio local network with a 2dB antenna, which had coverage in the whole machine hall, in a small area of the control room and a few meter outside the hydro power plant. During the fourth test session the service technician at the plant received an unexpected alarm and therefore needed to use the videoconference system outside the covered area, which interrupted the work. During the fifth test session we amplified the signal with another antenna (12dB) and gained a further few meters coverage outside the hydro power plant. Nevertheless, we received no extra coverage in the control room.

## **2. Which are the usability demands for videoconferencing in field?**

### **a) Which kind of terminal and display is suitable for videoconferencing in field?**

The most essential characteristic for a terminal suitable for videoconference in field is manageability. The terminal must be small and easy for the users to bring with them. Since the work at a hydro power plant includes narrow spaces, climbing etc. the terminal cannot prevent the flexibility of the service technicians. Additionally, the service technicians do not want to carry more equipment than they already do and the terminal should also be robust, i.e. manage damp environments and falls

### **b) What are the user interface demands?**

Usability is an essential factor when introducing new technology. Since we only tested one function i.e. direct communication between two locations, only one button is needed i.e. the “connect/disconnect”- button. However, the interface provided by Netmeeting is simple and we discovered no usability problems during the tests. Another option could be a voice controlled user interface since the work at a hydro power plant requires mobility and use of both hands.

### **c) Is sound and video required at both connections (service technician and expert) or is there any alternative that is suitable?**

None of the participants thought that video in both directions was necessary. However, according to the persons in the field, an image, which showed the image sent to the remote expert would help them direct the camera.

## 11 Recommendations

The evaluation and the following interviews resulted in valuable viewpoints, which was transformed into findings and recommendations regarding the governing quality parameters, the quality demanded to perform specific tasks in field equipment and transfer demands etc. The following section will present these findings and recommendations together with suggestions for future research.

### 11.1 Recommended Technology Requirements

The essential and governing quality parameter is the coverage, since if the coverage of the radio local network is poor it will affect the remaining quality factors of the videoconference i.e. result in poor audio and video quality. During the evaluation we used a radio local network with a 2dB antenna and an extra antenna (12dB) to amplify the signal. However, the signal was not strong enough to cover the whole hydro power plant and the belonging areas outside the plant. Consequently, extra amplification is needed to achieve the wanted coverage.

During the first four tests we used the maximum bandwidth, 2Mbit/second, which gave acceptable result. During the fifth test we managed to decrease the bandwidth to 1024Kbit/second before we got noticeable quality deterioration. However, a 2Mbit/second bandwidth is still recommended, since a buffer can be needed when the network is burdened with further traffic and multiple users.

None of the participants thought that video in both directions was necessary, which is confirmed by previous researcher, see section 3.3, and therefore half duplex transfer ought to be the most sufficient transfer for collaboration with a wearable user and a remote expert.

The current resolution (640×480) is satisfying since the remote expert did not have to watch especially small details. However, if the remote expert should examine small details, for example small cracks, a higher resolution might be necessary.

### 11.2 Recommended Equipment and Interface Requirements

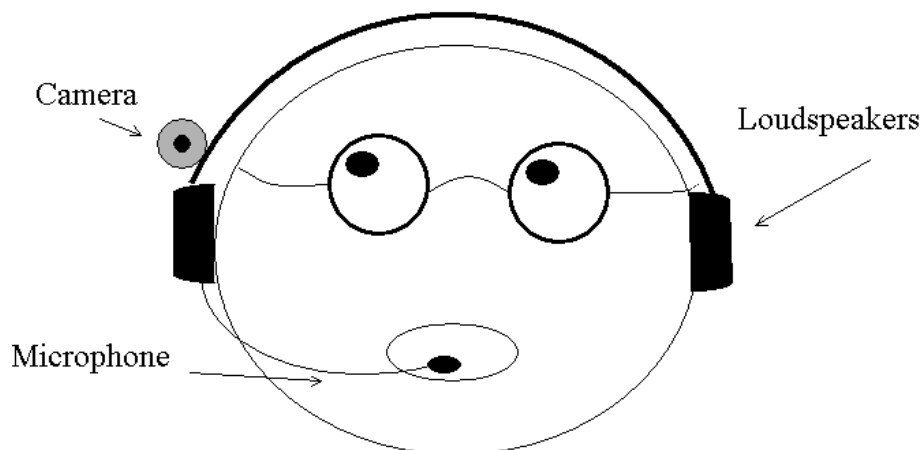
The equipment consists of four main parts: the camera, the terminal, loud-speaker and a microphone. The terminal should fit in a pocket, so the service technician easily can put it away while working, see figure 11.1. If possible, the terminal should also be water and shockproof.



**Figure 11.1** A terminal suitable for videoconference in field (Source: <http://www.oqo.com>)

To obtain an optimal audio quality the loudspeakers should be close to the ear and the microphone close to the mouth, and can for example be mounted on the ear defenders. The disturbing delayed echo, which occurred when the voice of the person's in the field voice reflected, should if possible be reduced with echo-cancellation. A more surmountable solution would be to let the remote expert carry a head-set as well.

The person in the field would benefit from seeing the same image as the remote expert or the camera should be mounted at the same height as the eyes, see figure 11.2. Furthermore, a light sight could be mounted at the camera to show the person in the field what the camera was showing. In the ergonomic section of this report Hestnes et al. (2001) suggested that the camera should have auto-iris and auto-focus, which could be a useful feature of the camera. The connection between camera and terminal should be wireless in order to simplify the service personnel's work.



**Figure 11.2** Suitable mounting for camera, microphone and loudspeakers

The interface provided by Netmeeting is simple and have few features. During the test we discovered no usability problems and the software could therefore be recommended to a future videoconference implementation.

### 11.3 Future Research

The natural proceeding of this project would be to realize these recommendations and perform a further evaluation, which could be considered as the final step before implementing the function at Vattenfall AB.

The equipment and interface recommendations in this study are particularly adjusted to the service personnel at the field's needs. Therefore, a further evaluation should focus more on equipment and interface recommendations of the remote expert.

The equipment in the further evaluation should, as far as possible, follow the recommendations described in the previous section. To develop a successful function that will be useful to the different business units at Vattenfall AB, the evaluation should also cover as many of them as possible. Furthermore, the function should be tested during a longer period of time and while performing more complicated task. A suggested evaluation arrangement would be to let the service personnel from the affected business units try the function by themselves during their daily work, and to perform regular follow-up meetings. The results from this evaluation approach will be more reliable since the user will perform authentic work assignments instead of simulated. A further evaluation should also involve external personnel i.e. persons who do not usually work in the investigated environment e.g. contractor and manufacturers. Moreover, as mentioned in section 10.3, to extract data regarding *exact limit values* of acceptable error rate, frame rate, resolution etc, a quantitative evaluation in a lab environment might be suitable.

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## Appendix 1 Scenario

Hanna has been working as a service technician for Vattenfall during three months and the work at Vattenfall is her first since she graduated from upper secondary school. To learn the work, she has been working together with more skilled service technicians. Today is the first time she handles the inspection at the hydropower plant by herself, and to simplify the assignment she uses a wearable video conferencing system. The system consists of a small camera fasten on to her head and a terminal with display and touch screen, which can be fasten on to her wrist. Since a hydropower plant has many stairs and narrow spaces, it is important that the equipment does not make the service technicians work more complicated. Therefore, the equipment must be small and comfortable to carry. Through the videoconference system she can communicate with Tomas, who is sitting in the control room. He is an experienced service technician, who has been working for the company over twenty-five years.

Hanna begins to turn the videoconference system by touching the screen and immediately Tomas shows up on the display. Furthermore, the inspection list also shows up beside the image of Tomas. Since it is the first time Hanna handles the inspection, she feels safe to have Tomas around. Moreover, by using the videoconferencing system it almost feels like he is there in person in spite of that he is located elsewhere and therefore is able to perform other assignments. Hanna starts the inspection by checking the oil pump. She believes that the values look correct and Tomas confirms this since he can observe the same things that Hanna can observe. Hanna registers the values from the oil pump and continues the inspection.

When she arrives to the cooler, the thermostat indicates too high temperature and therefore Hanna consults Tomas, who feels uncertain how to interpret the values. As a result, he decides to contact Malin, who is an expert on this kind of equipment. Tomas calls Malin and after discussing the problem they decide that it is best to let Malin see the problem for herself. Malin contacts Hanna and can now see the same view that Hanna sees through her desktop. To Malin, who is a very occupied woman, it is very practical to be able to remain at her office. Hence, she does not have to travel as much and she also has the most part of her resources at disposal.

By telling Hanna where to look, Malin investigates the cooler through the videoconference system. Twenty minutes later Malin discovers the problem and believes that Hanna can repair it temporarily. Thus, Malin sends Hanna a drawing, which shows up on her display, to help her with the repair. However, since Hanna is inexperienced, Malin guides her through every step of the process. When Hanna is finished she continues with the inspection without further problems.

## Appendix 2 Equipment

- **Walkabout HH3 ([www.forest-it.se](http://www.forest-it.se))**  
Rugged pen based mobile PC suitable for fieldwork. Rain and dust proof. Submersible for 5 min in 15cm water and can also manage minor falls.
- **Philips PCV740K ([www.philips.com](http://www.philips.com))**  
PC-camera
- **Logitech Stereo USB Headset 20 ([www.logitech.com](http://www.logitech.com))**  
Head phone
- **Microsoft Netmeeting ([www.microsoft.com](http://www.microsoft.com))**  
Videoconference software
- **D-LINK DWL-900AP+ 22Mbps ([www.dlink.se](http://www.dlink.se))**  
Wireless broadband router with built in switch
- **D-LINK DWL-650+ WIRELESS CARD PCMCIA ([www.dlink.se](http://www.dlink.se))**  
PC card
- **D-LINK ANT24-1200 ([www.dlink.se](http://www.dlink.se))**  
Antenna

## Appendix 3: Orientation Script (Swedish Version)

Välkommen och tack för att du medverkar i den här utvärderingen. Dina åsikter betyder mycket för oss.

Syftet med utvärderingen som du kommer att medverka i är att ta reda på vilka faktorer som påverkar användning av videokonferens i fält. Resultaten ska användas för en eventuell framtida implementation av videokonferens i fält d.v.s. det är ingen tjänst som ska implementeras nu och den utrustning som används under utvärderingen är bara ett verktyg för att ta reda på dina åsikter om videokonferensfunktionen, alltså ingen utrustning som kommer att användas i en eventuell implementation.

Utvärderingen kommer att vara uppdelad i två delar: en praktisk del och en intervju. Den praktiska delen är inge test av dig utan endast en test av videokonferensfunktionen, du kan inte misslyckas. Efter den praktiska delen kommer du att få svara på frågor som behandlar hur du upplever funktionen o.s.v. Utvärderingen kommer att spelas in och materialet kommer bara att användas som dokumentation.

*(Här kommer en beskrivning av uppgiften)*

Har du några frågor? Om inte kan vi börja med utvärderingen.

## Appendix 4: Topics Guide for Follow-up Interviews (Swedish Version)

*Om följande frågor inte besvaras under det praktiska testet bör de behandlas under den efterföljande intervjun. Frågorna är endast riktlinjer och kan anpassas efter situationen*

*Inledande frågor:*

1. I vilka situationer har man behövt expert tidigare?
2. I vilka situationer kan man komma att behöva en expert?
3. Vem är experten?
4. Räcker ord i sådana situationer?

*Testrelaterade frågor*

1. Hur upplevde du testsituationen?
2. Fanns det tillräckligt med ljus för att utföra uppgiften?  
Motivera
3. Var bildkvalitén tillräcklig för att se viktiga detaljer? Motivera
4. Var tal och bild tillräckligt synkroniserade? Motivera
5. Uppstod det störande fördröjningar av ljudet? Motivera
6. Uppstod det störande fördröjningar av bilden? Motivera
7. Var ljudkvalitén tillräcklig för att kunna utföra uppgiften?  
Motivera
8. Var hastigheten på kommunikationen tillräcklig för att utföra uppgiften? Motivera
9. Vad är viktigast bra ljudkvalité eller snabb kommunikation?  
Motivera
10. Hur skulle terminalen se ut för att fungera i den här arbetsmiljön? Motivera
11. Vilket är det bästa sättet att interagera med systemet för att det ska fungera bra i ert arbete? Motivera
12. Kändes funktionen lätt att använda? Stör den arbetet? Motivera
13. Finns det några andra funktioner som skulle kunna vara användbara?
14. Är bild nödvändigt i båda riktningarna? Motivera.

## Appendix 5: Example of Test Session (Swedish Version)

- E: Där kan du läsa av vad ytan ligger på, vad övre ytan ligger på.  
N: Och den ligger på...  
E: 51 och 20  
E: Ligger den på 51 och 20  
N: Jaa, det kan den nog göra  
E: Jag tycker jag ser det här ifrån... eller njaa lägre ligger den 51 och tio va?  
N: Där ligger den. Ser du den? Där jag pekar  
E: Ja, sänk lite på huvudet så ser jag pekfingeret  
N: Kameran är inte på samma ställen som mina ögon  
E: Nej, den är inte det. Du får bocka, du får hälsa, du får bocka lite  
E: Nu ser jag bra  
N: Mmm, vad ska jag ta mig för att göra här mer? Ska jag gå runt och titta eller?  
E: Ja, gå och kicka lite du så talar jag om vad det är för något du ser. Där har du instrumenten för fläktar och tilluften  
N: Dom känns inte så viktiga i dag.  
E: Nej  
N: Jag tror vi går ner för trappen, på stora golvet här.  
E: Ja gör det  
N: Här ser jag något som ser väldigt intressant ut.  
E: Där har du temperaturer på olika lager.  
N: Är det den svarta man läser av på?  
E: Ja  
N: Och det röda är något som man inte ska... är det larm?  
E: Där har du ju larm först och sedan har du ju utlösning. Det är inte många grader mellan larm och utlösning. Du får bocka fram lite gran så jag ser visarna. Så där ja. Den är uppe i 28 grader någonting den där första va.  
N: Ja  
E: Ja  
N: 15, 30  
E: Ja  
N: Och den i mitten ligger på ...  
E: 22  
N: Ja, precis  
E: Där har du 30 va? Nej, 28 va?  
N: Nja, 30  
E: Är det 30?  
N: Den är precis mellan 20 och 40  
E: Ja då är det 30  
N: Alla har samma temperatur ... larm?  
E: Ja, ungefär.  
N: Sen är det en till här uppe på sidan  
E: Ja, längre ner ser du vad det står för någonting. Det är något lager där också.  
N: Ja, det står bara siffror och bokstäver.

E: Ja, det står bara siffror. Jag kommer inte ihåg nu vad det är för temperatur.

N: 24 51 NT står det

E: Ja, NT?

N: Ja NT.

E: Ja, magnetiseringsutrustningen är det

N: Okej

E: Sedan har du ju klockorna framme där. Luft klockan den stora bruna där.

N: Då måste jag gå runt annars snubblar jag. Du menar den här stora bruna saken här?

E: Ja, den där är det luft i. Det är 40 kg luft i den där ungefär om du ser på visaren där.

N: Ja

E: 39 eller 40

N: Den röda där det är bara larmgränser? Den börjar bli varm i alla fall.

E: Nej det är lufttrycket. Sedan om du böjer dig lite grann ser du på vad oljan ligger på för nivå på skalan om du böjer dig mer. Du får krypa ner på knä.

N: Ja

E: Ja, där ska man läsa av mängden olja i klockan. Du har en tumstock på höger sida... på vänster sida så har du en tumstock

N: Ja

E: Eller måttband

N: Ja

E: Det läser man av när man rodar så man ser om oljan har försvunnit

N: Precis

E: Ja. Så ännu längre ner har du en till sådan där liten skala... på burken där

N: Ja, den här på golvet. Då får jag nästan lägga mig ner.

E: Där ja. Där är oljan i hela burken under

N: Ja. Är det det orange man läser av?

E: Ja. När pumpen startar då höjs ju trycket i klockan då ser man om de små orange fälten ändras då går de upp till ... Jag kommer inte ihåg vad står det på? På sidan?

N: Den lilla?

E: Nej den övre.

N: Nu ska vi se ...270? Kan det vara det?

E: Ja

N: Eller 27? 270?

E: 270

N: Nu rör de lite på sig

E: Nu klättrar den upp till 280 när pumpen startar

N: Ok

E: Så då får man stå och vänta där så man ser vad den går upp till då ser man ju föregående värde på ronddosan.

N: Jaa

E: Prova att gå ner till trappen där till höger. Nu blir det kanske ett sådant oväsen så nu hör väl inte du?

N: Vi får prova, jag har ju hörlurar.

E: Jaha, du har det

N: Ja det låter ju himla illa men jag hör ju dig. Det är väldigt mörkt i alla fall.

E: Tänd lyset där på knappen ... där ja.

N: Strålkastare står det.

E: Ja, den där, Du kan tända båda två om du vill

N: Så, ska jag gå ner en till eller?

E: Vänta där så går du in. Gå till vänster i trappen så har du en liten pump.

N: Till vänster

E: Du har en pump... nej till höger. Du har en pump står på golvet där nere

N: Nu hör jag lite dåligt

E: Gå till höger om trappen

N: Till höger?

E: Höger, höger, höger

N: Här har vi någonting bakom

E: Ja

N: Vad är det här som jag ser?

E: Den där filtrerar oljan till tanken till vänster om dig har du en stor tank och den där filtrerar oljan. Och så har du en liten du har ett filter sitter på den där.

N: Vad säger du ett...?

E: Du har ett filter ett blankt filter som sitter där. Titta om den där visar grönt eller rött?

N: Den visar grönt

E: Ok, då är filtret rent. Den visar rött när filtret är igensatt.

N: Ja, men då är den ok om den visar grönt i alla fall.

E: Ja och så går den också.

N: Vad hade jag gjort om den var röd hade man fått byta filter då eller?

E: Ja, då får man stänga de där två kranarna på sidan där

N: Ja

E: Om filtret och så får man skruva bort filtret och byta det. Insatsen och så byter man det. Det verkar ju bra

N: Ser du bra vad jag ser.

E: Ja, nu ser jag jätte bra, inga problem alls. Där nere är det inte mycket mer det är väl om man vill titta ner på maskinen så den inte läcker något vatten.

N: Här låter det mest illa. Ska vi gå upp igen då

E: Ja, det kan du göra

N: Nu låter det inte lika illa längre.

E: Gå efter vägen där... längre fram

N: Då har jag några gröna pelare där.

E: Ja, det är kylare de kylar oljan där. Sedan har du ett litet filter lite längre fram som det finns en spak på. Där har du den där spaken.

N: Ja

E: Lägg om den spaken. Vrid om den så man kör på det andra filtret

N: Vad sa du?

E: Ta tag i den där spaken och så vrider du om den åt andra hållet

N: Ska jag vrida neråt eller?

E: Vrid åt andra hållet. Så slipper jag göra det när jag kommer ditt

N: Så där då ser det rätt ut va?

E: Ja nu har du växlat filter

N: Härligt

E: Så ser du temperaturen på oljan på vägen... till vänster om dig har du en temperatur uppe på väggen.  
N: Så det var inte den här?  
E: Den visar också temperaturen.  
N: Den visar 25 grader. Uppe på väggen?  
E: Ja, där.  
N: Där uppe? De digitala siffrorna?  
E: Ja, 23 grader  
N: 23 grader  
E: Ja, det sköter sig bra det där  
N: Ja  
E: Nu kan du ju ronda det där åt oss  
N: Eller hur?  
E: Ja  
N: Det är lysande  
E: Ja, det är lysande  
N: Ja, det gick ju ganska bra, det är bara lite svårt att se vad du ser.'  
E: Ja, men nu ser jag golvet och trappen  
N: Mmm, är det något mer vi ska göra idag?  
E: Ja, jag ska ju ronda sedan. Vill du göra det så kan jag ju ledsaga dig runt hela stationen?  
N: Ja, skulle du våga lita på mig?  
E: Njaa, hur funkar den här apparaten nere i bulben?  
N: Hur den funkar?  
E: Ja.  
N: Ingen aning. Ska vi titta eller?  
E: Inte vet jag, det får väl du göra om du vill? Hör du mig där nere sen då?  
N: Jag hörde dig ganska bra när jag gick ner för trappen.  
E: Ja  
N: Om man har hörlurarna vill säga  
E: Ja  
N: Låter det så himla mycket värre om man klättrar längre ner?  
E: Nej men du kanske inte vill...  
N: Hörs det tydligt+  
E: Nej, men du vill kanske inte klättra ner där.  
N: Jag har gjort det så många gånger förut. Vi kan väl prova  
E: Ja  
N: Då får någon hålla i datorn bara  
E: Vilken stjärna det kom förbi där  
N: Gjorde det, ja Peter ja. En filmstjärna. Hoppas jag har risktillägg för den här datorn om jag tappar ner den.  
N: ...  
E: Jag hör inte vad du säger  
N: Nu hörs det väldigt dåligt. Det är ett lite högre ljud här inne. Jag klättrar nog upp  
E: Är du på väg upp igen?  
N: Det lät så där nere  
E: Ja, den är upp och ner nu  
N: Nu är jag uppe igen  
E: Ja, jag ser det



N: Det lätt alldeles, jag hörde ingenting där nere. Ni hörde säkert mig  
E: Ja, jag hörde dig lite grann  
N: Det vart ett för gällt ljud tror jag  
E: Ja, har du nyckel så du kommer in i ställverket där?  
N: Har vi nyckel så vi kommer in i ställverket? Vi kan höra om dom har det som sitter där borta?  
E: Den där dörren kanske är öppen också? Som jag tänkte på  
N: Vilken då menar du?  
E: Ja, jag vet inte riktigt... den där dörren till vänster där  
N: ...  
E: Ja, den där dörren  
N: Ställverk  
E: Ja, öppna. Den där är låst va?  
N: Nej, den är öppen  
E: Ja, då går du till höger där. Så tänder du lyset.  
N: Jag tänder lampan  
E: Ja, på höger sida tänder du lampan. Ja just det  
N: Precis. Här ser jag någon mätare som sitter på väggen.  
E: Ja, 26,7  
N: 26.7 eller hur?  
E: Du kan trycka in plusknappen. Tryck in plusknappen så får du se om det är jordfel. Om du trycker på plus där.  
N: Den till vänster  
E: Ja på plusknappen. Tryck på plus  
N: Är det den?  
E: Ja, får jag se visaren där. Nu ser inte jag siffrorna  
N: Är det den där med plus jag ska trycka på.  
E: Nu är du ju ute, nu ser jag maskinhallen  
N: Ja, det är för att jag hör inte dig där inne  
E: Nehe  
N: Jag kan se ljudet men jag hör inte  
E: Om du trycker på plusknappen så hör jag om det är jordfel eller inte?  
N: Är det den knappen?  
E: Ja  
N: Då trycker jag på den då  
E: Ja, så får jag se digitalsiffrorna där  
N: Det händer ingenting det här.  
E: Det ska det göra.  
N: Såg du något?  
E: Tryck på den andra knappen då. Jag ser ingenting det blir suddigt. Tryck på minusknappen då. Håll inne knappen  
N: Okej. Det blir perfekt. 13.3  
E: Då tar du plusknappen också  
N: Att man ska hålla den inne det förstod inte jag. 11.8  
E: Det är bra det där. Då vet vi var vi ska ta hjälpen någonstans sedan  
N: Ja, precis. Då är jag klar här inne då.  
E: Ja det är ok  
N: Då släcker vi lampan. Jag är så rädd när man ska trycka på nya knappar när man inte vet vad det är för något

E: Ja, men det där var ingen fara. Det är värre om du är inne i kontrollrummet och trycker på knappar.

N: Ja

E: Titta en sådan stjärna du har där då

N: Elle hur?

N: En sådan snygging va? En filmstjärna

E: Är han nyklippt?

N: Ja, nyklippt är han. Nu flyttade han på sig han vill inte vara med längre

E: Nej, han vill inte vara med på bild han heller. Har han blåställ på sig?

N: Ja, det är riktiga arbetare det där men bara på överkroppen

E: Han har bara väst på sig

N: Ja, det passar på honom vet du

E: Ja

N: Ja, vad ska vi göra nu då?

E: Åka hem och äta

N: Åka och kaka lunch

L.: Är du nöjd så där?

N: Jag är nöjd får se om Anna är nöjd?

I: Jag är jättenöjd

N: Då kopplar vi ner. Hej då

E: Hej då

## Appendix 6: Example of Personnel Interview (Swedish Version)

I: Hur kändes den här situationen?

N: Ja, jag tyckte det kändes ganska bra faktiskt. Det känns nog ännu bättre om man har en anläggningsnära koppling som kanske inte jag har, jag vet ju inte vad saker sitter. Det jobbiga är ju att luta sig ner som har kommit upp förut, att hålla på att ändra kameran.

I: Om du skulle ronda själv med hjälp av utrustningen, tror du att du skulle klara det?

N: Ja, det tror jag om kommunikationen höll hela vägen så tror jag det absolut. Jag tror man skulle kunna klara det ganska långt på telefon också måste jag säga och sedan kanske bara visa bilder för att verifiera det man gör. Att man snarare skulle kunna köra en långsam uppdatering på det man gör, att det man väl tittar på syns ordentligt.

I: Nu kunde du se den som du pratade med. Tror du att det kan vara till någon hjälp?

N: Nej, det hade jag ingen nytta av. Däremot skulle jag vilja se mer själv av det den andra ser. Den bilden som är stor i dag på det den andra ser skulle vara stor på min kamera visar, så att det är lättare för mig att se om jag ska se något för huvudtaget. Men om jag hade en kamera som satt vid ögonen skulle jag inte behöva se något alls eftersom jag vet att den andra ser det som jag ser.

I: Hur skulle man kunna interagera med systemet på bästa sätt?

N: Ska man nu ha en dator så att det inte bara är en kamera och telefon ska det ju vara någon touch, men helst ska det inte behöva vara det. Men man behöver inte interagera, det är ju uppkopplingen, klick.

I: Var hastigheten på kommunikationen tillräcklig?

N: Ja, när jag körde var det ju det, det verkade värre när dom körde. Men å andra sidan så vi det också när vi stod där på slutet så stod vi nära radiolanet men ändå blev det jätte konstigt så frågan är om det är Internet, den linan som är seg. Så vet jag att det blev när vi körde virtuella inspektionen, efter lunch blev det jätte segt, typ vid ettiden så vart nätet överbelastat. Så det kan vara det som inträffade. Det vi pratade med Lennart var om man hade en kamera med i maskinhallen så skulle man veta vad den personen befann sig. Man måste kunna lita på det man hör. För nu är ju problemet att om inte jag hör dig så kan inte jag säga att jag inte har jag någon mottagning för du hör inte. Men om man hade telefon så skulle man ha ljudet och sedan har man kameran då tror jag att man har en säkrare kommunikation och då klipper inte ljudet.

Bilden är bra för att verifiera, var är jag eller hur ska jag gå till väga men skulle det sitta en stor kamera uppe i taket då kan du ändå säga till den personen sväng vänster eller höger för då ser du var den befinner sig, sedan är det svårt i de trånga utrymmena men där täcker inte radiolanet i alla fall och frågan är om man behöver vara där. Man skulle försöka någon kommunikation med mobiltelefonen, headsetet och bilden bara. Då skulle man inte behöva headsetet utan det skulle räcka med att man ser bilden bara och då skulle man kunna ha en programvara som bara skickar bilden hit.

## Appendix 7: Example of Expert Interview (Swedish Version)

I: Det funkade ju bra mot vad det gjorde sist i alla fall.

I: Det var lite dåligt ljud

E: Jo men...

I: Det skär sig lite grann men jag tror att det är inställningarna till högtalarna. Jag tror att radiomottagningen är för dålig.

E: Ja, men kameran funkar ju

I: Ljuset var tillräckligt?

E: Ja

I: Du tyckte att du såg detaljer?

E: Ja, visst, står dom bara still och riktar in sig på det man ska titta på

I: Ja, man såg ju siffrorna.

I: Passade tal och bild ihop?

E: Ja

I: Var ljudkvalitén tillräcklig?

E: Det pep lite som du säger men det fixar man ju

I: Så det var inget som störde dig?

E: Nej, inte med tanke på det ljud som är där. Jag kan inte gå utan hörselskydd, det går inte.

I: Man kan ju tänka att högtalarna ska vara i hörselskyddet

E: Ja

I: När man ändå har det på så att säga

E: Det är precis som när man ska svara i telefon då går det inte. Men har jag proppen i och kåporna på då går det bra eftersom de hör mej.

I: Man kan ju tänka sig om det här att man ska ha de inbyggda i hörselskydden. Mikrofonen och så det finns ju jätte fina sådana

I: Får se vad du tycker om systemet när du ska pröva det?

E: Så jag ska gå runt där nere då och Lasse ska sitta här?

I: Ja, tack så mycket.