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Decentralizing the Control Room: Mobile Work and Institutional Order

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Abstract. This paper seeks to inform the ongoing redesign of air traffic management by examining current practices and the adoption of a new system aiming to relieve traffic control from work and reduce radio communication We report from ethnographic fieldwork among mobile, distributed airport ground personnel By examining the ways in which they use the 'old' technology, i e. VHF radio, we identify a set of important aspects of work carried out through radio talk These are: repairing misunderstandings, discussing the task-at-hand, and negotiating next actions. The new system fails to support this negotiation work, and is hardly ever used by the ground personnel. The distributed workers in the field make their own decisions and negotiate coordination with the tower based on local information. In this respect, current work practice is already decentralized to a certain extent The problem with the new system, we argue, is the idea to decentralize the organization by providing distributed workers with more information, whereas the current institutional arrangement for coordination is built upon highly formal and hierarchical ideas. When redesigning the system it is necessary to take into account the ways in which radio talk is used to carry out the everyday work among ground personnel

Introduction

Air traffic is constantly increasing. In the middle of the last century centralized air traffic control was introduced to handle the growing number of planes in a safe manner (La Porte, 1988). Today, as the growth continues, traffic control itself

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becomes a problem. In northern Europe, mainly in Sweden, a new concept for air traffic control, called CNS (Communications, Navigation and Surveillance), is being introduced. This is a joint research and implementation collaboration between the Swedish, Danish and German civil aviation administrations as well as Lufthansa, Scandinavian Airlines Systems (SAS) and the European Commission. It is a major effort aiming for a decentralization of the coordination system, by moving some responsibility out of the control tower to the pilots and other vehicle operators. This is addressed by launching a new communication system based on a standard (VDL Mode 4), featuring various new applications to support individual vehicle operators in the system (SCAA,1999). It is in the process of being adopted as a global standard from November 2001.[1] Important keywords in this effort are *collaboration* and *situational awareness*: Air traffic management should "make sure that the best use is made of all available resources and that potential problems are resolved in a collaborative and pro-active manner" (SCAA,1999:5) It introduces ideas of support for group work to a practice that traditionally has aimed for hierarchical and centralized control. Not surprisingly, the approach is therefore considered radical, and is meeting resistance in air traffic management circles.[2]

The purpose of this study is to inform design of coordination technologies by describing the organization of the everyday practices of a certain airport ground personnel category very important for air traffic management, namely those who keep the runways free from snow. The snow clearance personnel we have studied, use two systems two carry out their work: the traditional radio communication system and a new system (the first application for their use based on the design principle described above). The snow clearance vehicles are equipped with SnowCard. It is a "situation display", that provide the sweeping crew with a moving map where they could see dots representing other ground vehicles as well as those airplanes equipped with the new system. This is motivated by work-overload in traffic control, as well as too much talk on the radio system. The radio system is conceived as technically insufficient, and the talk itself can cause misunderstandings and failures in achieving coordination. The SnowCard system addresses these issues by giving the snow maintenance crew and the control tower an awareness system enabling them to see the location of snow clearing vehicles. However, during our fieldwork it became evident that the personnel did not rely on the new system in carrying out their work. Rather, they used the 'old' technology, the radio, to coordinate their work on the runways. Therefore, in this paper, we examine what the snow crew is doing with the radio, in order to be able to draw conclusions about how to design better tools for this activity.

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[1] Press release, Swedish Civil Aviation Administration, 2000-03-30

[2] Niklas Gustavsson, Swedish Civil Aviation Administration (Luftfartsverket), Norrkoping, Interview, October 2000

In the first part of the paper we present related work, our data collection, as well as explain the tools and manuals that influence snow clearance operations. We then present selected items from the fieldwork, together with our analysis. Finally, we draw conclusions to inform the design of support for this specific type of air traffic management.

Related Work

Two distinct ways of understanding work practice figure in the design of support for traffic control. In the documents from the Civil Aviation Administration, they discuss coordination either between autonomous users, or centralized coordination:

> Concept options will range between a "managed" ATM [Air Traffic Management] environment based on traffic structuring, greater traffic predictability, longer planning horizons and extensive automated support, to a "free flight" environment based on free routings and autonomous aircraft separation (SCAA,1999 6).

The CNS system will provide additional support for traditional forms of centralized management which structure and order the movements of the planes. The new and innovative approach concerns ideas that, in their most radical formulation, allow for free flight where the operators have the freedom to select their path and speed. Then, individual pilots will organize traffic through decentralized collaboration. The traditional perspective in aviation control understands coordination of air traffic as a centralized achievement, where traffic control holds a unique position, monitoring the system. The traffic controller has a number of information sources, e.g. radar and other personnel. Based on this information the controller visualizes the current state of the entire system, and decides on appropriate next action. This decision is based on a list of appropriate actions to take in the given situation. To coordinate the many people in the system, it is necessary that they behave in a predictable way, i.e. follow formal procedures.

The distinction is central in terms of CSCW research, where an important design choice is understood as either automating organizational work, understood as routine work in a predictable environment, or supporting the articulation of contingent and situated organizing activities (Schmidt et al 1996, Gerson and Leigh Star, 1986)

In the new perspective, coordination is achieved as a distributed activity where people and technology in collaboration achieve coordination (Goodwin & Goodwin, 1998 and Hutchins, 1995). Air traffic control holds a less privileged position, as one of many local settings. The controller's understanding of the system is only partial, and decisions about next action must be negotiated with other localities where participants have different understandings. To achieve coordination it is essential that people account for the local circumstances and contingent situations

in which they are involved. Thus, people do different things and hold different views on the system. Collaboration and mutual understanding is interactionally negotiated.

In the studies of control rooms of various sorts, it is usually the controllers and their teamwork that are in focus. Hughes et al. (1992) and Sanne (1999) show how the managers make their own work accountable for their colleagues, and how this is seen with peripheral awareness, as a way to e.g. repair mistakes. Hutchins (1993) considered the task of navigating a large vessel as a collaborative and distributed achievement. Watts et al (1996) have considered voice communication support for managers launching a rocket. They argued that a combination of different virtual meeting rooms increased awareness for the benefit of the collaborative work at hand. Further, Mackay et al. (1998) study air traffic controllers who were not located in a control tower, but had radar screens as a visual source of information about the location of the planes.

However, in order to influence the design of a more decentralized traffic control it is necessary to consider coordination as seen from outside of the control room. As pointed out by Bellotti and Bly (1996) with reference to the studies of navigation at sea, the managers in all these settings are themselves 'locally immobilized'. In their own research, Bellotti and Bly point to the importance of 'local mobility' where people walk between office rooms and then often have to leave their computers at the desktop. Consequently, this local mobility penalizes long distance collaboration. However, with the aid of mobile technology it is possible to continuously monitor the activities in the center. A similar approach is taken in the studies of traffic management at the London Underground. Heath and Luff (1992) study the local mobility of the station managers. They also found that the managers had much less awareness of the activities when they left the control room to move around at the underground station.

In this paper we will look at a different form of mobile work. The snow crew is undertaking a job where they are almost constantly on the move. The movement is more than an issue of moving to a different place of work - it is the work itself. The snow crew has this in common with many occupations involved in transportation. The thoroughgoing mobility is visible in the talk, the system that supports the work, as well as in rules surrounding the work. For them, the positioning of their co-workers is under constant negotiation.

Radio talk

This study is concerned with the practices of radio (UHF - ultra high frequency) communication. The use of radio for carrying out work has been studied mainly within the transport sector. In this section, we briefly outline relevant findings from these studies, focusing on features identified as unique for radio talk.

Pritchard and Kalogjera (2000) have examined marine radio communication. They argue that "the conversational structure and format of most messages is

simple, routine-like and therefore predictable." (2000:186). They show how the actual maritime VHF communications differ significantly from the highly formal standards.

In another study of marine radio communication, Robert Sanders examined the talk between vessels, commercial as well as recreational. He is interested in the fact that although these radios are intended for safely operating vessels, and with a prescribed language, they are widely used for other purposes, especially by recreational boaters. His focus is on conversational socializing (specifically laughter) observed over the radio. Both studies show how practices have developed for making a highly restricted technology more adjusted to everyday actual use.

The radio technology has some interesting implications for the talk situation. One main difference between face-to-face communication and radio talk is that when talking over the radio it is physically impossible for more than one person at a time to occupy the floor (Sanders, 2000:5).

Another relevant difference, pointed out by Sanders, is the fact that in order to say something on the radio the speaker has to do something more than just vocalize. There is a need to take the microphone and press the button before the talk can be transmitted and heard. This of course has the implication that the person speaking needs to have at least one hand free to operate the microphone. When engaged in physical work, this can sometimes be a constraint, and consequently lead to response delays.

The above-mentioned studies have mainly focused on the talk in itself, rather than looking at it in the context in which it occurs. Luff and Heath (2001) describe a setting (a railway in London) where the practices of radio use are closely linked to the practices of using a computer supported display system. They note how "the displays are utilized to make sense of the ongoing talk and also shape the production of interactions within that setting." (2001:28).

Method and setting

The fieldwork reported in this paper was carried out at Arlanda airport during January-February 2000. Arlanda airport is situated north of Stockholm. With its two runways and intense traffic it is Sweden's largest airport. There is a risk of snow during half of the year. From end of October to middle of April, there are people present twenty-four hours per day to run snow clearance operations. A minor part of their task is to clear the areas around the gates. The major task is to clear the runways and the areas in the vicinity. The aviation administration argues that they currently clean a runway, being forty-five meters in width and 3.3 kilometers long, in eight minutes. Extensive efforts are made to improve the operations.

The snow sweeping operation takes eight collaborating vehicles moving in a falling line (see below). Each vehicle is equipped with means to plough, sweep and blow away the snow. Therefore, they are referred to as the sweeping group.[3] The driver in the first, the lead sweeper, is responsible for radio communication with airport traffic control (the tower). The sweeping group collaborates with a "brake vehicle", a car that measures the friction of the runway before and after snow clearance.

On a total of five snow clearance occasions, we rode with the snow sweepers, sitting in their vehicles while they carried out their work on the runways and the surrounding areas. The vehicles normally had an extra seat next to the driver seat, where the researcher could sit. We normally organized it so that one of us always was in the lead vehicle. Being two people in the field made it possible to get different perspectives on the same situations. Some drivers talked a lot with us and were interested in explaining their work and their use of the systems, whereas others did not take much notice of us. It enabled us to focus more on the work and listening to the radio communication. During all this, we took extensive field notes.

Figure 1. The eight snow vehicles out on the runway, with the lead sweeper in the front and the others in a line behind

When in the vehicle with the snow sweepers, it was sometimes difficult to hear and comprehend the radio talk. In order to get the details of the ongoing talk, we made recordings. This was carried out during two days of the fieldwork. Due to the nature of the work, we had to wait for it to snow before going out with the snow sweepers. This meant that we spent a lot of time in the recreation room, in the garage, etc. That enabled us to talk to the snow crew and get their opinions of their work situation, as well as getting a sense of the workplace.

The material, the field notes as well as the recordings, were then transcribed. We went through the transcriptions, identifying a set of themes. A few sequences from the transcribed recordings, were then chosen as showing the issues we examine in this paper

[3] We have chosen to use the term 'snow sweepers' and 'sweepers' rather than the more obvious snow plougher or similar, because this is the way that they are referred to at the airport

The systems

The snow clearance operation is traditionally coordinated through radio communication on the ultra high frequency band (UHF). It is a simplex system, which means that it is only open for one transmitter at a time, but that everybody with radio equipment can listen. Only the strongest signal goes through if several people try to speak at the same time. The speaker has to push a button in order to transmit. It is possible to hear their use of the button since the beginning of a sentence is often clipped off, and the end is often followed by an audible click. This clicking sound is represented by the sign '#' in the transcripts.

In radio talk it is not easy to understand who's talking to whom. To avoid misunderstandings, formal rules define the way the participants speak. Every statement should be initiated by an identification of the speaker. Permission must be granted by the tower before any maneuver. All decisions must also be check-read to make sure that everybody heard it the same way. The manual states:

> When you want to drive onto the maneuver area, you must identify yourself (give your call signal) and tell where you want to go and - when needed - what way When the tower gives permission to drive on or to remain on the maneuver area, you shall check-read (i.e. repeat) the permission Even the request to "hold position" or to hold a certain distance from the runways shall be check-read End the check reading with your own call signal, so that the tower knows that it is the correct vehicle that is acknowledging the permission [4]

Further, it is strongly requested that radio conversations be "short" and "accurate". This is also expressed more straightforwardly in the manual, in capital letters as follows: "IN OTHER WORDS, NO UNNECESSARY 'CHAT' ON OUR RADIO COMMUNICATION SYSTEM!"

There are a number of radio channels that the personnel could use when they are doing their work. The channels of relevance for the work in the group are mainly channels one and two. Channel one is intended for communication with the tower. When on the runway, the snow crew is demanded to use channel one. This is mainly for security reasons, the tower has to be able to hear all the communication on the ground, and the ground personnel need to be in constant response to orders from the tower. The manual states:

> The Aviation Administration demands that radio communication be possible with vehicles are located and working in . the airports maneuver area. Here there is a demand for constant radio attention (SCAA,1999 14)

As soon as they leave the runways, the snow crew should switch to channel two, so that the tower would not be disturbed by their talk. Channel two is meant for communication within the sweeping group.

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[4] From the manual *Radio communication on airport* (UHF), page 47 [Translated from Swedish]

The snow clearance operation has been targeted by the designers behind the CNS concept. In the pursuit of expanding the system concept, a number of aircrafts was first equipped with new equipment. Then some snow clearance vehicles were included in the system and provided with situational displays with a moving map (SnowCard).[5] On a display presenting a map of the airports, a number of the sweeping groups' vehicles are represented by small dots. When the vehicles move around the airport the dots follow on the map. This is made possible by the positioning system in each vehicle and the digital radio communication link. The new data link is considered a "major breakthrough" giving each aircraft and other vehicles the ability to broadcast its position and identity to other vehicles as well as to the central traffic control (SCAA,1999:7). Below is a picture of the inside of one of the snow vehicles (Figure 2).

Figure 2 The inside of one of the snow vehicles. The SnowCard display is in the upper left corner of the picture The small radio receiver is hanging down from the ceiling of the vehicle, and is visible in the top middle of the picture.

Analysis

In the following we will present our analysis of the fieldwork. First, we will present our observations of the use of the SnowCard system. The remainder of the analysis then deals with the ways in which the snow clearance personnel use the traditional radio system to coordinate their work through talk. The reason for devoting more space to the use of the radio rather than the new system, is simply because the current work practice in the sweeping group relies on radio, and there are several things that the snow sweepers regularly and ordinarily do which do not seem to be possible using the new system. Therefore, in focusing on the current practices we hope to be able to inform the redesign of the new system, something which is discussed later in this paper.

New visual support for situational awareness

The new display system was introduced to increase situational awareness for vehicle operators in conditions of poor visibility due to the snow. Thus, the use of

[5] Swedish Civil Aviation Administration, SnowCard Arlanda, leaflet

the system should be observable in the way the drivers looked at the screen in parallel to looking out of the windshield, and in the rear mirrors.

On one occasion during our fieldwork, the sweeping group is sent to clear the runway. They have instructions to vacate the runway by a specific time. The lead sweeper turns and exits the runway. The driver constantly looks at the screen to oversee when all the other vehicles have exited. He then calls the tower telling them: "Tower, the sweeping group has now left the runway". Later he states that the SnowCard system allowed him to report directly to the tower. Before, he had to wait for the last driver to notify him by radio, and only thereafter call the tower. Now he could use the display instead. This lead sweeper consistently used the situational display when turning. He reported it useful for seeing if the group was holding together, and that no one was falling behind. Along with the adoption of the new system, he also frequently looked through the windshield. Interestingly enough, he would look out the windshield first; only after that would he glance at the display.

This lead sweeper had found some use for the new system. However, it was difficult to observe instances of personnel actually looking at the screen. When we addressed the issue, they told us that they did not find it useful. One member of the sweepers, when asked why he did not have his screen turned on, responded: "What does that *[the screen]* tell me then?" The researcher replied: "It tells you where the others are". The final comment by the driver reflects what many of them seemed to think: "I can tell that by looking out the windshield". Thus, in a sense, there were two competing visuals, the windshield and the SnowCard. The one taking precedence was the view from the windshield.

We conclude that, although the sweeping group found some use for the system, it was not at all important for them in coordinating their activities and doing the work.[6] The SnowCard did not influence the sweeping group's understanding of their situation in any important sense. It follows then that the new system did not have any impact on the coordination of their work. Rather, they continued to coordinate their moves on the runway using the old technology, i.e. the UHF radio. In the following we will therefore concentrate on the radio conversation, and the situational and local awareness provided simply by the view from the windshields of the vehicles.

Making decisions on the ground

During their work on the runways, the sweeping group is in constant contact with the tower to coordinate their movements. The talk between the tower and the sweeping group is regulated by rules (as described above). We will begin by

[6] It should be remembered that the situational display is installed only in a small number of vehicles, and that only a small number of the vehicles out on the tracks are sending information on their identity and position The promises of the system designers should be evaluated when a much larger number of vehicles are displayed And in this situation it could perhaps achieve more attention from the driver

looking at how the visual local information is used in the conversation between the tower and the snow crew. In the following example, it becomes evident that the snow sweepers make their *own decisions based on visual information on the ground*, rather than on information from the control tower.

In the first excerpt from the radio conversations, we will see how the lead sweeper and the tower repair a misunderstanding:

Excerpt 1

LEAD SWEEPER· tower to sweeping group #
TOWER· sweeping group #
LEAD SWEEPER I'm waiting here at Zulu Tango want to go Xray west#
(13.0 sec)
TOWER· sweeping group go Xray out east·· from hh ramp + #
LEAD SWEEPER sweeping group we would like to go out on zero eight twenty-six later when we have come down towards hh Xray Alpha #
(9 sec)
TOWER· h «sweeping group » I see so you are going Xray west? #
LEAD SWEEPER: yeah I saw that they took off from there so isn't it best to go from there then? #
TOWER· «absolutely the best» it is the absolutely best thinkable but I thought you said east but go Xray out west (up) to the meeting point #
LEAD SWEEPER: sweeping group ready for meeting point #

In the first section of this fragment, everything seemingly runs according to the manual. The sweeper reports their position - "I'm waiting here at Zulu Tango", and say that they want to continue west. After an unusually long pause the tower repeats, but repeats incorrectly, saying *east* instead of west. The long pause might suggest that the person in the tower was busy doing something else at the moment. The misunderstanding is not revealed until the tower hears the sweeping group's next planned action. The tower then displays uncertainties, shown in the slowly, prolonged address of the sweeping group in the next utterance.

The lead sweeper now states his reasons for wanting to go in that direction. Here is where it becomes evident that the snow sweeper uses visual information as a basis for his decision-making - "Yeah I saw that they started from there so isn't it best to go from there then?" He now shows that he has seen the planes, and from the direction in which the planes are going, has drawn a conclusion about where the sweeping group should go next. The person in the tower agrees with his decision, saying that his planned next action is "absolutely" the best way to go. Here she could have ended her turn, but she continues to explain for the sweeper how the misunderstanding came about. This is all done out of the institutional order of talk. The lead sweeper does not acknowledge her explanation at all in his next utterance, where he simply states that the sweeping group is ready. The repair of the misunderstanding between the tower and the sweeper is done in a conversational mode. They are not using any identification or address. By opting out of the institutional mode, they mark the topic for the conversation as

problematic. When the problem has been resolved, they get back into the institutional mode again.

This example nicely shows how the snow sweepers and the tower have different perspectives in the system that the ground air traffic management comprises. There is not one single unit with control; the control is distributed over various people, and the decisions are consequently also distributed, although against the manual considering both legitimate movements and radio use.

In the next excerpt, we will see a very illustrative example of the sweeping group making their own decisions on the ground. In this case, they cross the runway without permission from the tower, something which is highly prohibited:

Excerpt 2

SWEEPER Tower the sweeping group at Yan: kee (0 5) an we go Zulu south via Zulu Kilo? #
(17 0)
391 *Tower three nine one#*
TOWER eh· one (paus) three (paus) nine tower #

[Long section where vehicle 391 speaks with the tower Meanwhile, the lead sweeper sits ready with his radio in hand, waiting for a response. He looks in both directions, then crosses the runway]

391. three nine one (0.5) ready to make turns at south Yankee (0.5) at entrance Uniform #
(1 0)
SWEEPER· tower sweeping group (paus) we went Zulu south via the entrance Zulu Kilo ( ) Just so you know #
TOWER· the sweeping group driving Zulu south #
SWEEPER· eeping group#

In this excerpt, the driver is asking the tower for permission to cross the runway. The tower does not answer; there is a very long pause suggesting that the tower did not hear. Instead he talks to another vehicle, 391. The driver waits for the tower to give him permission to pass. After a while, still overhearing the tower's conversation with someone else, the sweeper crosses without permission, after having looked in both directions to see that it was clear.

What is interesting in this example is that the sweeper obviously does something that is against the institutional order of work, i.e. crossing without permission from the tower. However, the tower does not comment upon this. Instead, when the sweeper calls the tower to say where they have gone, "just so you know", the tower simply confirms. But the repetition is a repair of the breach against the institutional order of work, in that the tower repeats in the present tense. Instead of repeating "went" he says "driving". Obviously, confirming in the past tense would show that he had recognized that the sweeping group had already taken action; now instead he repairs by saying that they are about to do it. The tower and the lead sweeper thus *collaboratively repair the sweepers' breach of institutional procedure.*

In these two examples, it becomes evident that the mobile workers make decisions based on local, visual information. In the first example, the lead sweeper drew conclusions about where to sweep next from his visual information about where the aircraft were departing. In the second example, the sweeper crossed the runway using the same mundane method as one would use to cross a road: looking in both directions and then crossing. This was done without permission from the tower, thus against the institutional order of work as described in the manual. These examples show how the visual and the local are used in decision-making at the airport.

Inverting institutional order

In the formal plan of how the work at the airport is supposed to be carried out, it is the snow team which is supposed to ask for permission for their actions. In this excerpt we see the opposite; the tower asks the group (here the brake vehicle) for permission for aircraft to enter the area that the snow crew is currently clearing.

Excerpt 3

TOWER: «brake vehicle··» is it okay that we are getting in position e directly when you have e begun clearing on zero eight? #
BRAKE VEHICLE· yeah sure that's okay #
TOWER: thanks #

The tower begins by identifying the recipient (the brake vehicle) in a formal manner. Thereafter, the person in the tower opts out from the institutional to do something rather unusual in the communication between the tower and the sweeping group – he asks for permission for an action. Since asking for permission to do things is not something that the tower should do from the group, there is no institutional way of doing it. The informality of the question and the way it is phrased, leads the brake vehicle to continue in that mode. The rest of the exchange is conversational, in the lack of identification, repetition, as well as in the choice of words. The last part of the exchange is particularly interesting The tower thanks the sweeping group. It is remarkable that the tower displays thankfulness to the sweeping group for letting the aircraft be on the runway. This can be taken as evidence of the decentralized practice. The control tower does not decide what to do, the mobile workers have a say in the coordination of work as well.

In the next examples something quite similar occurs. In the formal plan of how the work at the airport is supposed to be carried out, it is the snow sweepers who carry out orders and the tower that gives orders. The tower normally does not give any *reasons* for orders; they simply state where the sweepers should go, not why. However, in the following example we can observe how the tower changes plans, and explains her reasons for doing so to the sweeping group.

Before this segment, the tower has displayed uncertainty about the plans by telling the group to wait. Also, there have been problems with the radio, something that the lead sweeper has commented on to the tower.

Excerpt 4

SWEEPER 391. yeah tower we are getting in position then and holding fifty at Yankee Hotel#
(0 3)
TOWER. eh three nine one with suite «do you think you can» get in position and begin by Yankee Juliet ((radio problems, unhearable)) later tonight and then we would need it cleared #
SWEEPER 391 yeah we will do that instead then (0.1) three nine one #
TOWER great ( ) hh hold fifty from zero eight on Yankee Juliet (0 1) three nine one #
(2 0)
SWEEPER 391: three nine one we are holding fifty at Yankee Juliet

In the first line in this excerpt, the lead sweeper tells the tower that they are putting their machines in position, getting ready to sweep Yankee Hotel. The tower then asks the snow sweepers to sweep another runway (Yankee Juliet) than previously agreed on. This involves a change in plans, and a break from the routine. This is obvious in several ways; she formulates a question, *asking* the snow sweepers if they can do this rather than telling them to do it. This means that she opts out of the institutional order of talk. She uses the polite "do you think that you can...", which gives the snow crew the theoretical possibility of declining to do so.

Furthermore, she does something that is rather unusual in the talk between the tower and the sweepers; she gives the reason for why a certain action should be carried out. She says that the reason why they should sweep another runway than previously decided upon is because they would need it later tonight for some reason. *The decision process in the tower is thus made more transparent to the sweeping group*; they are given reasons for decisions rather than just the decisions without a context.

Furthermore, the tower's use of "great" is a way to show gratitude towards the sweepers for being able to change their plans according to her wishes. There is no institutionally described way of showing appreciation and thankfulness; this is not regulated in the manual.

These two examples show the ways in which the sweeping group takes an active part in the decisions the tower makes about air traffic. The order of work was negotiated over the radio, and there was a discussion about what to do next. The tower was not simply given orders and instructions; they asked the sweeping group for permission and negotiated the best way of carrying out work. It can be concluded that the everyday practice is to some extent decentralized, in that the sweepers take an active part in the everyday decision-making on the airport.

Coordination within the sweeping group

In the following, we will look at the conversation within the sweeping group itself. We will see how the group use local knowledge, visual contact and radio talk in order to attend to highly local issues and problem on the runway.

In this case, there is a breach against the regulation stating that they should use channel one when on the runway. As soon as they leave this area the radios are switched to channel two. However, despite what the manual prescribes, the snow sweepers and other personnel sometimes use channel two when they are on the runway. This is seen in the following example, where the sweepers try to solve a problem with a machine. The sweepers all know that Peter is a novice. His vehicle is the last in the line of snow machines, but he cannot get it to run as fast as the others. Consequently, the distance between Peter and the rest of the group increases. This can of course be serious, since the group has to keep together and leave the runway by a certain time. Their talk about the machine is shown below:

Excerpt 5

PETER u:h . why doesn't he change gear now?#
(3 0)
SECOND SWEEPER: o you have the driver mounted?#
PETER The driver is mounted#
SECOND SWEEPER. >>I'm stepping on the gas and it's so heavy it hasn't been this heavy before?<<#
PETER No, not like this it's on. I have the accelerator pressed to the floor but it only reaches fifteen hundred revs (0.5) and thirtythree kilometers#
THIRD SWEEPER Check that the stop is really pushed#
(11 0)
PETER omething happens if I push the stop with my hand (.) Then he got to · thirtyfive at least#
THIRD SWEEPER· *[inaudible]* a bit hard But he's coming#
PETER it does # *[deleted section]*

The sweeping group is now about to exit the runway. When turning the corner, the lead sweeper turns around a looks out the window, to get a look at the vehicles lining up behind him. When he sees the large gap between Peter and the rest of the machines, he says to himself: "My God, is he that far behind!".

LEAD SWEEPER. Peter switch to two# (8.0) Peter switch to channel two#

Peter and the lead sweeper switch channels and discuss what to do with the malfunctioning machine. Peter says it "it's hairy." They decide that the vehicle should be taken back to the garage and replaced.

LEAD SWEEPER: yeah okay I will exit here at Golf or something *[switches the radio back to channel one]*

Peter starts with an open question about his machine "Why doesn't it change gear now?" This is not addressed to anybody in particular; rather it is a call for help to

whoever can help him. The snow sweepers know that Peter is a novice, and the second driver in the group responds quickly to help him out. The lead sweeper has a special responsibility for the group to adapt his own speed so that no one falls behind. He gets a good look at the team when the group turns and exits from the runway. This local awareness, as well as their knowledge of Peter's lack of experience, makes him take action and switch channel It is likely that the switch is made because he knows that there has been too much to talk already and he wants to avoid further blocking channel one. Although this is against the manual, we observed several instances when the snow sweepers would switch to channel two on the runway to talk about these types of issues.

It is worth noting that the practice of switching channels on the runway is visible to the tower since the request to change to channel two is made on the channel that is overheard by the tower. The lead sweeper claimed that he had never been discouraged or ordered not to use channel two by the tower. Thus, there seemed to be a common understanding that they could shift to channel two if they had to perform extended conversations. This could however be a dangerous way of pursuing co-ordination. If the tower had given the lead sweeper an urgent order, e.g. to leave the runway immediately, the lead sweeper would not hear it. However, the lead sweeper had developed a workaround to be able to receive these messages. The brake vehicle, with which the lead sweeper cooperated, was equipped with two radio receivers, and they were always listening to both channels. If it was within sight of the front sweeper he counted on the driver of the brake vehicle to warn him on channel two if the tower could not reach him at channel one. Thus, the institutional rules for the technical operation of the radio equipment were not in compliance with their actual needs, and they had therefore found other ways of collaboration to achieve safe ways of supporting coordination.

From these examples it is obvious that coordination within the snow crew is based on local, visual information obtained by looking out the windshield. Furthermore, we have seen how this information needs to be discussed over the radio. These examples point to the highly local-dependent information the sweepers use in their work. Keeping an eye on the machine in front of them, letting others know if there is a problem and if so how it should be adjusted. Together they take great responsibility for the machines and for leaving the runways clear. In this work the radio proves important, so important that the sweepers break the rules for radio use on the runways.

Discussion

Coordination of air transport is currently under reconsideration in Northern Europe. Air traffic authorities and airline companies are exploring new principles and technologies to redesign air traffic control. New, innovative techniques are

being developed that will not only support air traffic control in the tower, but also engage pilots and other vehicle operators in the coordination of activities. These systems are being considered as an alternative to radio talk. This paper considers the attempts of decentralizing coordination.

The work in the sweeping group that we have observed has been relatively unproblematic. Breakdowns occur in the system, but are resolved. However, the problem identified by the management and which initiated the design and introduction of the SnowCard system, still remains. There is an increase in traffic at the airport. Currently, they are in the process of building a third runway, something that is likely to intensify the risk of coordination breakdowns. If the goals behind the SnowCard system are to be met, that is increasing traffic capacity and safety, the design should be informed by an understanding of the current social practices.

The coordination of snow clearing can be understood as an ongoing interactionally negotiated practice. The tower and the snow clearers occupy different viewpoints in the system depending on their task and the situation. Coordination is then achieved through negotiations between different localities. There is not one single unit with control; the control is distributed over various people, and the decisions are consequently also distributed, although this goes against regulation. The snow sweepers and the tower have different perspectives in the system that the ground air traffic management comprises. This becomes evident in the topics discussed on radio, as well as in how they constantly would avoid the institutional formats for radio communication for various purposes.

We have found that the new system was of minor use for coordination. Instead the tower and the snow clearers used the radio communication system for coordination and negotiation of next actions. Radio talk, as well as visual sight, are still the most important tools to do the job. By examining radio talk-in-interaction between the snow crew and the tower, we have identified a set of important factors in radio talk. These are necessary to consider when designing alternatives, or additions, to talk, as the SnowCard does. Activities that were carried out in talk were:

- *Repairing misunderstandings.* When there had been a misunderstanding, based on e.g. a mishearing or differences in access to information, this was resolved through talk.
- *Negotiating the task-at-hand and intentions.* When there was a need to talk about what the next planned action was, both from the tower and the sweeping group, this was done through talk.
- *Talking about the work order and the order of talk.* Letting others know that they had done something that was believed to be inappropriate, or asking them the reasons for actions be stated.

These things were all found to be of great importance for the work and are difficult to accomplish within the institutional system. Further, conversational language was used to make it stand out from the institutional, thus stressing its extra importance, and that there was something out of the ordinary to attend to. This paper has also shown the many things that can be accomplished within a conversational mode. There is an interesting comparison with the talk on the radio and the manual itself When the manual wants to give extra emphasis to the fact that unnecessary talk or "chatting" on the radio is not appropriate, the text actually switches from institutional, neutral jargon, to more conversational and colloquial language. This implies a need for opting out of the institutional mode in order to mark the text as something that requires special attention, just like conversational mode was used in the radio talk. In the light of this, the need for informal conversations on the radio seems even more evident.

Implications for design

One motivation behind this study was to evaluate the resources available to coordinate the snow maintenance at the airport. The resources included the old technology, namely the UHF-radio, and how it was used alongside the newly introduced technology, the SnowCard. We found that the new system was not widely adopted by the snow crews.

The system is currently under consideration at other airports. Being the first evaluation of this system, we find it important to identify a set of factors that could influence a successful redesign of the system, or at least factors to influence the design process within this new systems concept. We argue that:

- *A decentralized approach for developing technical support does fit with current practice.* However, the current attempt has not yet become an important enough tool for them.
- *In the current use of the system, there are two competing sources for visual information* – the SnowCard system and the view from the windshields. The system is not used. Perhaps the system will be used in a greater extent when most of the vehicles on the airport, as well as the planes, are visible on the screen. It could also be used if more information was given on the other vehicles than their positions. We suggest that it could be of use to display which channels other vehicles are using on the UHF-radio.
- *A system giving visual information cannot give the information needed about next action.* Information about the location of a vehicle is not enough. It is not possible from the SnowCard system as it is today to ascribe intention to the small dots that represents the snow vehicles. This is something that has to be negotiated through talk.

- Thus, *design for increasing situation awareness must go hand in hand with the introduction of better tools for supporting the necessary negotiation work.*
- We suggest *a design approach that integrates visual information in the system, rather than considering it as an alternative to the radio system.*

The main problem and the reason for the limited use of the SnowCard system by the snow crew we have studied, lies in the underlying assumptions about what the system sets out to do. The system is designed so that more information about the current situation can be obtained by simply looking at the screen. This implies giving the snow crew more information, thus decentralizing the decision-making by enabling the crew to make their own decisions about their work. However, the existing formal institutional rules do not support these types of decentralized decisions We have seen in our fieldwork that the institutional order is frequently opted out of in order to carry out work. *This means that decentralized decision-making is not supported by the organization, as expressed in the manuals concerning snow clearance operations, but this is exactly what the SnowCard system sets out to support.* We believe that this is the key problem, and something that needs to be explicitly formulated and attended to in redesign.

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References

Bellotti, V and Bly, S., (1996) Walking Away from the Desktop Computer: Distributed Collaboration and Mobility in a Product Design Team, Proceedings of CSCW '96, (Cambridge MA USA, 1996), ACM Press

Bentley, J. A. Hughes, D. Randall, T Rodden, P. Sawyer, D. Shapiro and I. Sommerville, (1992) Ethnographically-informed systems for air traffic control, Proceedings of CSCW '92, ACM Press

Dourish, P and Belotti, V (1992) Awareness and Coordination in Shared Workspaces, in Proceedings from CSCW '92 ACM Press

Dourish, P and Bly, S. (1992) Portholes: Supporting Awareness in a Distributed Work Group, Proceedings of CHI '92, ACM Press

Gerson, E and Leigh Star, S., (1984) Analyzing due process in the workplace, ACM transactions on office information systems, 4

Goodwin, C. and Goodwin, M.H , (1998) Seeing as situated activity: Formulating planes, in Cognition and Communication at Work, (eds) Engestrom, Y. And Middleton, D Cambridge University Press

Heath, C. and Luff, P. (1992), Collaboration and Control - Crisis Management and Multimedia Technology in London Underground Line Control Rooms, Computer Supported Cooperative Work, Vol. 1 (1992), 69-94

Hughes, J., King, V. Rodden, T and Andersen, H., (1994) Moving Out from the Control Room· Ethnography in System Design, *Proceedings of CSCW '94*, Chapel Hill, NC, USA, ACM Press

Hughes, J A , Randall, D. Shapiro, D , (1992) Faltering from Ethnography to Design, Proceedings of CSCW '92, ACM Press

Hutchins, E. (1993) Learning to Navigate, in S. Chaiklin and J. Lave (eds) *Understanding Practice. Perspectives on Activity and Context*, Cambridge University Press, Cambridge

Hutchins, E , (1995) Cognition in the Wild, MIT Press

La Porte, T, (1988) The United States Air Traffic System: Increasing Reliability in the Midst of Rapid Growth, in *The Development of Large Technical Systems*, (eds.) Mayntz, R. And Hughes T P Frankfurt am Main: Campus Verlag

Luff, P and Heath, C , (1998), Mobility in Collaboration, Proceedings of CSCW '98, Seattle, Washington USA, ACM Press

Luff, P and Heath, C. (2000) Broadcast talk· Initiating Calls through a Computer-Mediated Technology, Working paper, Work Interaction and Technology Research Group, Management Centre, King's College, London.

Luftfartsverket, [Civil Aviation Administration] (1997), Radiokommunikation på flygplats (UHF) [Radio communication on airport (UHF)]

Pritchard, B and D Kalogjera (2000), On some features of conversation in maritime VHF communication, *Selected Paper from the 7th IADA Conference 1999*, Birmingham. eds Coulthard, M , J Cotterill and F Rock, Tubingen Max Niemeyer Verlag

Michael, M , (1996) Technologies and tantrums: Regulating hybrids in the case of 'road rage', Keynote speech ' at the Conference *Regulating Identities* (Queensland University of Technology, 1996) 2-4 October

Sanders, R E, (2000) Conversational socializing on marine VHF radio: Adapting laughter and other practices to the technology in use, in *Festschrift in honor of Robert Hopper*

Sanne, J. (1999) Creating Safety in Air Traffic Control, Arkivs förlag, Lund

SCAA, Swedish Civil Aviation Administration, VDLmode 4 (VHF Data Link for CNS Applications) in CNS/ATM, issue 1, 19991029

Schmidt, K and Simone, C., (1996) Coordination Mechanisms Towards a conceptual Foundation of CSCW Systems Design, Computer Supported Cooperative Work, 5

Suchman, L (1987), *Plans and Situated Action The Problem of Human-Machine Communication*, Cambridge, England. Cambridge University Press

Suchman, L '(1991) Centers of Coordination· A Case and Some Themes, in *Discourse, Tools, and Reasoning. Essays on Situated Cognition*, eds. Resnick, L.B., Saljo, R , Pontecorvo, C , Burge, B., Springer

Web address

Swedish Civil Aviation Administration, the SnowCard system http://blinder.lfv.se/ans/card/