Towards Critical Information Use in Mobile Work

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Abstract

When maintaining an aircraft the prevalent approach is of a condition-based character. This will mean a proactive way of avoiding catastrophes. This paper presents a case study carried out at the Såtenäs wing, one of the Swedish Air Force airbases. The maintenance work is performed within a risky and complex framework. The case study is analysed, and the aim is to identify problems in the mobile work situation. For this context the paper gives some ideas for mobile IT-support, where quick access to relevant information and documents is of vital importance. The knowledge and practical experience of the operators are of great value for decision making in complex situations.

Keywords: mobile work, coordination, aircraft maintenance, condition-based maintenance, knowledge work

BRT Keywords: DA, HB, GC

Introduction

Maintenance within different industrial areas has recently grown in importance. The main reason for this is to reach specific goals such as increased availability, decreased maintenance costs and higher quality of products. The key characteristic is that things will happen fast. A growing approach to maintenance is the condition-based maintenance, which is implemented in a variety of areas within the technical field. It is a maintenance approach, suitable to use when maintaining and handling equipment in complex technical systems. It is also an approach where it is of a great importance to use computers and electronically networks.

In the industrialised part of the world, we produce services on an increasingly larger scale. In the 1960s, 50 % of the population was employed in the industrial sector, to produce goods. Today, it is only about 25 % (Dahlbom, 1996). Services differ from producing goods in many ways. In producing goods the machines are stationary in a specific place. Services, on the other hand, are carried out where the customers or the artefacts to serve are located. This transformation from producing goods to performing services has affected the society causing it to be of a more mobile character. New ways to perform the work have increased in many organisations, because of the opportunity to be mobile but at the same time, available.

The aim of this paper is to find some constraints in the flight maintenance situation, according to the mobile and information dependent work. It will also try to find out some possible solutions to make the flight maintenance more effective and less cost and time demanding. The point of departure is to identify problems within the ongoing maintenance work. The project involves empirical studies of work, comprising studying the information needs, analysing the work practice and reaching the goals for the challenging work in the future. For these purposes one can describe the aircraft maintenance as a complexly interactive and technical system (Perrow, 1984).

The study has been carried out at Volvo Aero Corporation, where the development, manufacturing and maintenance of jet engines take place. Interviews and studies of the work practice have also been made at the Såtenäs wing.

To maintain an aircraft and a jet engine is very complex work. The jet engine consists of many interacting components and there are operators in the work to maintain and serve the whole technical system. The work is mobile as the aircraft change place and condition during the flight, from take-off to landing. The aircraft has to be maintained when it lands on one of the dispersed runways. A runway can be placed anywhere in the middle of nowhere. To do this work the operators need information about the actual conditions of the components of the aircraft. Some fault reports are produced by a built-in monitoring system. But there is actually no further information about the recognised fault and nothing about any faulty component. Nor is there any information to maintain or repair the aircraft. In fact, there is no satisfactory support for decision making.

Sensors in the jet engine gather signals about different parameters such as temperature, pressure, height and so on. Before planning the maintenance work the signals must be evaluated. The operators, the technicians, have to interpret and handle the information from the signals before taking maintenance action. Before performing maintenance work, the operators need information about the condition of the jet engine.

There are many challenges in the condition-based maintenance of the jet engine. There is need for improved applications for diagnosis, decision support and troubleshooting. It is vital that the co-operation between the operators and the management of knowledge has to be supported in the mobile work situation. Problem solving and decision making in collaboration will contribute to improve the knowledge and skills (Johansson, Snis, 1997).

Condition-based maintenance is applied as a maintenance concept in the aircraft industry. It is applied even in other technical domains, such as hydro power plants (Backlund, Larsson, Rhen, 1997), gas turbine engines (Loukis, Mathioudakis, Papalliou, 1994), the main engine in the American space vehicle (Guo, Merrill, 1991), diesel engines (Hansen, Autar, Pickles, 1994) and helicopter gearboxes (Jammu, Danai, Lewicki, 1995).

Research method

This study is based on the use of the JAS 39 Gripen military aircraft, and especially the RM12 jet engine, which is the jet engine Volvo Aero Corporation has developed further, on licence from General Electrics. The study has been carried out at Volvo Aero Corporation, where the development, manufacturing and maintenance of jet engines take place. Interviews and studies of the work practice have also been made at Såtenäs wing.

In order to get an understanding of the typical work of an aircraft fixer, the investigation is carried out as a case study. This is an adequate research method for the organisational laboratory, where participants face complexity and uncertainty in their field of work (Carstensen, Sörensen, 1997), (Vidgen, Braa, 1996). The aim has been to focus on the unique characteristics in the work situation in the actual context. The complexity of the case is reflected in that many different factors influence the service work situation.

Material from the maintenance work process has been acquired by qualitative empirical studies, especially qualitative interviews with both operators and executives at the wing of Såtenäs There has also been made observations of the maintenance work. Other sources due to the empirical findings was attending courses on the construction and maintenance of the aircraft and project meetings in the product support system project group at Volvo Aero Corporation. The case study covered a period of six months, during which the work of the flight technicians, and maintenance staff was studied. There have also been regular discussions with the developers of support systems at Volvo Aero Corporation during one and half a year.

Research background

Changing the character and use of information

Work has previously required both physical effort and human skill and experience. Much of the information was stored in the human heads. Conversations and various printed notes, placed here there and everywhere, also generated information. Today it is created much information in information and communication systems. Tasks, activities, events and objects are translated into information. But it must first be identified and broken down to its smallest components (Zuboff, 1988). Information technology is used to reach a higher degree of certainty and precision, than is provided by the human body. The alteration of information character and use also changes the character of work. This is because tasks and activities performed by operators are supported by explicit information.

Zuboff (1988) states three principal ways in approaching decision making; rules of thumb, having an intuitive feel of what is best and pursuing an explicit and logical analysis. Rules of thumb seem to be common among less good operators. The better operators often use the intuitive feeling. Though few operators use a fully rational approach.

Mobile and co-operative activities

CSCW, as a theme to focus on the development of computer systems, is developed to support people in their co-operative activities. There are many topics related to CSCW, i. e. decision support and human-computer interaction. The CSCW field takes its standpoint from practices in the rich interactive world, which is constructed by the participants. The emphasis is on supporting human workers with computer systems, rather than replace, the human workers with computer systems. As Bannon (1993) claims:

"CSCW can be seen as a research field involved in exploring a wide range of issues concerning co-operative work arrangements and its support via information technology."

It gives attention to how people's work activities are performed in different settings and how to support the work process through technology. CSCW could also be used for mobile purposes, providing new services to people in mobile situations, and in using information technology. In mobile situations it is important to pay attention to the people working in the setting. The field of mobile computing is focussed on the technology for mobile use, though CSCW is concerned with the overall technological issues and with exploring new ways of providing information technology support for co-operative work (Ljungberg, 1998).

The use of mobile IT always exists in an environment. It consists of both a physical and a social environment. In different situations the extent of the mobility varies, from more or less stationary work situations to entirely mobile work situations. In between, there are various kinds of movements. Kristoffersen and Ljungberg (1998) characterise different modalities of mobility, i. e. visiting, travelling and wandering. Visiting is working in different places. Travelling is working while travelling. Wandering is working while being mobile locally.

Complex work situations

Human-machine systems can often be seen as complex systems. Complex systems and interactions are subjects for serious consequences, if anything goes wrong. Perrow (1984) calls it high-risk systems, or high-risk technologies.

When analysing organisations and work situations of high-risk systems we become aware of problems that occur. There are errors in the system we would take into consideration and we need information about the error situation. Perrow (1984) focuses on the properties of the systems themselves, the potential for failure and their recovery from failure when he analyses high-risk systems. He claims to emphasise the errors that operators and designers make in running them. A definition on systems' accidents involves the unanticipated interaction of multiple failures, which are not linked in an anticipated sequence, though systems' accidents often start with a component failure, which in an aircraft, for example, could be a sensor error. Systems' accidents are focused on multiple failures that interact in unanticipated ways (Perrow, 1984).

Unfortunately systems can, in some cases, be designed in too complex a fashion. Operators interpret systems in different ways. Poorly trained or less experienced operators may see systems as highly interactive but more experienced operators find the very same systems to be more linear. The high degree of interactivity may be reduced; as both designers and operators gain more experience with systems. Then it is possible to design and interpret the systems more effectively. Technological development has an impact in bringing linearity into complex interactive systems, as the experience increases. But the development has an inherent transformation process, which leads to increased demands and requirements on systems. It will make them “improved“ with new interactions.

Designing new systems has also a social dimension. The governing of learning has a lot to do with changing the norms in a social context. Introducing a new information system is about changing norms and the social culture and changing the performance of work (Dahlbom, Mathiassen, 1993). According to Argyris and Schön (1996) learning occurs only by individuals and it merges out of the interaction between people.

In designing information systems there has to be a trade-off between humans and technical artefacts. The design process involves allocation of tasks between computers and humans. It implies modelling the human-machine interaction (Helander, Nagamachi, 1992).

The service work situation

This study is based on the use of the military aircraft JAS 39 Gripen, and especially the jet engine RM12, which is the jet engine Volvo Aero Corporation has developed further, on licence from General Electrics.

Changing maintenance approach

The new Swedish fighting aircraft is the JAS 39 Gripen. The Såtenäs wing is the first wing with the JAS 39 Gripen in operational action. In October 1997, the JAS 39 Gripen was declared operational and airworthy. In the process to start using this aircraft, there is a transformation in the maintenance concept, from time-based to condition-based maintenance. The big challenge is to strike a balance between cost and risk, ensuring efficient aircraft maintenance when required. Previously maintenance and service work activities have been much of a mechanical nature. If any component was damaged it had to be exchanged. But to avoid serious breakdowns, the time-scheduled activities were of a large scale.

Military aircraft maintenance is a mobile function and has always been so. The aircraft is located in different places, when it is grounded. The aircraft obviously takes off and lands in different places. There is need to serving and maintaining wherever the aircraft is located. Either the place for landing is not always known in advance. There is an uncertainty if spare parts and relevant information are available on that wing or airbase, where the aircraft just has arrived. Some information is on the aircraft, i e information about the actual condition of the equipment. Other information, such as the maintenance handbook and rules for trouble-shooting, is found at the airbase.

Analysis of the present work activities

The work activities performed in order to accomplish the maintenance activities have been analysed and synthesised into four different groups. The analysis deals with recent maintenance work, how it actually being carried out. It also presents design suggestions. For more details about the maintenance work, see Johansson and Snis (1998). There are some general characteristics in each of the groups, namely, that the work is often time-critical and safety-critical. Decisions are critical to all activities and the optimal decisions are demanded in most of the situations. The work activities are structured as process oriented, as the maintenance work going on from planning maintenance to finding possible faults and serving the aircraft. The different groups of work activities identified are:

- Planning and scheduling
- Acquiring information
- Diagnosing faults
- Contacting dispersed operators/experts

The groups of work activities are described in more detail below.

Planning and scheduling

The companies try to plan the maintenance programmes to ensure the smooth work load, so there is no more aircraft than necessary, which need service or maintenance at the same time. They also make a flight schedule for each aircraft. There is need to monitor the flight hours for each aircraft, if some activities are to be done after predetermined time-based flight hours. The maintenance planning information needs to be accessible when and where the aircraft has landed, so the operators could perform actual maintenance activities without delay. Otherwise the information will be sent for from the wing, as presently the case.

In regard to the time-based maintenance activities, there is also a problem due to faults, which occur unexpectedly. Faults can be connected to any component or components related to any planned service or maintenance activity. The operator has to decide which components to service or exchange. He/she has to consider which components are the most effective to exchange or service. Even if a specific component is not faulty, it can be necessary to exchange it because of negative effects when exchanging or servicing components close to it. Due to this problem the operator must know when the related components are subjects for action. The operator has to have knowledge about this problem and if components have to be exchanged because of damage when other components are fixed. Naturally, this has a great impact if the operator is experienced. An experienced operator knows more of the interactivity between different components. The more experienced operator faces the problem less complex and more comprehensive than a less experienced operator does.

Acquiring information

When the aircraft has landed the operators have to check the aircraft. The operators inspect the aircraft thoroughly and look, feel and smell to try and locate anything suspicious that might cause faults. If there is more than one operator, a discussion usually takes place if they have observed anything that might be considered constructive. The operator discusses with the pilot, if he has recognised something special or remarkable during the flight. The pilot also expresses his/her opinion or thoughts as to what has happened, when a fault occurred. It can also be valuable to have a discussion with an operator, who has previously localised faults in the actual aircraft. An aircraft is a kind of individual, often with its special characteristics. The knowledge and the experience of the operators are of great importance.

If it is possible to recognise a special fault, the trouble-shooting process is unnecessary. The issue of importance is to decide if the aircraft can be cleared to take-off within ten to fifteen minutes. On a display in the cockpit there is a quick-look of potential faults, discovered by the monitoring system during the flight. A fault report can be brought up by the operators to present a brief fault localisation, a fault code and a suggestion of exchanging any component. If there is not any fault information, not to maintain and service at a time-based basis, and the operator has done necessary inspections without finding any fault, it is easy to decide that the aircraft is cleared to take-off. But if something faulty is recognised the trouble-shooting process starts.

To interpret the fault codes at the cockpit display the operators must move to the airbase and look for the information in cover systems. Maintenance handbooks are also available at the airbase. Less experienced operators need to have access to these handbooks more often than more experienced operators. There is need to have the handbooks close to the actual maintenance site. Problems arise when the operator has to go to the airbase to have the instructions, thus causing maintenance delays. The handbook system also faces updating problems. When revisions or amendments are made, someone has to exchange old paper documents and replaces them with new paper documents. It is a very time-consuming process and there is a risk of forgetting to update all of the maintenance handbooks, resulting in out of date paper documents at the airbases.

All the flight data, gathered in the real-time monitoring system, is transferred to an external memory. The operators transport the external memory from the wing and out to the actual maintenance site. Then they transfer the flight data to the external memory before the memory is sent back to the wing for further evaluation. There is one operator at the wing who performs some evaluations of the flight data, to assess if anything is deviating from normal values.

A form has to be filled in by the operators when faults have occurred. In that form all the detailed information about the fault is documented. Then the information is registered in a centralised Air Force database, together with the maintenance actions performed.

Information is gathered accumulated through a process of searching information in different places, not always close to the place where the maintenance activities will be performed, that is to say where the aircraft is positioned at the time.

In order to perform an efficient and effective and airworthy work it would be an advantage to have all the required information on the aircraft. Information can be stored internally in the aircraft or externally, in a portable or a wearable computer.

Diagnosing faults

Evaluating and analysing the flight data can provide important information to the trouble-shooting process. The value of the analysis depends primarily on the operator's knowledge. In the system there is an opportunity to define evaluation parameters. When faults occur, rules have to be considered and tests must be performed to find any faulty components. The work also deals with finding the correct information in the cover systems. Sometimes, the operators need help from an expert to recognise what has caused the fault or damage. An enabler would be some kind of a virtual heads up display to access information at the moment the operators need it (Johansson, 1997).

Contacting dispersed operators/experts

In order to discover and confirm what is defective, less experienced operators sometimes need help from experts, very skilled in finding causes for the occurrence of fault. The expert could be a more experienced operator. He/she could also be any of the developing engineers at Volvo Aero Corporation (VAC). The operator has to describe the actual situation to the expert. Sometimes it can be a hard job for the operator to describe verbally what he/she sees, hears, feels and smells. Often the conversation can be cleared by the telephone, but on few occasions it is necessary for the expert come to the aircraft or the aircraft is transported to the expert. There is need to co-operate more efficiently.

In order to get some help from various operators/experts; there will be some advantages if there is an opportunity to send images or videos to experts located in other places. It would provide invaluable support to the expert if he/she would be able to look at images or videos distributed electronically and collaboratively. Another advantage would be that operators would be able to view and discuss the images and videos synchronously, at the same time.

A shared workspace and a shared memory, where operators asynchronously store, keep track of and access information about maintaining difficulties, should further increase the opportunity to share knowledge and improve the competence of the operators.

Discussion

Information use in decision-making

Mobile computing is drawn from the field of CSCW, which is assigned to support co-ordinated activities carried out by groups of individuals. Communication and problem solving between persons and dispersed groups are activities, which can be supported. Without dialogue, co-operation and information sharing among the operators the performing of mobile activities run the risk of being less effective. A shared workspace system can be an enabling technology for mobile and collaborative information and knowledge sharing (Bentley, Horstmann, Sikkel, Trevor, 1997). Information is critical to each decision-making situation. It is valuable if the shared workspace system is structured in some way that is useful in different situations. The consciousness of what is going on at the shared workspace system increase the usability of that system (Gutwin, Greenberg, 1998). It is also of great value to consider the real-time co-operation.

Luff and Heath (1998) claim that paper documents have a psychological function, as they are active tools in a dialogue. But this case proves that it is the components in question, which are the interesting subjects for activities. The operators who discussed the trouble-shooting or maintenance actions do not need a paper document, because they get together and focus on the faulty components, if they are located at the same place. If the operators are located at dispersed places it is a prerequisite to have a digital document to have quick access to the document. Digital documents are even more effective when there are copies sent to different places or could be retrieved at different places. This statement is confirmed of the pharmaceutical company, where the information sharing was successful when the staff would be able to write information into the database independent of location (Kristoffersen, Ljungberg, 1996). The digital documents belonging to each aircraft, and even each component, would act as casebooks on patients used in medical service. Operators could fill in digital forms instead of paper forms. To support the mobility, copies would not be sent to different places, with time delays. Instead the digital forms is accessible for people who need the information. The maintenance handbooks and the trouble-shooting schemes could easily been distributed by digital document. This solution should enhance the mobile character of the service work. It will also support a smooth updating of documents.

Knowledge in decision-making

Humans should perform all the activities requiring or being supported by human knowledge and experience, such as planning and assessment. The computer would release humans from routine work, as searching, tracking and accessing data. But all knowledge is somehow based on information. It is important to have access to information in order to process information. Information is critical in extracting knowledge. Knowledge is converted from information, when knowledge is personalised (Alavi, Leidner, 1999).

Learning by doing is a strategy to learn from experience. The trial-and-error concept means that humans learn by mistakes. This strategy is less suitable in the aircraft maintenance field, because it can cause unnecessary accidents. But there can be complications in the learning by doing process. In some situations, the consequences of our actions are in the distant future or in a distant part of a large and complex system. Senge (1990) claims that we have a learning horizon, a vision of time and space within which we assess our effectiveness. If the consequences of our actions go beyond the learning horizon, it becomes impossible to learn from direct experience. As Senge (1990) puts it:

"We learn best from experience but we never directly experience the consequences of many of our most important decisions."

Simulation involves learning by using simulation tools and is in this case a very useful strategy to increase the competence of the operators. By using simulation, it is also possible to reduce the problems within the learning horizon. In this case study one can see a problem regarding the need for experienced operators. It is an almost impossible task to grasp the interactivity between different components in all situations, especially when the operator is less experienced. It is a kind of design issue to elaborate some help instructions to reduce the complexity for novice or less experienced operators.

It is essential to study the concept of mobile and co-operative knowledge work to develop innovative technologies for supporting mobility and enhancing collaborative work in complex domains. Hence it is critical to take the process of maintenance work and the process of being mobile in consideration.

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