# THE USE OF IETMS IN TRAINING FOR MAINTENANCE ENGINEERS

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## ABSTRACT

In this paper the question is addressed how Interactive Electronic Technical Manuals (IETMs) can be used in the training of maintenance engineers. In order to investigate these questions, we adopted the following approach. We investigated the state-of-the-art concerning IETMs and training. An analysis was made of how an IETM could be used in the current courses for helicopter maintenance engineers. Several training scenarios were investigated: Training embedded in the IETM, IETMs as a source for learning materials, and as a tool in the learning process. Demonstrators were constructed showing how IETMs can be used in training. The electronic manual for a helicopter, available in SGML format, served as the source for the development of demonstrators. The demonstrators show that an instructor can develop tailored instructional materials by (re)-using existing electronic materials with standard presentation and word processing tools.

## AUTHORS' BIOGRAPHIES

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Robert de Hoog is associate professor of Social Science Informatics at the University of Amsterdam. He has been involved in several EU funded projects since the mid eighties in the area of knowledge based systems, project management and instructionally embedded computer simulations. He has also published many papers in this area. In addition he works on knowledge and information management. Currently he is the project leader of the EU funded IMAT project: re-using technical documentation for training purposes.

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## INTRODUCTION

Technical manuals in electronic form rapidly replace paper based technical manuals. This allows adding much more functionality to the manual, to support the maintenance engineers during their work. This development is mainly driven by the wish to make the re-use of information, and up-dating it, more efficient. Requirements from the perspective of education and training are not yet specified.

In this paper the question is addressed of how Interactive Electronic Technical Manuals (IETMs) can be used in the training of maintenance engineers. A related question is what kind of requirements should be placed on IETMs in order to be able to use them for training purposes. This research project was commissioned by the Royal NetherLands AirForce (RNLAF) (Barnard, Riemersma & de Hoog, 1998).

In order to investigate these questions, we adopted the following approach:

*1. Investigation of the state-of-the-art concerning IETMs and training.*

Although electronic manuals are rapidly emerging, there is not yet much experience with their use in every-day training. Fully integrated training environments have not yet been developed. However, there are promising opportunities to use IETMs as the source for training materials and to use them in innovative training environments. New forms of training will become possible, and/or will be made easier, such as case-based training and training-on-the-job.

*2. Analysis of how an IETM could be used in the current courses for helicopter maintenance engineers.*

In the training courses, trainees have to acquire knowledge about the helicopter and insight in its working. Much effort is needed to prepare the learning materials for the courses. In terms of efficiency, much can be gained by (re-)using electronically available materials. A main opportunity for new ways of training is the better integration of theory and practice made possible.

*3. Construction of several demonstrators showing new ways of using IETMs in training*

The electronic manual for a helicopter, available in SGML format, served as the source for the development of demonstrators. We investigated whether it is possible to use this SGML file for training purposes, making use of commercial-of-the-shelf tools. Six different learning and instruction situations are demonstrated. The demonstrators show that an instructor can develop tailored instructional materials by (re)-using existing electronic materials with standard presentation and word processing tools. Coupling the tools allows for fairly rich learning environments, which enable a variety of learner activities.

## CURRENT USE OF IETMS IN TRAINING

Nowadays technical manuals are increasingly becoming available in electronic form (e.g. SGML-based). Manuals can display (sub)components of technical devices (cars, airplanes, etc.) and provide textual links pointing to specific parts of the graphical information. IETMs are being developed according to emerging international standards and therefore share many common elements and features which can be retrieved and indexed for subsequent re-use.

The use of technical manuals for training is an interesting option for both military services and industry. Organizations dealing with high-tech systems and services spend significant amounts of resources to provide specialized vocational training, necessitating them to produce their own training material. With the advent of electronic technical manuals, new opportunities arise for a tighter coupling between technical manuals and training material, and for new ways of training, using multi-media technology.

Currently, a large percentage of the costs of developing specific Computer Based Training (CBT) programs is devoted to the acquisition and presentation of domain knowledge. Using the domain knowledge already incorporated in the IETM, can

reduce these costs, while at the same time ensuring that the knowledge remains accurate and up-to-date.
In the United Kingdom, The Royal Navy (UK) has a project to develop a prototype in which a CBT is linked with an IETM (Hammersley & Cook, 1998). Users can access the CBT from the IETM and they can return to the IETM from the CBT. One of the problems encountered is that the textual data in the IETM do not have the high level of granularity that is needed in order to re-use texts from the IETM in the CBT. However, full integration of CBT and IETM is still at the very beginning.
A project in which the re-use of information from IETMs is addressed is the European ESPRIT Project 8184 HyperMan (Aceti & Bernasconi, 1995). Its goal was to develop an open, collaborative system for the design, development & delivery of Interactive Electronic Technical Manuals in the field of equipment maintenance. HyperMan made available a set of tools to:
- design and produce hypermedia manuals
- design, produce and deliver simulation based training courses to learn to operate and maintain equipment.
The DIAS system™ produced by Siemens is a product that enables a close integration of all aspects concerning equipment. From a common knowledge base, four different applications can draw their information: an electronic documentation system, an intelligent diagnosis system, a modular, test site independent, test program and a modular training system. The latter is equivalent to an authoring environment interfaced with a common database.
Some empirical research is beginning to emerge in which electronic manuals are linked to educational applications. Especially in the United States military services are doing research on this topic, although there is not yet extensive experience in realistic settings (Jorgensen et al., 1995; Kribs et al., 1996; Morris & Dickason, 1996; Mark et al., 1996).
Jorgensen et al (1995) performed a study into the use of IETMs within the maintenance courses of the US Navy, to identify opportunities for the accelerated introduction of IETMs in the schools and the fleet on the basis of estimates of costs and impacts.
Kribs et al. (1996) present a survey of the use of IETMs for training and education in the US Defense organization. Of 37 military IETMs, 10 were used in training centers. Concerning the integration of IETMs and training, the most dominant concept is that of the “electronic classroom”. Kribs et al. draw attention to the danger that the current model of the classroom with an instructor in front of it, is transferred to the electronic classroom based on an IETM. In that case, no use is made of new opportunities the IETM might provide for training. However, in interviews with Navy personnel, the wish became clear to move the training from the classroom to the field, using intelligent IETMs and CBT, available on demand.
Morris and Dickason (1996) investigated the IETM/Automated Classroom (AC) of the US Navy in the domain of the Gas Turbine course. They investigated the technical aspects of the IETM/AC and the experiences of the users.
The study of Mark et al. (1996) reports a cost/benefit analysis of the implementation of IETM/AC technology within the Gas Turbine C school of the USA Navy. The results of this study showed that student performance scores are slightly improved. Cost reductions were realized in the areas of course time reduction and reproduction costs avoided.
As a general conclusion, Morris & Dickason (1996) can be quoted: “The IETM/Automated Classroom has tremendous potential to become tomorrow’s tradition by providing a new innovative learning environment”. However, one has to carefully analyze and rethink the courses and their organizational context before starting with this kind of concept.

## TRAINING ANALYSIS

In order to be able to relate possible uses of IETMs to the current training, an analysis was made of the training of helicopter maintenance engineers. We also interviewed experienced helicopter engineers. Manuals are, in principle, always used for the performance of all tasks. Experience in using the manual is therefore an essential factor in effective job performance. Using the manual involves more than just reading the relevant part and following the prescribed steps. The engineers need to understand what is stated, to be able to make connections between parts of the manual, to be able to find relevant system parts and to know how to perform the described procedures. The manual contains errors, so the engineer should not follow the manual blindly. Changing from paper manuals to electronic ones will not necessarily change this situation.
Courses for helicopter specialists (avionics and engine) have been recently developed by instructors at the RNLAF school. These courses have a duration of seven weeks. The goal of the courses is for the trainees to acquire theoretical knowledge about the system. Trouble shooting is not a main topic. However, the trainees sometimes get assignments about hypothetical cases (for example: what would happen if this component were deficient). With these cases, they learn to reason about the system.

Practical skills have to be acquired during training given at the shop floor. Trainees are also taught how to use the manuals. They have to learn how to look for descriptions of sub-systems and components via the numbering-system. At the end of the course, the trainees know where all the system-components are located and what their function is. They do not have to remember everything by heart, but they must be able to recognize (parts) of schematic representations of all components.

The RNLAF highly values the acquisition of system knowledge. In the Netherlands, engineers need to have a solid theoretical background because they have to be able to perform a variety of tasks on their own, as well as to diagnose a variety of problems.

In the courses, trainees use the syllabi provided. Most of the text-blocs and the pictures in the syllabi are derived from the material, which was used in the training the instructors originally got from the helicopter manufacturer. Many of the pictures can also be found in the technical manual, but not all of them. In addition, many more pictures are derived from the flight manual, such as the displays in the cockpit and the different display pages of instruments. In the syllabus no direct references are made to the technical manual.

Apart from the syllabus, instructors create and use (large numbers of) overhead transparencies in the lessons. On many of these transparencies, pictures from the syllabus are shown, and components are colored in order to focus the attention of the trainees to certain aspects or to the connection between components. To keep the information in the courses up-to-date, the instructors derive information from the service bulletins about modifications.

The learning goals for the engine maintenance course have been further analyzed in order to acquire more insight in the nature of the information that has to be extracted from the IETM, if the IETM is going to be used as a source for learning material. In Table 1, the training goals are represented in broad categories. The categorization principles are the desired behavior of the trainee (for example “being able to name”) and the content of what has to be learned. This content is directly related to the structural and functional components of the helicopter. Most of the actual learning goals of the specialist course fall in the first six categories: trainees have to be able to name structural and functional aspects of the helicopter components. Learning goals 1, 2, 3, 7 & 10 can, in principle, be linked easily with information from the technical manual. The components, their features and the location can be found in the manual. Learning goals 4-6 are more difficult; it is not always possible to get information about the goal, function, and composition directly from the manual. For the other learning goals, it is possible to find basic material in the manual about the aspects to be learned, such as diagrams and settings. However, this material needs to be transformed for the trainee in order to be able to attain the learning goal. Or the trainee needs to get directions about what features should be paid attention to and how to deal with the information.

| | **Learning goal categories** | **Example of a learning goal** |
|---|---|---|
| 1 | Naming of parts | name the components of the windshield panels |
| 2 | Naming of characteristics of parts (such as number, type, material etc.) | name the types by down fittings |
| 3 | Naming of or pointing at the location of parts within the overall system | point out the location of the main components of the fire protection system |
| 4 | Stating the goal of a part | state the goal of the dash-actuator |
| 5 | Stating the function of a part | state the function of the swash plates |
| 6 | Describing the structural composition of a part | describe the structure of the main rotor blade |
| 7 | Naming, describing and procedures for maintaining or operating (sub-)systems | describe how the power assurance test can be performed |
| 8 | Naming of differences between system states or system set ups | name the difference between primary and reversionary mode |
| 9 | Naming what to do when a (part)system is in a certain state | describe under which conditions and how we may change something about the weights of the blades |
| 10 | Naming of safety requirements | name the dangers that may occur during system operation |
| 11 | Describing diagrams | describe the block diagram of the electric power system |
| 12 | Explaining the working of a system/component | explain the working of the shock absorber |
| 13 | Explaining used terms/indications (such as on displays) | explain the indications on the maintenance panel of the utility system |

Table 1. Categorization of learning goals and examples

## USING IETMS IN TRAINING

The introduction of electronic manuals in the training process offers a variety of new possibilities. An IETM can be used in training in several ways:
- Training embedded in the IETM
- IETM as a source for learning material
- IETM as a tool in the learning process

For some of these scenarios we developed a coherent set of demonstrators, illustrating possible uses of electronic technical documentation in an instructional setting. For this we used only commercial-of-the-shelf products. This approach reflects the *main goal* we tried to achieve with the demonstrator: to show how any instructor who is somewhat familiar with standard presentation and word processing tools can develop tailored instructional material by (re)-using existing electronic material. A *second goal* was to obtain insight into the problems one could encounter when trying to use the specific material chosen: the SGML files for maintenance of helicopters. To operate on and enhance this base material, use was made of a viewer, called IADS**,** developed by the USAF and freely available. IADS takes an SGML file and displays it in a readable form on a computer screen. Once available in IADS, the document can be transformed into an interactive one by inserting hotspots that refer either to other sections of the manual or to (almost) any other executable program outside IADS. Other tools were Microsoft PowerPoint, Microsoft Word 97, Paintshop Pro and a Webbrowser. We emulated a number of instructional settings of which one could assume that an instructor at the school, having available the same tools, could create them within reasonable time. The topics chosen were the (partial) disassembly and re-assembly of a fuel tank and the diagnosis of a fault in the avionics system. In the following sections we will discuss the different uses of IETMs in training and provide descriptions of some of the demonstrators.

### Training embedded in the IETM

An IETM might be constructed in such a way that not only experienced maintenance engineers can use it for the maintenance of the system, but that it can also be used for the training of inexperienced engineers. The most advanced electronic manuals will probably have instructional facilities embedded in them. They will contain procedures that just have to be followed in order to do the repair or maintenance job. One can ask for more instructions or details if needed. Pictures or videos will be used to show how to perform a task in great detail. An example is the IETM for the Apache helicopter of Boeing. In this case, the user of the manual can be guided step by step through the maintenance task at hand. The user can follow the procedures and ask for more information and explanation if a procedure is not clear. The training in this approach is focussed on performing a task, not on learning about the system. One could call this approach a “follow-me” approach: the user does not have to understand why a procedure has to be performed or to have insight in the complete procedure, he/she only has to follow the steps the IETM prescribes.
Kribs et al. (1996) discuss the question whether training content should be incorporated in the IETM itself. Although the dominant opinion is that it should, so that it can be used on demand by a user, the authors have some doubts about this idea. They conclude that this: “... do not seem to have had any advantages and may have been a detriment to being able to update the training materials independent of the IETM document” (p.51). In the Gas Turbine IETM, the instructor guide and the training guide were part of the IETM and stored on the IETM CD-ROM, but this made it impossible to change these guides. As an alternative, the authors see the integration of databases by a common definition of technical and data elements. A more modular approach seems the best guarantee for the uptake of innovations in the teaching context.

### The IETM as a source for learning material

In this approach, the IETM is not directly used in the training process, but it serves as a source for learning material. This means that one takes directly the relevant parts from the IETM and incorporates them in the learning material so that the material is always easy accessible and up-to-date. This does not mean that the material from the IETM is always directly usable in a learning context. The material might be too detailed, complex or incomprehensible for a beginning trainee. The constructors of learning material still have to author the learning material, write explanations, make overviews, construct simplified schemes etc. When pictures and graphics in the IETM are build-up in a modular way, it becomes much easier to author these.
Three situations in which IETMs are used as a presentation source were investigated in more detail:
1 Classroom presentations
2 Learning with the IETM
3 The electronic syllabus

These situations stay close to the way in which

training is currently given. The situations were realized in demonstration programs, and are described in more detail in the next sections. In these situations, a distinction is made between the data in the electronic manual (in SGML format) and the viewer (IADS) with which the data can be made visible. Changes and additions can be made on the level of the viewer, leaving the data of the manual intact.

*1. Classroom presentations*

The instructors can use the IETM to construct their own material for classroom presentations. For example, if the instructors devote a lesson to the fuel tank of the helicopter, they can show images of the tank, its components, the flow of fuel etc. It is also possible to show the relevant pages of the technical manual, telling the trainees how these page are built up, to which parts special attention should be paid etc. From a didactic point of view, this situation is not different from the current situation in which overhead transparencies are used with pictures copied from one of the manuals. Classroom presentations can be made in several ways:

- *The instructor prepares a presentation off-line*

In this situation, the instructor copies pictures or texts from the IETM to a presentation program such as Microsoft PowerPoint. The instructor can make changes to the information from the technical manual. The electronic slides can be augmented by remarks or explanations, parts can be colored etc. By using programs like PowerPoint, it is also possible to make presentations that are more dynamic. For example, the fuel stream can be shown by letting a colored stream go through the different pipes. It is also possible to store personal annotations of the instructor with the PowerPoint presentations. In this way, the instructors can have their own electronic annotated presentations; this is also very handy if a new instructor has to take over the lessons.

- *The instructor prepares a presentation with dynamic links*

The instructors can also prepare presentations by using dynamic links between the presentation program (e.g. Microsoft PowerPoint) and the IETM. In this case, the information is not copied from the IETM, it just remains there. The presentation program and the IETM are both running, and the presentation can switch between them. In the presentation program the instructor defines on which slide, and where on the slide, a link is made with the IETM in order to show some page or image. It is also possible to make an overlay on a picture from the manual, for example adding an arrow to show the location of a component. This dynamic linking has the advantage that when the IETM is changed, the presentation can make use of the updated information automatically. If, for example, a component is added to a part of the system, the presentation automatically shows the new picture. However, there might be problems with this concept. If overlays are used, these might no longer be correct. For example, the arrow might no longer point to the right component in the newly updated picture. Other problems are that information is no longer inserted in the new IETM version or the position of the information in the IETM has been changed so the link is no longer valid. In this last case, instructors should get a warning, so they can change the presentation according to the new version.

- *DEMONSTRATOR 1: Instructor teaches using a PowerPoint presentation and the IETM*

We built a PowerPoint presentation demonstrating reuse of a picture from the electronic manual and the ability to animate pictures from the manual and jumping from the PowerPoint presentation to manual and back. Inserting the picture as an object keeps a link with the manual: every time PowerPoint is started it asks whether the user wants to update. In this way the picture in the presentation is always the same as the one in the manual. Figure 1 demonstrates disassembly steps added to the picture from the manual, with the following features:

- when running the presentation the arrows appear in the sequence that has to be followed
- colors of the arrows indicate the type of expertise needed for the action
- additional features like tag E328 are indicated

When moving the mouse over ‘Steps 6 and 7’ the instructor can activate the electronic manual at precisely the page where this topic is treated.

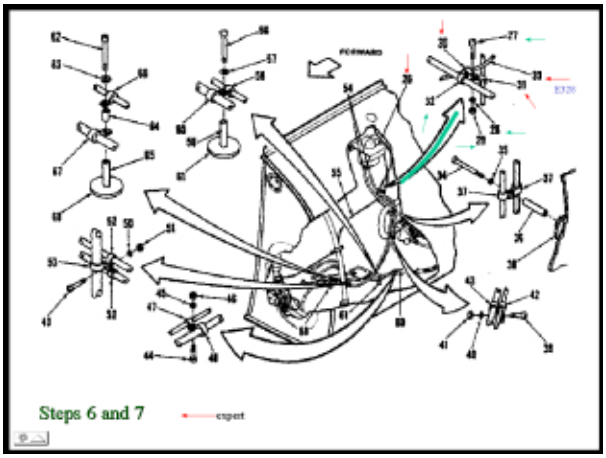



Figure 1. PowerPoint slide to illustrate and animate steps in the (electronic) manual

*2. Learning with the IETM*

It is also possible to let the trainees learn with the IETM on their own. In this case, the trainee gets the assignment to study certain parts of the IETM or to answer questions or solve problems with the aid of the IETM. The instructor adds comments and directions to the IETM to help and to guide the trainee in the learning process. The comments can be texts, pictures or other multi-media presentations. The comments are not really added to the IETM itself, but to the viewer. In this way the data in the IETM are not changed, only a link is made with the material constructed by the instructor. This ensures the integrity of the IETM information. The viewer can show that there is a link to other information by presenting a hotspot, an icon or some other indication. By a system of passwords and the option to make information public or private, it is possible to make information available for the right target group and to have one's own personal annotations, both for trainees and for instructors. The same IETM can have different versions of the viewer: a general one for the whole trainee-group, and private ones for each trainee. Learning with the IETM can take place in the following ways:

- *Comments*

The instructor adds comments to parts of the IETM, giving additional information or explanations to the trainee. If trainees study a certain part of the IETM, they can see whether there is extra information available. If they click on the hotspot, the information is made available to them. The instructor can also add his/her own personal annotations. By making these comments private ones, the trainees are not able to open them.

- *Annotations by trainees*

The trainees study part of the IETM (and extra information from the instructor). They add their own private remarks. If they revisit the IETM, they can also study their own annotations. They can also store their questions about parts that they do not understand in order to ask the instructor in the next lesson for more explanation. In this way trainees get a personalized version of the IETM. However, it is still clear which information originates from the IETM and which information is a personal remark. It is also possible to make the remarks public; this means available for other trainees and for the instructor. The trainees can see each other's comments and learn from each other. Maybe remarks from a former training group are also still available, so they can learn from them as well. For example, they can be warned that a certain part is very difficult. If the instructors also get access to the remarks of the trainees, they get thus more insight in the problems of trainees.

- *Following a learning path*

Instead of telling the trainees which parts of the IETM they have to study, these directions could be incorporated in the (viewer of) the IETM. The instructor defines a learning path through the IETM, which the trainee can follow. If a certain part has been studied, the path can be followed to another part to study next. This can be realized by adding a list of bookmarks, which the trainee has to follow one by one. It is possible to build in some control system for the instructor in order to see whether the trainee did indeed visit all the parts of the IETM. The trainee can be asked to leave a mark at each part he/she has visited or to answer a question inserted by the instructor at the part to be visited.

- *DEMONSTRATOR 2: Learner learns with electronic manual only*

In this situation, the instructor can insert instructional elements in the electronic manual. We implemented two examples. First, the instructor can insert questions in the electronic manual by using the 'Notes' feature of IADS. The learner can answer these questions using the same facility. By means of the option of linking Private or Public Notes to access codes, the instructor can control who is answering which questions. Figure 2 shows a screen of this example (questions are in Dutch). Inserting these questions amounts to no more than filling the Popup Window 'User Defined Notes' in Figure 2. In this example also guidance is given to the learner on which parts of the manual warrant special attention and allows the learner to note that these parts have been visited. A Message PopUp Window will appear after clicking on the 'Leerpad Advies' hotspot in Figure 2 (advice in Dutch). The learner can use the Notes facility for writing down that the parts indicated were visited.

- *DEMONSTRATOR 3: Learner learns with electronic manual and PowerPoint presentation*

In this demonstrator, the learner can activate a PowerPoint presentation, made by the instructor, when studying the electronic manual. In doing this, the PowerPoint viewer is activated which allows for running the presentation only, and leaving the original file untouched. By means of inserting a hotspot in the manual this can be easily achieved by the instructor. Different actions can be associated with a hotspot, which include features inside the manual (frame, target, message) and outside the manual (notably program and multimedia). With this facility, basically any program can be started.

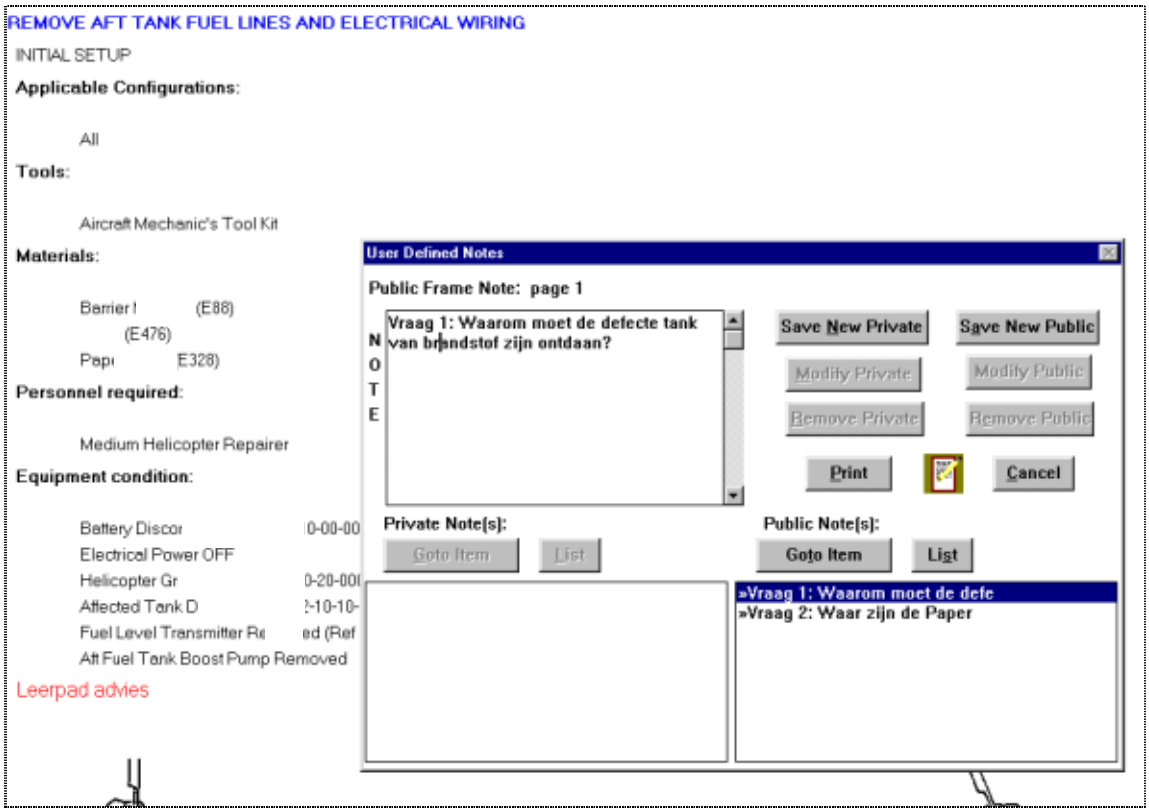


Figure 2. IADS Reader display of questions in the electronic manual

*3. The electronic syllabus*

All these different situations can be combined in an electronic syllabus. The syllabus consists of material taken from the IETM combined with information, comments, assignments etc. added by the instructor. The information from the IETM may be copied, but may also be dynamically linked. The latter case is much more flexible and changes in the IETM are automatically reflected in the syllabus. The additional learning material may consist of all kinds of multi- and hypermedia material. The syllabus can make use of the facilities described in this paper such as private and public parts, bookmarks, embedded learning paths and assignments. The electronic syllabus can be linked to a wordprocessor, including drawing facilities and hyperlink facilities. This enables trainees to make their own hypermedia presentations. The electronic syllabus can also have a connection with communication applications such as e-mail or internet (intranet), allowing trainees to work together over a distance or to contact the instructor at another location. The syllabus can also be located at the intranet. The electronic syllabus thus becomes a working document or even a learning environment.

- *DEMONSTRATOR 4: Learners learn by using an electronic syllabus*

The syllabus is produced by the instructor, the learner cannot change the underlying document. In the syllabus the learner can jump between the components of the learning environment (syllabus, workbook, electronic manual, explication) by clicking on the hyperlinks. The syllabus is produced by using MSWord97, saving it as an HTML document. When the learner clicks on the HTML document the linked Webbrowser is activated which displays the syllabus and enables the hyperlink.

**The IETM as a tool in the learning process**

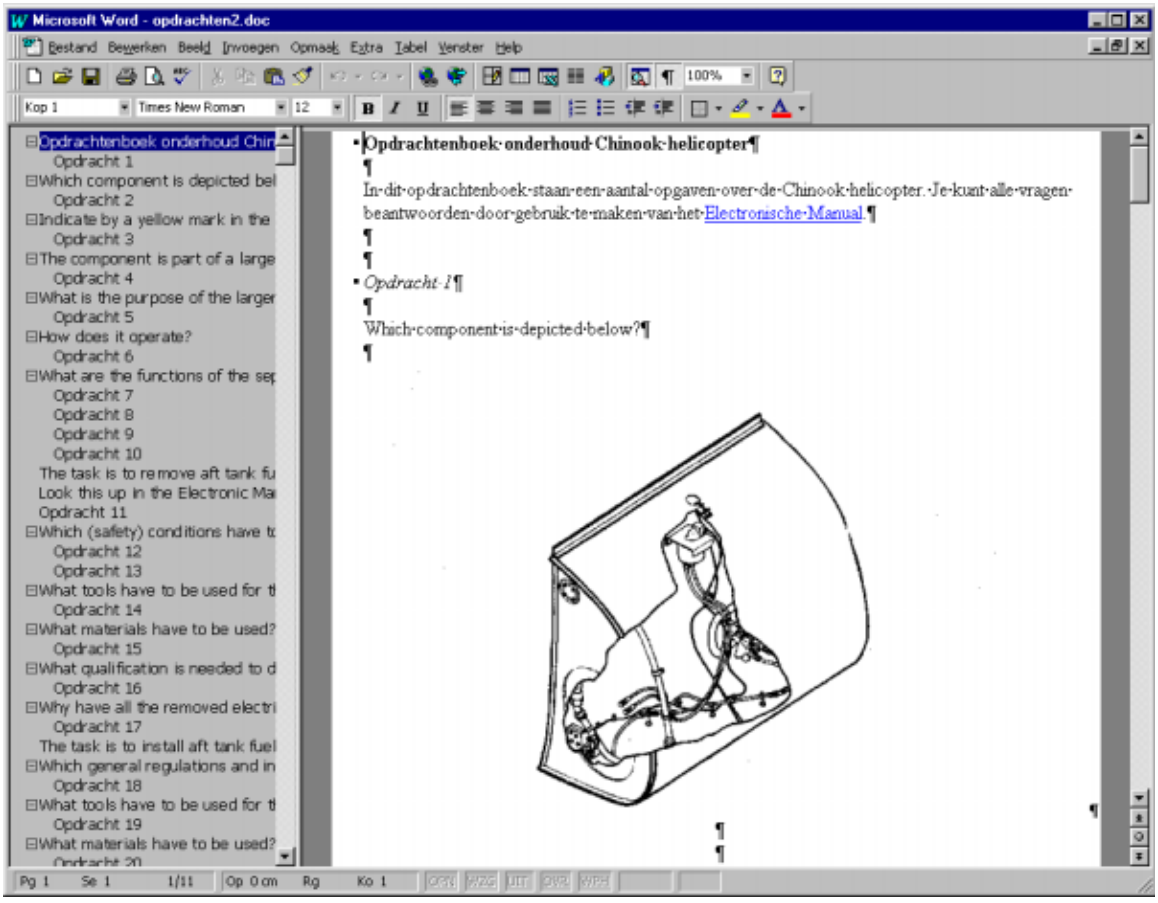
The use of IETMs may also facilitate training in which the trainees have to take a more active role, such as case-based training. The trainees may be presented with assignments to find information about components or to find the right procedure to diagnose a fault and to fix a certain component. In this way the trainees become acquainted with the system information as well as with using the IETM. When some parts of the manual are too difficult, the instructor may add annotations to help and to guide the trainee. The IETM can be used in a CBT environment in which cases are stored as well as solutions and solution paths. Such an environment

guides the trainees during their search in the IETM, gives feedback and evaluates the solutions.
Two different situations are distinguished:
1 Working on assignments
2 Learner support and feedback systems

*1. Working on assignments*
The instructor constructs assignments. For example: “Describe the function of component X”. These can be given to the trainee, who has to go to the IETM to find information that is needed to find a solution for the given problem. The assignments can also be placed in the (viewer of) the IETM. The trainee studies a certain part of the IETM and gets an assignment placed there by the instructor. The trainee places the answer in the answer field of the assignment. Each trainee can do this either in a private section or in a public section. In the first case, this facility can be used for tests or individual work. In the second case, trainees can work together. The instructors can have their own private version, where the correct answer is placed. The instructor looks at the trainees’ answers and compares them to the correct answer. It is possible to place individual feedback in the private version of each trainee, or to give general feedback in the public version.
In order to investigate whether it is feasible to develop a problem-based learning approach, we constructed assignments directly related to the learning goals in Table 1 and checked whether these could be made by using the manual. Some examples are given in Table 2.

| What are the characteristics of part X? |
|---|
| Find in the IETM from which parts system X is assembled. What goal is served by this system? Can you derive the goals of the parts? |
| What is the function of system X and of its parts? |
| When component X has to be replaced, what is the procedure to do this? Which tools have to be used? |
| Discuss with other learners the importance of general safety aspects or regulations. Make a checklist. |
| Given a description of symptoms, find out the underlying cause and the options to repair this. Find out when to choose a certain option and how to do it. |
| Study system X and make a scheme of all components and their mutual locations |
| Depict the flow of oil in system/component X |

Table 2. Example assignments



- *DEMONSTRATOR 5: Learner answers assignments in an electronic workbook using the electronic manual*

In this situation, the electronic manual is combined with a workbook containing assignments. The workbook is in MSWord 97 allowing for dynamic links between documents. The learner can use the electronic workbook to answer the assignments by consulting the electronic manual. Figure 3 shows how the first page of the electronic workbook looks. Clicking on the 'Electronische Manual' activates the IADS Reader at the relevant page of the electronic manual. The MSWord97 display feature is 'Online reading', giving a layout version of the document. The left-hand part of the page allows for direct paging: by clicking on an element, the right hand part jumps to the associated page. This enables fast and easy searching in complex documents.

*2. Learner support and feedback systems*

The facilities described above can be expanded and made more complex by creating a computer-based learning environment that monitors the search paths of the learner, evaluates them and provides direct feedback. In this way the learners can be coached during the search and results can be evaluated during and at the end of the assignment. The learning environment can have a database of assignments. For the acquisition of trouble-shooting skills, the instructor can make cases. The learner solves the problem, using the information and procedures in the IETM and communicates the solution to the instructor. A CBT environment can support this process. When the application keeps track of the learners' results, it can suggest cases to the learner which are tuned to diagnosed weaknesses of the learner.

A differently oriented development is the creation of immersive learning environments. Such an environment heavily uses metaphors for representing the normal task-environment. Maintenance and everything linked to it is represented as a virtual workplace with store rooms for materials, a tool room for tools and measurement gear, an actual working room, an office to get assignments, a technical office with specialists which can be consulted and so on. This kind of simulated learning environment is realized in the Hyperman project (Aceti & Bernasconi, 1995).

- *DEMONSTRATOR 6: Learner learns/performs computer supported troubleshooting by using the electronic manual*

The last situation we explored addressed the problem of learning troubleshooting of electronic components (Avionics). In the paper manual this consists of a number of steps one has to perform, displayed as tables. By using the electronic version we 'animated' the troubleshooting logic by guiding the learner through the steps interactively, that is asking a question depending on the answer to the previous question. The text in the manual will be displayed by IADS as a table. Clicking on either 'yes' or 'no', the learner will activate the related part of the troubleshooting table. In this way, the learner is guided through the troubleshooting process.

## CONCLUSIONS AND FURTHER RESEARCH

In this paper, new developments were discussed raising the question whether the current maintenance and training concept should be reconsidered with the introduction and wider availability of IETMs. New skills related to working with IETMs have to be acquired in a systematic way. Learning how to use the manual and to become acquainted with it, is an important part of the training. It may be useful to do many exercises with the manual already during the course, since it was observed that the use of a technical manual is central to most of the maintenance tasks. Experience in using the manual is therefore an essential factor in effective job performance. Using the manual involves more than just reading the relevant part and following the prescribed steps. The engineer needs to understand what is stated, to be able to make connections between parts of the manual, to be able to find relevant system parts and to know how to perform the described procedures. The concept of problem based learning can be seen as a valuable extension of the current curriculum for maintenance engineers enhancing the acquisition of knowledge as well of skills. For all types of training goals, possibilities for meaningful problem based assignments have been shown, which require the use of the technical manual now and of IETMs in the future.

The introduction of IETMs further offers great opportunities for developing forms of instruction that integrate learning and working. Maintenance engineers will have the IETM at their disposal at their workshop and will have experience working with the IETM. These conditions make it easy to introduce learning-on-the-job. By using educational applications linked to the IETM, engineers can spend time at their workshop to learn in their own time and pace. By adding the possibility to seek contact with a

training center by means of different telematic facilities, help and guidance can be provided. Just-in-time learning can be introduced by training the maintenance personnel just before they have to perform a certain (complex) task. This training may take the form of rehearsing what the engineer already has learned before, but it may also concern new information. Learning may not just be restricted to individual engineers, but may take place in the organization as well. For example a large repair job may be simulated with the aid of the IETM by a repair team with different specialists, discussing the different options and learning about possible ways to proceed. More organizational learning will take place when a facility is added to the IETM in which experiences with repair jobs can be stored, both formal experiences, with links to the procedures in the IETM, and more personal notes of the various engineers.

Further research on IETMs and training is conducted in the IMAT-project (Integrating Manuals And Training), within the European Esprit framework *(RTD in information technologies work programme,* Project Programme 29175*)*. The aim of the IMAT project is to develop methods, tools and guidelines to bridge the gap between complex technical equipment and its corresponding technical documentation and training materials. This will be done through IT solutions that make technical documentation available in forms that allow flexible re-use and tailoring documentation to specific user needs (storage, management and distribution of documentation, and training). Experience gained during practical operations can be collected, filtered and shared by using organization wide memories. The IMAT tools, methods and scenarios can assist companies in the transition from paper-based training to a training which is based on effective and efficient use of available electronic documentation. The IMAT system will be developed for and tried out in the partner organizations in three industrial domains: aircraft maintenance, car repair and traffic control systems. The innovative aspects of the IMAT-project are:

- the development of technical data ontologies to support flexible re-use of existing electronic documents combined with tools to automatically analyze electronic documents,
- the development of a corporate memory to enhance processes of knowledge management related to manuals and training,
- the development of educational ontologies to facilitate the process of producing adequate and up-to-date training material.

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