Multi-Media NDT Procedures and Online-Maintenance Assistance in the Frame of the European R&D Project INDeT (Integration of NDT)

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Abstract Advanced information technologies are undergoing vast changes. Only a few years ago, hyper- and multimedia were still in their infancy. A European research group with considerable participation of Airbus studied the possibilities of developing in-service applications from these technologies. Hundreds of pages of paper, mainly text, illustrated by some graphics in black and white, properly sorted into DIN A4 folders with an overall thickness of 12 cm and a weight of approx. five kilograms - this is the documentation (NTM – Non-Destructive Testing Manual) according to which the most advanced civil aircraft are carefully and reliably tested for damage such as cracks, corrosion or deformations.
An electronic demonstrator of a Multi-Media-Maintenance Manual (4M) has been designed, developed and tested for its suitability for daily business within the framework of the research project “Integration of Non-Destructive Testing”, (INDeT). It is designed to substantially improve the efficiency of future maintenance processes by using multimedia and remote diagnostics systems. Further, in case of possible problems during a maintenance operation, the maintenance engineer can log into the computers of specialists at the aircraft manufacturers’ via a telephone line. A small camera transmits live pictures of the aircraft – all around the world if required. The specialist can now view the problem area and rapidly support the engineer. Complicated descriptions on the phone and handwritten notes transmitted per fax belong to the past. This process is called Online-Maintenance Assistance (OMA).
The deployment of the modern information technology will result in saving significant amounts of time and thus also reduce costs for the manufacturer (development of new procedures/instructions) and the airlines (application of these procedures/instructions).
Creating and ensuring uniformity of structures and work processes in manuals and procedures will additionally result in a considerable reduction of the “human factor” as a potential influence on the measured results. By using multimedia-based forms of procedures and manuals, these procedures will be “less misinterpreted”, as animations and links within documents can point out changes and new items more effectively.

1. Introduction

The Non-Destructive-Testing (NDT) community in the aerospace business has done a lot of research on new technologies to enable new and effective ways to inspect aircraft structures. Less research has been done on the “infrastructure” for NDT. These infrastructures are:
Non-Destructive Testing Manual (NTM)
- NDT procedures
- Adjustment and handling of complex NDT equipment
- Support for NDT staff at Airlines and Maintenance and Repair Organizations (MRO)
- Collection and analysis of structural life cycle data

These topics and some others were worked out in the INDeT project.

The overall objective of the INDeT project was to "Give the aeronautical industry the benefit of the introduction of powerful modern and economic tools offered by the Information and Communication Technologies (ICT) for the development and the improvement of non destructive inspection methods and concepts in production and maintenance, resulting in saving costs - both for the manufacturers and airlines -, increasing efficiency and reliability of the diagnosis and guaranteeing high levels of safety".

2. What is INDeT?

INDeT was an European research project in the Fifth Framework Program (FP5) of the European Commission (EC). It started in 2002 and was finished in 2005. 13 partners from all over Europe were participating:

- Aerospace OEM
  - Airbus in Spain and Germany
  - EADS-Corporate Research Center, France
  - Alenia
  - Dassault

- Universities and Institutes
  - University of Applied Sciences Furtwangen, Germany
  - University of Central Lancashire (UCLAN)
  - University of Limerick, Ireland
  - CNR-ISTI, Italy

- Small and Medium Enterprises (SME)
  - Tanner, Germany
  - NDTexpert, France
  - Tecnatom, Spain
  - IntelTec
  - Sogitec

The main topics which have been investigated in INDeT were:

- 4M (Multi-Media Maintenance Manual)
- 3MP (Multi-Media Maintenance Portal)
- ProEx (Problem Oriented Export System)
- OMA (Online Maintenance Assistance)
- LCM (Life-Cycle Monitoring)
- TAO (Tools Adjustment and Operation)
- Remote NDT assistant
- Virtual NDT environment

The main focus of this paper is on 4M, 3MP, ProEx, TAO and OMA.
3. Why INDeT?

Information and communication technologies like Internet, mobile phones, and more generally computer-based systems belong now to our daily life. These fabulous modern tools contribute widely to decrease paper media, speed up the circulation of information and strengthen reactivity when you have to face up to difficulties. Today, inspection electronics are already frequently coupled with PC technology, which will surely still increase in the near future. This means that the majority of the modern inspection equipment already has the hardware platform for the documentation system.

Besides, the aeronautical industry still uses a lot of paper media especially for maintenance inspections for airlines. Current procedures and manuals written exclusively in English can sometimes be difficult to understand and interpret. The result can be that this bulky mass of papers and documents to store persuades the inspector not to use the last updated procedure version or to glance quickly through the modifications mentioned without remembering them. Airlines often rebuild manufacturers’ raw data and re-split the contents of manuals/procedures in order to get the exact information needed to answer end-user expectations. The difficulties with the application are thus not the result of poor technical implementation. Rather, the medium (paper) is the decisive parameter that prevents an improvement of applicability.

4. The 3MP

One of the main questions during the project was, how to handle and organize the tools which have been developed. The solution was a platform, from which all application can be selected and started. This platform was named: Multi-Media Maintenance Portal (3MP) (refer to figure 1).

![Diagram](image_url)

Figure 1: Multi-Media Maintenance Portal (3MP)
The documentation for maintenance is handled in several different manuals, e.g.:
AMM – Aircraft Maintenance Manual
MPD – Maintenance Planning Document
MRB – Maintenance Review Board
SRM – Structural Repair Manual
NTM – Non-Destructive Testing Manual
Within the INDeT project the NTM was analyzed and transferred into the multi-media demonstrator.

So some years ago, the NTM was a fully paper-based document. Hundreds of pages of paper, mainly text, illustrated by some graphics in black and white, properly sorted into DIN A4 folders with an overall thickness of 12 cm and a weight of approx. five kilograms – this is the documentation (NTM – Non-Destructive Testing Manual) according to which the most advanced civil aircraft are carefully and reliably tested for damage such as cracks, corrosion or deformations. This paper document was than “digitized”. That means, that the paper documents were transferred one by one onto a CD. So the weight was reduced, but the type of documentation was still the same.

The change to multimedia documentation will bring a range of innovations for the operator. Addressing the human factor is an important point in aeronautics as it influences directly inspection reliability. First it will be possible to develop multi-media procedures where the structure, its characteristics and the inspection conditions can be more clearly illustrated, using relevant pictures, drawings, photos, CAD part descriptions or movies. This will be a definitive benefit in understanding for operators whose mother tongue is seldom English. For complex procedures, more specific information will also be inserted in order to avoid potential interpretation error. A digital documentation will be adaptive, interactive and more accessible thus easier to consult, and operators will be more disposed to read it. Indeed, in the case of multi-media information, it is quicker to find the required item, using key-words and embedded links. IT tools enable as well to highlight the most important points such as a revision in procedure. The inspector will also have the opportunity to familiarize with new NDT methodologies and emerging technologies in a user-friendly way. The information being easier to access and to interpret, time would be saved in the preparation, realization and interpretation of inspection operations thus saving cost.

The multi-media elements, which are used in the 4M are:

- Photos
- Films
- Animation
- Colored Graphics
- Sound
- CAD drawings

The 4M contains test guidelines for non-destructive maintenance and servicing of aircraft in multimedia form. It is operated directly by an inspector working within or on the aircraft, on a notebook or tablet PC.

An example of the layout can be seen in figure 2.
Current 4M work focuses on a solution of how the individual parts of NDT inspection procedures can be linked together. Today, there are two types of NDT inspection procedures (ignoring so-called general information for the time being):

- **Standard procedures**
- **Special procedures**

Special procedures are specified for a certain aircraft type and a certain component on that aircraft type, which is also reflected in the chapter-section-subject numbering as stated in ATA iSpec 2200. Standard procedures, on the other hand, are not specified for an aircraft type or component, but rather for a certain NDT inspection technique (e.g., visual technique) and a certain structural configuration of the component to be inspected (such as honeycomb sandwich structure). The benefit of this approach is that standard procedures can be reused across almost all aircraft types, and specific procedures refer to these standard procedures, where appropriate.

In a paper-based environment, cross references of the kind “Refer to standard procedure xy” are provided in a specific procedure, asking the NDT inspector to look up the referred information in another document. In an electronic environment, as envisioned in INDeT, it would be possible to present these cross references as hyperlinks. This will, however, result in a constant switching back and forth between various NDT inspection procedures. It is the objective of INDeT to linearize the linked standard and specific procedures, as illustrated in the following graphic. The result is one single NDT inspection procedure (refer to figure 3).
In the authoring process, cross references from specific procedures to standard procedures are set as required. The publishing process then takes the referred elements and “pastes” them into a new – linearized or serialized – inspection procedure. This allows that only the required information will be made available to the NDT inspector, a switching back and forth is obsolete.

In 4M, the link between a standard and a specific procedure is indicated by an arrow. Clicking on the arrow displays the corresponding part of the referenced procedure (refer to figure 4).

![Figure 4 – Navigation in the 4M](image)

**Contents of functional and multimedia nature**

The structure and contents of the test specifications for the non-destructive maintenance follow the domain standard, namely the ATA iSpec 2200. This would need to be modified with respect to two aspects for the INDeT, while the new structure is kept compatible with the standard. On the one hand, the XML-based structure of the texts has been enriched functionally in the microstructure. On the other hand, now, elements are also available for additional media like animation sequences and videos. The iSpec 2200 prescribes that text should be almost exclusively in the form of lists, and presented accordingly (cf. modified block style). This leaves out any consideration for the function of individual sentences or paragraphs. On the contrary, the test specifications in 4M are remarkable because the text here is treated, for instance, as pre-requisite, prompt for action or result. The customized front-end facilitates the communication between inspector and system. Contents in the form of multimedia documents are available in the test specifications through hyperlinks, and are marked with the respective icons. These are shown in a separate window in the 4M. If necessary, the inspector can also call animation sequences with background information about various types of damages, for instance. Extensive video sequences explain how to handle the individual steps in a complex procedure. A media concept defines which media is best suited for conveying what type of informative content.

**Why scroll or jump?**

Many of the aircraft-specific test specifications contain references to parts of other, so-called standard specification procedures. These are independent of the aircraft and general in nature, so that they can be used in different, specific contexts or specifications. In this way, the effort involved in compiling and changing individual specifications can be re-
duced. Whereas, if an inspector were to work exclusively with a printed or PDF-version of an NTM, he would have to copy the referenced standard specification, if any, and print them too. In a conventional hypertext system, on the other hand, he can jump to the relevant specification using the hyperlink. Here, the danger of getting “lost in hyperspace” should not be underestimated. The referencing mechanism between specific test specifications and standard test specifications has been used in 4M as well. However, the reference is resolved automatically at the time of publication. The referenced parts of the text are then inserted in all those places where the inspector actually needs them. In 4M, only a linearized test specification is shown.

4.2 Problem-Oriented Expert System (ProEx)

Since 4M will provide new access strategies to NDT inspection procedures, a first attempt was made to specify a problem-oriented expert system. ProEx closes the gap between the detection of an accidental damage by the customer and the applicable NDI technique which has to be supplied by the Non-Destructive Testing Manual (NTM).

ProEx is conceptualized as a fictitious dialogue among the system and the NDT inspector. For example:
System: “What aircraft type are you working on?”
NDT inspector: “A321.”
System: “Where is the affected area?”
NDT inspector: “Outer flap/LH.”

The NDT inspector specifies this area by navigating a digital mock-up (see figure 5).

Figure 5 – Problem-Oriented Expert System (ProEx)

In addition to the location of the affected area on the aircraft, the system knows that this area is a FRP composite made from monolithic CFRP. Consequently, many different steps are required to judge the unexpected irregularity. At several steps in the problem-solving process, the NDT inspector is asked to perform one or more NDT inspection procedures stored in 4M. During the whole process, all questions and answers (see figure 6) are tracked and displayed in abbreviated form in the main navigation box. For protocol purposes, a detailed display is also possible. A printable PDF version of the protocol can be generated on the fly and – if required – be sent by fax or email to another person.
4.3 Tools Adjustment and Operation (TAO)

Modern NDT equipment is going to be more complex. This will cause a more difficult adjustment and use in in-service. TAO is a solution where the basic data for complex equipment is stored within the NDT procedure in the 4M. While the NDT equipment is connected to the 4M, one click on a hyperlink is enough to transfer all necessary data. An example is shown in figure 7.

4.4. Online Maintenance Assistance (OMA)

The aim of this task was the development of communication procedures for performing remote and local assistance to the inspectors by means of real-time NDT/NDE data/information processing and knowledge-based inspection training, set-up and diagnosis. To this end a standardized general architecture, called OMA system, for running the relevant remote operations (data/information transfer/treatment, communication/authentication tools) has been developed. The OMA is conceived as a process where in-service (human and machine) operators are provided both with tools combining on-field measurements with additional relevant knowledge (automatically generated by heterogeneous information
stored in remote databases) and real-time expertise (embodying the management of a complete work-flow to remotely revise and approve inspection procedures). The system supporting the smart assistance operation is based on the use of mobile instrumentation suitably connected to a distributed network of knowledge sources. OMA integrates different communication channels (Intranet/Internet/GSM) among the users in order to support the diagnosis.

When a local telecommunication infrastructure is not accessible, GSM mobile phone networks can be used. In figure 8 the system developed to perform on-line assistance using GSM networks is shown. The system supports the following collaboration services:

- **Audio conference**: the participants have the possibility to illustrate the problem helping the expert to get a better understanding of the situation at the aircraft.
- **Video conference**: in critical situations the expert can get a better impression of the situation navigating with the NDT inspector around the inspection area, pointing to important locations and observing operations and their results.
- **Recording of images and video clips.**
- **Still image annotation / editing**: the remote NDT inspector is able to point to relevant regions.
- **Data Transfer**: the acquired images or video clips can be transferred to the NDT specialist, via an email client or FTP service.
- **Collaboration (Whiteboarding)**: relevant parts of acquired images can be pointed out with graphic primitives, such as lines and circles giving the participants the possibility to solve the problem by interactive collaboration.

The designed experiment to test this system consists in a remote assistance with ET (eddy current testing) array Omniscan device, applied to corrosion detection between fuselage & acoustic insulation panels. In this experiment, the local NDT operator and the remote NDT expert directly exchange data, pictures and live videos. This application case has been demonstrated during the survey performed at the end of the project.

Finally, the experiments performed showed the potential and great advantage of remote assistance tools. They allowed NDT operators facing a difficulty to get a simple, quick and valuable answer.

In the present state of NDT in maintenance, operators often face difficult situations: either they need help to adapt their inspection, or they are simply not allowed to adapt a procedure because of their level of certification. OMA is a great step forward that may increase significantly European aircraft manufacturers’ competitiveness.
5. Customer Survey and Demonstration

The analysis of existing NDT inspection procedures and the definition of customers’ needs was part of the project, as well. The idea was to involve customers from different cultural regions, to understand their interpretation of current manuals and procedures. The partners involved were: Aeroflot, Air France, Alitalia, EADS Sogerma, Iberia, Korean Air, Lufthansa, NorthWest Airlines, Officine Aero-Navali, Royal Air Maroc, Shannon Aerospace ltd, South African Airways, TAM

During the first year of the project, an exhaustive analysis of existing NDT inspection procedures was conducted using the so-called Problem Typology. One of the goals of a widespread customers’ survey implemented at a representative number of airlines and MRO stations was to validate this analysis. In addition, the survey was also to bring to light the requirements 3MP must meet. These relate to – among others – the IT infrastructure, environmental conditions, working conditions and demographic data of the target group. At the end of the project the demonstrator was presented to nearly the same airlines and MRO’s to see, if we have taken their inputs from the initial survey into account. The response was very positive: our vision of future NDT inspection procedures in multimedia format clearly meets the customers’ needs. By envisioning multimedia content to support the NDT inspection process, we will not only exploit the potential modern computer technology provides today. We will also respond to a short-term wish expressed by the end users.

Finally, 3MP was tested under real conditions with NDT inspectors. The feedback for all tested applications (i.e. 4M, ProEx, TAO and OMA) was very positive. In general, the users had no problems using 3MP and the implementation of multimedia elements was more than welcomed. 3MP can be considered a major application for enhancing future NDT inspection processes.
6. Conclusion

Beside the development of new and innovative NDT technology, the improvement of the daily work of the inspectors all over the world, was the target of the INDeT project. The multimedia design, that is made possible by electronic documentation systems, allows to prepare instructions in a totally new form: real images, animation, video sequences demonstrating procedures, 3D modeling of an inspection situation that can be manipulated as a replacement for a traditional 2D drawing represent just a few of the possibilities offered by the range of aids for the inspector which have become feasible. Integrated evaluation aids such as defect catalogue, a catalogue of possible displays of the inspection equipment, etc. up to expert systems were developed within the INDeT project.

The Non-Destructive Testing Manual (NTM), which is used today within the aerospace industry, has a very simple structure and is not able to provide an interactive communication with the user. The handling of Standard Procedures and Special Procedures documented in a paper manual lacks ease of use, because the Standard procedure has to be referred to from the corresponding Special Procedure. So one always needs two or sometimes more procedures for one single inspection task. Modern electronic media, as developed in INDeT, can be used to solve this problem. With a smart structure and documentation it is possible to provide the inspector with the right and precise amount of information required for an inspection task. The 4M system will enable the generation of procedures on demand after computer controlled input of the actual inspection problem, and provides the user with a procedure which contains only such information as is actually required to solve the specific inspection task.

To solve the today’s problem within the field of handling accidental damages in a smart way, a Problem-Orientated-Expert-System was developed. This tool is closing the gap between the determination of an accidental damage by the customer, and the applicable NDI technique, which has to be supplied by the Non-Destructive Manual (NTM). These tools could help the inspector to make the right decisions, using the experience of the manufacturer.

It has been shown, that with the Online-Maintenance-Assistance (OMA) tool it would be possible and beneficial to support airlines and MRO’s all over the world via mobile networks.