Articulation of Operational and Training Materials

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Abstract

This paper presents the concept of articulation of operational and training materials. It is based on the results of the ArtiFACT project (Articulation of FCOM, Courseware and Training.) On the one hand, operational materials are progressively shifting from paper to electronic support. Both user needs and electronic possibilities guide the subsequent transformation. Training materials are available on electronic support for a long time. Thus, it is obviously interesting to transfer training experience in the design and development of electronic support to current operational needs. On the other hand, training has progressively become performance support over the years, i.e., initial training largely continues during operations and needs to be supported consequently. Articulating operational and training materials benefits to both sectors of activity.

Introduction

In many complex operational domains, such as aircraft operations and maintenance, the actual work and training to perform the tasks are organized separately. The organizations that are responsible for developing, operating and maintaining the systems, as well as training operators, are often separate organizations or departments. The same group of people does not often create technical manuals, operational manuals and training materials. Consequently, these materials may differ considerably, although most of the topics treated are the same. Some of the consequences are:

- inefficient ways of producing material, much re-doing of material, leading to high development costs;
- inconsistencies between different documents, leading to potential problems for safety and effectiveness;
- ineffective ways of training and lack of transfer of training, because procedures at work differ from the ones trained.

Now that much of the training, technical and operational documentation is becoming electronic, opportunities open up for integration of material and for re-use of material. In this paper we describe how integration and re-use of mate-

rial can be developed in different forms. We investigated the articulation of aircrew operational manuals and related computer-based training material.

The work described in this paper was performed in the ArtiFACT project (Barnard et al. 2002) that was carried out for Airbus, for the development of documentation and training. The next section introduces operational and training documentation. The ArtiFACT methodology is presented. The articulation concept is explained in the light of the differences and commonalities between operational and training documentation. An architecture of articulation is proposed introducing the concept of documentary units (Payeur 2001). Examples of documentary units and a method to use them in courseware development are provided.

Operational and Training Documentation

This work is based on the Flight Crew Operating Manual (FCOM). The Airbus FCOM consists of four large volumes in paper format that must be available in the cockpit at all times. The FCOM is an essential part of the operational documentation for a commercial aircraft. A manufacturer must supply it. This documentation should be developed according to human factors principles (Tremaud, 2000). Its uses are many and varied, and its content must be updated continually to stay current with the deployed fleet. As such, the FCOM is a dynamic document. The Airbus FCOM is also available in electronic format, created in HTML from the paper version, and as such a page-based document.

The training material contains courseware for pilots who have to learn how to fly a new type of aircraft. The current Airbus courseware has been carefully developed, following well-established didactic principles and is currently available in PowerPoint. The system part of the courseware has the following structure for most parts, such as for electric or hydraulic:

- a system description, with schemes and images of the panels and screens in the cockpit;
- normal operations describing how a fully operational aircraft has to be operated in normal conditions;
- abnormal operations, describing what happens if some systems fail and the actions the pilot should take;

- a summary;
- a quiz, for self-testing.

For a long time, different departments created both kinds of documents. Courseware development is based on an analysis of the pilot's tasks and related training goals. Although courseware development strongly relies on operational documentation, and the definition of the items in the training curriculum refer to the documentation on a detailed level, the actual courseware is developed independently from the other documentation.

Training and operational material could be much closer together, developed simultaneously, or even integrated. We will use the term "articulation" for this coordinated development of both kinds of material.

Methodology and First Results

The articulation concept was investigated using two methods: the Group Elicitation Method (GEM) (Boy 1996) and individual interviews. GEM provided a first account including consensus and differences among aviation personnel. A group of seven people was asked the following questions. How do you see the ArtiFACT (Articulation between FCOM And Courseware/Training) concept implemented? What will be the gains and losses of an integrated FCOM and courseware? Please describe the concept according to its usability (i.e., how it should and/or will be used). How will this new type of electronic FCOM be created and revised? How do you see interactions between actors in operations and training? How will its content evolve? How will responsibilities be distributed?

The Group Elicitation Method (GEM) is a brainwriting technique augmented by a decision support system for constructing a shared memory. The *brainwriting* technique was introduced more than three decades ago to facilitate the generation of ideas or viewpoints by a group of people. This method can be used to stimulate a group of experts with the goal of silently expressing their expertise on a precise issue (a question). It enables a group of experts to construct a written shared memory. Each person takes a sheet of paper and reads the issue to be investigated. He/she then adds several viewpoints and puts it back on the table, where the set of papers constitutes a shared memory of the meeting. The process of choosing a piece of paper, reading, writing viewpoints and replacing the paper on the table, is continued until each person has seen and filled in all the papers. Thus each person is continually confronted with the viewpoints of the others and can react by offering a critique or new viewpoints. Generally, a considerable number of viewpoints can be amassed with this procedure. A decision making procedure is implemented to express consensus and divergences.

There are different opinions on whether or not content and format of the FCOM and the courseware should differ from one another. Distinctions between the FCOM and courseware are noted: FCOM is customized, courseware is generic; FCOM is a reference, courseware is an introduction; FCOM answers a question, courseware is for ac-

quiring knowledge; FCOM is exhaustive, courseware not; FCOM is becoming one "electronic document", courseware is distributed into several materials; the courseware is linear in structure, ensuring that the trainee has seen all the necessary information. These differences come from the question of whether the objectives of operations and of training can converge or not. As one person wrote: "I do not operate in the same way as I learn how to operate".

The results of the GEM session and the interviews led to the following attributes for articulation:

- *Customization*, i.e., the ability of a document to be modified by a customer, e.g., an airline, to adjust corporate culture or other specific requirements.
- *Versioning*, i.e., the development and maintenance of different versions of the same document, or the development of different documents on the same topic (e.g., a manufacturer document versus an airline document).
- *Consistency*, i.e., the commonality of schematics, wording and references among documents and other training means such as trainers and simulators.
- *Paper-less cockpit and paper-less courseware*, i.e., the dependency of training on the way operations are being implemented. It is hard to imagine having only electronic training means and no paper support, but if training takes place using the same means available in the cockpit, paper should not be used as it will not be available in the cockpit.

Operational and training documentation should be contextualized. Context is used to denote both internal and external events related to the use of the FCOM and courseware. Internal events are mostly related to the on-board ECAM system (Electronic Centralized Aircraft Monitoring). External events are related to weather conditions and air traffic control (ATC) for example. The main question is how pilots will interact with the FCOM taking into account the context, either by entering contextual information by themselves or by an automated context-sensitive FCOM. The FCOM will be improved by the use of advanced media which enable the display of intelligent graphics showing the actual context experienced in flight or manually selected. Contextual access to FCOM in both training and operations is seen as an important notion. The relation to the context can change the way we learn something ("what if" scenarios during basic system learning activity).

The attributes that were found important in our study relate to several aspects operators gave a high priority in the NASA/FAA Operating Documents project (Seamster & Kanki 2000) on the overall organization of documents (such as merging and reducing the number of manuals) and on standardization of information in different manuals.

Differences and Commonalities

Differences between Operational and Training Documentation

An easy solution seems to be to have just one FCOM, used both in training and in operations. In principle, there are no major technical constraints to have a full integration of FCOM and courseware. The basic question to be addressed is: should there be a fundamental difference between the electronic documentation for training and for operations? In operations, the most important thing is to get quickly the correct answer on the question "What should I do in this situation and how?" In operations the pilot needs quick access. The content should be concise; you do not always need all kinds of animations for example. Information may sometimes be more specific for operations than for training. For example, trainees do not need to know the exact values of all kinds of parameters that could be provided in a courseware. However, pilots might want to look-up the exact figures in operations.

In training, knowledge about the system has to be built-up step-by-step. A pedagogically sound way of presenting information is essential. It is the first time the trainee goes through a large part of the FCOM information. Courseware is intended to introduce and explain. During learning, trainees build a mental image of a certain part of the information; they do not need to know the complete picture to start with. Only later on, they have to acquire a complete view. The objective of the courseware is to give information to the trainees to enable them to acquire this view. After the training, they have the information in the FCOM as a reminder. It is important to learn to refer to the FCOM, because a pilot cannot have everything exact and directly accessible in his or her head at any time.

In addition, both in operations and in training, complete detailed information should be available for reference purposes. The courseware is currently structured in a linear manner. It builds up knowledge very carefully, starting with explaining the system in a functional way, going to normal operations and next to abnormal operations, aiming to explain the working of the systems, giving summaries and quizzes. This is a different model than the one of the FCOM, which aims at finding the right amount and level of information in a specific context.

In summary: two elements are important to consider, in which courseware and operational documentation differ:

- The interactive didactic element in the courseware: the questions asked to the trainee, with different answer options, which can be answered correctly or not and the feedback on the answer. The trainee can also take actions, such as clicking on a button, and get feedback on it. This element is important for training but not for operations.
- The sequential aspect in the courseware: the information is presented in a certain sequence in order to let the trainee build up knowledge and know-how on the system. Conversely, the operational documentation should be organized for easy random access at any time and in context.

Commonalities between Training and Operations

The aim of a training system should be to place the trainee in an environment which optimizes the ability to learn. An assumption is that a primary learning objective of flight training is to build a suitably robust world model of the desired environment to enable safe and efficient aircraft operation.

Traditionally, initial type training for pilots has used the approach of teaching systems in isolation, (e.g., hydraulics, avionics, engine), in order to give detailed background knowledge of that system, and then integrate the systems at a later date. This assumes the need to know technical detail to operate the aircraft. With a low tech aircraft this is a sound philosophy, as limitations are only controlled or exceeded by the pilot, and the pilot is the direct interface between the machine and its performance.

However modern aircraft are highly complex robotic devices and it is not possible to build a valid mental model of the aircraft and operation using traditional techniques in a reasonable time scale. A different approach is required. As a basic minimum, the pilot is required to know how to operate the aircraft, how it will respond, and not necessarily how it works in detail. Airbus has an advanced program for designing training courses which effectively acknowledges this. This method facilitates analysis of the operating environment into functional tasks, so allowing training to be targeted at these functions. They are in effect mainly cognitive tasks required to be completed in various circumstances by the pilot.

Current training approaches are more task-based and scenario-based. They attempt to bring the trainee in a situation which resembles the real operational world and to present him or her with training tasks which are closely related to the real operational world, training and working come closer together. A didactic method of realizing this is for example asking the trainee to start a subsystem in the aircraft by clicking on buttons on the screen showing the control panel.

While training in complex technical and operational domains is moving towards more task-based approaches, at the same time, it is more and more acknowledged that learning does and should not stop right after a course, but should be integrated in the working life of modern operators.

At present, initial training at Airbus for pilots converting to a new type of aircraft consists of 25 or 26 days of intensive training. By the end of this training, the pilot should have reached a suitable standard to be capable of basic aircraft operations. In practice this is the beginning of the actual learning process, and the process of becoming a proficient operator involves continuous learning throughout a career. The learning process is therefore inherently a function of operations, and both operations and training should be considered as one, and not separate functions. Training and learning therefore take place in:

- an initial learning phase, where a basic operation is learned to enable the pilot to conduct safe flight, which enables:
- ongoing learning "on the job", which never ceases.

Although there is a need for an initial intensive learning phase, there is no reason why the same basic learning principles should not apply to both phases. Indeed if the documentation used in both is the same, "operational learning" is facilitated both for the individual and the organizational structure required to promote it. Training materials are then performance support tools. If this approach to operations is taken, then operational material should be presented in such a way as to be easy to learn, and training material should be as close to operational material as possible.

Architecture of Articulation

The main question is: how to develop an architecture for articulated operational and training material which serves both the advantages of efficient development while serving also the different goals of operations and training most effectively?

The underlying structure of the proposed architecture starts with a database of documentary units (Payeur 2001). Documentary units are small, consistent elements of information. They may consist of texts, pictures, schematics, animations, interactive elements, and so on. Documentary units can be hierarchically organised, allowing having several versions of one unit. This might for example be the case when there are different variations in aircraft systems. This means that each airline can have an FCOM, which consists of documentary units, which are geared towards their own fleet. Documentary units enable easy and quick modification. As information in the FCOM is complex, many modifications will be made during the lifetime of an aircraft type. Modifying the FCOM will mean modifying the relevant documentary unit and installing a continuous web-based mechanism for publicizing the new version. The airlines can download the units and thus modify their FCOMs. The documentary units have tags, meta-data, attached to them. These meta-data concern administrative aspects, such as for which specific type of aircraft they are meant, and which sub-system they concern, and so on.. The system should provide capabilities for adding contextual information that would enable appropriate search, retrieval and understanding. Examples of contexts are phase of flight, weather conditions, failures, and so on.

Documentary units contain various kinds of information that may be superficial, e.g., telling how to turn off a subsystem, or very detailed, e.g., giving exact data about the performance limits of a subsystem.

The information of the FCOM is categorized on three levels (Blomberg, Boy, and Speyer 2000). These levels are becoming a standard for the FCOM. Level 1 contains "what/how" information, to use immediately in the cockpit, on level 2 "why" information is given, the system rationale providing more details to understand level 1 information, and on level 3 more detailed and expert information is given, to understand and to study the other two levels. Normally in operations in the cockpit, only information on level 1 is needed to be able to perform a task. Level 2 information can be required by the pilot to get an explanation about why the action had to be performed. This information might be read afterwards. Level 3 information will usually be too detailed and will be read for reference purposes or if the pilot wants to have a better understanding of the aircraft and its functioning. For training level 1 and 2 are equally important, but also some parts of the level 3 information might be of interest.

To provide the pilot with the right information, and the right level of information at the right time, the information should be linked to the task he or she is performing or should perform. Tasks are for example strongly related to the phases of flight and the state of the aircraft (Ramu 2001). In training one has to make sure that a representative set of tasks is addressed in the training material. By linking the documentary units to tasks, suitable information for operations and for training can be provided from the database. If both training and operational documentation is to be task-oriented, how could the database of documentary units be developed from this perspective?

1. Define the operator's tasks and the training goals. The development of training usually starts with a detailed task analysis and definition of training goals. Several methods and tools are available to this. For example Instructional Design methods (Gagné, Briggs, and Wager 1992; Merrill 1994) and tools like Designer's Edge (Allen Communication) support this analysis. Airbus had its own method, ADOPT, which is also based on ideas from Instructional Design.
2. Define the training necessary to be able to perform the tasks, up to the level of training items. Training items are the smallest elements in training for example a module in the courseware.
3. Break down the training items into information that can be defined as documentary units.
4. Define documentary units at all the three levels, maybe with an option to skip level 3.
5. Choose the right kind of medium or modality of each documentary unit.
6. Check whether there already exists a documentary unit which provides the information (some tasks need the same information).
7. Create the documentary unit in such a way that it is as understandable as possible for a not-experienced operator.
8. Tag the documentary units with the task to which it belongs and the context in which it is to be performed, and by doing this automatically create a link to the knowledge, skills and attitudes needed to perform the task.

Of course these steps will have to be iterated many times before completeness of documentation can be reached. It might be the case that not all information is inserted in the documentation that is needed for legal, standards or com-

pleteness reasons, or that information is needed for other purposes and other personnel next to operators. This information could be added using other methods. However, the meta-data should make clear that these documentary units are there for other purposes than training and operations. In this way a database can be build which contains all the necessary information for operations and for training.

Examples of Documentary Units

If we look at the pieces of information currently used in the courseware and in the FCOM, it is clear that it is not just a matter of taking the current FCOM, to cut it into fragments and to re-use them for training purposes. For example the graphics and pictures of (sub)systems used in both documents are different. In the FCOM they are black and white and give all the technical details. In the courseware, they are colored, leaving away non-functional details, showing them as a pilot would see them, and sometimes even animated.

In figure 1, an example is given of the same system (thrust lever) from the FCOM on the left, and from the courseware on the right (Gillett, Barnard, and Boy 2002). Note that in the picture from the FCOM more details are given like the holes in which the screws can be placed to fix the lever and the component underneath the operation area. These details might be very interesting for the engineer who has to install or maintain it, but for the pilot it is completely irrelevant. Also the view in the courseware is presented as the pilot would see it, in the FCOM it is shown from the side, a view you will not get in the cockpit.
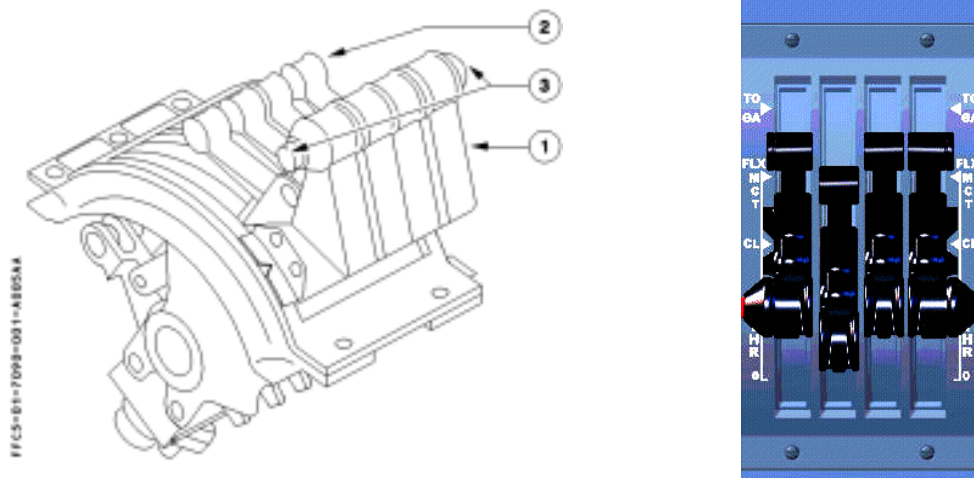

Figure 1: Graphic from FCOM and courseware.

This is not to say that one picture is better than the other, it just depends on the purpose for which the information needs to be used. In training and for operations, the picture on the right hand side might be easier to explain how to use this device, but for level 3 information, a more technical picture might be needed to explain all the details.

Also for text, documentary units will have to be written in a style, which is directly related to tasks. For example, sometimes texts in a certain part of the FCOM describe both standard operation procedures and procedures for emergency situations at the same time. To be able to provide the pilot and the trainee with the suitable information, parts should be presented one at a time. In the cockpit the aircraft systems "know" whether normal or abnormal operations have to be performed. In new generation aircraft, the pilot is warned by the ECAM. In the courseware, abnormal situations are only treated after the trainees have understood the normal procedures. In figure 2 an example is given of such a mixed text.

FCOM 3.06.10 P1
The diversion strategy (descent and cruise speed schedules) shall be selected, and specified in the operator's routes specifications, as a function of the prevailing operational factors (e.g. obstacles clearance requirements). If the standard strategy does not allow the aircraft to clear obstacles, the pilot must use a drift down procedure. If an engine failure occurs at any point on the route, the net flight path must clear the obstacles on the drift down part by 2000 feet and on the climb part by 1000 feet.

Figure 2: Mixing operational policies with standard procedures in the FCOM

Conclusion

There is a strong need to articulate operational and training documentation for several reasons. First, technology is evolving very fast and documentation should be modified accordingly. Thus, an integrated mechanism that relates operational and training documents will improve productivity and consistency, and consequently safety. Second, articulation makes emerge the need for new media configurations for on-the-job training and performance support that are already necessary concepts and tools in practice. In addition, operational documentation provides realism both in initial and recurrent training. Third, articulation allows for easy customization of both operational and training materials to a specific aircraft configuration or an airline culture. Fourth, articulation provides a very interesting capability of knowledge reuse.

Ideas developed in this paper could be useful for the design of current and future aircraft documentation articulated around operations and training. There are two issues that need to be further investigated: context-sensitive indexing and the training of documentation authors.

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