Information Needs for Flight Operations: Human-Centered Structuring of Flight Operations Knowledge

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ABSTRACT
Operational documentation needs to be structured to be appropriately generated, updated, searched and routinely used. This paper presents the current flight crew operating information, and the methodological approaches that we have used to carry out the INFO project (Information Needs for Flight Operations). During this project, we carried out experiments using the Group Elicitation Method (GEM) and scenario analysis sessions. We reviewed constraints on new information development and of new dissemination approaches. We also developed and validated guidelines for preparing and disseminating aircraft operating guidelines. Three levels clearly emerged from the study: flight manual information for the cockpit (need-to-know) with very fast and very easy access (paper or electronic); FCOM for reference (nice-to-know); training manuals that provide rationale, notes and explanation, adapted to various regulations and requirements from authorities.

Keywords
Operations manuals, documentation structuring, revisions, FCOM, flight operations.

INTRODUCTION
Human writing has always helped people to structure their mind. Throughout the writing process, it is continuously necessary to augment, clean and cut. It is therefore necessary to incrementally process information bases accumulated by re-aggregation and filtering: the layout of facts (the what); the explanation of their functions and relationships (the why); the concrete use (the how).

We have entered a period where the "paper book" is going to be complemented, if not largely supplanted, by the "electronic book". Documentation of flight operations, pilot-machine interfaces and aircraft systems, are affected by the extraordinary integration of electronics. Efficiency and safety in particular dictate a better adaptation of documentation content and structure to front-line actors such as airline pilots or any other (maintenance) agents in touch with the aircraft. Operational documentation will be revisited for future aircraft products, as driven by current evolution in electronic databases and information processing and by current human factors work performed with aircraft knowledge practitioners such as pilots and engineers.

This paper presents the current flight crew operating information, and the methodological approaches that we have used to carry out the INFO project (Information Needs for Flight Operations). It provides the results of INFO investigations. In particular, three levels of documentation structuring and use are presented. The balance of the paper starts a discussion and presents recommendations.

FLIGHT CREW OPERATING INFORMATION
Flight operations rely on information that is accurate, up-to-date, easy to access and use. As aircraft have become more complex, the amounts and types of needed operating information have grown. As a result, the task of preparing, maintaining, distributing, accessing and using operating information has become more challenging to everyone. The Flight Crew Operating Manual (FCOM) for a commercial aircraft is an essential part of the documentation that must be supplied by a manufacturer such as Airbus Industrie. In spite of significant advances in aircraft design, particularly relative to the cockpit, the FCOM format and medium have remained basically unchanged for years. It continues as a "classic" paper document contained in portable binders that can be updated periodically by physically replacing or adding pages. In many ways, it is similar in concept and operation to the books of airport and approach charts. The total "system" to generate and maintain the FCOM has also not changed significantly in recent years, even if advances have been made in systems for storing and using documentation electronically. These advances hold great promise for simplifying the task of maintaining a current FCOM with accurate individual aircraft effectivity (Petiot, 1998). They also have the potential to reduce the information search and retrieval time. For example, Airbus Industrie's current objectives include:

- simplified management of the manuals;
- development of a module-based structure and in contrast to a page-based structure;
- color incorporation;
• availability of three levels of information.

The introduction of new FCOM delivery media and two-way online electronic data transfer suggested the possibility that the existing view of the format, function and use of the FCOM may have to evolve in order to take maximum advantage of the benefits inherent in the new approach. Consequently, a human-centered design approach was developed based on user requirement gathering. The INFO project was launched as a cooperation among the aviation industry and research on human and computer sciences. The main objective of INFO was to make an unbiased and user-centered determination of the requirements for an enhanced FCOM system for the current generation of Airbus aircraft (A320/A330/A340). A secondary objective of the study was the development of recommendations for a totally new concept of FCOM architecture and style targeted towards a new type of aircraft or any future generation of aircraft still to be launched.

One area of particular focus for the project was the definition of levels of detail for information in an FCOM. This hierarchy would enable users to separate information considered essential for the operation of the aircraft by the manufacturer from clarification and amplification material that could be used optionally at operator discretion.

METHODOLOGICAL APPROACHES

Airline sessions

The main objective of interview sessions with airline pilots and documentation specialists was to obtain user input on FCOM characteristics such as level of detail, context of use and organization. Two structured data collection activities were conducted in parallel sessions to elicit knowledge from experts, i.e., Group Elicitation Method (GEM) (Boy, 1996), and Scenario build-up sessions. The group involved in the GEM session during a first day was involved in the Scenario session the next and vice versa.

Typical GEM session

The following methodological steps were carefully followed:
1. Brainwriting or viewpoint gathering or elicitation.
2. Concept formulation live with participants.
4. Recommendations on generated issues.

The intent of the GEM sessions was to stimulate broad-based and unconstrained thinking about critical issues related to the development and use of an FCOM. The specific question used to stimulate the initial discussions was: How should an FCOM be designed to best meet the existing and future information needs of users (crews, trainers and developers)? GEM involved a dozen domain experts who were all asked to write their viewpoints on the following questions:

- What determines the level of detail that is appropriate at a given time?
- What format/medium? Can paper be eliminated? Proper use of color?
- What effectivity mechanism?
- What indexing mechanism would you recommend?

Typical Scenario session

Four methodological steps were carefully followed:
1. The INFO team worked with the group as a whole to attempt defining the three most important contexts of use of an FCOM.
2. The INFO team also worked with the group as a whole to attempt to define the three most important distinctions among levels of detail or information importance in an FCOM.
3. The three contexts and three levels of detail were then assembled into a matrix with contexts as the rows and detail as the columns. For each cell in the matrix both scenario groups respectively developed a definition of FCOM content characteristics that met that context and level of detail.
4. During a "redlining exercise" selected sections of the A320 chapter relative to "Flight Controls" from Volumes 1 (System Description) and 3 (Abnormal and Emergency) of the FCOM were distributed to all participants and classified according to the definitions developed in the matrix.

At the end, some time was left for an open discussion of whether the matrix cell definitions work in classifying most of an FCOM. Examples were asked (from sections other than those discussed) of where it might not work well or where it was particularly well suited. There was a high degree of consistency within the two GEM sessions and within the two Scenario sessions. In addition, there was a high degree of consistency across the two types of data collection even though the GEM was more broadly focused than the Scenario activities.

Experimentation of levels with Airbus Industrie specialists

The three levels generated from the interview results were experimented with Airbus Industrie training pilots and documentation specialists. The importance and relevance of the defined levels was tested, as well as the ability of the Airbus personnel to allocate levels to current FCOM content. The three examples processed in-house were different from those used in the airline sessions. A decision tree based on the three levels was validated for routine use by operations documentation writers.

INFO PROJECT RESULTS

General issues

The major issue that drove GEM experiment results is that it is the organization of the FCOM that is critical. Several related issues emerged clearly:
Participants wanted more information, i.e., they wanted explicit rationale of what is provided in the FCOM and, at the same time, they wanted usable information (easy to use and to retrieve); also, understanding is always an important issue and pertains most of all to system philosophy.

Participants clearly differentiated between three levels:
1. flight manual for the cockpit (need-to-know) with very fast and very easy access (could be paper or electronic);
2. FCOM for reference (nice-to-know) that is suggested to be electronic;
3. training manual that provides rationale, notes and explanations, adapted to various regulations and requirements from specific national and international authorities.

Participants agreed on the fact that:
- the process of temporary revisions has to be improved (it would be better to choose tail numbers for the effectivity even if several participants would like to be able to manage the effectivity in their own company);
- the organization of the FCOM is crucial to improve the handling of revisions;
- the paradigm of documentary units should be used to handle revisions.
- Participants insisted on the need for good cross-referencing, especially for failure management.

Specific Level of Information issues
Although apparently quite different in their approach, there was significant consistency between the two Scenario sessions in terms of implications for FCOM design and distribution. From the inputs of each airline group a 9-cell matrix was developed consisting of 3 contexts and 3 levels of detail. As seen from the above the three contexts that evolved from the first group were "Training," "On-board Use" and "Updating." Training was described as a situation in which in-depth knowledge is needed and sufficient time exists to impart it. On-board, FCOM is the reference book in case it is needed in the course of normal, abnormal or emergency flight situations. Updating is really a shorthand way to describe the function of alerting a crew to differences that have emerged since they were trained or last updated. The three levels of detail defined by this first group were expressed in descriptive terms of "What/How To Do," "Why Am I Doing This Now" and "Why it Works."

The contexts of use of the second group were actually quite similar to those proposed in the first. "Training" was common to both sessions. "Abnormal/ Emergency" is, in fact, a subset of On-board procedures. "Pre-Flight Planning," is similar to "Updating," while not identical, since it involves developing an understanding of the aircraft to be flown before the flight is started. Participants of the second group also identified similar types of levels of detail, although their descriptions were decidedly more engineering-oriented. The "Interface" level corresponds well with the "What/How To Do" description developed in the first group. A flight crew takes actions ("What they do") through the flight deck interface. The "Single System" level is not fully the same as the "Why Am I Doing This Now" level. However, one can draw a correspondence between both by considering that the immediate actions on the cockpit that are prescribed in the "What" level very likely initially impact only a single system. The concepts, therefore, are similar. The third level is simply "All Else." This simplistic view was not an attempt to reduce the importance of this type of detailed information that is essentially the same as the "Why it Works" category. Rather, it was simply viewed by the participants as a category for all information that is more detailed than the "Interface" or "Single System" levels.

As no single descriptor or concept was considered adequate, a decision tree approach was used. Obviously the manufacturer needs to provide all the information that they have on the aircraft, but it also needs to be the one to point out the baseline, "must have" information necessary to operate the plane. After the matrices were identified in the airline meeting, the participants used the levels classification scheme that they had proposed to "redline" several selections from the A320 FCOM. This exercise also helped identify suggestions for FCOM improvement. The redlining indicated that:
- FCOM text could be readily classified into three levels of detail.
- The unit of classification for FCOM text would likely have to be quite small for the existing FCOM content and organization since it mixes all three levels of detail quite extensively.
- There was surprising agreement among the participants in each group on what the classification should be for each test FCOM portion. A trained and experienced technical writer should be capable of defining a valid consistent level for each unit of classification.

Unit of Classification
In order to classify parts of the FCOM into levels, it is first necessary to define the concept of "the unit of classification" or documentary unit. This unit then becomes the basis for assigning a level. It also becomes the smallest "building block" upon which an FCOM can be built whether electronic or paper. While it might be suggested that the type of information of an FCOM, e.g., procedures, would constitute units of classification, the data from the interview sessions suggest they do not. Procedures, which intuitively appear to be largely autonomous information units, were divided by participants into all three levels of detail during brainstorming discussions. With regard to descriptive material from FCOM Volume 1, the situation becomes even more difficult. This material is essentially pure text separated by headings in a more or less classical...
If definitive specifications for units of classification cannot be productively used, the alternative is to define units based on their level of detail. Although this is a recursive definition, it would appear to be both unambiguous and straightforward to apply. Under such a definition, a unit of classification or documentary unit does not have a specific physical description such as a paragraph or procedure. Rather, a unit is defined as a continuous block of text or data, all of which is at the same level of detail. It would be the change in level of detail that should signal the end of one unit and the start of the next, rather than any characteristic or format of the text or data.

Levels of Detail - Individual Models

The airline data collection led to the identification of a variety of "models" of level of detail each of which has some operational merit. These models and their associated levels of detail (in no particular order of importance) are presented in the table here below. The model names were selected to be descriptive of the underlying concepts inherent in the levels. None of these models by itself appears sufficiently comprehensive to meet the filtering needs of technical writers. In order to overcome this, a combination of the attributes of several (or even all) of most of the identified models was used and formed into a decision-tree format. With this approach, asking a set of questions linked by "ANDs" or "ORs" would be used to derive the ultimate level for a documentary unit.

<table>
<thead>
<tr>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context-related</td>
<td>Needed for flying</td>
<td>Needed for understanding and</td>
<td>Requires judgments and regulatory</td>
</tr>
<tr>
<td></td>
<td></td>
<td>troubleshooting</td>
<td>information that the author may not have</td>
</tr>
<tr>
<td>System-based</td>
<td>About user interfaces</td>
<td>About a single aircraft system</td>
<td>Relatively easy to classify, but not sufficiently encompassing to address</td>
</tr>
<tr>
<td></td>
<td></td>
<td>About multiple systems or system</td>
<td>all of the topics in an FCOM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>interactions</td>
<td></td>
</tr>
<tr>
<td>Situational</td>
<td>What it did; What do I do?</td>
<td>Why it did it; Why I should do it</td>
<td>Relatively easy to classify, but not sufficiently encompassing to address</td>
</tr>
<tr>
<td></td>
<td></td>
<td>What happens when it does/I do this</td>
<td>all of the topics in an FCOM</td>
</tr>
<tr>
<td>Inquisitive</td>
<td>What is happening?</td>
<td>Why is it happening?</td>
<td>Similar to situational but may be slightly easier to apply</td>
</tr>
<tr>
<td>Intuitive</td>
<td>Non-intuitive safety-related</td>
<td>Other safety-related</td>
<td>Difficult to determine what is intuitive and what is safety-related.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-safety-related</td>
<td>Therefore, likely not reliable</td>
</tr>
<tr>
<td>Resultant</td>
<td>What I must do</td>
<td>What it produces</td>
<td>Relatively easy to classify, but not sufficiently encompassing to address</td>
</tr>
<tr>
<td></td>
<td></td>
<td>How it affects the system</td>
<td>all of the topics in an FCOM</td>
</tr>
<tr>
<td>Cognitive</td>
<td>Information directing actions</td>
<td>Information supporting decisions</td>
<td>Somewhat subjective to classify and not directly safety related</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Information supporting knowledge</td>
<td></td>
</tr>
<tr>
<td>Goal-oriented</td>
<td>Safety</td>
<td>Comfort or efficiency</td>
<td>Difficult judgment for an author to make. Airbus must designate someone</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Understanding</td>
<td>to make the judgment</td>
</tr>
<tr>
<td>Urgency</td>
<td>Need to know (existence)</td>
<td>Nice to know (values)</td>
<td>Difficult judgment for an author to make. Airbus must designate someone</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Background and implementation</td>
<td>to make the judgment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>details</td>
<td></td>
</tr>
<tr>
<td>Content source</td>
<td>Legal or regulatory</td>
<td>Manufacturer</td>
<td>Makes decision relatively easy but manufacturer’s information may be as</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>important for safety as regulations</td>
</tr>
<tr>
<td>Cumulative</td>
<td>Line pilots must know</td>
<td>Check pilots must know</td>
<td>May be difficult to get agreement on what goes at each level</td>
</tr>
<tr>
<td>Manufacturer</td>
<td>Every pilot must know</td>
<td>Not essential for everyone, but</td>
<td>This is some of the main information customers think is missing at present</td>
</tr>
<tr>
<td></td>
<td></td>
<td>recommended</td>
<td></td>
</tr>
<tr>
<td>Understanding</td>
<td>How to use</td>
<td>System</td>
<td>A clear hierarchy but difficult to define</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Meta-knowledge</td>
<td></td>
</tr>
<tr>
<td>Level 1</td>
<td>Level 2</td>
<td>Level 3</td>
<td>Comments</td>
</tr>
<tr>
<td>--------</td>
<td>--------</td>
<td>--------</td>
<td>----------</td>
</tr>
<tr>
<td>the cockpit</td>
<td>rationale that provides more detail to understand the first Level</td>
<td>necessary to understand and learn the first two levels</td>
<td>boundaries between levels</td>
</tr>
</tbody>
</table>

**Level Decision Tree**

The version shown here was updated based on findings from the data collection with documentation specialists and includes the category explanations used during testing. Definitions are straightforward and unambiguous.

**Level 1 information**

- **(1.1)** A legal, regulatory or defined industry standard requirement. Any JAR, FAR or other airworthiness requirement or regulation, governing federal, province, state or municipal law, or widely accepted standard (e.g., Air Transport Association [ATA], International ATA)
- **(1.2)** Specification of an interface action that the pilot must take (activate, move, push, enter, feel, sense, etc.) The interface excludes all controls, displays and internal and external communications gear. Also included are parts of the aircraft structure surrounding the interface that the pilot may have to touch or feel for temperature, and so on.
- **(1.3)** Aircraft or pilot interface outputs or results that a pilot on duty can perceive. Any sound, light, movement or tactile input that is above the threshold for a pilot operating the aircraft from the cockpit and with normal sensory capabilities to detect. This includes stimuli from outside the cockpit that can be sensed inside.
- **(1.4)** Points the manufacturer has determined are necessary for every pilot operating the aircraft. This is a judgment of the "must know" information covering all aspects of aircraft operation. Can a pilot be competent without the information? If the answer is no, it meets the criterion.
- **(1.5)** Points that the manufacturer has determined to be safety critical. This is a judgment of information that is critical to avoiding a safety of flight problem or recovering safely when a problem arises.

**Level 2 information**

- **(2.1)** Philosophy of system design, i.e., an explanation of why a particular design alternative was selected. This is particularly important when there are other obvious design possibilities.
- **(2.2)** Rationale for performing an action, i.e., an explanation of why a particular action alternative was selected. This is particularly important when there are other obvious action possibilities.
- **(2.3)** Rationale for system response or behavior, i.e., an explanation for why the system responds in a particular manner. This is particularly important when the response is not really intuitive.
- **(2.4)** Responses of a system or aircraft to pilot inputs, i.e., a description of the response of a system or the entire aircraft to a pilot's input when that response is not needed by the pilot in a closed loop control operation.
- **(2.5)** Training, check rides or testing rather than line operations, i.e., information needed to satisfy requirements other than the requirement to fly safely on the line.
- **(2.6)** Support of decision-making, i.e., information to support cognitive processes that may have a relationship to flight safety, comfort or efficiency under low probability contingencies.
- **(2.7)** Flight comfort or efficiency (including wear and tear) but not safety, i.e., knowledge that helps give the passengers a better trip or increases profit (decreases cost) but is not related to safety.
- **(2.8)** Points the manufacturer has determined are not essential but recommended for every pilot operating the aircraft, i.e., the « nice to know » information that might make the difference between acceptable and exceptional efficiency and reliability (standards).

**Level 3 information**

- **(3.1)** How the system works, i.e., background for those interested in details not needed in day-to-day operation.
- **(3.2)** Diagnosis/Troubleshooting of how the system works, i.e., details for examining subsystem interactions and finding problems whose symptoms are not readily apparent.
- **(3.3)** Expert knowledge not likely needed in flight, i.e., the depth of information arising from the design and operation of the aircraft but which is not related to anything the flight crew can do about the safety, comfort or efficiency of the flight.

**Application by Airbus Documentation specialists**

The levels defined from the airline sessions were found extremely appropriate, with only minor changes required. They were clear to users, easy to apply and should be easy to interpret by Airbus specialists and pilots who learned the levels and their meanings quickly. Level determination is a participatory design activity that should involve both the documentation specialist and a pilot. The process of assigning levels forces a re-analysis of text content and can highlight inconsistencies. Obviously, the task of classifying existing and new FCOM text into levels can be made more efficient, consistent and error-free using appropriate task aids and software tools. Work was started
CONCLUSION AND RECOMMENDATIONS

The INFO project aimed at assessing current and future information needs for flight operations. It reviewed constraints on new information development and of new dissemination approaches. It also developed and validated guidelines for preparing and disseminating aircraft operating guidelines. It mainly recommended an authoring process and proposed candidate levels of detail based on existing FCOM material and on extensive rethinking of airline user needs. Two different data collection approaches involving a substantial number of participants resulted in very consistent findings.

INFO recommends to envisage a "paperless" system end-to-end but it assumes that paper will stay for a long time. Compatibility between manufacturers will be important to consider as "tagged" digital versions are to be distributed to airlines. Possible limitations may come from the Data Type Definition (DTD) generated by the FCOM Working Group (FCOM WG) of the ATA’s Technical Information Communications Committee (TICC). The INFO study confirmed that users want easy customization and that effectivity and context of use (conversion training, operations, recurrent training) are key variables. Updating appeared to be essential with several associated issues such as timeliness (lag and frequency of updates) and ease of execution; method of delivery and use (Internet, intranets, e-mail, and so on); airline feedback on aircraft modifications and airline-generated changes; effectivity problems difficult for pilots to determine; "return loop" for airline data and updating cues; need to keep TRs for paper editions or consider entire reprints; revision numbering across editions and propagation of revisions; user ability to move among versions and functional equivalence.

INFO recommends closely considering information needs in the context of abnormal, emergencies and ECAM procedures. There appears to be too much mixing of "how" and "why" to the extent that future FCOMs would have to be reorganized to make single topics more contiguous. Hence INFO developed a "Level of Detail" decision tree that should contribute to help distinguish levels of information, notwithstanding liability implications to be examined: how to use the cockpit; system rationale to understand; meta-knowledge to understand and learn.

Three levels clearly emerged from the study: (Level 1) safety/legal/operating level (what to do), i.e., flight manual information for the cockpit (need-to-know) with very fast and very easy access (paper or electronic); (Level 2) philosophy of use/rationale (why it is so), i.e., FCOM for reference (nice-to-know); (Level 3) detailed information level (how it is done), i.e., training manual that provides rationale, notes and explanation, adapted to various regulations and requirements from authorities.

INFO clearly highlighted that - for cockpits that are as "visual" as glass cockpits - color should be included in flight operational documentation even on paper versions that cannot be eliminated. Electronic operational documentation is certainly expected in the near future as a complementary training aid and performance support tool. Pilots would be able to use it at home or onboard to access details or improve understanding. This last issue appears as important as ever, i.e. the need to understand the philosophy is predominant to enable pilots to effectively work to expected standards.

In addition, the definition of levels also provides a basis for selective use or filtering of the FCOM contents by customers themselves for their own needs with respect to the importance placed on the information by the manufacturer and/or airworthiness authorities. It must be noted that Airbus Industrie was not alone in recognizing that cockpit documentation human factors issues were likely to arise as part of any complete or partial transition from paper to electronic delivery. In the USA, NASA and FAA funded a project to examine operating documents. Aircraft manufacturers are actively engaged in the ATA FCOM WG to the point that the ATA has now adopted an FCOM knowledge stratification scheme proposed in this paper for the electronic flight manuals it is specifying for the future.

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