Evaluating Electronic Flight Bags in the Real World

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ABSTRACT
Over the past few years, the Volpe National Transportation Systems Center (Volpe Center) has developed several tools that can be used to evaluate Electronic Flight Bags (EFBs) from a human factors perspective. The tools are needed because EFBs are sophisticated devices that may be approved for use through a relatively abbreviated process, in accordance with the guidance in the 2003 Federal Aviation Administration (FAA) Advisory Circular (AC) on EFBs (AC 120-76A). The newest tools were developed in coordination with the FAA Aircraft Certification Service and Flight Standards Service. They are documented in a draft FAA document known as the "EFB Job Aid." In this paper, the use of all of these different tools is described briefly, and the tools are compared and contrasted.

Keywords
Electronic Flight Bag, EFB, approval, evaluation, human factors tool, design, operations, operational approval

INTRODUCTION AND BACKGROUND

Customer interest in Electronic Flight Bag (EFB) technology remains strong. A 2005 industry survey by Yeh and Chandra [7] shows that the number of EFB products and manufacturers continues to expand. As a result of all this consumer interest, the Federal Aviation Administration (FAA) is seeing an increase in the number of applications for approval of EFBs. Guidance for the approval of EFBs is contained in the 2003 FAA Advisory Circular (AC) 120-76A, *Guidelines for the certification, airworthiness, and operational approval of electronic flight bag computing devices*. This document is also known as the EFB AC [4].

The guidance in AC 120-76A is complex. One reason for this complexity is that EFBs need to be evaluated from different perspectives. All EFBs that are approved under this AC will require an *operational evaluation* to ensure that the flight crew can *use* the new system safely (e.g., without undue distraction, and with appropriate training and procedures). In particular, complex applications that require crew interaction, such as flight performance calculators or electronic charts, will undergo a more formal review than simpler, non-interactive applications, such as electronic document viewers. Systems that have more complex hardware will also require a *design approval* to ensure that the EFB does not impair the functionality of existing flight deck systems.

As more FAA inspectors, in particular inspectors at regional field offices, began to handle the approval of EFBs, it became clear that the guidance in AC 120-76A needed clarification and supporting material. FAA field inspectors were having trouble interpreting the EFB AC. In response to this need from field offices, the FAA recently drafted the EFB Job Aid, with assistance from the Volpe Center [5].

The EFB Job Aid is a *companion* document to the EFB AC. It provides additional clarification to supplement the recommendations and processes outlined in the AC, but is not intended to establish new policies. The primary intended audience for the EFB Job Aid is the FAA inspector, but the materials are also useful to EFB manufacturers and operators. The EFB Job Aid is a *draft* document that is currently being coordinated within the FAA. Coordination can be a long and involved process. In the meantime, FAA inspectors can choose to use the document as is, on a trial basis.

New tools to support consideration of human factors issues during operational approvals were developed for the EFB Job Aid; these new tools will be discussed in detail below. The last section of the EFB Job Aid contains a short tool for assessing the EFB user interface at a high level. The development and testing of that tool is documented elsewhere [1, 2].

All of the EFB usability-assessment tools were developed at the request of the FAA, which acknowledges that EFBs could have a significant impact on issues such as workload, errors, training, operating procedures, and workflow. In fact, the EFB AC contains substantial information on human factors issues. Still, some EFBs will go through only minimal usability testing during design and development, and they will undergo a streamlined FAA review as well, in accordance with the process stated in the EFB AC. Although the new technology will be deployed more quickly, there will be less opportunity to catch problems because of the less formal review.

Therefore, an important goal of the EFB usability assessment tools is to make FAA EFB human factors assessments more efficient. The tools promote a more efficient review because they ensure that all parties are well informed about the evaluation, and because they facilitate consistent documentation for the approval.

In this report, all of the EFB usability assessment tools will be compared and contrasted. The goal of this report is to give the reader an appreciation for the whole set of tools, and how and when they can be used most effectively. Although the tools were designed for use by regulatory authorities, industry users could use them to improve EFB systems. For example, designers could anticipate problem areas and address those issues in advance of a regulatory evaluation. Therefore, we use the generic term "evaluator" instead of "inspector," to refer to the user of the tools.

EFB ASSESSMENT TOOLS

Five distinct tools have been developed for the purpose of evaluating EFBs from a human factors perspective. These tools are listed below:

1) EFB Human Factors Design Review Checklist
2) EFB User-Interface Assessment Tool
3) Guide for Developing Simulator and Validation Flight Scenarios
4) Operational Evaluation Questions
5) Line-Operations Evaluation Job Aid

All but the EFB Human Factors Design Review Checklist listed above are part of the draft EFB Job Aid [5]. The EFB Human Factors Design Review Checklist (formerly known as the "Detailed Tool") and the EFB User-Interface Assessment Tool (formerly known as the "High-Level Tool") are documented in [1, 2]. Note that there is no requirement for either the FAA or industry to use any of these tools.

While the tools provide a good starting point for EFB assessments, they need to be tailored for the specific situation because the EFB systems that undergo FAA review vary widely. Some applications for approval will come from airline operators with numerous crews; other applications will come from small operators with just a few aircraft and crews, who operate under different FAA regulations from the airlines. The EFB systems may be relatively simple stand-alone devices, or they could be installed in the aircraft (e.g., the Boeing EFB) [7]. Because the design of the tools does not make any assumptions about the capabilities of the EFB, or the complexity of their use in operations, the inspector needs to customize the tools for specific situations.

Figure 1 below shows an overview of the tools from the perspective of when they can be used, relative to the maturity of the EFB system. The solid gray lines in the figure mark the typical period for using that tool, and the dashed gray lines denote other periods when the tools could be useful. The EFB Human Factors Design Review Checklist and the EFB User-Interface Assessment Tool focus on individual aspects of the EFB hardware and software, while the other tools consider the system as a whole, in the context of the operational flight task.

The EFB Human Factors Design Review Checklist is based on the foundation provided in [3], which provides detailed supporting material on EFB design and evaluation. It is most appropriate for evaluating the early system because it focuses on specific design aspects, such as selection of fonts. In contrast, the EFB User-Interface Assessment Tool is a more versatile tool, because it can be used at any time during system development. The EFB User-Interface Assessment Tool is designed to identify the significant interface issues from the users perspective, e.g., overall consistency. Issues identified by this tool are ones that may have been overlooked by designers who were focused too closely on the details of the system design.

The three tools in Figure 1 that consider the operational use of the EFB may be used at different stages of system development. The Guide for Developing Simulator and Validation Flight Scenarios helps the evaluator develop and run simulator scenarios that are too costly or too dangerous (or just unnecessarily risky) to test in real flights. This guide can be used prior to the development of a flight-testable unit.

The Operational Evaluation Questions address the user interface from both an operational and design perspective. The questions can be used prior to developing a flight-testable unit, but their utility may be limited until a more mature system is developed. Some questions in this set may be useful to the manufacturer or customer earlier in development, as shown by the dashed line in Figure 1, but the FAA inspector is most likely to use the Operational Evaluation Questions only after training and operational procedures for using the EFBs have been developed by the operator.

The Line Operations Evaluation Tool has questions that address the impact of the EFB on safety and operations. It is most appropriate for use during a line operational evaluation, i.e., when the system has been deployed and is being observed and evaluated during initial use.

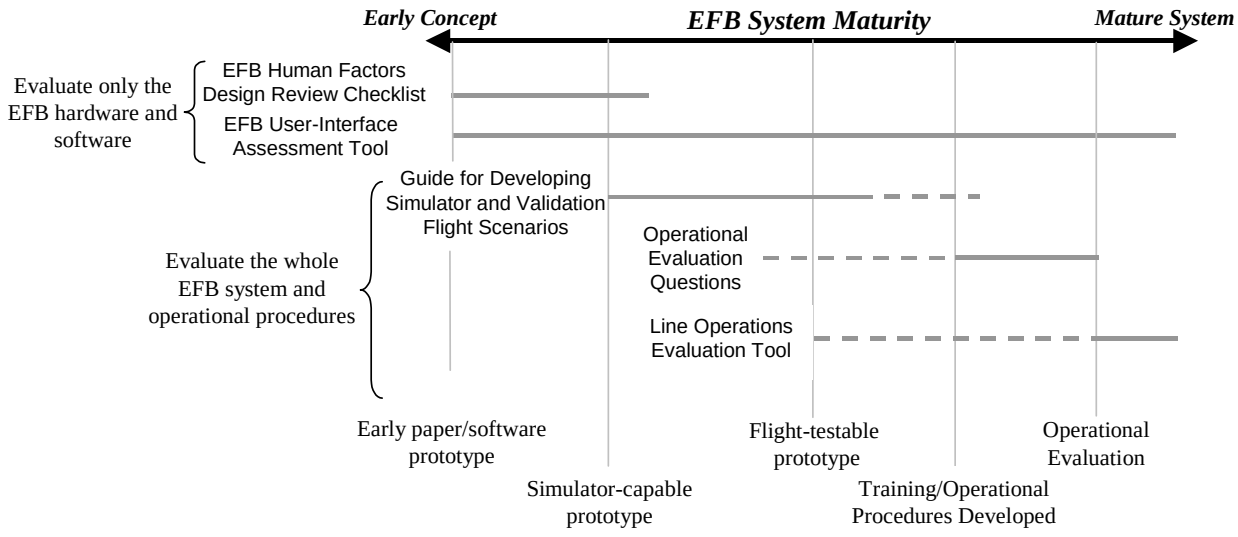

Figure 1. Overview of EFB usability assessment tools.

This would be the first time that line crews use the system, so it is a good stage to assess whether the EFB system can be used by the "average" crew, as opposed to those who have high level of system knowledge, and perhaps a special interest in its success.

Each of these tools will be described in more detail in the following sections in terms of how they are expected to be used and what types of findings an evaluator can expect.

EFB Human Factors Design Review Checklist

The EFB Human Factors Design Review Checklist was originally developed for use by Aircraft Certification specialists in an office (i.e., "desk-top") evaluation. Now, however, we see this tool as being more suited for use by a manufacturer or designer, particularly applications developers. The evaluator does not need to be a human factors specialist to use this tool.

The EFB Human Factors Design Review Checklist contains nearly 200 specific items that a designer can check the system against. One example is "Labels should be drawn in horizontal text." The value of these specific items is that they help to catch straightforward design problems (e.g., choice of font) quickly. However, the specificity of the items also makes it less useful for catching problems that are subtler or more global, such as navigation philosophy.

Because of the number of items in the EFB Human Factors Design Review Checklist, it takes approximately one-half to one full day for someone who is familiar with its items to complete an evaluation with this tool.

EFB User-Interface Assessment Tool

The EFB user-interface assessment tool was also originally developed for use by Aircraft Certification specialists. However, it may be used as a reference by anyone evaluating an EFB in an office/desk-top environment, including FAA inspectors, system manufacturers, and customers. Again, human factors expertise is not required to use this tool effectively. The EFB User-Interface Assessment Tool contains a short list of EFB usability topics to consider during a brief office evaluation. These topics cover a wide range of user interface characteristics, such as symbols and graphical objects, formatting/layout, user interaction, error handling and prevention, and automation. Some specific examples of topics to consider include: physical ease of use, legibility and distinctiveness of symbols and graphical icons, arrangement of information on the display, number of inputs to complete a task.

To use the EFB User-Interface Assessment Tool, the evaluator goes through the items for each topic, commenting on each one. For each item in the tool, the evaluator should note any issues, and provide supporting examples from the EFB. If s/he chooses, the evaluator can also provide preliminary assessments of problem severity. Because the capabilities and designs of EFBs vary from system to system, there is some overlap between the topics. This helps to ensure that all aspects of the user interface are considered at some point during the evaluation.

The full EFB User-Interface Assessment Tool is just 2.5 pages long, and an evaluation using this tool can take as little as one hour. The evaluation can be done by an individual, or in small teams of two or three evaluators. Evaluations of the same system by multiple teams can also be conducted and then synthesized to gain a deeper level of understanding of how well the system works. An investment of a few days can help to uncover subtle global issues, and is well worth the additional effort.

Guide for Developing Simulator and Validation Flight Scenarios

Simulator and/or in-flight validation tests may be needed to fully determine the suitability of an EFB (see AC 120-76A Paragraph 12 (j), pp. 21-22 [4]). The goal of these tests is to ensure that information provided by the EFB is at least equal to that obtained from pre-EFB methods, particularly for unusual and high-workload situations. As mentioned earlier, these tests consider both the EFB system, and the operational context in which it is used.

The Guide for Developing Simulator and Validation Flight Scenarios contains sample event-based scenarios that may be helpful in constructing EFB validation scenarios. Examples are given for each phase of flight. For example, for preflight planning, the evaluator should check that the results of flight performance calculations performed on the EFB match values obtained from previously approved methods. For the cruise phase of flight, the evaluator should observe the use of the EFB during abnormal events such as an engine failure, or smoke in the flight deck.

The examples in this tool are only generic suggestions; each operator's proposed EFB functionality and software will vary and scenarios should be customized for the particular situation. For example, if the EFB supports applications that are not mentioned in the tool, the evaluator should try to develop similar tests for these other applications. Also, if the operator prohibits use of the EFB under certain conditions (e.g., takeoff or landing), then those scenarios need not be considered during the evaluation.

It will not always be necessary to dedicate a set of simulator or flight tests to evaluating the EFB. In some cases, the tests could be conducted as part of the operator's field evaluation of the EFB, or, if the operator has approved line operational simulator scenarios, the EFB could be integrated into these existing scenarios to provide a basis for evaluation. Some of the suggested simulated emergency procedures may only be appropriate in a simulator or training device. While these tests may be expensive, they do serve a unique and important function, and may be necessary in some cases.

Operational Evaluation Questions

This tool is used for a comprehensive analytical evaluation of an initial EFB system installation. The whole system is considered, including system design, installation, training, operational policies, and procedures. Approximately 50 topics are addressed in 18 pages. Similar to the items in the EFB Human Factors Design Review Checklist, these topics also originated in [3].

The questions in this tool are often open-ended. There is little, if any, prescriptive guidance here. Figure 2 provides an example, on Interacting with Charts on the EFB. The first part of the example (a) contains operational questions about how the pilot uses the charts software. The second part (b) contains two design-related questions, about what information is being shown, how the user switches between states, and how the current state is indicated. This example illustrates how the items in this tool consider the EFB system from an integrated point of view.

It is assumed that the user of these questions is an experienced evaluator, although human factors expertise is not necessary. It is assumed that the evaluator will draw from his/her experience working with other aircraft systems and overall flight experience to make sensible judgments in response to the questions. In some cases, this may mean that different evaluators will come to different conclusions initially. We view this as a means of opening a dialog between evaluators. Areas of EFB use that are unclear should be discussed openly, and mitigations should be developed as a team, with all parties (regulator, operator, and even the manufacturer if needed) involved.

The Operational Evaluation Questions are intended to address a wide variety of operators/equipment, so the evaluator will need to customize use of these questions. For example, for simple EFBs (e.g., Class I, Type A as described in [4, 5]), certain questions may not be applicable. Some questions have sub-items, which could be questions or considerations that clarify and expand upon the primary question, but some sub-items may not be applicable to the specific situation.

Line-Operations Evaluation Job Aid

The Line Operations Evaluation Job Aid helps the evaluator record observations about in-flight use of EFB systems. The tool fits on a single sheet of paper printed on both sides. It is designed for use during a several-month-long operational evaluation that is required by the FAA [4], but an operator can also use it effectively prior to the formal operational evaluation. Use of this tool can be customized as appropriate for the situation.

The questions in the Line Operations Evaluation Job Aid encompass general operations and safety related functions. For example, can the pilot use every application as intended, without too much distraction and workload? Are training and procedures sufficient, given that there may be some accommodations for EFB use (e.g., procedural cross-checking of data). These questions help to identify and scope problem areas, and could facilitate diagnosis and resolution of any underlying issues.

All of the questions in this tool help the evaluator to gather enough information to make a judgment on the two key questions at this final stage:

1) Can the flight be conducted as safely with an EFB as with the methods/products it is intended to replace?

2) Does the EFB add an unacceptable level of complexity for any critical activity or phase of flight?

Note, however, that there is no formal record of a pass or fail rating. This is deliberate, because no *single* observation of EFB use should determine whether the system is acceptable or not. Instead, a set of observations should be collected, and the records should be reviewed in aggregate.

Interestingly, an operator could customize this tool to obtain more information than a regulator would require. For example, for the question "Were usage errors frequent?" the operator could add a numerical rating to assess more quantitatively how frequent usage errors were (e.g., 1 = rare, to 7 = frequent). The higher resolution response scale could give the operator a better understanding of how to improve the system for efficiency, as opposed to just making it acceptable to an authority. The distribution of scores could identify topics where there is large variability between flight crews, which could indicate a need for improved training, or other mitigations.

COMPARISON OF TOOLS

Table 1 shows a different view of the five EFB evaluation tools. Each tool is compared along five dimensions: Scope, User(s), Investment, Benefit, and Limitations. Scope refers to the characteristics that are addressed in the evaluation and the environment in which the evaluation is conducted. The User(s) column identifies characteristics of the evaluators who could use the tool. The Investment column indicates how much time and other resources would be required to conduct an evaluation with a particular tool. The Benefits column describes what types of results one can expect. The Limitations column lists any caveats on using the tool, e.g., issues that will not be addressed.

5.1.4 Interacting with Charts

a) Can crews use the electronic charts as well as they can use paper charts?

— Can crews find and read specific detailed information (e.g., a radio frequency) on the electronic charts quickly (using zooming and panning as needed)?

— Can crews use the electronic charts to orient themselves and track their progress as they fly the procedure (using zooming and panning as needed)?

— Is there significant workload associated with configuring the electronic charts while flying the procedure (e.g., zooming/panning or other display customization)? Is display reconfiguration necessary often?

b) If de-cluttering is supported, can the crew easily switch between a de-cluttered and normal (not de-cluttered) display?

— Is there a clear indication if and when any safety-related display elements are suppressed?

Figure 2. Example from the Operational Evaluation Questions.

Tool	Scope	User(s)	Investment	Benefits	Limitations
EFB Human Factors Design Review Checklist	Analytical ("desk-top") detailed assessment of user-interface • Specific items for some common applications	Best suited for Applications developers • Any level of human-factors expertise	Low to moderate • Office environment • Approximately one day for evaluation; half-day for simple EFBs	• Uncovers specific design issues (e.g., font choice) quickly	• Best used early in the system development • Does not address operational use of system (e.g., training/procedures)
EFB User-Interface Assessment Tool	Analytical ("desk-top") high-level assessment of user-interface • Specific items for some common applications	Broad Range • Aircraft operators • FAA inspectors • Applications developers • Any level of human-factors expertise	Very low to moderate • Office environment • Short time up front (e.g., 1 hour) • Optional additional time for data synthesis (a few days)	• Uncovers "big" issues (e.g., potential for confusion) quickly • With data synthesis, can uncover subtle structural problems • Good for validating EFB system design concept	• Data are subjective and qualitative so the impact of the issues is difficult to document • Does not address operational use of system (e.g., training/procedures)
Guide for Developing Simulator and Validation Flight Scenarios	EFB system design (both installation and user-interface), *and* operational use of the EFB system, especially in unusual operating conditions • Note that the tool provides examples, but needs to be heavily tailored	Best suited for aircraft manufacturers or operators because of need for simulator or aircraft for the tests • FAA may request a simulator or validation flight during the approval process • Human factors expertise is beneficial	High, but simulator tests are less costly than flight tests • May be worth the cost for testing sophisticated, or highly complex EFB systems (e.g., EFBs that are integrated with aircraft systems)	• Validates overall system use under unusual operating conditions (e.g., low-visibility operations) • Could be used throughout EFB system development (from concept to mature design) • Could provide quantitative data	• May not be worth the cost for simple or evolutionary EFB systems • Data analysis could be complex; human factors expertise may be required
Operational Evaluation Questions	Comprehensive analytic ("desk-top") assessment of EFB system operational use *and* system design • Intended for use in approving *initial* EFB system installations	Intended user is the FAA inspector from the Aircraft Evaluation Group, a part of FAA Flight Standards • Operator and manufacturer should be prepared to support the FAA inspector's evaluation • Requires experienced evaluators (not human factors expertise)	Moderate • Approximately one day for evaluation • Some parts can be done in an office environment, but the aircraft and installation should be well understood	• Validates initial use of EFB system for a particular flight deck • Considers all aspects of EFB use, including system design, installation, training, and procedures	• Relies upon evaluator's experience in customizing the tool for the evaluation and in making appropriate assessments
Line Operations Evaluation Job Aid	Practical ("line-operations") assessment of EFB system operational use • Intended for use in evaluating EFB system use over multiple observations	Best suited for operator and FAA operations inspector • Any level of human-factors expertise • Operators could customize the tool to provide more quantitative data for internal assessments	Very low to moderate • Use to record notes during and after *observation* flights • Collect records for multiple flights. Data should be aggregated and analyzed across the observations	• Validates overall system use in normal operations at a relatively low cost • Can uncover training/procedural issues • Can uncover variances between end-users (pilots) via multiple flight observations	• Does not address design of EFB system • In simplest form, does not collect quantitative data

Table 1. Comparison of EFB usability assessment tools.

Table 1 identifies some similarities and some differences between the tools. In the end though, the tools all serve different purposes, and each one adds value to the evaluation when used appropriately. In order to select a tool or tools for a specific evaluation, the evaluator should consider the overall goal for the evaluation (its scope), the system maturity at the time of the review, the time available per review, the number of opportunities for reviewing the system, and the number of evaluators who will participate. Some EFB evaluations will be short and simple, involving only a few people, and others will be long and complex, involving many individuals. The key is to make sure that all possible options for a human factors evaluation are considered at the beginning of the approval process.

Note also that there is no "wrong" way to use the tools. The tools are designed to promote a thoughtful structured exploration and review of the EFB system from a human factors perspective. With the exception of a few items (e.g., on the use of the color red), the tools do not tell the evaluator the "best" or "correct" way to design the EFB. EFBs are uniquely designed for and fitted to the environment in which they will be used. Whatever issues are uncovered with the tools should be considered carefully, and the evaluator's best judgment, along with the opinions of the applicant, should be used in making a final assessment and plan for action.

Although this approach may seem ad hoc, there is support for it (see the discussion in [6]). A significant benefit can be obtained just by incorporating the tools into the overall evaluation process. And beyond that benefit is the fact that using the tools helps to make the human factors evaluations more structured, more consistent, and more comprehensive than they would be otherwise.

SUMMARY AND CONCLUSIONS

In this paper, we describe five different tools for assessing EFB from a human factors perspective. Different users can use these tools at different stages of EFB development, for different purposes.

The tools have been developed and documented for the FAA, but are also of use to the EFB manufacturers and customers. While the tools could be used to anticipate the results of a regulatory evaluation, their underlying benefit is twofold. First, most of the tools are simple to use by non-human-factors experts, so they can be useful to developers who do not have human factors staff in-house. Second, early use of the tools can reduce the redesign associated with poor system interfaces, and ensure that the EFB system is more usable in the long run, which produces benefits for everyone—the regulatory authority, the manufacturer, the customer, and the pilot.

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