PRELIMINARY HUMAN FACTORS FINDINGS FROM THE FAA CAPSTONE 3 ELECTRONIC FLIGHT BAG – AIRPORT SURFACE MOVING MAP OPERATIONAL EVALUATION

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The Federal Aviation Administration (FAA) Office of Runway Safety is interested in understanding the impact of an airport moving map with ownship position on operational usability and safety. To gather data on the use of this technology, the FAA is sponsoring airlines to equip revenue aircraft with an airport moving map on an Electronic Flight Bag (EFB) and to provide evaluation data to the FAA to help understand the safety impact. Understanding the human factors implications of an airport moving map is a key component of this effort. The FAA, the US DOT Volpe Center, and MITRE CAASD developed a process for gathering human factors feedback on the technologies throughout the operational evaluation using surveys, interviews, and observations. This paper will present the current status of the operational evaluation and the preliminary findings.

In 2008, the Federal Aviation Administration (FAA) Office of Runway Safety announced an initiative to evaluate the use of an airport moving map on an Electronic Flight Bag (EFB) and/or an approved aural runway safety alerting system on operational safety. An airport moving map provides a rendering of the airport's runways, taxiways, and buildings, based on information in a database that contains positional information for the location of airport surface elements. Own-aircraft position (i.e., ownship) may be superimposed on the airport moving map and updated in real-time. An airport moving map may be presented on avionics equipment that is installed or mounted in the flight deck (e.g., as one application on a multi-function display or on an EFB display). The purpose of the operational evaluation is twofold: (1) to assess the safety impact of an airport moving map with ownship position during airport surface operations, and (2) to gather information on the usability of the airport moving map software, EFB hardware, and other EFB software. Several FAA offices are also providing support for this effort, including the Office of Aircraft Certification; Flight Standards Services; and Human Factors Research and Engineering Group. Researchers from the John A. Volpe National Transportation Systems Center (Volpe Center) and the MITRE Corporation's Center for Advanced Aviation System Development (CAASD) are assisting in the human factors implementation and data collection for this effort.

The FAA has awarded contracts to four airlines: Atlas Air, CommutAir, Shuttle America, and US Airways. Each airline proposed to equip approximately 20 revenue aircraft with two EFBs hosting the airport moving map software. The aircraft type in which the EFB will be installed differs by airline, but each airline will equip the same type of aircraft in their fleet for the purposes of the operational evaluation. The airlines were allowed to select their own EFB hardware and/or software manufacturer(s) based on their specific needs. Therefore, there are slight differences in the EFB installation, EFB hardware, and EFB software from one airline to another.

Four different EFB hardware platforms (from three different EFB manufacturers) will be used during the operational evaluation. All the airlines will mount the EFB by the pilot's side window (one on the left side of the flight deck, and the other on the right side), although the specific mounting device differs for each airline. For example, two airlines have selected mounting systems that allow the EFB to be rotated (e.g., from portrait to landscape mode and vice versa), whereas one airline has selected a mounting system that locks the orientation of the EFB in landscape mode. In regards to EFB software, all the airlines selected the same manufacturer for the airport moving map but different software versions. Several airlines will also use electronic chart, electronic document, and logbook software, but the manufacturers for those products differ. These differences in the EFB hardware and software used from one airline to another will offer an opportunity to identify and understand the usability of a range of EFBs and EFB products.

To gather human factors information on the technologies, surveys, interviews, and observations will be administered and/or conducted throughout the operational evaluation with each airlines' pilots. The next section describes each data collection technique. The operational evaluation is in its inception stages, and each of the airlines is in different stages of installation and equipage. The third section of this paper describes the current state of data collection, and the fourth presents the preliminary findings.

Data Collection Techniques

Three techniques have been developed to gather human factors data throughout the operational evaluation: surveys, interviews, and observations. Each of the techniques is described below.

Surveys

Two surveys, each suited to meet different goals, will be administered to gather information throughout this evaluation. One is the *Capstone 3 EFB Survey*, which is a survey administered on the EFB and captures information specific to a particular taxi segment. This survey is intended to obtain pilots' opinions of whether the airport moving map with ownship position and/or EFB offered a perceived operational or safety benefit based on pilots' familiarity with the technology and the airport. The survey also collects feedback on areas where the technologies can be improved, for example in terms of database accuracy or in terms of pilot interface/usability. Pilots who used the airport moving map during taxi answer questions on airport moving map safety. For pilots that did not use the airport moving map (e.g., because the pilot was taxiing and was primarily looking out-the-window or if the airport moving map was not available or not needed), questions addressing the impact of the EFB are to be completed instead. The Capstone 3 EFB Survey is intended to be completed twice for each flight operation: the first time enroute after the pilot had used the airport moving map or EFB at the departure airport, and a second time after landing at the arrival airport, when the aircraft is parked at the gate. The number of questions is limited so that it can be completed during revenue operations in approximately one to two minutes. Airlines committed to have their pilots complete the survey at least once per flight segment.

The other survey will be administered on the web. The *Online Survey* gathers feedback regarding pilots' interaction with the airport moving map and EFB. This survey is intended to address a more comprehensive set of safety/usability issues than can be captured by the short Capstone 3 EFB Survey. For the Online Survey, a database of 64 human factors questions was developed addressing topics pertaining to the airport moving map software, EFB, training, and demographics. The 64 questions are not intended to be presented all at once due to concerns about completion time, but rather used as the source for creating several online surveys, each of which contain only a subset of the items. The different surveys can be rotated throughout the operational evaluation, so only one survey is "live" at a time. Questions related to the use of the airport moving map include pilots' perceptions regarding the role of the airport moving map in supporting position awareness, the legibility of the airport surface depiction (e.g., runways, taxiways), the ease of making adjustments to map range and orientation, and the perceived overall impact on workload and heads-down-time. The questions examining the use of the EFB include the ease of accessing information, the consistency of information presentation, the readability of that information, and the usability of buttons and controls. Responses to items on this survey are not expected to change from one flight to another, so the survey can be completed when pilots have more time than they would during line operations.

The survey questions on both the Capstone 3 EFB survey and Online Survey were developed from previous research evaluating the use of an EFB during line operations or examining how an airport moving map display with ownship position may support position awareness on the airport surface (e.g., FAA, 2001). It is important to note that the purpose of these surveys is to develop a general understanding of pilots' perceptions regarding these technologies and not to compare performance across airlines. The EFB and airport moving map, the operational procedures regarding their use, and the training provided will differ from one airline to another. In administering the surveys, it is expected that pilots will be appropriately trained in the use of the airport moving map application and EFB so that they can use it properly and provide meaningful feedback.

The surveys offer pilots from all the participating airlines the opportunity to provide feedback on the usability of the EFB and/or airport moving map. The surveys can be used in conjunction with interviews of limited number of pilots from the participating airlines (as described next) to fully understand the impact of the EFB and/or

airport moving map. For example, survey responses can be probed during interview to gather more information on a usability concern. Additionally, information gathered from interviews can be used to develop new questions for the Capstone 3 EFB and online surveys.

Interviews

Several airlines indicated they would provide researchers an opportunity to speak with pilots directly about their experiences with the airport moving map and EFB display. Such a setting would allow for more detailed responses and could provide a framework for interpreting the responses provided by the Capstone 3 EFB and Online surveys. Sample questions were developed to structure the interviews; for example:

- Did the airport moving map show the information you needed to establish, maintain or regain position awareness on the airport surface? In general, how does your position awareness with airport moving map on EFB compare to your position awareness when using a paper airport chart only?
- Did you encounter any problems or confusing issues with the airport moving map? For example, was ownship position ever shown incorrectly, was the information shown on the map located in incorrect locations, or did you have any problems interpreting the information shown on the airport moving map display?
- Were there any surprises when you were using the EFB (did the EFB ever do something different than you expected)? If so, please describe the situation.

Additional questions and discussion points may arise during the interviews based on pilots' responses.

Each interview is expected to last approximately 30 minutes. The interviews are intended to be conducted with pilots from each airline throughout the operational evaluation.

Observations

Several airlines have provided the opportunity to observe the EFB installation and pilots' use of the airport moving map and EFB in their simulators. These observations provide an opportunity for conducting human factors assessments of the installation of the EFB (e.g., mounting issues) as well as an informal usability assessment of the hardware and software. The information gathered through the observations will be used to revise and refine the questions presented on the surveys and asked during the interviews. The observations will also provide insight into the feedback gathered through the surveys and interviews.

Assurances of Confidentiality

To encourage airline support for the human factors data collection, both MITRE CAASD and the US DOT Volpe Center provided assurances to the airlines that the raw information they provided in support of the operational evaluation would be kept confidential and that the airlines would not be mentioned specifically by name in the reporting of any results. Because the purpose of the interviews were to understand the potential human factors concerns associated with this technology and not to compare the different technologies or the differences in the implementation across the airlines, the findings from the interviews and simulator visits are presented in this report without specifically identifying the airline or the EFB manufacturer.

Data Collection Status

Surveys

1032 responses were received for the Capstone 3 EFB Survey, and 16 pilots completed the Online Survey as of February 2011.

Interviews

Two airlines have so far provided the opportunity to conduct interviews.

Airline 1. Two interview sessions have been conducted with this airline. The first was conducted in October, 2009, during the airline's internal test trial of the EFB hardware and software. In this session, the Volpe Center and MITRE CAASD led an informal focus group with 20 pilots. The pilots were using the EFB for viewing

electronic charts and documents but had not started using the airport moving map software yet. During the focus group, each pilot was asked to indicate what they liked most about the EFB and what they liked least about the EFB. Pilots were then provided the opportunity to raise and discuss other issues. Separate from the focus group, an opportunity to interview pilots two at a time in a training simulator was provided; these discussions focused on gathering pilot opinions on the impact of the EFB on their operations.

After the test trial ended, Airline 1 chose to make extensive modifications to their EFB hardware and software configurations, and the airline invited the Volpe Center and MITRE CAASD to conduct a second interview session in February 2011. Airline 1 was in the early stages of re-integrating the EFB technology into their fleet, but 13 of the pilots in the focus group had used the EFB in its new configuration. Additionally, 9 of the pilots had previous experience with an EFB (from the first test trial). The airline had not yet introduced the airport moving map. Similar to the first interview session, each pilot was asked to describe what they liked most about the EFB and what they liked least about the EFB. The opportunity to interview pilots two at a time in the training simulator was again provided.

Airline 2. In June 2010, the Volpe Center visited Airline 2 and conducted informal usability evaluations of the EFB and EFB software with the airlines' pilots. The purpose of these sessions was to identify and understand any potential human factors concerns with the software suite the airline was using for the Capstone 3 operational evaluation. During the session, the Volpe Center met with 5 pilots. The pilots, working in groups of 2 or 3, were asked to view and use the different software on the EFB. For example, pilots were asked to develop a logbook describing a typical flight. Pilots were also asked to use the electronic charting software to look up the charts needed for a flight, pull specific charts for a flight, and view them. It is important to note that unlike the pilots from the previous interview session, none of these pilots had been trained on the EFB or the software. Rather, the purpose of the review was to gather the pilots' first impressions of the EFB and to understand the intuitiveness of the software.

Observations

Team members from the FAA, MITRE CAASD, and US DOT Volpe Center have conducted three simulator visits so far. During each simulator visit, team members were provided the opportunity to taxi and/or fly the simulator using the airport moving map. The Volpe Center defined four scenarios to facilitate the simulator visits: two involved an aircraft taxiing out and then taking off; the other two involved the aircraft landing and then taxing in. However, in most cases, team members elected to taxi using their own scenarios.

Preliminary Findings

Pilots liked the idea of an "electronic flight bag", particularly as a replacement to their traditional flight bag. One feature they especially liked was a "push/pull" functionality, which can be used to "send" a current image of the information on one EFB to the other EFB. Several pilots indicated that the push/pull function facilitated communication between the Captain and First Officer. In fact, one Captain commented that he sometimes has his First Officer pull up the charts needed and "send" them to him. For example, one pilot can highlight the departure frequency on a chart and send it to the other pilot, which facilitates the briefing. During a demonstration trial of this software, this pilot noted that when flying into KBOS, he received four runway changes, and the ability to highlight the necessary information on the 10-9 chart and send the chart back and forth on the flight deck was beneficial.

Despite the potential benefits of an EFB and airport moving map, pilots' ratings in response to the question "How useful was the EFB" tended towards the negative. On a scale of 1 (negative) to 5 (positive), pilots, on average provided a rating of between 1 and 1.5 across the first three months of preliminary data collection. The preliminary results from the surveys, interviews, and observations were examined to identify potential usability issues with respect to the EFB hardware and software that may have led to these low ratings. These are discussed below.

Usability of EFB Hardware

Several human factors issues were noted with respect to the EFB's installation, touch screen sensitivity, and brightness.

Installation. Pilots at one airline noted that the installation (i.e., location and mounting system) of their EFB could impede their movement on the flight deck. This issue was noted primarily by captains, who bumped into the EFB while accessing the tiller, although a few first officers mentioned they also sometimes bumped into the EFB as well. These events occurred primarily during taxi operations when the pilot's seat is adjusted close to the flight deck for approach and taxi. Pilots' body size is a contributing factor, such that larger pilots tended to note this as an issue. Pilots mentioned that they keep the EFB in landscape mode (i.e., horizontal orientation) during taxi, take-off, and landing as a workaround. However, in some cases, the locking mechanism for the mounting system was failing; consequently, the EFB could not be locked into landscape mode.

Touch screen sensitivity. All the EFBs used during the operational evaluation will have a touch-screen display. One recurring issue noted throughout the interviews concerned the responsiveness of the touch screen. Some pilots found that some EFB touch screens did not always respond immediately to a touch, whereas others noted that the same touch screens could be too sensitive. Additionally, several pilots at one airline noted that touching the display with their finger did not always produce the desired input; one example given was that the touch screen did not work with cold fingers. To better interact with the EFB, some pilots indicated they use a pen as a stylus; upon hearing this, other pilots noted that they found pen markings on the EFB displays. Unfortunately, using a pen as a stylus could lead to damage of the EFB display (e.g., scratches) and make finger input more difficult. Consequently, one pilot indicated that he was concerned about the durability of the touch-screen display in the long-term.

Brightness. All the pilots at one airline indicated that glare on the EFB was an issue that affected display readability. In particular, the EFB display was not bright enough to be readable during daylight without having the shade down. Some pilots mentioned that on bright days, the EFB can reflect an uncomfortable amount light off of its screen and into the pilot's eyes. Additionally, the night mode was considered to be too bright. In fact, one pilot noted that rather than use the night mode, he used the brightness function at the display to adjust the contrast of the EFB. These issues with readability were reflected in responses to the online survey. On a 5 point scale (1: bad, 3: neutral, 5: good), the average pilot rating for readability was as follows: readability under various lighting conditions (mean = 1.7), readability from sitting position (mean = 2.2), and readability under night mode (mean = 2.5), color readability under all lighting conditions (mean = 2.7).

Software Usability

Human factors observations regarding the use of the airport moving map and other EFB software was collected primarily from the simulator visits. Although the focus of the operational evaluation is the airport moving map software, usability feedback was gathered on other software used on the EFB (e.g., electronic charts and electronic documents) and discussed in this section. Note that the purpose of the evaluations was not to compare the software applications but rather to develop a general understanding of common human factors considerations for EFB software. Thus, specific details for a software application are distinguished only when necessary for understanding the issue.

Airport moving map. Several pilots noted that the aircraft position represented by the ownship symbol on the airport moving map differed from that depicted on their navigation display. In one instance, the nose of the aircraft on the airport moving map was represented by the center of the ownship symbol. For the navigation display, however, the nose of the aircraft is represented by the nose of the ownship symbol. The location within the ownship symbol that corresponds to the position of the aircraft should be consistent across the flight deck.

Electronic Charts. Feedback on two different electronic chart software applications was gathered during the interview sessions. Two primary issues were noted. First was inconsistency between the paper and electronic charting information. At one time during the operational evaluation, pilots at one airline used paper charts from one manufacturer and electronic charts from a second manufacturer. During this time, pilots indicated that the information on the paper charts was laid out differently from the electronic charts, so that they sometimes could not find the information they needed on the electronic chart quickly. One pilot noted that on one flight, he received a runway change and could not easily find a new frequency on the electronic chart. Consequently, two pilots indicated that they relied primarily on their paper charts, although they continue to load the electronic charts on the EFB so that they stay current and familiar with the procedure for doing so. (Note: Since that interview session was conducted, that airline has switched its electronic chart manufacturer so that both the paper and electronic charts are

provided by the same manufacturer. However, this concern was included since it calls attention to the potential impact of the inconsistency in the presentation of charting information.)

A second issue was a failure to preserve the modifications made to electronic charts. Pilots noted that if they left an electronic chart (e.g., by displaying another chart or viewing another page) and then return to it, the zoom settings (map range) is reset to a default level. At one airline, pilots noted that they commonly zoom in on to a chart and then rotate it, but when the chart is rotated, the zoom level is reset to a default level. In some cases, pilots encountered EFB speed and reliability issues, such that these two actions (rotate and zoom) would lock up the EFB.

Electronic documents. Feedback on two different electronic document software applications was also gathered. In general, pilots considered electronic document library an improvement over their paper documents, because it was much more comprehensive than what they could carry in their traditional flight bag. However, pilots noted two examples of when the electronic document did not match the paper one: one was the availability of titles for each document chapter, and the other was in the page numbering. The pages of the electronic document are numbered according to the page in the pdf file, whereas the pages in the paper document are numbered by section number (e.g., page 7-35). This inconsistency may be confusing and increase the time it takes to find the appropriate section or text.

Conclusions

The Capstone 3 operational evaluation intends to examine the potential for safety gains on the airport surface with an airport moving map and to understand the human factors implications involved with the integration of airport moving map displays into the flight deck. The Capstone 3 operational evaluation is still in its inception, so the findings reported here are preliminary. In Fiscal Years (FY) 2011 and 2012, MITRE CAASD and the Volpe Center will continue to work with the FAA to coordinate with the participating airlines as they continue and complete their equipage and submit data in support of the Capstone 3 operational evaluation.

The preliminary feedback has identified potential human factors areas of concern that may be of interest to FAA evaluators or manufacturers developing EFBs and/or airport moving maps, and these findings may inform the design and evaluation process. As with any new technology, the functions and capabilities for EFBs and airport moving maps will continue to evolve, and it will be important to stay abreast of this evolution to understand the human factors implications.

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