

Office of Runway Safety Washington, DC 20591

Capstone 3 Electronic Flight Bag (EFB) – Airport Moving Map Operational Evaluation: Human Factors Report

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METRIC/ENGLISH CONVERSION FACTORS

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| LENGTH (APPROXIMATE) | LENGTH (APPROXIMATE) | | | | |
| 1 inch (in) = 2.5 centimeters (cm) | 1 millimeter (mm) = 0.04 inch (in) | | | | |
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| 1 yard (yd) = 0.9 meter (m) | 1 meter (m) = 3.3 feet (ft) | | | | |
| 1 mile (mi) = 1.6 kilometers (km) | 1 meter (m) = 1.1 yards (yd) | | | | |
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| 1 square inch (sq in, in ²) = 6.5 square centimeters (cm ²) | 1 square centimeter (cm ²) = 0.16 square inch (sq in, in ²) | | | | |
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| 1 tablespoon (tbsp) = 15 milliliters (ml) | 1 liter (l) = 21 pints (pt) | | | | |
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For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price \$2 50 SD Catalog No. C13 10286 Updated 6/17/98

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Executive Summary

In 2008, the Federal Aviation Administration (FAA) Office of Runway Safety sponsored an operational evaluation to:

- understand the safety impact of an Airport Moving Map with ownship position on a Class 2 or Class 3 Electronic Flight Bag (EFB) and/or an approved aural runway safety alerting system, and
- (2) gather information on the usability of the airport moving map software and EFB hardware.

Seven airlines were selected to participate in the Capstone 3 operational evaluation, but only three of the seven airlines established an EFB program: Atlas Air, Shuttle America, and US Airways. None of the airlines chose to implement an aural runway safety alerting system. The goal of this report is to document the human factors effort conducted as part of the operational evaluation, including potential issues with respect to the implementation of Airport Moving Maps and/or EFBs.

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. The results indicated that pilots liked the idea of an "electronic flight bag", particularly as a replacement to their traditional flight bag. Subjective ratings showed that pilots felt the EFB was relatively useful, although 24% of pilots indicated experiencing at least one issue with the EFB during one or more phases of flight. Potential human factors issues identified throughout the operational evaluation fall into the following six categories:

- 1. **Ownship Position Errors**: There were 81 reported position errors (out of 1662 responses; 4.88%) related to ownship or the airport moving map at 18 airports. None of these errors were related to ownship position with respect to runways. Of the reported errors, 1 pilot noted ownship was drawn on or near the edge of the taxiway the aircraft was on, 1 pilot indicated that ownship was drawn on the wrong location in the ramp areas, and 79 pilots noted "Other" errors that did not involve runways, taxiways, grass, or ramp areas.
- 2. **EFB Mounting/Location**: The location of the EFB sometimes impeded the pilot's movement on the flight deck. Additionally, the EFB mounting systems sometimes failed so that pilots could not "lock" the EFB into portrait or landscape mode.
- 3. **Touch Screen Sensitivity**: Several pilots indicated that their finger inputs did not always register immediately on the EFB. Additionally, technology trends have introduced interaction conventions (e.g., "pinch" to zoom), and some pilots attempted to apply gestures from iPad and iPhone systems to PC-based systems, which did not recognize the input.
- 4. **System Responsiveness**: Some pilots felt that the response rate of the EFB was slow and that the recovery time was too long (e.g., to bring up a new chart or document), particularly in time-critical situations.
- 5. **Display readability**: Poor display readability and glare was often cited as a factor that prevented the EFB display from being readable during daylight.
- 6. **Consistency**: Inconsistency in the presentation of information elements (e.g., symbols) or controls with other avionic information (electronic or paper) increased the time to find information, uncertainty in the reliability of the information, and disuse of one or more sources of information. Examples of inconsistencies included differences in the depiction of electronic chart symbols and in the paper chart layout; differences in the layout of a virtual keyboard from one software application to another on the same EFB; and inconsistencies in the presentation of ownship system on their EFB with other flight deck displays.

The information presented is intended to help inform the EFB and airport moving map design and evaluation process. This report is intended to be of use to the Federal Aviation Administration in developing guidance material for EFBs and airport moving maps. 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.

Acronyms

| AC | Advisory Circular |
|--------|---|
| ACARS | Aircraft Communications Addressing and Reporting System |
| ADS-B | Automatic Dependent Surveillance - Broadcast |
| AGD | ADS-B Guidance Display |
| AMM | Airport Moving Map |
| AQP | Advanced Qualification Program |
| ARINC | Aeronautical Radio, Incorporated |
| ASAP | Aviation Safety Action Program |
| ASDE-X | Airport Surface Detection Equipment, Model X |
| ATC | Air Traffic Control |
| CAASD | Center for Advanced Aviation System Development |
| CDTI | Cockpit Display of Traffic Information |
| CFR | Code of Federal Regulations |
| DOT | Department of Transportation |
| EFB | Electronic Flight Bag |
| FAA | Federal Aviation Administration |
| FMS | Flight Management System |
| IATA | International Air Transport Association |
| ICAO | International Civil Aviation Organization |
| ITP | In-Trail Procedure |
| MOU | Memorandum of Understanding |
| NASA | National Aeronautics and Space Administration |
| PMA | Parts Manufacturers Approval |
| RAAS | Runway Awareness and Advisory System |
| RITA | Research and Innovative Technology Administration |
| RTCA | Radio Technical Commission for Aeronautics |
| RVR | Runway Visual Range |
| SAMM | Surface Area Movement Management |
| SMM | Surface Moving Map |
| STC | Supplemental Type Certificate |
| TSO | Technical Standard Order |
| US | United States |
| USB | Universal Serial Bus |
| XGA | Extended Graphics Array |

1 Introduction

The Federal Aviation Administration (FAA) Office of Runway Safety is interested in understanding the impact of an airport moving map with ownship position and/or approved aural runway safety alerting system on operational usability and safety. To gather data on the use of this technology, the FAA Office of Runway Safety sponsored seven airlines to equip revenue aircraft with an airport moving map on a Class 2 or Class 3 Electronic Flight Bag (EFB) and/or approved aural runway safety alerting system and to provide evaluation data to the FAA to help understand the safety impact. Several FAA offices also provided support for this effort:

- Office of Aircraft Certification, Technical Programs Branch (AIR-120);
- Office of Aircraft Certification, Avionics Systems Branch (AIR-130);
- Flight Standards Services, Air Transportation Division (AFS-200);
- Flight Standards Services, Flight Technologies and Procedures Division (AFS-400); and
- Human Factors Division.

The FAA Office of Runway Safety tasked the John A. Volpe National Transportation Systems Center (Volpe Center) and the MITRE Corporation's Center for Advanced Aviation System Development (CAASD) to assist in the implementation and data collection for this effort.

This report is intended to summarize the human factors activities completed as part of the Capstone 3 EFB – Airport Moving Map operational evaluation. Human factors included the following four activities:

- 1. Develop and administer a set of surveys to gather data on the human factors/pilot interface aspects of the EFBs as well as issues associated with their operational use and safety,
- 2. Coordinate with the participating airlines, EFB manufacturers, and airport moving map providers to understand the status of their equipage for the operational evaluation,
- 3. Coordinate and conduct interviews during the operational evaluation to understand usability and safety implications of an airport moving map on an EFB, and
- 4. Analyze the questionnaire data.

This report is organized into the following four sections. Section 2 describes the status of the participating airlines in September 2012, when the program ended. Section 3 describes the surveys designed to gather human factors information from this operational evaluation and the data protection agreement coordinated with the airlines to collect this information. Section 4 provides the results of data collection, and Section 5 contains a discussion of recurring human factors issues.

2 Participating Airlines

Seven airlines were selected to participate in the Capstone 3 EFB – Airport Moving Map operational evaluation, but only three of the seven airlines established and supported an EFB program: Atlas Air, Shuttle America, and US Airways. The status of these three airlines is described in Table 1. Summaries for each of the Capstone 3 participating airlines are provided following the table.

Table 1 highlights the following information:

- The EFB hardware and airport moving map software selected. Details on display characteristics of the EFB hardware (e.g., the display size and display resolution), the location of the installation, and a list of other software to be used on the EFB is also included.
- The number and type of aircraft equipped (Note that all three airlines proposed installing two EFBs on each aircraft)
- Status of the equipage and schedule
- Training method

Some of the Capstone 3 airlines also participated in other EFB-related activities and provided human factors input on the usability of the EFB from these other efforts, as described in Table 2.

| | Atlas Air | Shuttle America | US Airways | |
|--------------------------|--|---|---|--|
| EFB | Astronautics AMT for content management (ECS is integrator) | DAC (Canard is integrator) | Goodrich | |
| Hardware Class | Class 3 installed | Class 3 avionics, installed as Class 2 | Class 3 installed | |
| Display Size | 10.4inch (8.0"x10.3"x1.132") | 8.4" (9.9" x 6.9") | 10.4" | |
| Orientation | Landscape | Landscape (Mount allows rotation to portrait) | Landscape (Mount allows rotation to portrait) | |
| Resolution | XGA 1024 x 768, Active Matrix Liquid Crystal Display | XGA 1024 x 768 | XGA 1024 x 768 | |
| Aural Alerting System | No | No | No | |
| Airport Moving Map | Jeppesen Airport Moving Map (Version 7.0) | Jeppesen Airport Moving Map (Version 7.0) | Jeppesen Airport Moving Map (Version 7.0) | |
| Operating Shell | AMT/Windows OS | Jeppesen/Windows OS | Windows OS A330 (Windows + Certified OS | |
| Aircraft | 19 747-400F (17 funded under Capstone 3 program). Delivery for three Atlas Air aircraft is delayed but six Polar Aircraft are being provisioned as well. | 20 ERJ-170 proposed 22 completed | 20 Airbus 319 (Note: 20 A330 to be equipped for ADS-B evaluation) | |
| # EFBs / aircraft | 2 | 2 | 2 | |

Table 1. Equipage of Capstone 3 Participating Airlines

 Table 1. Equipage of Capstone 3 Participating Airlines (continued).

| | Atlas Air | Shuttle America | US Airways | |
|-----------------------------------|--|--|---|--|
| Equipage schedule | TBD. Atlas Air received approval/issuance of the STC in April 2012 and the first PMA was issued in June 2012. Atlas Air did not complete installation of their aircraft before September 2012. Atlas Air will roll EFBs to the line as aircraft are available. They anticipate it will take approximately 3 months to install EFBs on all aircraft. | Initial EFB equipage completed Sept 2009. EFB configuration modified in June 2010. Shuttle America has completed their participation in this program. | EFBs installed in 20 A319s; EFBs activated in 16 A319s. Activation of EFBs was delayed by power transfer issues. 16 A330 aircraft equipped (5 activated) Installation of surface moving map in simulator completed in June 2011 | |
| EFB location on flight deck | R2 and L2 window-mount | Side-mount by window (in place of chart clip) | Below sliding window sill on both sides | |
| EFB Installation Configuration | Mount with slider (EFB orientation is fixed) | Below the side windows; ball mount allows EFB to be rotated 360° and tilted | Below the side windows | |
| Battery | Lithium polymer (this will be part of STC) | Nickel metal hydride | No battery | |
| Communication | USB. Initial launch will not have wireless capabilities. 3G/4G in the future | ACARS | Start with 3G capability, restricted to use on the ground. No wired connections. | |
| Other EFB applications | Electronic charts (Jeppesen Chart Viewer), electronic documents for Atlas Air company forms, and AMT journey log | Electronic charts (Jeppesen chart viewer), electronic documents (via pdf viewer) | Electronic charts (Jeppesen chart viewer), electronic documents (Jeppesen/ARINC document viewer) | |
| Proposed training method | Computer based training/ distant learning. Recurrent ground school and Proficiency Checks will also cover EFB use. Atlas Air has completed pilot training. The AMM training materials are complete and approved. | Hands-on training in simulator (in St. Louis). Sessions consisted of one-on-one training with an instructor and check airman, crewmembers in front. | Four-part training module (the last module is an evaluation module) and a bulletin that informs pilots they should use paper if they are not comfortable with the EFB and to try using the EFB in low workload situations. EFBs installed in two A319 simulator and A330 simulators, but pilots will not be mandated to use EFBs during training. All check airmen were given an overview of the EFB and EFB software, and each check airman was required to conduct a 15-minute briefing on the EFB to demonstrate their understanding and their ability to teach it. | |

Table 2. Capstone 3 Airlines: Other ongoing EFB-related airline activities.

| | Atlas Air | Shuttle America | US Airways |
|--|--|--|---|
| Other Activities (beyond the minimum required by the contract) | Equip the entire 747-400F fleet if additional funding is received. Consider use of Samsung 7.7" tablets (Class 1 EFBs) to show electronic manuals and other documents. Atlas Air would like the tablets to be data- connected via 4G or wi-fi with possibility of creating wi-fi charging facilities at base locations. Batteries have long life but mitigations are also proposed (battery packs plug into the devices to mitigate battery failures or create operational redundancy with additional tablets.). | Equip the entire fleet (43 aircraft). Shuttle America would like to have the latest aircraft with the latest equipment, and develop an AQP training program, like the major airlines. | A330 aircraft will be equipped with EFB, ADS-B In and ADS-B Out. This project is conducted as part of the FAA ADS-B Program Office's test of ADS-B Out, ADS-B-In, and CDTI with AGD. Joint testing with ACSS for certification of Surface Airport Movement Manager. US Airways is submitting data for the Capstone 3 surveys from their A330 aircraft. |

Atlas Air

- Installation
 - Atlas Air planned to install Astronautics Class 3 EFBs on 19 of their Boeing 747 aircraft (17 of which were funded under the Capstone 3 program). Installation of the EFBs was not completed before September, 2012. Additionally, delivery for three Atlas Air aircraft was delayed, but Atlas Air planned to provision up to six Polar Aircraft. Eighteen aircraft were wired to support the EFBs.
 - Atlas Air planned to launch with Jeppesen's Airport Moving Map, Version 7.0. The Jeppesen Airport Moving Map application was integrated into AMT's Flightman software. AMT Flightman is managing multiple applications including Jeppesen's electronic charts, Airport Moving Map, electronic manuals, a journey log, company forms, and the Capstone 3 EFB survey. Atlas Air also had an onboard performance system application.
 - Atlas Air received the Supplemental Type Certificate (STC) for the installation and activation of their EFB in April, 2012. The first Parts Manufacturers Approval (PMA) was issued in June 2012. Atlas Air conducted configuration testing with the integrated EFB hardware and software in their simulator and labs. The tests identified issues with processing speed, were resolved in conjunction with Jeppesen but delayed initial installation of the EFBs. Atlas Air planned to conduct user acceptance testing in September 2012 and anticipated beginning installation in October. The installation will be phased in to the fleet to better address issues (if any) that arise. Atlas estimates that it will take approximately three months to install units on all aircraft. This timeline is contingent on available ground time.
- Training

Atlas Air began their EFB training program in mid-March, 2012 and completed in by mid-April, 2012. The training took approximately 15 days to complete. The training program includes a module that highlights differences for the Dash 8.

Shuttle America

- Installation
 - Shuttle America initially equipped 20 aircraft with the DAC EFB and MapTech electronic charting software in September 2009. No airport moving map was installed at that time. Shuttle America intended to equip with the MapTech airport moving map, but decided to move to Jeppesen Flight Deck Pro 7.0 early in 2010.
 - The aircraft were equipped in two ways. *Phase 1* aircraft EFBs were not connected to the 429 data bus, so the EFBs could not show ownship position (20 aircraft). *Phase 2* (Capstone 3) aircraft EFBs were connected to the 429 data bus and presented ownship position on the Airport Moving Map (20 aircraft).
 - EFBs were installed in Shuttle America's ERJ-170 simulators at FlightSafety International (FSI) in St. Louis, Missouri (see Figure 1). As shown in the figure, the EFBs are mounted under the side window (in place of the clipboard where pilots currently clip their paper charts).



Figure 1. EFBs in the Shuttle America simulators (ERJ-170).

• Training

Shuttle America provided hands-on training for the EFB and airport moving map software in their simulator (in St. Louis). Through the evaluation, Shuttle America was considering how the EFB would be used during line operations (e.g., pilot techniques and procedures for EFB use based on what works during line operations) and to establish those procedures.

Data Collection

Pilots at Shuttle America participated in two focus group conducted by the FAA, Volpe Center, and MITRE (October 2009 and February 2011). Both focus groups were held at their training facilities in Indianapolis, Indiana. During the focus groups, pilots provided feedback on the usability of the EFB hardware (e.g., its accessibility on the flight deck, the readability of the display).

Additionally, Shuttle America began submitting data to the FAA/MITRE in support of the operational evaluation in January 2010. Data collection stopped in February 2010 when Shuttle America began their integration with the Jeppesen Airport Moving Map software. Data collection resumed in August 2010 with pilots submitting feedback online regarding the usability of the EFB.

• Shuttle America concluded their participation in the Capstone 3 program in February 2012 with plans to transition to a new generation of EFBs.

US Airways

- Installation
 - US Airways selected the Goodrich EFB hardware and the Jeppesen Airport Moving Map software. US Airways has installed EFBs on 20 of their A319 aircraft; EFBs have been activated in 16 aircraft. Activation of the EFBs on the A319 fleet was delayed by a power transfer issue. The EFBs have no battery and can tolerate only a 200ms power interruption. On some aircraft, however, the power transfer when the engines were started exceeded this 200ms limit, and in some cases, the EFB shut down and became corrupted. The fix for the power transfer issue required issuance of an STC.
 - The EFBs are mounted under the sliding window on both sides (see Figure 2). The EFBs can be rotated so that the information can be viewed in landscape or portrait mode. The EFB slides with the window to prevent any egress issues. US Airways installed EFBs in four of their aircraft simulators: two A319s and two A330. The EFBs in the A330 simulator are mounted using a slider, so they will not rotate.



Figure 2. EFBs in the US Airways simulators.

- US Airways had previously received Phase 4 authorization (OpSpecs A061) to use the EFBs; in this phase, pilots will continue to carry paper onto the flight deck. US Airways expects to remain in their EFB evaluation period for some time. Only 20 aircraft in their A319 fleet are being equipped with EFBs, so the airline will not remove paper right away. Once US Airways has completed EFB installation and activation in all 20 of their A319 aircraft and A330 fleet, US Airways will begin a 6-month look at the reliability of EFBs on the flight deck as well as how pilots are acclimating to the EFBs.
- Training

US Airways provided their pilots with a four-part training module (the last module is an evaluation module) and a bulletin on EFB use. The bulletin informs pilots they should use paper if they are not comfortable with the EFB and to try using the EFB in low workload situations. Pilots may also use the EFBs in the simulator, but they are not mandated to use the EFBs during training. Additionally, all check airmen were given an overview of the EFB and EFB software, and each check airman was required to conduct a 15-minute briefing on the EFB to demonstrate their understanding and their ability to teach it.

At this time, US Airways has completed training on the Jeppesen applications. However, due to delays in the activation of the EFBs, US Airways plans to introduce a training module to refamiliarize pilots with the EFB once EFBs in all 20 A319 aircraft have been activated.

• Other EFB efforts

US Airways is equipping 20 A330 aircraft for an Automatic Dependent Surveillance – Broadcast (ADS-B) flight operational evaluation sponsored through the FAA Surveillance and Broadcast Services Program Office. The EFBs will host the ACSS SafeRoute product (SAMM: Surface Area Movement Management) and Jeppesen software. EFBs have been installed in 16 A330 aircraft. US Airways has defined four phases for this effort:

- Phase 1. EFBs are installed with a Windows operating system and run Type A and B software. Pilots who fly the A330s are asked to use the Jeppesen Airport Moving Map software on the ground.
- Phase 2. EFBs will be installed with the DEOS (Type C) operating system to begin US Airways' in-flight operational evaluation. US Airways will uninstall the Windows operating system in this phase, until they determine how the two operating systems can be run simultaneously. Only Type C software can be used in this phase. US Airways plans to use the UCDTI software which include SAMM, merging and spacing, and ADS-B In-Trail Procedures (ITP).
- Phase 3. EFBs will run a Windows operating system for Type A and B applications and a DEOS (Type C) operating system.
- Phase 4: US Airways will begin a 6-month evaluation period to examine the reliability of the EFBs.

As of September, 2012, US Airways was still in Phase 1 of this effort. Once Phase 2 is approved, US Airways will activate one A330 aircraft to test the SAMM product.

Data Collection

US Airways started submitting survey responses for the EFB survey in March 2011. Data was submitted from 13 A319 aircraft and three A330 aircraft.

One of the issues that potentially influenced the response rate was the two-step process required to submit the survey. When pilots completed the survey, they needed to exit the survey, and then go to the EFB menu system to select a button to hit send. Data could be sent only at the gate. Consequently, it was possible that some pilots were simply exiting the survey before transmitting the data.

US Airways set up the transmission of the EFB survey data so that during the pre-flight process, the flight crew could select a "transmit" button that submitted the survey responses provided by the previous flight crew. (This configuration was necessary because pilots could not submit survey data via the AT&T 3G network when they were en route and the wireless card was turned off.) US Airways and MITRE discussed the possibility of developing software that would allow the survey to be submitted automatically once it was completed by the pilots (i.e., to eliminate the need for pilots to hit the "send" button).

3 Surveys

The FAA originally proposed to collect data regarding the safety impact of the airport moving map and EFB using the EFB during line operations, e.g., when the aircraft was at the gate. However, the participating airlines indicated that significant time constraints would limit pilots' ability to provide input on the airport moving map/EFB if this were the only opportunity for data collection. Several airlines indicated a desired turn-around time between flights of approximately 20 minutes and noted that taking time to complete a survey could impact their flight operations. Thus, rather than present only one survey for the evaluation, the Volpe Center coordinated with the FAA and MITRE to design three surveys: *Capstone 3 EFB Survey, Online Survey*, and *Interview Survey* (included as Appendix A). Each survey was suited to meet different goals, depending on the operational setting.

Section 3.1 provides an overview of the three surveys and the design considerations used in developing them. Section 3.2 describes the user guides developed to support the airlines in implementing the surveys. Finally, Section 3.3 details the data collection opportunities.

3.1 Survey Design

The intent in developing the surveys was to develop a comprehensive list of questionnaire items that could be used throughout the operational evaluation. The techniques were also intended to be used for all the airlines regardless of their specific EFB hardware and software. Four steps were taken to develop the data collection tools. First, the Volpe Center, FAA, and MITRE conducted discussions with airlines to identify and understand operational issues that could influence data collection during the operational evaluation. Second, questionnaire items used in previous airport moving map or EFB research studies were collected and reviewed to identify those that would be relevant to this operational evaluation. Such a review could allow data collected in this effort to be compared with results from previous research studies. Third, questionnaire items were developed to address issues of interest that were not covered as thoroughly in previous research. Finally, the surveys were distributed for public comment to the participating airlines, industry, and FAA organizations working on this program prior to a Capstone 3 EFB-Airport Moving Map Industry Day in January 2009. One airline and two manufacturers submitted formal comments. Additionally, feedback from attendees at the FAA-industry meeting was obtained from a review of the surveys during the meeting.

The content and method of administration for the three surveys are described below and summarized in Table 3. The surveys were intended to be only a starting point for identifying issues with the EFB and/or airport moving map. It is important to note the purpose of these surveys was to develop a general understanding of pilots' perceptions regarding these technologies and not to compare performance across pilots or airlines. The pilot completing the survey was not asked to provide any identifying information.

The EFB and airport moving map application, the operational procedures regarding their use, and the training provided differed from one airline to another. In administering the surveys, it was expected that pilots would be appropriately trained in the use of the airport moving map application and EFB so that they could use it properly and provide meaningful feedback. The surveys would be identifiable according to the airline submitting the responses, so that the context and reasoning for pilot responses, particularly any unfavorable ones, could be understood. It may be the case that an unfavorable response regarding the airport moving map or EFB was not due to the technology but rather a consequence of an issue that was unexpected that must be fixed or mitigated.

Table 3. Overview of Pilot Surveys

| | Capstone 3 EFB Survey | Online Survey | Interview Survey | |
|--|--|---|--|--|
| Purpose | Gather key information specific to taxi events that have just been completed | Gather more details about taxi events at a time more convenient to the pilot | Collect contextual insight and subjective reactions through face-to-face discussions | |
| Survey Environment | On the aircraft | At home/office (outside of the aircraft) Crew lounge, training/simulator facilit | | |
| Proposed Method | Survey installed on EFB | Web-based | In person | |
| When to complete Immediately after take-off or landing At pilot | | At pilot's discretion | Coordinated with each airline | |
| Content | Quick perceptions on operational/safety benefits and areas for improvement (1-5 rank & multiple choice) | More in-depth, covering demographics and various aspects of SMM and EFB (1-5 rank & multiple choice) | Open-ended questions addressing pilots' experiences with the EFB and airport moving map | |
| Number of Items | 10 | 33 | Approximately 10 | |
| Estimated completion time | 1-2 minutes | < 15 minutes | approximately 30 minutes | |

Capstone 3 EFB Survey (see Appendix A)

This survey addressed information specific to a particular taxi segment. The survey was 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 the second time after landing at the arrival airport, when the aircraft was parked at the gate. The surveys were intended to be completed *after* taxi out and take-off or *after* landing and taxi-in for every airport. The number of questions was limited to 10 items so the survey could 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 survey was intended to obtain pilots' opinions of whether the airport moving map with ownship position and/or EFB provided an operational and/or safety benefit and areas for improvement, such as database accuracy or pilot interface/usability.

The first six questions of the survey gathered background information regarding the flight (e.g., airport name, pilot's responsibility during the taxi, visibility). Two survey paths followed, depending on whether the aircraft was equipped with the airport moving map and whether pilots referred to the airport moving map (see Figure 3). Pilots who indicated that they used the airport moving map then answered four questions specific to the usability of the software and accuracy of the airport moving map. Because it was expected that some pilots would not use the airport moving map (e.g., the pilot taxiing may be looking out-the-window during the entire taxi or the pilots may be very familiar with the airport and taxi route), the survey included four questions to collect information specific to the usability of the EFB. These EFB-specific survey questions were completed only if pilots indicated that they did not use the airport moving map. The EFB-specific survey questions also allowed airlines who were able to implement the EFB on the flight deck before using the airport moving map software to begin data collection.



Figure 3. Capstone 3 EFB Survey Paths.

Note that the questions presented on the EFB Survey could be modified (as needed) to gather additional usability information or clarification on the EFB and/or airport moving map software.

This survey was administered on the EFB. MITRE developed the software for the survey and a process for the airlines to electronically transmit the survey responses to MITRE. MITRE coordinated a Memorandum of Understanding (MOU) with each Capstone 3 airline to ensure pilot anonymity and data protection through the collection and analysis of the EFB Survey responses.

To support the implementation of the surveys, a detailed user guide describing how the survey on the EFB should be completed was developed and provided to all the airlines (Appendix D). A one-page summary was also developed, with specific instructions for addressing errors in the airport moving map (Appendix E).

Online Survey (Appendix B)

The purpose of this survey was to capture a comprehensive list of safety/usability issues. We developed 64 questionnaire items addressing pilots' interactions with the airport moving map application, the EFB, and if available, any aural runway safety alerts. Note that although none of the participating airlines planned to initially equip with aural runway safety alerts, survey questions were developed to support human factors data collection if this capability was implemented. These survey items were not presented all at once to limit survey completion time; rather, they were intended to be used in a series of surveys, each of which contained only a subset of the items. Thus, the Online Survey that was deployed contained approximately 30 items.

Responses to items on this survey were not expected to change from one flight to another, so the survey could be completed when pilots had more time than they would during line operations. The survey was to be administered online on a website hosted by MITRE. Per the MOU, MITRE would ensure pilot anonymity and data protection through the collection and analysis of the Online Survey responses.

The Online survey addressed four topic areas:

- Airport Moving Map Safety
- EFB

- Background/Demographics/Training
- Other Software

Questions related to *Airport Moving Map Safety* included 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* addressed the ease of accessing information, the consistency of information presentation, the readability of that information, and the usability of buttons and controls. *Background/Demographics/Training* questions gather information on pilots' flight experience and familiarity with EFBs and airport moving maps. Finally, survey items addressing *Other Software* were developed to gather usability feedback on other software (in addition to the airport moving map) that airlines used during the operational evaluation, e.g., electronic charts, electronic documents, or a traffic display.

Interview Survey for Airline Training/Simulator Facilities and/or Pilot Lounges (Appendix C)

Several airlines provided an opportunity to speak with pilots directly about their experiences with the airport moving map application and EFB display either at airports or at their simulator/training facilities. Such a setting allowed for more detailed responses and provided a framework for interpreting the responses provided by the operational and usability surveys. This survey provided a list of questions to structure the pilot interviews. Additional questions and discussion points were expected to arise during the interviews.

3.2 Survey Usability and Findings

MITRE led the development of the software to support the electronic administration of the "Question for Display on the EFB" and the "In-Depth Optional Survey". The Volpe Center developed the actual survey questions and coordinated with MITRE to design the user interface for the survey software. Before fully deploying the Capstone 3 EFB survey, the human factors team evaluated the user interface for the survey and the understandability of the questions themselves. One concern from the FAA and airlines in implementing the survey during revenue flight operations was the time required to complete the survey. Thus, a key focus of the usability evaluations was to find out how long the survey took to complete. The feedback from the usability evaluations was incorporated into the redesign of the survey.

As part of preliminary visits with two airlines, the Volpe Center and MITRE researchers conducted informal usability evaluations of the Capstone 3 EFB survey. This section notes key human factors considerations identified through the usability evaluations and the resolution.

• Completion time

The time required to complete the survey was evaluated with pilots from two airlines (Airline 1 and Airline 2). Pilots were presented with a take-off scenario (e.g., imagine that you departed Atlanta on a clear day and are now in cruise flight) and then asked to complete the survey. Pilots were presented with 2-3 different scenarios so that we could see whether familiarity with the survey influenced response time. On average, pilots took approximately 90 seconds to complete the survey the first time (i.e., when they were not familiar with the questions). By the second time pilots completed the survey, the completion time dropped to around 40 seconds.

• Understandability of the survey questions

Issue: The question on the survey requesting that pilots indicate whether they were the one who taxied the aircraft on the airport surface or not was not well understood. The original wording of the survey question was as follows:

Position: Taxiing or Not Taxiing

Note that although most airlines assign taxi responsibility as a function of flightcrew role – that is, Captain (taxi) or First Officer (not taxiing), we chose not to use flightcrew role as the basis for the survey responses to protect the identity of the respondents. Additionally, in some rare cases, a flightcrew may be composed of two Captains, one of whom is acting as the First Officer.

Many of the pilots from both airlines interpreted "position" as being where the aircraft was and not where they were sitting. Pilots from Airline 2 thought that the terms "pilot flying"/ "pilot not flying" were more suitable, but this implementation may be appropriate only for that airline, where procedures require that the pilot flying be the one who taxies.

Resolution: The word "Position" was removed, and numbers to identify each survey question were added. The question now appears as:



• Airport Information

Issue: The EFB survey does not currently check to ensure that a valid airport code is entered. *Resolution*: No change. MITRE monitored the EFB survey results and examined the likelihood for data entry errors. Based on the initial pilots' responses, it was determined that checking the airport code at the time of data entry was not necessary.

• Virtual keyboard

Issue: The keyboard used to enter airport information on the survey displays 6 keys on a row (e.g., the letters on the first row are A - F). One pilot noted that this layout is inconsistent with the FMS keyboard, which has 5 keys on a row (e.g., the letters on the first row are A - E).

Resolution: No change. The number of keys presented on FMS keyboards varies from 5 keys/row -7 keys/row, depending on the type of aircraft. Customizing the keys on the virtual keyboard for the FMS survey to match the number of keys on the FMS keyboard for the different aircraft used by the airlines would require creating a customized survey for each airline.

Issue: The only means for correcting an error is to select the "clear" button, which erases input one letter at a time. Two pilots thought that the action performed would be better described as "backspace", since they expected "clear" to erase the entire field. Additionally, the virtual keyboard provided for the EFB survey allows only one way of editing entries (via the "clear" button). For consistency with the virtual keyboards on other applications used by Atlas Air, a button to erase the entire field may be desirable.

Resolution: No change. The "clear" button is consistent with the action performed by the FMS on the flight deck.

• Accessing the EFB Survey

Issue: Each airline will have their own process for displaying the survey depending on how the survey is integrated into their EFB.

Resolution: A process should ensure that pilots understand where the EFB survey is located and how to access it.

• Display Orientation

Issue: One airline is currently displaying the survey in landscape mode rather than portrait mode. Consequently, each page of the survey was scaled to fit a 1024 (length) x768 (height) display (rather than a 768 (length) x 1024 (height)). Because the survey was designed to be presented in portrait mode rather than landscape mode, the following user interface issues occurred:

- Time of Day, RVR: The button labels for the responses are not centered within the button.

- The lengths of the lines used to separate each question were customized for portrait mode. Consequently, the lines are drawn only halfway across the page.

Resolution: No change. There were four options discussed for addressing these issues:

- a. Display the EFB survey in portrait orientation. The EFB is installed in a landscape orientation off to the pilot's side (i.e., under the side window). Note that this assessment of orientation is based on the frame of reference of the EFB. If the frame of reference used to judge the EFB orientation is that of the pilot facing out the forward window, then the EFB can be considered to be shown in portrait mode. This is how pilots will view their approach charts. However, the presentation of the survey would differ from the presentation of other software on the EFB.
- b. Continue to display the portrait version of the EFB survey in landscape mode since the issues are only cosmetic.
- c. Rescale the EFB survey when it is presented in landscape orientation to resemble a portrait orientation. (Note: One disadvantage of this option is that the size of the buttons on the touch screen will be reduced in size as a consequence, and therefore, the buttons must be evaluated to ensure they are still usable.)
- d. Create a separate landscape version of the EFB survey. Alternatively, the EFB survey application should check if the display is configured in portrait or landscape mode and display the survey accordingly. This will avoid customization of the survey for individual airlines and same software version can be used with all airlines irrespective of the EFB hardware display.

3.3 Data Collection Issues and Opportunities

The Volpe Center spoke with each airline about any potential considerations or concerns regarding data collection from the airline perspective as well as various opportunities for supporting the data collection (e.g., to increase the response rate). As part of these discussions, it was determined that the Volpe Center would track the timeframe each airline started their data submission for the Capstone 3 EFB survey, the in-depth optional (online) survey, and the coordinate individual interviews with each airline's pilots through the airline project manager.. Additionally, the Volpe Center was tasked with gathering feedback on the accuracy of the airport moving map databases. The results of these discussions with each of the three participating airlines are described in Table 4.

Table 4. Data collection considerations and opportunities.

| | Atlas Air | Shuttle America | US Airways | |
|---|--|---|---|--|
| Survey Considerations | N/A | Pilots were asked to complete the survey at least once a day in cruise flight only. | Priots were instructed to complete the survey in the air and on the ground. Transmission of the EFB survey data was part of the pre- flight process; the flight crew selected a "transmit" button which submitted the stored survey responses provided by the previous flight crew. US Airways submitted data for both their A319s and A330s (as able). MITRE configured the EFB survey to distinguish from which aircraft the data was being collected. | |
| Timeframe for Beginning EFB and Online Survey Data Submission | TBD | August/September 2011 from three test aircraft | March 2011 | |
| Interviews/ Observations | EFB units are currently installed in the simulator only for testing purposes and removed after the testing has been completed. | At recurrent training sessions (conducted every week in Indianapolis) or simulator visit to St. Louis. | The EFB/surface moving map was installed on a simulator in Charlotte, but no observations could be conducted during actual training sessions. | |

4 Results

This section presents an overview of the findings from the data collection efforts conducted through August 2012. The data shows that pilots responded positively to the use of airport moving map and the EFB. Pilots liked the idea of an "electronic flight bag," particularly as a replacement to their traditional flight bag. Additionally, the mean subjective ratings for the airport moving map suggested there was utility in position awareness, in increasing safety of taxi operations and in making it easier to perform other flight deck duties. However, there were some human factors issues identified related to the potential for ownship position errors; EFB mounting/location, which impeded pilot's movement on the flight deck; touch screen insensitivity; system unresponsiveness, poor display readability due to glare; and inconsistency in information presentation across flight deck systems.

Section 4.1 describes the findings from the Capstone 3 EFB Survey and Section 4.2 presents notes and observations from interviews and simulator visits.

4.1 Capstone 3 EFB Survey

This section describes the results of the EFB Survey. The results presented here cover the period from March 2011 to August 2012. A total of 2560 responses were received during this period; 1974 responses reported having the airport moving map onboard the aircraft, of which 312 reported never using the airport moving map. This resulted in a total of 898 reported using the EFB only. 1178 responses (46%) were from the Pilot Taxiing while 1382 (54%) were from the Pilot Not Taxiing.

4.1.1 Airport Moving Map

Of the 1974 responses that reported having the airport moving map onboard the aircraft, 312 (15.8%) reported never referring to it while 1662 (85%) reported referring to it during taxi. The results presented here are based on these 1662 responses.

The following are the 5 questions regarding the airport moving map that pilots answered:

- 1. How often did you refer to the airport moving map display on this segment?
- 2. How did the position awareness provided by the airport moving map with ownship compare to a paper/electronic airport chart only?
- 3. How did the airport moving map affect other duties compared to a paper/electronic airport chart only?
- 4. How did the airport moving map affect the safety of taxi operations on this segment?
- 5. What was the most significant position error of ownship or the airport moving map that you observed during this taxi segment?
 - No Errors,
 - Ownship was drawn on the wrong runway,
 - Ownship was drawn on or near the edge of my runway,
 - Ownship was drawn on the wrong taxiway,
 - Ownship was drawn on or near the edge of my taxiway,
 - Ownship was drawn in the grass,
 - Ownship was drawn in the wrong location in the ramp areas,
 - Other

Figure 4 shows the average ratings for the first four questions on the airport moving map. Pilots reported referring to the airport moving map fairly frequently with a mean rating of 3.69. They also reported that the airport moving map increased safety (mean = 4.37), increased position awareness (mean = 4.37) and that it was relatively less difficult to perform other duties (mean = 4.01).

Figure 5 shows the percentage of pilots who reported observing different ownship position errors. 95.1% of pilots who responded observed seeing no errors in ownship position. Among the pilots who did report

errors, one pilot reported seeing ownship drawn on the wrong location on the ramp area. Another pilot reported seeing ownship drawn on or near the taxiway, and 4.8% of pilots reported seeing "Other" errors in ownship position. Of note is that none of the pilots reported an error in ownship position with respect to runways. A list of the airports at which an error was reported and the type of error is listed in Table 5. Numbers in the cells indicate the number of reports of that particular error at that particular airport.



Figure 4. Average ratings for how often pilots referred to the airport moving map, the airport moving map's impact on position awareness, ease of performing other duties and impact on safety.



Figure 5. Percentage of pilots who reported observing different ownship position errors.

| Airport | Runways | Taxiway | Ramp | Other Error |
|--|---------|---------|------|-------------|
| Charlotte/Douglas International Airport (KCLT) | | 1 | | 27 |
| Boston Logan International Airport (KBOS) | | | | 14 |
| Ronald Reagan Washington National Airport (KDCA) | | | | 11 |
| Dallas/Fort Worth International Airport (KDFW) | | | | 1 |
| Philadelphia International Airport (KPHL) | | | | 8 |
| Chicago O'Hare International Airport (KORD) | | | 1 | |
| LaGuardia Airport (KLGA) | | | | 7 |
| Phoenix Sky Harbor International Airport (KPHX) | | | | 1 |
| Denver International Airport (KDEN) | | | | 1 |
| John F. Kennedy International Airport (KJFK) | | | | 1 |
| Minneapolis-St Paul International/Wold-Chamberlain Airport (KMSP) | | | | 1 |
| Frankfurt International Airport (EDDF) | | | | 1 |
| Leonardo da Vinci–Fiumicino Airport (LIRF) | | | | 1 |
| Hartsfield - Jackson Atlanta International Airport (KATL) | | | | 1 |
| Palm Beach International Airport (KPBI) | | | | 1 |
| Indianapolis International Airport (KIND) | | | | 1 |
| Memphis International Airport (KMEM) | | | | 1 |
| Unknown | | | | 1 |
| TOTAL | 0 | 1 | 1 | 79 |

Table 5. List of airports for which pilots reported errors on the airport moving map or ownship position.

4.1.2 EFB Survey

A total of 898 responses were received for the EFB survey; 312 of these were from pilots who reported having the airport moving map onboard the aircraft but never referred to it at all. The results from all 898 pilots are presented here.

The following are the four questions regarding the EFB that the pilots answered:

- 1. Was the workload required for completing a task with the EFB equal to or less than the workload for completing the task with paper?
- 2. How did the addition of the EFB in the flight deck affect the time available to scan other displays?
- 3. How useful was the EFB?
- 4. Were there any problems with the EFB system hardware or software during the flight? If Yes:
 - During pre-departure
 - During taxi out
 - During take-off/climb-out
 - During cruise

- During approach/landing
- During taxi in



Figure 6 shows the average ratings for the first 3 questions regarding the EFB.

Figure 6. Average ratings for the workload performing other duties with the EFB, time available to scan other displays with the EFB on the flight deck and the usefulness of the EFB.

Pilots rated the EFB as relatively useful (mean = 3.69). Pilots were relatively neutral in their responses to the workload required for completing a task compared to using paper (mean = 3.44) and the time available to scan other displays with the addition of the EFB on the flight deck (mean = 3.37).

Of the 898 responses about the EFB, 75.31% reported no problems with the EFB software and hardware. The remaining reported problems in at least one phase of flight, up to six phases of flight. These phases of flight included during pre-departure, during taxi out, during takeoff/climb-out, during cruise, during approach/landing and during taxi in. The pilots reported encountering problems with EFB software/hardware in a total of 314 phases of flight. Figure 7 shows a breakdown of the proportion of reported problems by phase of flight.



Figure 7. Proportion of Reported Problems with EFB Software/Hardware by Flight Phases

30% of the total problems encountered were reported to have occurred during pre-departure. Similar proportions were reported to have occurred during taxi out (28%) and taxi in (26%). Five percent of the problems encountered were during approach/landing and during taxi out, separately. The remaining 6% occurred during cruise.

In summary, the responses pertaining to the usefulness of the EFB were relatively positive. However the responses were relatively neutral when considering the amount of time available to scan other displays and the workload required to perform a task with the EFB compared to using paper. One possible explanation for this relatively neutral response to the use of the EFB on the flight deck could be that problems with EFB software or hardware were reported by approximately one quarter of respondents.

4.2 Simulator Visits and Interviews: Notes and Observations

The Volpe Center coordinated with each airline to facilitate a simulator visit for the Capstone 3 project team to observe each airline's installation of their EFB and their operational use of the airport moving map. Additionally, throughout the operational evaluation, the Volpe Center was tasked to coordinate and conduct interviews with pilots from the participating airlines to understand the usability and safety implications of the airport moving map on the EFB. One request from the airlines regarding their pilots' participation in these interviews was a letter or agreement stating that their pilots would not be held liable for any information discussed during the interviews. (The letter of data protection assurance drafted by the Volpe Center Office of Chief Counsel that was provided to the airlines is provided as Appendix F.)

4.2.1 Interviews

Two airlines provided the opportunity to conduct interviews.

Shuttle America. Two interview sessions were conducted with Shuttle America's pilots. 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. At the time, 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, Shuttle America 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. Shuttle America 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.

Atlas Air. In June 2010, the Volpe Center visited Atlas Air 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 issues with the software suite the airline was using for the Capstone 3 operational evaluation. During the session, the Volpe Center met with five pilots. The pilots, working in groups of two or three, 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.

4.2.2 Simulator Visits

Team members from the FAA, MITRE, and US DOT Volpe Center have conducted four simulator visits. Team members visited Atlas Air in June 2010 (in conjunction with the pilot interviews), US Airways in August 2010 and then again in March 2011, and Shuttle America in February 2011.

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 involving 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.

4.2.3 Findings

The findings from the interviews and observations from the simulator visits are presented in the following three sections. Section 4.3 describes the feedback received regarding the usability of the EFB hardware, and Section 4.4 provides the findings related to the EFB software.

The purpose of the interviews was to understand the potential human factors issues associated with this technology and not to compare the different technologies or the differences in the implementation across the airlines. Thus, the findings from the interviews and simulator visits are presented in this report without specifically identifying the airline or the EFB manufacturer. Rather, the four airlines will be referred to as Airline 1, Airline 2, Airline 3, and Airline 4, and the EFB manufacturers for each airline will be referred to as EFB 1, EFB 2, EFB 3, and EFB 4, correspondingly.

4.3 Usability of EFB Hardware

Pilots liked the idea of an "electronic flight bag", particularly as a replacement to their traditional flight bag. One feature they especially liked was the 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.

Several human factors issues were noted during the focus group and interview sessions with respect to interaction with the EFB hardware itself. These issues were organized into four topics: installation, touch screen sensitivity, speed/reliability, and brightness.

• Clutter

Pilots generally thought that the EFB could help reduce clutter on the flight deck by providing electronic access to their charts and documents, thus removing the need for paper on the flight deck. However, if the EFBs were disabled (as was the case for several aircraft), the EFB was considered to be a cause of clutter because the EFB occupied valuable space under the left and right side windows where pilots' could previously clip their paper charts. Pilots reported placing their paper charts on top of their traditional flight bags instead but noted that such placement was not stable (the paper tended to slide off the flight bag) and was perceived to increase their heads-down time compared to looking at their paper charts when it was clipped to the chart clip under the side window. One pilot requested the functionality to remove the EFB from its mounting system when the EFB was disabled.

(A similar complaint that inactive EFBs were occupying valuable space was noted at a second airline. Anecdotal reports indicated that pilots at that airline used rubber bands around the EFBs to hold their charts on the EFB.)

• Installation

- Location: Pilots at one airline noted that the installation of their EFB was such that it could impede pilots' movement on the flight deck. This was mentioned primarily as an issue for a captain accessing the tiller, although a few first officers mentioned they also sometimes bumped into the EFB. These events occurred primarily during taxi operations when the pilot's seat is adjusted close to the flight deck for approach and taxi. Pilots mentioned that they keep the EFB in landscape mode (i.e., horizontal orientation) during taxi, take-off, and landing as a workaround. Pilots' body size is a contributing factor, such that larger pilots tended to note this as an issue.
- Mounting Device: Pilots at one airline particularly liked the ball-mount system that allowed the EFB to be rotated and tilted. Several pilots noted that the mounting system allowed easy adjustment of the EFB screen to facilitate readability in various lighting conditions. In particular, although several pilots noted that glare was still an issue during the day, most of these pilots also indicated that the new ball mount allowed the EFB to be shifted so that the display could be moved out of direct sunlight.

However, the ball mount does not allow the EFB to be moved laterally (e.g., sliding function). Consequently, pilots may have differing opinions on the whether the mounting location of the EFB on the flight deck is optimal. In fact, one pilot noted that the current position/location of the EFB was good for viewing information in a landscape orientation, but that when he rotated the EFB to portrait mode, he wished he could slide the EFB a few inches along the window sill to optimize his view.

Finally, some pilots at Airline 1 reported that the locking mechanism on the mount was failing, so that the EFB position could not be locked in the landscape mode. One pilot used paper towels to try to lock the EFB in landscape mode. In another case, the EFB fell off the mount. That mounting device has since been replaced.

- Other: Airline 1 placed the EFBs on the flight deck at the location where the chart clip used to be. Consequently, one pilot noted there was no space on the flight deck to write. In some cases, the pilot put the paper on top of the EFB touch screen to write.

• Touch screen sensitivity

Several pilots from Airline 1 and Airline 2 provided feedback that some EFB touch screens did not always respond immediately to a touch. Pilots at Airline 1 also noted that touch screens on other EFBs could be too sensitive. Several pilots at Airline 1 noted that their finger did not always produce the desired input. One example given was that the touch screen did not work with cold fingers. A second example was scrolling through a drop-down menu (e.g., to select a chart). To better interact with the EFB, some pilots at Airline 1 indicated they use a pen as a stylus. In fact, during the observation sessions, we observed pilots using pens as styli (e.g., a pen or pen cap). During the focus

groups, some pilots said that they found pen markings on the EFB displays. Using a pen as a stylus could lead to damage of the EFB display (e.g., scratches) and make finger input more difficult.

One pilot noted concern about the durability of touch screens in general; based on his previous experience with touch screen technology, the sensitivity of the touch screen tended to degrade over time.

• Speed/Reliability

Several reports addressing the speed/reliability of the EFB were noted throughout the focus groups. Several pilots at Airline 1 noted that the system response of their EFB was slow. Several pilots indicated that they would often try to enter a series of control inputs to the EFB, similar to what they do with their FMS displays, but unlike the FMS, which could process the multiple inputs, the EFB would lock-up. The EFB did not present any indication as to whether an input had been received or was in processing. In fact, during the individual interview sessions at Airline 1, in one case, a pilot appeared to hesitate since he was unsure whether the EFB was going to respond or not. Most of the pilots indicated that the EFB had locked up on them at one time or another. When the EFB did lock-up, pilots needed to wait until the system recovered by itself, which took several minutes.

As the results of a change in the hardware and software configuration in the middle of the operational evaluation, most of the pilots at this airline noted that the processing speed of the new EFB hardware was improved in the current configuration compared to the previous one. However, several pilots still perceived that the EFB system response was sometimes slow (e.g., to bring up a new chart or document). The EFB software provided the ability to pre-load the electronic charts needed for a flight, and pilots noted that these pre-loaded charts could be displayed in a timely manner. However, pilots were concerned about the speed and time required to pull up a *new* chart in time-critical situations, e.g., a last-minute runway change.

• Brightness

All the pilots at Airline 1 indicated that glare was an issue; the EFB display is 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 is too bright. 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. One pilot indicated he would like the ability to change between day and night mode without having to back out of the current application and return to the main menu. (Note that Airline 1 implemented a new mount to address the glare issue.)

• Technology Interoperability

Several instances were observed in which pilots interacted with the EFB using actions and expectations inherited from iPhone/iPad technology. For example, several pilots initially used a pinching motion in their attempts to zoom (rather than tap on the display). Additionally, one pilot in the first focus group with this airline commented that he would like the electronic chart orientation to adjust automatically when he rotated the EFB from portrait to landscape mode.

4.4 Software Usability

Although the focus of the Capstone 3 operational evaluation is on the impact of the airport moving map software during surface operations, the participating airlines are using the EFB to display other software, such as electronic charts (See Section 4.4.2) and electronic documents (See Section 4.4.3). Human factors feedback on the usability of all software on an EFB was gathered when possible. Therefore, this section provides information not only on the human factors issues noted with respect to the airport moving map but also electronic charts, electronic documents, and electronic logbooks.

4.4.1 Airport Moving Map

Human factors observations presented in this document regarding the use of the airport moving map were collected primarily from the simulator visits.

• Ownship depiction

The ownship symbol is presented when the aircraft's taxi speed is 40 knots or less. Consequently, FAA observers noted that during a high-speed landing, the ownship symbol appeared only after the aircraft had entered or exited the high-speed taxiway. The FAA Office of Runway Safety plans to review the landing taxi speed distributions collected from ASDE-X data to fully understand the variations in taxi speeds during landing for small, medium, and large aircraft.

• Map range

Two FAA observers expected the Airport Moving Map to "reset" to a zoomed-out full airport view once the aircraft had taken off. Instead, the Airport Moving Map continues to display the "last" view of the airport surface as ownship takes off.

4.4.2 Electronic Charts

Feedback on two different electronic chart software applications was gathered during the interview sessions. 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 electronic charts. Thus, the two software applications are distinguished in the discussion only when necessary.

• Inconsistency between paper and electronic charting information

At one time during the operational evaluation, pilots at Airline 1 used paper charts from one manufacturer and electronic charts from a second manufacturer. 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 the interview session was conducted, Airline 1 has switched its electronic chart manufacturer so that both the paper and electronic charts are provided by the same manufacturer. However, this issue was included since it calls attention to the potential impact of inconsistencies between different presentations of charting information).

• Procedures for updating charts

- Pilots at Airline 1 expressed concerns regarding the currency of the charting software. The update cycle for the Jeppesen electronic charting software was every 14 days, but this was inconsistent with the update cycle for their ARINC software, which was every 28 days. As a result of this inconsistency, pilots would sometimes see messages stating that their charts were out-of-date. (Note: Airline 1 has since worked with their electronic chart manufacturer to update their charts on a 28-day cycle.)
- At Airline 1, one pilot noted an issue with the update process in which only a subset of the charts were updated. The EFB had indicated at start-up that the charts were up-to-date, but when actually looking at the charts, the pilot noticed that they were out-of-date. (Note that this issue was brought to maintenance.)
- Pilots may need training on the procedures for updating and using charts. With paper charts, pilots receive new paper charts before their effective date and refer to the old paper charts in the meantime. One pilot at Airline 2 commented that he was not clear how charts would be updated on the EFB and what to do if he pulled up new charts on the EFB before their effective date.

• Interacting with charts

- Zooming: Many pilots at Airline 1 indicated that the two levels of zoom provided for electronic charts were too constrained. (The three levels of zoom allowed in the airport moving map software were better received.) Additionally, when zoomed in on a chart, observations of one pilot and comments by another suggested that they did not realize icons (blue brackets at the edges of the EFB display) were provided to indicate that parts of the chart was off-screen. In fact, one pilot thought that the bottoms of some of the charts had been cut off.
- Highlighting: One electronic chart software offers a "HiLight" feature that allows the user to highlight portions of the electronic chart or Airport Moving Map. Pilots liked the ability to highlight information on their charts. However, pilots noted that the width of the highlighting was wide and noted that a line could easily cover two taxiways, particularly if the taxiways are close together.

Additionally, observations suggested that some pilots did not realize that certain functions are not available when the HiLight feature is on, such as zooming and panning. For example, some pilots tried to zoom by tapping on the screen when the EFB software was in HiLight mode and did not understand why the zoom function did not work.

- Pilots at both Airline 1 and Airline 2 noted that the current configuration of the chart should be preserved if pilots leave a chart (e.g., by displaying another chart or viewing another page) and then return to it. At Airline 1, pilots noted that they commonly zoom in on the chart and then rotate it, but when the chart is rotated, the zoom level is reset to a default level. Given the speed and reliability issues encountered by pilots at Airline 1 (see Section 4.3), one pilot noted that this combination tended to lock-up his EFB, despite the fact that these two actions are quite common.
- Most of the pilots at Airline 1 indicated that they used the EFB to view their charts. Because many charts are drawn in landscape mode, several pilots at Airline 1 indicated they rotate the EFB hardware so that it sits horizontally (in landscape mode) to view their charts. The exception was for approach charts, which pilots viewed in portrait mode. Pilots indicated that for complex airports, they preferred landscape mode so that they could see more of the airport diagram.
- The electronic chart software used by Airline 2 constrains chart rotation to a clock-wise direction (i.e., to the right). Each click of the button rotates the chart 90°. Because Airline 2 has installed the EFB so that it is mounted in a landscape orientation off to a pilot's side, the pilots noted that they will most likely rotate their approach charts so it is drawn in portrait orientation on the EFB. For pilots who sit in the left seat, this rotation can be accomplished by a single click. For pilots who sit in the right seat, however, three clicks are required. Several pilots asked whether it was possible to configure the direction of the rotation to reduce the number of clicks needed.

• Sharing charts

Pilots should be trained on the process for transferring charts so that they clearly understand whether sending/accepting the charts will add to what is already in the chart clip (e.g., with additional charts) or replace the entire chart clip. Additionally, training should clearly indicate whether sent charts are automatically uploaded to the other screen or if the receiving EFB must accept the transfer.

One issue with the sharing/sending of charts was noted. For one software product, sending an approach chart that is being viewed in portrait mode was displayed "upside-down" on the receiving EFB. Despite this issue, it is worthwhile to note that two pilots especially liked this feature because they felt it facilitated crew communication. 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.

• Back-ups

Three pilots were concerned about the fact that they had no back-up if the EFB failed (e.g., if there was no airport diagram). (Note that pilots continued to carry their paper charts onto the flight deck at the time this data was collected.)

• Notes

Several pilots at Airline 1 indicated that they often annotate their paper charts, but this is not possible with electronic charts. One pilot suggested functionality to create and store their notes to take from one aircraft to another (e.g., on an USB drive).

4.4.3 Electronic documents

Feedback was gathered on two different electronic document software applications. Pilots at Airline 1 considered the 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. Pilots at this airline also felt that the electronic document library offered a more efficient method for interacting with documents than a paper format.

The human factors considerations noted below are intended to apply to *all* electronic document software. Differences between the two electronic document applications are distinguished when necessary.

• Presentation of titles

Titles should be provided for all chapters in the electronic document. Pilots at Airline 1 commented that some chapters in their electronic document did not have titles.

• Search

Implementing the search function so that a search can be conducted for keywords in specific subsections of a document (rather than to continuously search the entire document as a whole) could make the search process more efficient.

• Consistency between electronic and paper mediums

One pilot from Airline 2 noted that the page numbering used for electronic document application was inconsistent from the paper document. 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.

4.4.4 General Usability

• Inconsistency across software applications

An EFB can host software from several manufacturers. Consequently, consistency in the presentation of information elements and controls can be difficult to achieve. This inconsistency can increase the potential for error. For example:

- The method to *display* a virtual keyboard may be inconsistent across software applications. For example, to display the virtual keyboard in one software application, the user may click on the virtual keyboard icon at the top of the page. In a different software application, the virtual keyboard may appear automatically when the user clicks on a data field. Pilots should be trained to understand how to enter information for each software.
- The design of the virtual keyboard itself may differ for each software application on the EFB. There is currently no "standard" design for virtual keyboards.

• Inconsistency in the display of ownship position

Several participants noted that the aircraft position represented by the ownship symbol differs between the airport moving map and their navigation display. For the airport moving map, the nose of the aircraft is represented by the center of the ownship symbol. For the navigation display, 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.

Soft controls/tabs

Controls used for navigation should not obscure information on the display. For example, some pilots at Airline 1 indicated that soft controls used to navigate through the different electronic charts can get in the way. Although a function was provided to hide the controls, pilots noted that an extra step would then be required to redisplay the controls.

• Labels

- All soft controls should be labeled. Some controls presented on the EFB used by Airline 1 were not labeled but could be selected to perform an action. Additionally, the terminology used for labels should be descriptive of the action performed. At Airline 2, several pilots noted that a key on the virtual keyboard labeled "ESC" did not move them out of the virtual keyboard as they expected (e.g., "escape out") but rather moved the position of the cursor in a data field back to the start of the data field.
- Labels for the EFB software used by Airline 2 were icons rather than text labels. However, the pilots interviewed did not understand the meanings of some of the icons. Note that pilots had not been trained on the software before this evaluation. When icons are used instead of text labels, the icons should be meaningful for the functions labeled. Only a brief glance at the icon should be needed to determine the correct function. Several participants noted that permanent text labels or "tool tips" (text labels that appear when the cursor lingers over the icon) could be useful.

• Error Prevention

When the user restarts the EFB, the EFB should check to determine if data loss is possible (e.g., charts stored on the chart clip). If so, the EFB should prompt for confirmation before executing the command.

• EFB Integration with Other Aircraft Systems

Several pilots at Airline 1 asked if information they entered into their FMS could be transferred to the EFB; for example, arrival and departure airport, which would facilitate finding the necessary electronic charts. Additionally, several pilots noted they would like notes made in the FMS scratch pad, such as taxi instructions provided by Air Traffic Control (ATC), to upload automatically to the EFB and to transfer graphically on the Airport Moving Map; this highlights the level of integration that pilots hope for with EFBs.

5 Summary and Recommendations

Preliminary human factors findings highlight the optimism and excitement that pilots have for EFB and airport moving map technology. Collectively, the results of the Capstone 3 evaluation indicate that pilots are positive about these technologies. The majority of pilots reported using the airport moving map when it was available and perceived a benefit in understanding their position awareness on the airport surface as well as for overall safety. (Note that MITRE was tasked to conduct an objective quantitative analysis to empirically examine the impact of an airport moving map on safety.) Additionally, the mean ratings showed pilots to be relatively positive about the EFB. Pilots rated the EFB as relatively useful, although 24% of pilots indicated experiencing an issue with the EFB during one or more phases of flight.

The results also note six potential human factors issues from the survey responses, interviews, and observations:

- 5.1 Ownship Position Accuracy
- 5.2 EFB Location
- 5.3 Use of Touch Screen
- 5.4 System Responsiveness
- 5.5 Display readability due to glare/reflections
- 5.6 User Interface Consistency

These six human factors issues are described in the following sections. For each issue, applicable human factors considerations provided in FAA regulatory and guidance material and identified from general human factors research are also included. The FAA specifies regulatory and guidance material for airport moving maps in:

- Technical Standard Order (TSO)-C165, *Electronic Map Display Equipment for Graphical Depiction of Aircraft Position*, issued on September 30, 2003, and
- Advisory Circular (AC) 20-159, *Obtaining Design and Production Approval of Airport Moving Map Display Applications Intended for Electronic Flight Bag Systems*, which was issued on April 30, 2007, address design requirements for surface moving map displays.

TSO-C165 invokes RTCA DO-257A, *Minimum Operational Performance Standards for the Depiction of Navigational Information on Electronic Maps*, which defines minimum performance standards. RTCA DO-257A applies to equipment that is intended to provide ownship position on an electronic map display, whether it is on the airport surface, in-flight, or vertical situation display. RTCA DO-257A notes that the intended function of the airport moving map display is two-fold: (1) to assist flightcrews by enhancing their position awareness with respect to ownship location on the airport surface, and (2) to improve position awareness for taxi operations. Based on these intended functions, the display of misleading information on the airport moving map display or loss of function of the airport moving map are considered to be minor failures (see RTCA DO-257A, Section 2.1.8).

If the surface moving map is presented on an Electronic Flight Bag (EFB), then the following documents may also apply:

- AC 120-76B, Guidelines for the Certification, Airworthiness, and Operational Approval of Electronic Flight Bag Computing Devices, and
- AC 20-173, Installation of Electronic Flight Bag Components
- <u>FAA Order 8900.1</u>, Volume 4, Chapter 15, Section 1. Electronic Flight Bag Operational Authorization Process

• Human Factors Considerations in the Design of Electronic Flight Bags (EFBs) by Chandra, Yeh, Riley, and Mangold (2003) provide relevant guidance.

Note that some of the guidance included in this section is excerpted from regulatory and guidance material that is not EFB-specific but rather applicable to *all* avionics. Thus, some of this information may be applicable for inclusion in future updates to regulatory and guidance material specific to EFBs.

5.1 Ownship Position Accuracy

Potential Issues: There were 81 reported position errors (out of 1662 responses; 4.88%) related to ownship or the airport moving map at 18 airports. None of these errors were related to ownship position with respect to runways. Of the reported errors, 1 pilot noted ownship was drawn on or near the edge of the taxiway the aircraft was on, 1 pilot indicated that ownship was drawn on the wrong location in the ramp areas, and 79 pilots noted "Other" errors that did not involve runways, taxiways, grass, or ramp areas. (No additional detail was provided on these errors.)

TSO-C165/RTCA DO-257A notes that the display of misleading information on the airport moving map is considered a minor failure. Nevertheless, it is important for the pilot to understand the potential sources of errors in the depiction of ownship position on moving map displays and to ensure that this is addressed in the avionics pilots' guides and in pilot training.

Recommendations from FAA Regulatory and Guidance Material:

- The total system accuracy shall be sufficient for the intended operation, and shall not exceed 100 meters (95%). The installed system should be evaluated to confirm compliance with the requirement in section 2.3.1. [TSO-C165/RTCA DO-257A, 3.2.3]
- The Aerodrome Moving Map Display (AMMD) shall provide an indication if the accuracy implied by the display is better than the level supported by the total system accuracy. [TSO-C165/RTCA DO-257A, 2.3.1]
- The aircraft position sensor horizontal positional accuracy for runways shall be less than 36m. [TSO-C165/RTCA DO-257A, 2.3.1.1.]
- The aerodrome total database accuracy for runways shall be 43m or less. [TSO-C165/RTCA DO-257A, 2.3.1.1.1]
- The aircraft position sensor horizontal positional accuracy for taxiways shall be less than 36m. [TSO-C165/RTCA DO-257A, 2.3.1.1.2]
- The aerodrome total database accuracy for taxiways shall be 65m or less. [TSO-C165/RTCA DO-257A, 2.3.1.1.2]

5.2 EFB Location

Potential Issues: The location of the EFB on the flight deck sometimes impeded the pilot's movement on the flight deck or was considered to be a cause of clutter if the EFB was disabled. In addition, pilots reported that over time, the mounting systems failed.

Recommendations from FAA Regulatory and Guidance Material:

- Each pilot compartment must be arranged to give the pilots a sufficiently extensive, clear, and undistorted view, to enable them to safely perform any maneuvers within the operating limitations of the airplane, including taxiing takeoff, approach, and landing. [14 CFR § 25.773(a)(1)] Related guidance: 14 CFR §§ 23.773(a), 27.773(a)(1), and 29.773(a)(1) are worded slightly differently.
- Flight deck display equipment and installation designs should be compatible with the overall flight deck design characteristics (such as flight deck size and shape, flightcrew member position, position

of windows, external luminance, etc.) as well as the airplane environment (such as temperature, altitude, electromagnetic interference, and vibration). [AC 25-11A, 16.b.(1)]

- The display system components should not cause physical harm to the flightcrew under foreseeable conditions relative to the operating environment (for example, turbulence or emergency egress). [AC 25-11A, 16.b.(8)]
- The installed display must not visually obstruct other controls and instruments or prevent those controls and instruments from performing their intended function (§ 25.1301). [AC 25-11A, 16.b.(9)]
- The display components should be installed in such a way that they retain mechanical integrity (secured in position) for all foreseeable conditions relative to the flight environment. [AC 25-11A, 16.b.(11)]

5.3 Use of Touch Screen

Potential Issue(s): Several pilots provided feedback that their finger inputs did not always register immediately on the EFB - sometimes as the result of cold fingers, and as a result some tried to use a pen as a stylus. Additionally, technology trends (e.g., iPad and iPhone) are introducing interaction conventions for all touch devices; for example, pilots attempted to apply gestures from iPad and iPhone technology to PC-based systems, which did not recognize the input.

Recommendations:

- Consider integrating an associated support for stabilizing the pilot's hand, and for providing a reference point when positioning fingers, if appropriate. Ensure that touch screens do not result in unacceptable levels of workload, error rates, speed, and accuracy. [AC 20-175, 3-5.a]
- Ensure that touch screens resist scratching, hazing, or other damage that can occur through normal use. Demonstrate that the system will continue to provide acceptable performance after long-term use and exposure to skin oils, perspiration, environmental elements (e.g., sun), impacts (e.g., clipboard), chemical cleaners that might be used in the flight deck, and any liquids that might be brought onboard by flightcrew members (e.g., coffee). [AC 20-175, 3-5.b]
- If a touch screen's calibration can drift or degrade, provide touch screen calibration procedures and other maintenance-related items to ensure proper calibration and operation. Include these procedures in the instructions for continued airworthiness, per § 2X.1529. [AC 20-175, 3-5.c]
- The location of the pilot's finger touch, as sensed by the touch screen, should be predictable and obvious. [AC 20-175, 3-5.d]
- Soft keys on the touch-screen display should have a region around them where touches are not recognized to prevent inadvertent activation. (Beringer and Peterson, 1985).
- Feedback should be provided within 100 ms to indicate that a touch has been received (Cardosi and Murphy, 1995; NASA, 1995, 9.3.3.4.7). This feedback can be tactile, auditory or visual in nature.
- A soft key button should activate only when it is pressed and released. If a button is pressed but not released (e.g., a user drags his/her finger away before releasing it), the button should not activate. Additionally, the area where the finger was released should not activate.

5.4 System Responsiveness

Potential Issue(s): Some pilots felt that the response rate of the EFB was slow and that the recovery time was too long (e.g., to bring up a new chart or document), particularly in time-critical situations. *Recommendations from FAA Regulatory and Guidance Material:*

• The system should provide feedback to the user when user input is accepted. If the system is busy for an atypical time with internal tasks that preclude immediate processing of user input (e.g.,

calculations, self-test, or data refresh), the EFB should display a "system busy" indicator (e.g., clock icon) to inform the user that the system is occupied and cannot process inputs immediately. The timeliness of system response to user input should be consistent with an application's intended function. The feedback and system response times should be predictable to avoid flightcrew distractions and/or uncertainty. [AC 120-76B, 13.e]

- Any lag introduced by the display system should be consistent with the airplane control task associated with that parameter. [AC 25-11A, 31.d.(1)]
- The overall system lag time of a dynamic image relative to real time should not cause flightcrew misinterpretation or lead to a potentially hazardous condition. Image failure, freezing, coasting or color changes should not be misleading and should be considered during the safety analysis. [AC 25-11A, 31.g.(3)]
- The display shall respond to operator control inputs within 500 msec. [TSO-C165/RTCA DO-257A, 2.2.4]

Note: It is desirable to provide a temporary visual cue to indicate that the control operation has been accepted by the system (e.g., hour glass or message). It is recommended that the system respond within 250 msec.

- The display shall update the displayed minimum required information set at least once per second. [TSO-C165/RTCA-DO 257A, 2.2.4]
- Maximum latency of aircraft position data at the time of display update shall be one second, measured from the time the data is received by the system. [TSO-C165/RTCA-DO 257A, 2.2.4]
- Movement of map information should be smooth throughout the range of aircraft maneuvers. [TSO-C165/RTCA-DO 257A, 2.2.4]

5.5 Display readability due to glare/reflections

Potential Issue(s): Glare was often cited as a factor, which prevented the EFB display from being readable during daylight. Glare could sometimes be reduced by shifting the EFB out of direct sunlight (e.g., via a ball mount or other mounting system); however, requiring the pilot to adjust the display to prevent glare could distract the pilot from other tasks and increase the time to retrieve information and pilot workload.

• Each pilot compartment must be free of glare and reflection that could interfere with the normal duties of the minimum flight crew. This must be shown in day and night flight tests under nonprecipitation conditions. [14 CFR § 25.773(a)(2)]

Related guidance: 14 CFR §§ 23.773(a)(2), 27.773(a)(1), 29.773(a)(2) are worded slightly differently.

• Evaluations should be conducted under all potential lighting conditions to include dawn or dusk conditions with the sun near the horizon, higher sun angles (both in front, behind, and directly overhead the airplane), and during night conditions (both dark night and moonlit conditions). Also evaluate the affect various internal lighting selections and levels have on readability and usability of airplane equipment and systems and the ability to see outside the cockpit. [PS-ACE100-2001-004, Appendix A]

Related guidance: PS-ANM-01-03A, Appendix A is worded slightly differently.

- This must be shown in day and night flight tests under non-precipitation conditions (§ 25.773(a)(2)). The criteria and the basic workload functions and factors for a minimum flightcrew are described in Appendix D to part 25, § 25.1523. [AC 25-11A, 16.a.(11)]
- Reflectance of the display should be minimal to ensure display readability. [TSO-C165/RTCA DO-257A, 2.2.3]

5.6 User Interface Consistency

Potential Issue(s): Inconsistency in the presentation of information elements (e.g., symbols) or controls with other avionic information (electronic or paper) can increase the potential for error. In the Capstone 3 operational evaluation, inconsistency was noted in several ways. First, pilots who viewed electronic charts from one manufacturer and paper charts for a different manufacturer noted inconsistencies in the depiction of electronic chart symbols and in the chart layout. Second, pilots noted inconsistencies in the layout of a virtual keyboard from one software application to another – both on the same EFB. Third, pilots noted inconsistencies in the presentation of ownship system on their EFB with other flight deck displays. Such inconsistencies increased the time to find information, uncertainty in the reliability of the information, and disuse of one or more sources of information.

Recommendations from FAA Regulatory and Guidance Material:

- The EFB user interface should be consistent and intuitive within and across various EFB applications. The interface design (including, but not limited to, data entry methods, color-coding philosophies, terminology, and symbology) should be consistent across the EFB and various hosted applications. [AC 20-176B, 12.b.]
- Display information representing the same thing on more than one display on the same flight deck should be consistent. Acronyms and labels should be used consistently, and messages/annunciations should contain text in a consistent way. Inconsistencies should be evaluated to ensure that they are not susceptible to confusion or errors, and do not adversely impact the intended function of the system(s) involved. [AC 25-11A, 31.b]

6 Conclusion

The Capstone 3 operational evaluation intended to examine the potential for safety gains on the airport surface with an airport moving map. There was particular focus on understanding the human factors implications involved with the integration of airport moving map displays into the flight deck. Atlas Air and US Airways continue to make progress on their EFB and Airport Moving Map programs. Shuttle America, which was the first airline of the three to equip all 20 of their proposed Capstone 3 aircraft with EFBs (but without the airport moving map software) concluded their program participation in February 2012 with plans to transition to a new generation of EFBs.

The information presented in this report is intended to help 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.

Appendix A. Capstone 3 EFB Survey

This survey addresses information specific to a particular taxi segment. It is expected to be completed for every airport, either when the aircraft is parked at the gate or en-route, as determined by the airlines and the FAA. The survey administration may be customized for some airlines that fly back and forth between the same airports several times over the course of a day.

The proposed set of questions address pilots' perceptions of whether the airport moving map with ownship position or EFB provided an operational and/or safety benefit and collects information on potential mitigating factors (e.g., visibility and lighting conditions) and any areas where the technology can be improved, either in terms of database accuracy or pilot interface/usability. The first six questions are intended to be completed by all pilots. Pilots who used the airport moving map application during taxi are then asked to answer four questions on airport moving map safety. For pilots that did not use the airport moving map (e.g., because the pilot was taxiing or if the airport moving map was not available or not needed), three questions addressing the impact of the EFB are to be completed instead.

The questions below include proposed changes to the Capstone 3 EFB Survey as of August 2010.

Title: EFB Survey, [Date will be filled-in automatically]

Airport (4-letter ICAO identifier): _____

Crew Responsibility: ____ Taxiing ____ Not Taxiing

- 1. Is this EFB equipped with software that shows the position of your own aircraft on an airport map while taxiing? ____Yes ____No
- 2. Time of day:
 - ____ day ____ dawn/dusk
 - ____ uawn/uus
- 3. RVR:
 - ____> 5000 ft
 - ____ 2401 ft to 5000 ft ____ 1501 ft to 24 ft
 - _____ 801 ft to 1500 ft
 - _____ <= 800 ft
- 4. Surface movement conditions:
 - ____ dry
 - ____ wet
 - _____ snow
- 5. How familiar were you with the taxi route you were given on this taxi segment?

| Not familiar | | | | Very familiar |
|--------------|---|---|---|---------------|
| 1 | 2 | 3 | 4 | 5 |

6. How often did you refer to the airport moving map on this taxi segment?

| Never | | | | Very frequently |
|-------|---|---|---|-----------------|
| 1 | 2 | 3 | 4 | 5 |

IF pilots responded 2 or higher to Q6, then complete Airport Moving Map Safety survey items (SMM7 - SMM10).

IF no airport moving map was available for the airport (Q1) OR if pilots did not refer to the airport moving map (response 1 to Q6), then pilots will complete survey items addressing EFB usability (EFB7 – EFB10). Airport Moving Map Safety (Shown if pilots respond with 2 or higher to Q6)

SMM 7. How did the position awareness provided by the airport moving map with ownship depiction compare to a paper/electronic airport chart only?

| Decreased Awareness | | No Difference | | Increased Awareness |
|---------------------|---|---------------|---|---------------------|
| 1 | 2 | 3 | 4 | 5 |

SMM 8. How did use of the airport moving map affect other duties compared to a paper/electronic airport chart only?

| More difficult to | | No Impact | | Less difficult to |
|----------------------|---|-----------|---|----------------------|
| perform other duties | | | | perform other duties |
| 1 | 2 | 3 | 4 | 5 |

SMM 9. How did the airport moving map affect the safety of taxi operations on this segment?

| Decreased Safety | | No Difference | | Increased Safety |
|------------------|---|---------------|---|------------------|
| 1 | 2 | 3 | 4 | 5 |

SMM 10. What was the most significant position error of ownship or the airport moving map that you observed during this taxi segment?

_____ No errors.

_____ Ownship was drawn on the wrong **runway**

_____ Ownship was drawn on or near the edge of my runway

- _____ Ownship was drawn on the wrong **taxiway**
- _____ Ownship was drawn on or near the edge of my taxiway
- _____ Ownship was drawn in the grass
- _____ Ownship was drawn in the wrong location in the ramp areas
- ____ Other

EFB Usability (shown only asked if pilots respond "1" to Q6)

EFB7. Was the workload required for completing a task with the EFB equal to or less than the workload for completing the task with paper?

| More difficult to | | No Impact | | Less difficult to |
|----------------------|---|-----------|---|----------------------|
| perform other duties | | | | perform other duties |
| 1 | 2 | 3 | 4 | 5 |

EFB8. How did the addition of the EFB in the flight deck affect the time available to scan other displays?

| Decreased | | Did not Change | | Increased | |
|-----------|-----------------------|----------------|---------------|-----------|-------------|
| | 1 | 2 | 3 | 4 | 5 |
| EFB9. | How useful was the H | EFB? | | | |
| V | Vorse than paper only | | No Difference | | Very Useful |
| | 1 | 2 | 3 | 4 | 5 |

EFB10. Were there any problems with the EFB system hardware or software during the flight?

 No

 Yes

 During pre-departure

 During taxi out

 During take-off/climb-out

 During cruise

 During approach/landing

 During taxi in

Appendix B. Online Survey

This survey addresses usability issues associated with the design of the airport moving map and EFB. The purpose of this draft was to capture a comprehensive list of safety/usability issues, so this survey consists of over 60 items. However, we anticipate that the final survey will include only a subset of these items. In fact, one idea for implementation is to develop a series of surveys for administration online and rotate the surveys throughout the evaluation.

The responses to items on this survey are in general not expected to be flight-specific, but rather to reflect pilots' overall perception to the technologies. The survey is designed to be completed when pilots have more time than they would during line operations.

Four main topics are addressed in this survey: airport moving map safety, EFB, background/demographics/training, and aural runway safety alerts.

- *Airport Moving Map Safety* survey items collect pilots' opinions regarding the role of the airport moving map in supporting position awareness, the readability/legibility of the application, the ease of making adjustments to map range and orientation, and the overall impact on workload and heads-down-time.
- *EFB* survey items examine the ease of accessing information, the consistency of information presentation, the readability of that information, and the usability of buttons and controls.
- *Background/Demographics/Training* items collect pilots' flight experience, their previous experience with an airport moving map and/or EFB, and their previous training.
- Finally, *Aural Runway Safety Alerts* examine pilots' opinions on the impact of these alerts on position awareness, whether the volume of the alerts was appropriate, and the frequency of false alerts. Although none of the Capstone 3 airlines will equip with an aural alerting system at this time, these items were included so that they can be used if the capability is installed in the future.

The questions below include proposed changes to the Capstone 3 online Survey as of October 2011.

How often do you refer to the airport moving map?

| Never | | | | Very frequently |
|-------|---|---|---|-----------------|
| 1 | 2 | 3 | 4 | 5 |

Note: IF pilots respond 1, skip Section I.

1. Were you aware of any position errors of <u>ownship</u> or the airport map?

_____ Yes _____ No

If yes:

At which airport (4-letter ICAO identifier)?

What was the most significant position error of ownship or the airport map that you observed at that airport?

- ____ No errors.
- _____ Ownship was drawn on the wrong runway
- _____ Ownship was drawn on or near the edge of my **runway**
- _____ Ownship was drawn on the wrong taxiway
- _____ Ownship was drawn on or near the edge of my taxiway
- _____ Ownship was drawn in the grass
- _____ Ownship was drawn in the wrong location in the ramp areas
- ____ Other

Please provide additional information on the position error (e.g., where was your aircraft, where was it shown on the airport moving map, what was the approximate size of the error).

2. Were there any problems with the EFB hardware or software during the flight?

____ No

_____Yes

- _____ During pre-departure
- _____ During taxi out
- _____ During take-off/climb-out
- _____ During cruise
- _____ During approach/landing
- _____ During taxi in

Please describe the error.

I. Airport Moving Map Safety

3. Use of the airport moving map during taxi _______ the time available for crew duties (e.g., completing checklists) compared to using a paper/electronic chart.

| Decreased | | Did not change | | Increased |
|-----------|---|----------------|---|-----------|
| 1 | 2 | 3 | 4 | 5 |

4. The airport moving map ______ crew resource management compared to using a paper/electronic chart during taxi operations.

| Hindered | | Did not change | | Improved |
|----------|---|----------------|---|----------|
| 1 | 2 | 3 | 4 | 5 |

5. The airport moving map assisted me in following my taxi route.

| Strongly Disagree | | | | Strongly Agree |
|-------------------|---|---|---|----------------|
| 1 | 2 | 3 | 4 | 5 |

Strongly Disagree Strongly Agree 2 5 1 3 4 The airport moving map provided sufficient awareness of my position when approaching *runway-taxiway* 7. intersections. Strongly Disagree Strongly Agree 5 2 3 4 1 The airport moving map helped me determine which taxiway I was on. 8. Strongly Agree 5 Strongly Disagree 2 1 3 4 9. The airport moving map showed the information I needed to establish, maintain, and regain position awareness on the airport surface. Strongly Disagree Strongly Agree 5 3 1 2 4 10. Use of the airport moving map during taxi _____ _____ the workload associated with taxi operations compared to using a paper/electronic chart alone. Did not change Decreased Increased 2 4 5 1 3 If you indicated an increase in workload (1 or 2), please indicate why. 11. Use of the airport moving map _____ _____ my understanding of taxi route clearances when communicating with air traffic control. Interfered with Did not change Improved 2 1 3 4 5 12. Compared to using a paper chart/electronic chart alone, the airport moving map reduced my chances of turning on the wrong taxiway. Strongly Disagree Strongly Agree 1 2 3 4 5 13. The airport moving map was: Easy to Use Difficult to Use 2 3 1 4 5 **Readability/Legibility** 14. The display symbol for my aircraft (ownship) was easy to identify. Strongly Disagree Strongly Agree 2 1 3 4 5

6. The airport moving map provided sufficient awareness of my position with respect to *runways*.

| 15. | The ownship symbol did not | . Interfere with | i the legionity of t | axiway of fully | way labels. |
|-----|--|-------------------------|----------------------|-----------------|-------------------------------------|
| | Strongly Disagree | 2 | 3 | 4 | Strongly Agree 5 |
| 16. | The position of ownship on | the map displa | ay was sufficiently | accurate. | |
| | Never 1 | 2 | Sometimes 3 | 4 | Always 5 |
| 17. | Ownship symbol heading/di | rectionality w | as accurate: | | |
| | Never 1 | 2 | Sometimes 3 | 4 | Always 5 |
| | If inaccurate, the heading/dia stationary turning otherwise moving. | rectionality w | as incorrect when | he aircraft wa | s: (Check all that apply) |
| | Please describe the condition | ns under whic | h this error occurre | ed. | |
| 18. | Runways were easily disting | uishable from | n taxiways and othe | er movement a | reas on the airport moving map. |
| | Strongly Disagree 1 | 2 | 3 | 4 | Strongly Agree 5 |
| 19. | The airport features shown of | on the map dis | play were in the sa | me relative po | osition as seen_out the window. |
| | Strongly Disagree | 2 | 3 | 4 | Strongly Agree 5 |
| 20. | The location of the airport m | noving map in | the flight deck all | owed it to be s | een easily. |
| | Strongly Disagree 1 | 2 | 3 | 4 | Strongly Agree 5 |
| 21. | The display brightness adjus lighting conditions I encount | tment was eff tered. | ective in producin | g an acceptabl | e range of brightness levels in the |
| | Strongly Disagree | 2 | 3 | 4 | Strongly Agree 5 |
| 22. | I could read all text on the m | ap display in | the lighting condit | ions I encount | ered. |
| | Strongly Disagree | 2 | 3 | 4 | Strongly Agree 5 |
| 23. | The size of the map display | was adequate | for the information | n presented. | |
| | Strongly Disagree 1 | 2 | 3 | 4 | Strongly Agree 5 |

15. The ownship symbol did not interfere with the legibility of taxiway or runway labels.

Map Range and Orientation

24. It was easy to adjust the map range.

| | Strongly Disagree 1 | 2 | 3 | 4 | Strongly Agree 5 | |
|-----|---------------------------------------|-----------------------------|----------------------|-------------------|-----------------------------|---------|
| 25. | The speed with which the | map was redu | rawn when the map | range was adju | sted was adequate. | |
| | Strongly Disagree | 2 | 3 | 4 | Strongly Agree 5 | |
| 26. | Did you adjust the orienta YesNo | tion of the air | port moving map (e | e.g., north-up ve | rsus heading-up)? | |
| | If yes, which orientation ofNorth Up, | lid you use? Heading Up, | Both North | Up and Headir | ng Up | |
| Ge | neral | | | | | |
| 27. | Were you aware of any poYesNo | osition errors of | of ownship or the ai | rport map durin | g this taxi segment? | |
| | If yes: Which airport were you a | t (used during | taxi segment, 4-lett | ter ICAO identi | fier)? | |
| | What was the most signif | icant position | error of ownship or | the airport map | that you observed at that a | irport? |
| | Ownship was | drawn on the | wrong runway | | | |
| | Ownship was | drawn on or n | ear the edge of my | runway | | |
| | Ownship was | drawn on or n | ear the edge of my | taxiwav | | |
| | • · · · · · · · · · · · · · · · · | | | | | |

- _____ Ownship was drawn in the grass
- _____ Ownship was drawn in the wrong location in the ramp areas
- ____ Other
- 28. How did the use of the airport moving map during airport surface operations affect your heads-down time when compared to a conventional paper/electronic chart?

| Increased | | Did not Change | | Decreased |
|-----------------|---|----------------|---|-----------------|
| Heads-Down Time | | - | | Heads-Down Time |
| 1 | 2 | 3 | 4 | 5 |

29. Use of the airport moving map was not disruptive to my out-the-window scan compared to the use of a paper chart/electronic chart.

| Strongly Disagree | | | | Strongly Agree |
|-------------------|---|---|---|----------------|
| 1 | 2 | 3 | 4 | 5 |

30. The information shown by the airport moving map sufficiently matched what I saw out the window.

| Strongly Disagree | | | | Strongly Agree |
|-------------------|---|---|---|----------------|
| 1 | 2 | 3 | 4 | 5 |

31. Occasionally, the information on the airport moving map display was difficult to interpret.

| Strongly Disagree | | | | Strongly Agree |
|-------------------|---|---|---|----------------|
| 1 | 2 | 3 | 4 | 5 |

32. My company's crew procedures for using airport moving map displays are sufficient for safe and efficient surface operations.

| Strongly Disagree | | | | Strongly Agree |
|-------------------|---|---|---|----------------|
| 1 | 2 | 3 | 4 | 5 |

II. EFB

33. I was always clear about which display page was active.

| | Strongly Disagree | Se | ometimes | | Strongly Agree |
|-----|--------------------------------|---------------------|----------------------|-----------|------------------|
| | 1 | 2 | 3 | 4 | 5 |
| 34. | I could access the information | on I needed with v | ery few actions. | | |
| | Strongly Disagree 1 | 2 | 3 | 4 | Strongly Agree 5 |
| 35. | The EFB was in a location w | where it was easy t | to use. | | |
| | Strongly Disagree 1 | 2 | 3 | 4 | Strongly Agree 5 |
| 36. | The EFB display placement | did not interfere v | with flight deck op | erations. | |
| | Strongly Disagree 1 | 2 | 3 | 4 | Strongly Agree 5 |
| 37. | The user interface was consi | stent and easy to | understand. | | |
| | Strongly Disagree 1 | 2 | 3 | 4 | Strongly Agree 5 |
| 38. | The layout of information of | n the screens was | easy to follow. | | |
| | Strongly Disagree 1 | 2 | 3 | 4 | Strongly Agree 5 |
| 39. | The size of all buttons/contr | ols were easy to u | se. | | |
| | Strongly Disagree 1 | 2 | 3 | 4 | Strongly Agree 5 |
| 40. | All buttons/controls are labe | led consistently w | vith their function. | | |
| | Strongly Disagree | 2 | 3 | 4 | Strongly Agree 5 |

41. All buttons/controls were easy to understand and remember. Strongly Disagree Strongly Agree 1 2 3 5 4 42. The readability of the text on the EFB was acceptable from my seating position. Strongly Disagree Strongly Agree 2 3 5 1 4 43. If the text was too small to be read easily, it was easy to zoom in on it to make it legible. Did not Use Strongly Disagree Strongly Agree 2 3 0 1 4 5 44. The information on the EFB was readable in the lighting conditions I encountered. Strongly Agree 5 Strongly Disagree 2 3 1 4 If you responded 1 (Strongly Disagree), please indicate under which lighting conditions the information on the EFB was **not** readable. Bright sunlight - Sun coming in the forward window _____ Bright sunlight - Sun coming in the side window _____ Bright sunlight - other _____ Low ambient lighting conditions (dawn, dusk, heavy overcast) _____ Night flight/overhead light 45. All of the colors could be interpreted under all lighting conditions I encountered. Strongly Disagree Strongly Agree 1 2 3 4 5 If you responded 1 (Strongly Disagree), please indicate under which lighting conditions the colors were not readable. _____ Bright sunlight - Sun coming in the forward window _____ Bright sunlight - Sun coming in the side window _____ Bright sunlight - other _____ Low ambient lighting conditions (dawn, dusk, heavy overcast) Night flight/overhead light 46. The EFB was easy to read in the night mode. Did not Use Strongly Disagree Strongly Agree 2 3 0 1 4 5 47. I could switch easily between applications. Did not Use Strongly Disagree Strongly Agree 3 0 1 2 5 4

| | The system responded imn | nediately t | o user inputs, e.g., feedba | ick when a | button was pushed. |
|-------------------|--|--|---|-------------------|-------------------------------|
| | Strongly Disagree 1 | 2 | 3 | 4 | Strongly Agree 5 |
| 49. | System processing never sl | lowed to the | he point where normal use | e was impa | ired. |
| | Strongly Disagree 1 | 2 | 3 | 4 | Strongly Agree 5 |
| 50. | How did the EFB affect the | e time ava | ilable to scan other displa | .ys? | |
| | Decreased 1 | 2 | Did not Change 3 | 4 | Increased 5 |
| 51. | Did you use the push/pull f | function to | share information from o | one display | to the other? |
| | How did this function affect | ct your co | mmunications with your c | crew memb | er? |
| | Interfered with 1 | 2 | Did not change 3 | 4 | Improved 5 |
| III. | Background/Demo | graphics | | | |
| | | | | | |
| 52. | Crew Position :Pilot | Taxiing | Pilot Not Taxiing | g | |
| 52. 53. | Crew Position :Pilot [*] Total Hours Flown: | Taxiing | Pilot Not Taxiing | 95 | |
| 52. 53. | Crew Position :Pilot Total Hours Flown: 1,500 hours or 1,501 to 3,000 1 3,001 to 7,000 1 More than 7,000 | Taxiing less hours hours 0 hours | Pilot Not Taxiing | g | |
| 52. 53. | Crew Position :Pilot ⁴ Total Hours Flown: 1,500 hours or ⁴ 1,501 to 3,000 f 3,001 to 7,000 f More than 7,00 Last 90 days: | Taxiing less hours hours 0 hours | Pilot Not Taxiing | g | |
| 52. | Crew Position :Pilot ⁷ Total Hours Flown: 1,500 hours or ⁷ 1,501 to 3,000 f More than 7,000 f More than 7,000 Last 90 days: 25 hours or less 26 to 75 hours 76 to 125 hours 126 to 225 hours More than 225 | Taxiing less hours hours 0 hours | Pilot Not Taxiinş | g | |
| 52. 53. 54. | Crew Position :Pilot ⁷ Total Hours Flown: 1,500 hours or ⁷ 1,501 to 3,000 f 3,001 to 7,000 f More than 7,00 Last 90 days: 25 hours or less 26 to 75 hours 126 to 225 hours 126 to 225 hours More than 225 Have you flown an aircraft | Taxiing less hours hours 0 hours s rs hours equipped | Pilot Not Taxiing with an airport moving n | g nap before 1 | the start of this operational |

 Yes If so, please answer the following by placing a ''X'' on ALL applicable lines.

 ______as a test flight or sim evaluation

 _____as part of a simulator evaluation

 _____as part of revenue service

 _____other (please write in your response →):

evaluation?

- 55. Please estimate the approximate number of **taxi segments** that you have operated with an airport moving map. (Keep in mind to count two if you used airport moving map at both ends of a flight):
 - _____ 10 or less _____ 11 to 50 _____ 51 to 100 _____ 101 to 200
 - _____ 201 or more
- 56. Have you flown an aircraft equipped with an EFB before the start of this operational evaluation? _____ No

| Yes I | If so. | nlease | answer | the | fol | lowing | hv | nlacing | a ''X'' | ' on ALI | annlicabl | le l | lines |
|----------|----------------|--------|---------|-----|-----|--------|-----|----------|---------|----------|-----------|------|-------|
| 1001 | ., <i>s</i> v, | prouse | and the | | , | | • • | practing | ~ 11 | 01011111 | . appneae | | |

- _____ as a test flight or simulator evaluation
- _____ as part of revenue service
- _____ other (please write in your response \rightarrow): ______

Please indicate the approximate number of flights that you have operated with an EFB:

- 5 or less 6 to 25 26 to 50 51 to 100
- _____ 101 or more

Please indicate which applications you used on the EFB:

- _____ Electronic Charts
- _____ Electronic Checklists
- _____ Electronic Documents/Manuals
- _____ Flight Performance Calculations
- _____ Flight Planning
- _____ Weather
- _____ Logbook
- _____ Other. Please specify: ______

57. When do you complete the short survey on the EFB most frequently (choose one)

_____ after take off _____ after landing _____ about the same

58. The training I received on how to use the airport moving map was adequate.

| Strongly Disagree | | | | Strongly Agree |
|-------------------|---|---|---|----------------|
| 1 | 2 | 3 | 4 | 5 |

What additional training would you like?

59. The training I received on how to use the electronic flight bag was adequate.

| Strongly Disagree | | | | Strongly Agree |
|-------------------|---|---|---|----------------|
| 1 | 2 | 3 | 4 | 5 |

What additional training would you like?

IV. Aural Runway Safety Alerts

Was an aural runway alerting system provided?

_____ Yes

If Yes, pilots will be asked to complete Section IV.

60. The aural alerts provided sufficient awareness of my position with respect to runways.

| Strongly Disagree | | | | Strongly Agree |
|-------------------|---|---|---|----------------|
| 1 | 2 | 3 | 4 | 5 |

61. The aural alerts were always accurate.

| Strongly Disagree | | | | Strongly Agree |
|-------------------|---|---|---|----------------|
| 1 | 2 | 3 | 4 | 5 |

If you disagree (1, 2), please indicate which aural alerts were presented in error: [Note. The alerts listed below are specific to the Runway Awareness and Advisory System (RAAS)].

| | Approaching | Runway – | On | Ground | Advisories |
|--|-------------|----------|----|--------|------------|
|--|-------------|----------|----|--------|------------|

- _____ On Runway Advisories
- _____ Approaching Runway In Air Advisories
- _____ Distance Remaining Landing and Rollout Advisories
- 62. The volume of the aural advisories was:

Too LowJust RightToo Loud12345

Did you adjust the volume of the aural advisories? _____ Yes _____ No

63. The volume of the aural advisories interfered with other communications.

| Strongly Disagree | | | | Strongly Agree |
|-------------------|---|---|---|----------------|
| 1 | 2 | 3 | 4 | 5 |

64. The volume of the aural advisories did not interfere with other tasks on the flight deck.

| Strongly Disagree | | | | Strongly Agree |
|-------------------|---|---|---|----------------|
| 1 | 2 | 3 | 4 | 5 |

65. The training I received on the aural alerting system was adequate. No additional procedures or policies are required to use it.

| Strongly Disagree | | | | Strongly Agree |
|-------------------|---|---|---|----------------|
| 1 | 2 | 3 | 4 | 5 |

Appendix C. Interview Survey for Airline Training/Simulator Facilities and/or Pilot Lounges

Many airlines have indicated an opportunity for face-to-face meetings with pilots either at their facilities or at airports. The items in this survey provide starting points for discussions with pilots about their experiences with the airport moving map and EFB. It is expected that additional questions will be raised in these face-to-face meetings.

Airport Moving Map

1. 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?

Is there any information you would like to add to the airport moving map? Is there any information you would like to delete from the airport moving map?

2. What do you consider to be the most effective feature(s) of the airport moving map technology in preventing runway incursions? Why?

When do you think the airport moving map is most useful (e.g., in low visibility, at complex and/or unfamiliar airports, when clearing a runway)?

Were there any properties of the airport moving map that could potentially reduce safety?

3. 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?

How did you resolve this situation?

- 4. What problems or errors do you think other pilots might encounter with the airport moving map display?
- 5. What feature(s) or aspects of the airport moving map system do you think could be improved?
- 6. How did the airport moving map influence your communication with your crew member? What impact did it have on your ability to complete other duties?

How did the airport moving map influence your communication with air traffic control?

7. Are any rules/procedures needed to support better use of the airport moving map applications?

Electronic Flight Bag

8. Did you encounter any problems finding information on the EFB?

If yes, which applications? Also, please describe the problem.

- 9. 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.
- 10. Did you ever get any failure or error message flags? Please describe the conditions.
- 11. Do you feel that the airline's EFB policies, procedures, and training, were sufficient for efficient and safe EFB operation?
- 12. Did the EFB provide the ability to share information from one display to the other? If so, did you use this function? If yes, please describe the operating conditions. If no, why not?

Appendix D. EFB Survey: User Guide

Overview

The EFB Survey contains 10 questions that address information specific to the taxi segment most recently completed. The survey is expected to be completed for every airport, either when the aircraft is parked at the gate or en-route, as determined by the airline and the FAA. The survey is designed to be completed in 90 seconds or less.

To answer a question, touch the button on the display that corresponds most closely to your response. The shade of the button touched will change to indicate that it has been selected. You must answer all the questions on a page before you can go to the next page. A status bar is provided at the top of each page to indicate your progress through the survey. A "Back" button is provided if you want to review your responses, and an "Exit" button is included on every page if you need to exit the survey before completing all 10 questions. (Note: If you exit the survey prior to completing all 10 questions, the partial survey will not be retained in the data base. If you wish to go back in to complete the survey, you will receive a new blank survey form.)

When the survey has been completed, touch the "Submit" button at the bottom of the last screen. This will submit the survey responses so it can be downloaded and sent to the FAA. You are asked to complete the survey for each taxi segment whenever possible, even if the answers are the same.

Step-by-Step Instructions EFB Survey Page 1



- 1. Enter the 4-letter ICAO airport identifier. If you are completing this survey in the air, enter the airport identifier for the departure airport. If you are completing this survey at the gate, enter the airport identifier for the arrival airport.
- 2. Enter your crew position: Taxiing or Not Taxiing.
- 3. Indicate whether a surface moving map was available for the airport you entered in (1).
- 4. Touch the "Next" button to go to the next page. (Note: The "Next" button can not be selected until you complete all the questions on this page.)

EFB Survey Page 2



- 1. Enter the time of day you conducted the taxi operation: day, dawn/dusk, night.
- 2. Indicate the RVR at the airport when you conducted the taxi operation.
- 3. Enter the condition of the airport surface: was it mostly dry, mostly wet, or mostly snow?
- 4. Rate how familiar you were with the taxi route you were given during the taxi segment. A "5" indicates that you were very familiar with the taxi route; a "1" indicates that you were not familiar with it.
- 5. Indicate how often you referred to the surface moving map display during the taxi segment. A "5" indicates that you referred to it very frequently; a "1" indicates that you never referred to it.
- 6. Touch the "Next" button to go to the next page. (Note: The "Next" button can not be selected until you complete all the questions on this page. You may use the "Back" button if you would like to review your responses on the previous page.)

If a surface moving map was available *and* you indicated that you referred to it, then you will see four questions addressing the usability of the surface moving map display (go to Step 1 on Page 51). Otherwise, you will see with four questions addressing the usability of the EFB (go to Step 1 on Page 53).

EFB Survey (SMM usability) Page 3

NOTE: *This is the page you will see if you used the surface moving map.*

| EFB Survey | | 08/07/09 | | | |
|--|---|---|--|--|--|
| How did the position moving map with own airport chart only? Decreased Awareness 1 2 | awareness pro ship compare No Difference | ovided by the surface to a paper/electronic Increased Awareness | | | |
| How did the surface compared to a paper More difficult to perform other duties | moving map af /electronic airp No Impact 3 | fect other duties port chart only? Less difficult to perform other duties 4 5 | | | |
| How did the surface moving map affect the safety of taxi operations on this segment? Decreased Safety No Difference Increased Safety | | | | | |
| Exit | Back | 4 5 | | | |
| | | | | | |

- 1. Answer the three questions on this page to provide your impressions of the surface moving map and the effect it had on your taxi operations.
- 2. Touch the "Next" button to go to the next page. (Note: The "Next" button can not be selected until you complete all the questions on this page. You may use the "Back" button if you would like to review your responses on the previous pages.)

EFB Survey (SMM Usability) Page 4

NOTE: *This is the page you will see if you used the surface moving map.*



1. Indicate whether you noticed any position errors of ownship or the surface moving map during the taxi segment.

In rare cases, the information on surface moving map display may not match the out-the-window view (for example, as the result of a positioning error, airport survey error, or system latency). This question collects information on any error in ownship position or the airport map so that it can be verified and corrected. Because it is possible that there may be more than one error observed, pilots are asked to take note of the *most significant* position error observed when responding to this survey question and report the location of the error. In the case of any differences between the information on the surface moving map display and the out-the-window view, the information out-the-window takes precedent.

If you notice an error, please follow your airlines procedures to provide further details, such as the size of the error, the actual location of your aircraft, and where ownship was drawn on the surface moving map display. You may also log on to the online survey to provide this information.

2. Touch "Submit" when you are done to ensure that your responses are properly saved.

EFB Survey (EFB Usability) Page 3

NOTE: This is the page you will see if you did not use the surface moving map.



- 1. Answer the three questions on this page to provide your opinions about the EFB.
- 2. Touch the "Next" button to go to the next page. (Note: The "Next" button can not be selected until you complete all the questions on this page. You may use the "Back" button if you would like to review your responses on the previous pages.)

EFB Survey (EFB Usability) Page 4

NOTE: *This is the page you will see if you did not use the surface moving map.*



1. Please indicate if there was a problem with the EFB hardware or software during the flight, and if so, the phase of flight in which the problem occurred.

If you notice an error, please follow your airlines procedures to provide further details about exact nature of the problem with the EFB hardware or software (such as difficult to read the enroute chart). You may also log on to the online survey to provide this information.

2. Touch "Submit" when you are done to ensure that your responses are properly saved.

Appendix E. Capstone 3 EFB Survey Instructions

The EFB Survey contains 10 questions that address information specific to the taxi segment most recently completed. The survey is expected to be completed for every airport, either when the aircraft is parked at the gate or en-route, as determined by the airlines and the FAA.

To respond to each of the survey questions, pilots should touch the button on the display that corresponds most closely to their response. A "Back" button is provided if the pilots want to review their responses, and an "Exit" button is included on every page if the pilot needs to exit the survey before completing all the questions. (Anytime the pilot exits the survey prior to completing all 10 questions, the partial survey will not be retained in the data base.)

When the survey has been completed, touch the "Submit" button at the bottom of the last screen. This will submit the survey responses so it can be downloaded and sent to the FAA. Pilots are asked to complete the survey for each taxi segment whenever possible, even if the answers are the same.

The following question is an attempt to collect information on any error in ownship position or the airport map so that it can be verified and corrected.

What was the most significant position error of ownship or the airport map that you observed during this taxi segment?

_____ No errors.

- _____ Ownship was drawn on the wrong runway
- _____ Ownship was drawn on or near the edge of my **runway**
- _____ Ownship was drawn on the wrong taxiway
- _____ Ownship was drawn on or near the edge of my taxiway
- _____ Ownship was drawn in the grass
- _____ Ownship was drawn in the wrong location in the ramp areas
 - ____ Other

In rare cases the information on surface moving map display may not match the out-the-window view (for example, as the result of a positioning error, airport survey error, or system latency). In the case of any differences between the information on the surface moving map display and the out-the-window view, the information out-the-window takes precedent. Because it is possible that there may be more than one error observed, pilots are asked to take note of the *most significant* position error observed when responding to this survey question and report the location of the error.

If an error is noticed, the pilot is encouraged to follow procedures established with each airline for providing further details on the error.

Appendix F.Volpe Center Data Protection Assurance

CRITA John A. Volpe National Transportation Systems Center U.S. Department of Transportation

Volpe Center Capstone 3 Interviews Data Protection Assurance

This document describes how the Volpe Center will protect data submitted for the purpose of evaluation during the Capstone 3 Electronic Flight Bag – Surface Moving Map (EFB – SMM) operational evaluation. The strongest source of protection of confidentiality is that the Volpe Center will not record names or any personally identifying information from interviewees. Any personally identifying information received from the airlines inadvertently will be removed to prevent creating a record of the information in the project databases. Airlines will have the opportunity to review the interview questions beforehand.

Please be assured that the Volpe Center has taken affirmative steps to minimize the collection of personally identifiable information and to maintain anonymous data collection. Should any Volpe Center employee receive a work-related subpoena to testify about any information collected, s/he must notify Volpe legal counsel, who will treat it in accordance with Department of Transportation regulations at Title 49 CFR Part 9 – Testimony of Employees of the Department and Production of Records in Legal Proceedings. 49 CFR Part 9.5 provides: "No employee of the Department may provide testimony or produce any material contained in the files of the Department, or disclose any information or produce any material acquired as part of the performance of that employee's official duties or because of that employee's official status unless authorized in accordance with this part, or by other applicable law." One of the purposes of Part 9 is "To protect confidential, sensitive information and the deliberative process of the Department." (49 CFR §9.2 (5))

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