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The purpose of this symposium is to identify and address common human factors issues with new and emerging avionics technologies, share lessons learned, and to provide an understanding of how the Federal Aviation Administration (FAA) applies human factors research to enhance aviation safety. Flight deck technologies have been changing at a rapid pace, requiring updates to Federal Aviation Administration (FAA) regulations, guidance, and policy. This symposium will focus on flight deck technologies that will assist in NextGen implementation by improving flight crew awareness through Cockpit Displays of Traffic Information (CDTI), Airport Moving Maps, Primary Flight Displays (PFDs), and portable technologies. The results of this human factors research helps enable the FAA Office of Aviation Safety to develop and update establish evaluation criteria, operational procedures, and training recommendations.

Modern avionics are key to achieving NextGen's goals to increase efficiency, enhance safety, and improve situation awareness, both in the air and on the ground. New and emerging flight deck technologies have been changing at a rapid pace, and research is needed to identify the human factors/pilot interface issues associated with them. Pilot performance and efficiency during NextGen operations, support for the infrastructure needed to enable efficient and safe use of these advanced flight deck technologies, and the corresponding impact on operational safety are important considerations. The results of human factors research will help the FAA Aviation

Safety Organization establish evaluation criteria, operational procedures, and training recommendations.

The purpose of this symposium is to address new and emerging avionics technologies to highlight key research issues, share lessons learned, and discuss how the FAA uses the results of this research. This symposium will focus on flight deck technologies that will assist in NextGen implementation by improving flight crew awareness through Cockpit Displays of Traffic Information (CDTI), Airport Moving Maps, Primary Flight Displays (PFDs), and portable technologies. Common themes across multiple avionics projects include usability, system integration, symbology, controls, human/pilot error mitigation, workload, and distraction.

This symposium consists of five presentations. The first addresses the FAA's research needs associated with new avionics technologies, describe the general process for how research projects are initiated and coordinated, and how results are transitioned to implementation in the field or in regulation. The next four presentations address human factors challenges with new technologies focusing on symbology design, human interaction with information automation, information acquisition via electronic versus paper mediums, and the approval and evaluation of new technologies.

FAA Flight Deck Human Factors

The FAA recognizes human factors as a critical contributor for improving aviation safety and acknowledges that role in Order 9550.8, *Human Factors Policy* (FAA, 1993). This Order highlights that long-term improvements in aviation safety will be the result of consistent support for human factors research, analysis, and development and the implementation of those results (FAA, 1993). The role and implementation of human factors is spread throughout the Agency. The FAA Human Factors Division provides scientific and technical support for civil aviation human factors research. They manage, direct, and coordinate the FAA's human factors program for both flight deck and air traffic control. With respect to the flight deck, the FAA Human Factors Division provides research support to the FAA Office of Aviation Safety (AVS; Aircraft Certification and Flight Standards Services), who is responsible for the certification, production approval, and continued airworthiness of aircraft as well as the certification of pilots, mechanics, and others in safety-related positions. AVS performs two key activities: (1) evaluating and approving new or modified aircraft, equipment, operators, procedures, maintenance, etc. and (2) developing regulatory and guidance material. The goal of the FAA Flight Deck human factors research program is to provide research input to support these activities.

Human factors research into new technologies and operations enables a data-driven approach to the human factors aspects of new technologies and operations, analysis of safety data, and many other areas. This research is important for identifying potential or emerging safety issues, upcoming technologies and operations, and current operational safety issues, and to provide the research data to inform and support the AVS regulatory and oversight activities. Writing regulations and policy is difficult because it is important to write the guidance to say what is intended as well as to be clear as to what is *not* intended. In applying research products to the regulatory process, it is important for researchers to understand the role of AVS and what is needed, to use the same terminology or identify how it is different, and to provide data so AVS can be better positioned to know what should *not* be approved. The success of a research program is determined by how results of research are used. The benefit to the FAA is to develop and update establish evaluation criteria, operational procedures, and training recommendations. In some cases, industry may also benefit from the research results.

One example of a research success is the FAA's Electronic Flight Bag (EFB) research program. An EFB is an electronic display system that can be used to present data, such as electronic charts, checklists, documents, or to conduct basic calculations. EFBs can take many forms from a laptop or tablet computer to an installed display and processor in the flight deck. Figure 1 presents an overview of the steps from the initiation of research to implementation of a research program. The figure is intended to reflect the general process for initiating research and transitioning the results to implementation in the field or in regulation.

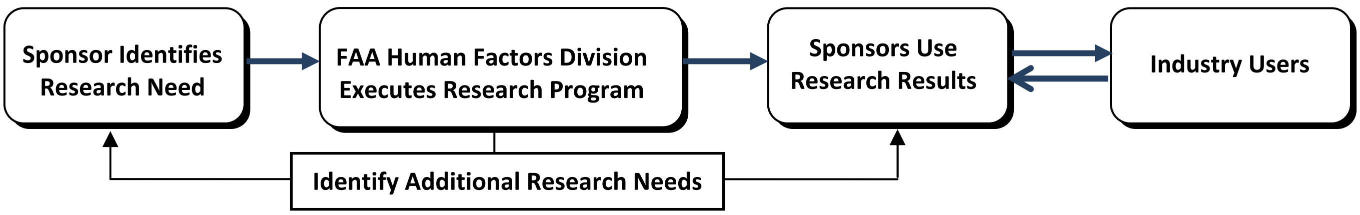

Figure 1. Research to Reality.

In the first block, technical sponsors in safety organizations within the FAA identify a research need and communicate that need to the research organization. For this particular example, the Electronic Flight Bag (EFB) research program was initiated by the FAA Human Factors Division in response to a research requirement from AVS to provide a capability for FAA Certification and Flight Standards personnel to evaluate human factors aspects of EFBs. Once this research requirement was identified, the FAA Human Factors Division sponsored the United States (US) Department of Transportation (DOT) Volpe Center to conduct this research, as noted in the figure by the second block. During the execution of this research program, Volpe Center researchers coordinated with FAA technical sponsors, the FAA Human Factors Division program manager, and the EFB industry, including EFB manufacturers, airline operators, and EFB software providers. The research products included a general reference on human factors considerations for EFBs, industry surveys to provide information on the state-of-the art, and EFB evaluation tool kits. (For a full list of EFB research results, see www.volpe.dot.gov/coi/hfrsa/work/aviation/efb.)

As a result of this coordination, AVS incorporated many of the results in policy and guidance material. This is Step 3 in Figure 1. The FAA referenced the Volpe Center EFB research in AC 120-76A, *Guidelines for the Certification, Airworthiness, and Operational Approval of Electronic Flight Bag Computing Devices*, and this information was also incorporated into subsequent revisions. The Volpe Center research was also used to develop the initial EFB Job Aid (Notice N8200.98). Notice N8200.98 has since expired, but the information was incorporated into FAA Order 8900.1, volume 4, chapter 15, Section 1, *Electronic Flight Bag Operational Authorization Process.* As a result, the Volpe Center research continues to influence any user who has sought approval of authorization to use an EFB because the research was referenced in FAA regulatory and guidance material.

In some cases, the research sponsored by the FAA may also support industry, as shown by the last block in Figure 1. As part of the Volpe coordination, industry participated in several efforts throughout the research projects to test Volpe-developed products. This collaboration benefited the FAA who received better research products as a result and industry who received human factors input on their products.

Examining the Intuitiveness of Traffic Symbology for CDTIs, Stephanie Chase, US DOT Volpe Center

The purpose of this research effort was to develop an understanding of which traffic symbol attributes are perceived to be useful by pilots and which symbol shapes and their properties (e.g., fill, shape, or color) are intuitive for pilots. The Volpe Center developed a paper-based questionnaire that comprised three tasks. In Task 1, pilots rated the usefulness of several attributes of traffic symbols. In Tasks 2 and 3, pilots were shown symbols from current and proposed symbol sets and asked to identify which symbols were representative of an information type or combination of information types. Seventy-nine pilots with a variety of flight experience participated in the study. The results indicated that color is an intuitive cue of airborne vs. ground traffic, although the shade of brown can be problematic since it is confusable with yellow at low brightness levels. Overall shapes indicating direction, such as a chevron, were found to be representative for directional information; non-directional symbols were found to be less intuitive and, in some cases, caused confusion. Other information types, such as data quality, generated mixed results. Initial findings indicate that alert information is perceived to be very useful to pilot while off scale and data quality less useful. Additional research is needed to further determine the usefulness of this information and how it relates to the intuitiveness for pilots.

Comparing Use of Electronic vs. Paper Documents on the Flight Deck, Juliana Goh, MITRE

EFBs provide a device to store and view documents, charts and maps that have traditionally been presented on paper. Given the increased use of EFBs on aircraft in commercial operations, it is important to understand any performance differences in how information is acquired, understood and retained when using electronic displays versus paper. It is also important to take into account different design related considerations when electronic displays are being used.

In general, acquiring textual information from electronic displays is at least as good as doing so from paper. Studies from the 1980s, based on extended reading from Cathode Ray Tube (CRT) displays showed, in general, that reading performance was slower than from paper. This difference could, however, be minimized and, in some cases, eliminated, when certain factors (e.g. double spacing, negative contrast) were taken into consideration. More recent studies based on better quality displays (e.g. Liquid Crystal Display) focused on variables (e.g. age and prior experience with electronic displays) other than display quality that could explain differences in reading performance from the two media. With regards to acquiring spatial information, the use of electronic maps have been demonstrated to be superior to paper maps because of the ability to selectively layer information when using an electronic display.

The research literature also suggests various design considerations to be made in the use of electronic displays: legibility, navigation and customization. Legibility refers to the clarity with which information is presented to the user. Navigation refers to the ease with which the user is able to locate him/herself within the body of text and go to locations within the text to retrieve the needed information. Finally, customization refers to the ability to interact with the electronic display or document in a manner that supports an individual's cognitive activities.

Information Automation, Bill Rogers, Honeywell

Flight Deck Information Automation (IA) as a distinct type of automation was proposed by Billings (1991). IA can integrate, summarize, distribute, format, abstract, prioritize, categorize, calculate, and process information in a variety of ways to support pilot tasks. It can include decision, task, and information management aids. With the proliferation of systems on the flight deck that are intended to provide information and situation awareness for the flight crew (e.g., EFBs, DataComm systems, advisory systems, decision aids, electronic charts, etc.), issues related to IA systems are likely to increase, but as a distinct type of automation, it is not well understood; often the term "automation" is used to describe automated systems of all kinds, including control automation, information automation, and management automation. Human Factors issues that are associated with control automation, such as mode confusions, may not be as important to IA, and certain types of human factors issues and pilot errors might be prevalent in interacting with information automation that are minimal for other types of automation.

FAA-sponsored Honeywell work focused on IA will be described here. The overall goal of this work is to provide recommendations for designers and evaluators of IA systems to assure that Human Factors issues unique to IA systems are identified and mitigated. Work will be described that defines IA and presents a framework for comparing and contrasting it to other types of automation. Specifically, a framework distinguishing different types of automation by utilizing human information processing stages, and a characterization of what entity is being controlled, will be described. Based on this automation framework, types of Human Factors issues for IA were identified and will be described, especially those that are hypothesized to be unique to IA or that likely manifest themselves in a substantially different way for IA than for other types of automation. Further, characteristics of IA that could impact user performance and user-IA system interaction, such as complexity and opacity, will be described in the context of potential risks and mitigations.

Finally, plans for empirical studies to evaluate the issues and mitigations identified analytically will be described, and examples of the intended outputs of the project will be provided.

Guidance and Tools for the Evaluation/Certification of NextGen Primary Flight Deck Displays, Nadine Sarter, University of Michigan

Aircraft technologies and operations can be expected to continue to grow in complexity. This trend brings with it an increase in the number of pilot responsibilities and the amount of data that is available to, and needs to be considered by flight crews. One important flight deck display that has changed significantly in recent years is the Primary Flight Display (PFD). More information has been added to this display (e.g., terrain information and synthetic vision), and a considerable number of different designs have been proposed. This project focuses on helping the FAA develop approval criteria for future PFDs. In particular, though not exclusively, the issue of clutter is being examined. Clutter has been defined as the result of high information density and/or poor layout of information. Performance effects of clutter are the result of an interaction between these display-related factors and top-down operator-related factors, such as experience. In an effort to provide guidance for the design and evaluation/certification of PFDs for advanced aircraft, we have conducted a survey of current PFD designs and another survey of pilots' operational experiences with these PFDs. We also reviewed and compiled existing research findings and regulatory documents that are relevant to the evaluation of PFDs. This has resulted in a draft general guidance documents and a PFD evaluation checklist for certification personnel. Finally, we are conducting simulation studies to develop eye tracking-based assessment tools that can detect the various attentional costs associated with clutter. These tools will be useful to manufacturers by informing the development and iterative refinement of PFDs as well as providing supportive evidence for the effectiveness of a proposed design.

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