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Addressing Human Factors/Pilot Interface Issues for Avionics

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FOREWORD

This document was prepared by Special Committee 233 (SC-233) and approved by the RTCA Program Management Committee (PMC) on December 19, 2017.

RTCA, Incorporated is a not-for-profit corporation formed to advance the art and science of aviation and aviation electronic systems for the benefit of the public. The organization functions as a Federal advisory committee, and develops consensus-based recommendations on contemporary aviation issues. RTCA's objectives include but are not limited to:

- coalescing aviation system user and provider technical requirements in a manner that helps government and industry meet their mutual objectives and responsibilities;

- analyzing and recommending solutions to the system technical issues that aviation faces as it continues to pursue increased safety, system capacity and efficiency;

- developing consensus on the application of pertinent technology to fulfill user and provider requirements, including development of minimum operational performance standards for electronic systems and equipment that support aviation; and

- assisting in developing the appropriate technical material upon which positions for the International Civil Aviation Organization and the International Telecommunication Union and other appropriate international organizations can be based.

The organization's recommendations are often used as the basis for government and private sector decisions as well as the foundation for many Federal Aviation Administration Technical Standard Orders and several advisory circulars.

Since RTCA is not an official agency of the United States Government, its recommendations may not be regarded as statements of official government policy unless so enunciated by the U.S. government organization or agency having statutory jurisdiction over any matters to which the recommendations relate.

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EXECUTIVE SUMMARY

The aviation accident rate is at the lowest rate it has ever been with 0.23 fatal accidents per million departures of commercial passenger operations[1] though the general aviation market still hovers around 1 fatal accident per 100,000 flight hours (Airbus, 2016; Boeing, 2016; Federal Aviation Administration, 2016). One result that has not changed with the aircraft accidents is the consistent finding that the majority of accidents have human error as a contributing factor (Wiegmann & Shappell, 2001; Shappell et al., 2007; Dismukes, Berman, & Loukopoulos, 2007). These findings emphasize the importance of addressing human factors throughout the product development and certification process. The consideration of the design aspects that impact human performance and the process for evaluating the human factors aspects will lead to easier to use, more efficient, more reliable and safer systems, as well as reduce the need for costly redesign.

Recognizing the importance of human factors, the Federal Aviation Administration (FAA) requested that RTCA form a committee to identify a recommended process for evaluating the human factors/pilot interface aspects of avionics as well as to document some prevalent human factors issues that may aid the early identification and resolution of these issues as part of the engineering design and evaluation process. The FAA documented this information previously in expired FAA Notice 8110.98, *Addressing Human Factors/Pilot Interface Issues of Complex, Integrated Avionics as Part of the Technical Standard Order (TSO) Process*. The original notice only addressed the TSO process, however human factors issues were being regularly identified late in the Type Certificate (TC), Supplemental Type Certificate (STC), and Amended Type Certificate (ATC) processes with installed avionics. The goal of this RTCA document was to extend the expired FAA Notice to address these processes. In addition, the FAA aimed to promote the early identification and resolution of human factors issues as part of the engineering design and evaluation process.

RTCA formed Special Committee 233 made up of individuals representing industry and certification authorities with human factors experience in product development and certification. Described herein are practices that capture an effective process for evaluating the human factors aspects of avionics (Section 2) and a compilation of prevalent, recurring human factors issues identified during past certification programs in an effort to avoid common pitfalls (Section 3). Section 2 is based on the original steps in expired FAA Notice 8110.98. Considerations were made for extending the process to include TC, STC, and ATC. For Section 3, the aim was not to identify every human factors issue encountered but to provide representative samples. The focus remained on two core principles: (1) identifying human factors aspects in a generic evaluation process that could be tailored as appropriate and used by both avionics manufacturers, Original Equipment Manufacturers (OEMs), and certification authorities alike, and (2) including only those human factors issues that were recurring in the certification process and had a clear human factors basis.

The anticipated implementation of this special committee's RTCA document is to be acknowledged in a new FAA information-only advisory circular. It is meant to aid in the early identification of human factors aspects and the resolution of pilot interface issues as part of the engineering design and certification process, but is not intended as a means of compliance for certification. Regulatory requirements and guidance take precedence over the content of this document. Section 2 can be used as a guide that, if followed, should minimize the number of late and costly design changes. Section 3 can be used to identify specific human factors aspects to consider when designing avionics and/or conducting human factors/pilot interface evaluations of avionics.

The end of this document provides a form to submit comments and considerations for future updates to the document. Comments should be provided to RTCA at 1150 18th Street NW, Suite 910, Washington, DC 20036, addressed to Rebecca Morrison, Program Director.

[1] Boeing accident statistics consider worldwide jet airplanes heavier than 60,000 pounds (Boeing, 2016).

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1 PURPOSE AND SCOPE

1.1 Introduction

The objective of this document is to increase human factors[1] awareness by the individuals who are responsible for the design and certification of systems and equipment and related interfaces designed for use by the flightcrew. This applies to systems and equipment that are certified at the box level or installation level. The term "flightcrew" is used in this document to represent a pilot, flight engineer, or flight navigator assigned to duty in an aircraft during flight time per Title 14 Code of Federal Regulations (CFR) Part 1 Section 1.1. This document aims to facilitate the identification of flightcrew interface aspects, considerations, and risks to design and aid the resolution of the human factors issues associated with the avionics. The importance of addressing the human factors aspects of the design is highlighted in the *Operational Use of Flight Path Management Systems - Final Report of the Performance-based Operations Aviation Rulemaking Committee/Commercial Aviation Safety Team, Flight Deck Automation Working Group* that identifies incidents and aviation accidents that have occurred due to pilot-machine interface breakdowns, such as manual flight path control errors, controlled flight into terrain, mode confusion, and over reliance on automation. The report highlights the impact of highly integrated flight decks[2] and poorly integrated retrofit solutions and how each can increase the flightcrew knowledge requirements and add complexity, which may result in pilot confusion and errors during flight operations in all phases of flight.

The Federal Aviation Administration (FAA) previously documented information on human factors in the expired FAA Notice 8110.98, *Addressing Human Factors/Pilot Interface Issues of Complex, Integrated Avionics as Part of the Technical Standard Order (TSO) Process*. This RTCA document extends the expired Notice beyond avionics submitted for new or amended Technical Standard Order (TSO) Authorization to include installed electronic systems (and associated controls, displays, labels, and placards) used by the flightcrew[3] that are submitted for a Type Certificate (TC), Supplemental Type Certificate (STC), or Amended Type Certificate (ATC) under 14 CFR and Certification Specification (CS) Parts 23, 25, 27, and 29. The FAA intends to implement this document in an information-only advisory circular (AC). Regulatory and guidance material takes precedence over this document.

This document outlines a process for identifying the flightcrew interface aspects of a system as part of the engineering design and certification process, and provides previously approved design examples of how human factors aspects were addressed. Neither the process nor the examples are meant to be prescriptive. Therefore, "must" statements are not contained herein unless they refer to certification authority regulations. Good practices and lessons learned are provided as a means to inform the development and certification process in an effort to avoid common pitfalls that have been observed in past certification efforts.

[1]The FAA Reauthorization Act of 2016 defines human factors as "a multidisciplinary field that generates and compiles information about human capabilities and limitations and applies it to design, development, and evaluation of equipment, systems, facilities, procedures, jobs, environments, staffing, organizations, and personnel management for safe, efficient, and effective human performance, including people's use of technology". When applied specifically to the field of aviation, the aim is to use human factors knowledge to improve safety, efficiency, performance, and reliability through the focus on how pilot performance is impacted by systems, procedures, and training.

[2]The term "flight deck" is used interchangeably with "cockpit" throughout the document. There is no difference in meaning between the two terms as used in this document.

[3] For the purposes of this document, the term "avionics" includes installed electronic systems and all associated controls, displays, labels, and placards used by the flightcrew.

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It is assumed that the reader has an understanding of human factors or access to human factors specialists and therefore this is not a 'how to' human factors document. The intended readers include Original Equipment Manufacturers (OEMs), including the Designated Engineering Representatives (DERs), Authorized Representatives (ARs), Unit Members (UMs) or Organization Designation Authorization (ODA) holders who represent both industry and the certification authority, flight test pilots, flight test engineers, as well as human factors specialists and other personnel at the Aircraft Certification Offices (ACO) and Flight Test Branch of the appropriate certification authority. This document is meant to aid in the early identification of human factors aspects and the resolution of flightcrew interface issues as part of the engineering design and certification process, but is not intended as an MOC for certification.

This RTCA document contains the following sections:

Section 1 covers the introduction and overview of the document (current section).

Section 2 presents recommended steps for evaluating the human factors/pilot interface aspects of flightcrew systems during the engineering design and certification process to facilitate future approvals and streamline or establish commonality in the certification process. The process is not intended as a means of compliance (MOC) but rather as guidance for identifying and resolving flightcrew interface issues. Section 2 describes an iterative approach in which human factors aspects are identified, addressed and issues resolved continuously throughout the development program and not something left for the formal test phase at the end of a certification program. The recommended process has been successfully applied in previous aircraft programs and can be used as a guide for both the applicant and the certification authority as they go through a certification program. The process described in Section 2 is intentionally generic so as to fit into the overall certification effort, with the understanding that the scope of the activities should be tailored to the size of the project. Adherence to the process is a recommendation only. To assist in the evaluation of human factors aspects, good practices from past certification programs are provided as examples for carrying out each process step.

Section 3 provides examples of prevalent, recurring human factors/pilot interface issues that have been identified during previous certification programs. The identified issues are not a comprehensive list of all possible flightcrew interface issues but are meant to serve as an aid in the early identification of certification topics of discussion. Approved design examples emphasize the design aspects that resolved a particular human factors issue but are not the only method available to address the issue. Implementing the design examples in this document does not guarantee certification approval but instead represent good design practices that have led to an effective means for resolving the issue. Also included are a number of lessons learned that include design and evaluation considerations from a human factors perspective. When existing regulations and guidance are applicable, it is noted. The human factors topics compiled from previous programs that generated the most frequently recurring certification issues include:

- Display Hardware Characteristics (Display Viewing Envelope, Display Luminance, Reflectivity, and Brightness Control including Retrofit Considerations, Latency)
- Information Presentation (Color including Retrofit Considerations, Symbology, Display Labeling, Clutter, Timeliness of Information)
- Alerting, Annunciations, and System Status Indications (Degradation of Sensor Sources, Crew Alerting Systems, Inhibits and Control of Nuisance Alerting, Retrofit Considerations: Integration Using Equipment from Multiple Suppliers)
- Controls (Feedback, Control Labeling, Functionality, Cursor Control Devices, Touch Screens)

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- Flight Deck Arrangement (Visibility and Readability, Reach Accessibility)
- Automatic Flight Control and Flight Guidance Systems (Awareness of System Modes and States, Low Speed Alerting and Mode Transitions, Autopilot Engagement/Disengagement, Manual Control During Autopilot Use, Vertical Navigation, Retrofit Considerations: Flight Directors and Flight Path Markers, Retrofit Considerations: Automatic Flight Control System (AFCS) and Autopilot (AP) Integration with Servos)

Section 4 provides the list of committee members.

The document also contains four appendices.

Appendix A contains human factors related regulatory references and guidance applicable to Title 14 CFR for Parts 23, 25, 27 and 29 aircraft, and European Aviation Safety Agency (EASA) CS for Part 25. Also, industry standards and other human factors related documents referenced in this document are listed in this appendix.

Appendix B provides websites for human factors related regulatory and guidance material and industry documents.

Appendix C contains the glossary of terms used in this document.

Appendix D is a list of acronyms and abbreviations.

Note that throughout the document regulations and guidance material are referenced. When the guidance is applicable to all Title 14 of the Code of Federal Regulations, Parts 23, 25, 27, and 29 aircraft, the abbreviation 2X is used, such as 2X.1301 *Function and installation*.

In this document, technical and guidance references with "()" indicate that the most recent version of the reference should be used. See Appendix A for the versions available at the time of publication of this document.

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2 RECOMMENDED PROCESS FOR ADDRESSING HUMAN FACTORS/PILOT INTERFACE ISSUES

2.1 Objective of the Process

This section provides a recommended process for demonstrating compliance to human factors related regulations as well as identifying, evaluating and resolving human factors/pilot interface issues. The process is intended to be guidance and not a means of compliance (MOC). While the focus of the process is certification, it is understood that identifying and resolving the human factors issues of the pilot interface is conducted as part of both the engineering design and certification process. In fact, addressing the human factors aspects of the pilot interface is an activity that is best conducted early and continuously throughout the engineering design development program and not something that happens only at the end of a program during the formal certification test phase. As such, there may be some information generated as part of the engineering design process that could be used for certification as well. This information may include the results of engineering analyses, evaluations (mock-ups, bench, laboratory, simulator or aircraft) as well as other methods used to identify and resolve human factors issues.

The process described in Section 2.3 addresses the importance of involving the certification authority early in the overall development process for the identification and resolution of human factors certification issues related to avionics. This recommended process is intended to be useful for both the applicant and the certification authority as it describes the expectations of each in addressing human factors/pilot interface issues during the certification approval process. Specifically, the recommended process defines methods and deliverables expected by the appropriate party. The ultimate goal of this section of the document is to present a well-understood, timely and consistent process to promote safe systems as well as to minimize late and costly required design changes.

2.2 Description of How the Process is To Be Used

The process steps identified in this section are intended to be used as a guide for both the applicant and the certification authority.

The process includes five steps, which explicitly focus on activities that have unique human factors aspects:

1. Concept Review
2. Agreement on Plan for Human Factors Compliance
3. Applicant Continues to Develop the Product
4. Formal Testing (conformed articles)
5. Certification Deliverable Submittal and Certification Authority Review

Each of the five process steps includes all or many of the following items:

- *Description of the Activity* for the process step
- *Inputs* that are recommended to carry out the tasks and activities of the process step
- *Tasks and Activities* carried out in the process
- *Outputs* are recommended deliverables resulting from the process step. These may include formal and/or informal reports, white papers and/or position papers, requirement documents, and documentation of decisions and agreements.

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- *Relevant References* that are intended to give users recommendations on where to go for additional information but are intended to be neither prescriptive nor exhaustive
- *Good Practices* or previously certified examples that are informational only but are deemed helpful from past programs in carrying out the process step

The process steps detailed in Section 2.3 are generic so that they can be implemented in various certification and approval types, e.g., Technical Standard Order (TSO), Type Certificate (TC), Supplemental Type Certificate (STC), Amended Type Certificate (ATC) as well as across the various Title 14 Code of Federal Regulations (CFR) aircraft classes and categories (i.e., Parts 23, 25, 27, and 29). The recommended process steps may need to be tailored to the different certification and approval types as well as across the 14 CFR Parts. Certification authority regulations (including Issue Papers and Certification Review Items) as well as guidance take precedence over the information in this section. Throughout Section 2.3 there are references to tailoring by certification method (e.g., Technical Standard Order Authorization (TSOA[1])) and by aircraft class (e.g., airplane) including operational category (e.g., transport).

The plan to show compliance to human factors related regulations may be affected by the approval of the equipment and systems selected for installation. For example, if the system or equipment already holds a TSOA that contains human factors related requirements, then, depending on the category of aircraft, installation credit may be requested for those human factors aspects approved under the TSO approval. For instance, if the technical standards require a specific color set, font size, display viewing angle, etc., the TC, STC, ATC applicant may request credit for those aspects to satisfy the human factors aspects of the applicable Part 23, 25, 27, or 29 aircraft certification regulations. The advantages and disadvantages of this sequential use of a TSOA for TC, STC, or ATC are outlined in Table 2-1. The table also outlines the advantages and disadvantages of doing a TSOA concurrently with a TC, STC, or ATC.

[1] The term TSOA is used generically throughout the document and is meant to encompass authorizations by all of the overseeing certification authorities such the Federal Aviation Administration (FAA), European Union, Transport Canada, etc.