U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

ORDER
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National Policy

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SUBJ: Simple and Complex Electronic Hardware Approval Guidance

This order explains how Federal Aviation Administration (FAA) aircraft certification staff can use and apply RTCA, Inc. document RTCA/DO-254, *Design Assurance Guidance for Airborne Electronic Hardware*, when working on certification projects. In this order you'll find discussion and FAA interpretation of RTCA/DO 254 sections. Because it's impractical to cover all situations or conditions, supplement these instructions with good judgment when handling problems.

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Chapter 1. Introduction

1. Purpose of this Order.

a. We've written this order to supplement RTCA/DO-254, and to give you guidance for approving both simple and complex custom micro-coded components. This guidance applies to airborne systems and equipment, and the airborne electronic hardware of those systems when you work in a certification project (i.e., type, supplemental, amended, and amended supplemental) or technical standard order authorization. This order accepts RTCA/DO-254 as the means by which an applicant can seek FAA approval. If an applicant proposes another means, including achieving acceptable design assurance for these components by using verification and/or architectural strategies at the system or equipment level, then we may need to develop more guidance (such as issue papers) on a project-by-project basis.

b. If an applicant follows RTCA/DO-254 for level D components, then we don't need to review the life cycle data. However, we will review it if the applicant chooses to use their existing design assurance practices, as allowed by Advisory Circular (AC) 20-152, *RTCA, Inc., Document RTCA/DO-254, Design Assurance Guidance for Airborne Electronic Hardware,* Paragraph 1.b. Refer to FAA part-specific policy for exceptions.

2. Audience. Managers and staff of the FAA Aircraft Certification Service, including any persons designated by the administrator, and organizations associated with the certification process required by Title 14 of the Code of Federal Regulations (14 CFR).

3. Where to Find this Order. You can find this order at http://www.faa.gov/regulations_policies/orders_notices and on the FAA Regulatory and Guidance Library (RGL) website at http://rgl.faa.gov.

4. Cancellation. FAA Order 8110.105 Chg 1, issued on September 23, 2008, is cancelled.

5. Explanation of Changes.

a. FAA Order 8110.105, Chg 1, dated 9/23/08, Chapter 2, was restructured to allow flexibility in conducting simple and complex custom micro-coded component reviews.

b. FAA Order 8110.105, Chg 1, dated 9/23/08, Chapter 3, was deleted to allow alignment with risk-based directives in O8040.4A. However, some of the worksheets from Chapter 3 were retained in Appendix C of this FAA Order 8110.105, Revision A.

c. Appendix C was added to retain some worksheets taken from the deleted Chapter 3.

6. Some Useful Definitions. For the purposes of this order, the following definitions apply.

a. Simple Hardware Item: An item with a comprehensive combination of deterministic tests and analyses appropriate to the design assurance level that ensures correct functional performance under all foreseeable operating conditions, with no anomalous behavior.
--*Source: RTCA/DO-254, paragraph 1.6*

Note: We use the definition above from the body of RTCA/DO-254, not the definition in Appendix C that leaves out the words "appropriate to the design assurance level."

b. Custom micro-coded component: A component that includes application specific integrated circuits (ASIC), programmable logic devices (PLD), field programmable gate arrays (FPGA), and other similar electronic components used in the design of aircraft systems and equipment.
-- S*ource: AC 20-152*

Note: A custom micro-coded component is normally packaged as a single integrated circuit based device for mounting on a circuit board, or a higher-level assembly. "Component" doesn't mean surface mounted resistors, capacitors, or other individual electronic components. "Component" also doesn't mean circuit board assemblies, line replaceable units (LRUs), and other higher-level items.

c. Complex hardware item: All items that are not simple are considered to be complex. See the definition of simple hardware item.
-- S*ource: RTCA/DO-254, Appendix C*

d. Design Assurance: All of these planned and systematic actions used to substantiate, at an adequate level of confidence, that design errors have been identified and corrected, such that the hardware satisfies the application certification basis.
--*Source: RTCA/DO-254, Appendix C*

e. Design Process: Creating a hardware item from a set of requirements using the following processes: requirements capture, conceptual design, detailed design, implementation, and production transition.
--*Source: RTCA/DO-254, Appendix C*

7. Simple and Complex Hardware Topics Covered.

a. AC 20-152 explains to applicants that if they follow RTCA/DO-254, then they'll demonstrate compliance to regulations and gain FAA approval for *complex* custom micro-coded components of airborne systems and equipment. The AC, however, doesn't recognize RTCA/DO-254 as a way to demonstrate compliance to regulations for *simple* custom micro-coded components.

b. RTCA/DO-254 explains that a hardware item can be an LRU, a circuit board assembly, or a component. Further, Section 5 states that design processes may be applied at any hierarchical level of the LRU, circuit board assembly, or component. Components include commercial off the shelf (COTS) components, integrated technology components like hybrid and multi-chip modules, and custom micro-coded components. From here on, we call custom micro-coded components either *simple* electronic hardware (SEH) or *complex* electronic hardware (CEH). This order applies only to SEH and CEH, not the broader scope of hardware items defined in RTCA/DO-254.

c. In this order we supplement RTCA/DO-254, explaining how to review SEH and CEH (chapter 2).

d. In the latter part of this order, we clarify RTCA/DO-254 for both SEH and CEH on the following:

- Modifiable components (paragraph 4-2).
- Certification plans (paragraph 4-3).
- Validation processes (paragraph 4-4).
- Configuration management (paragraph 4-5).
- Assessing and qualifying tools (paragraph 4-6).
- Approving hardware changes in legacy systems using RTCA/DO-254 (paragraph 4-7).
- Acknowledging compliance to RTCA/DO-254 for TSO approvals that don’t reference RTCA/DO-254 (paragraph 4-8).
- Commercial-off-the-shelf (COTS) intellectual property (paragraph 4-9).
- Verification processes (paragraph 5-2 for SEH and paragraph 6-2 for CEH), and
- Traceability (paragraph 5-3 for SEH and paragraph 6-3 for CEH).

Chapter 2. SEH/CEH Review Process

1. Applying RTCA/DO 254 to Reviews.

a. RTCA/DO-254, section 9 describes the certification liaison process. This process sets up communication and understanding between the certification authority and an applicant. Section 9.2 says that the authority may review the hardware design life cycle processes and data to assess compliance to RTCA/DO-254. This chapter does not change the intent of RTCA/DO-254.

b. We may use both on-site and desk reviews to review SEH and CEH. Additionally, we can delegate both on-site and desk reviews to designees. In this chapter, we focus on on-site reviews since they give you better access to hardware personnel, to all automation, and to test setup. When preparing for an on-site review, the certification authority should do the following with the applicant and/or hardware developer:

(1) Agree on the scope of review(s) that will be conducted.

(2) Agree on date(s) and location(s) of the review(s).

(3) Identify the certification authority's personnel involved.

(4) Identify any designees involved.

(5) Develop the agenda(s) and expectations.

(6) List the hardware data to be made available (both before and at the review(s)).

(7) Clarify how the review(s) will be conducted.

(8) Identify any required resources, and

(9) Specify when and how you'll communicate your review results, which may include corrective actions and other post-review activities.

2. Objectives of the SEH/CEH Review Process.

a. As the FAA-certifying authority, you review the hardware design life-cycle processes and related data to gain assurance that a product submitted as part of a certification application complies with the certification basis and satisfies the applicable objectives of RTCA/DO-254. Hardware reviews help both you and the applicant determine if a particular project will meet the certification basis, applicable guidance, and satisfy the RTCA/DO-254 objectives by providing:

(1) Timely technical explanation of the certification basis, RTCA/DO-254 objectives, FAA guidance, issue papers, and other applicable certification requirements.

(2) Visibility into how the applicant implemented their processes and generated the resulting data.

(3) Objective evidence that SEH and CEH adhere to approved hardware plans and procedures.

(4) The opportunity to monitor designee activities, if applicable.

b. We should determine the level of authority involvement in a SEH or CEH project, and document it as soon as possible in the project life cycle. Appendix C provides examples that may be used to determine the level of involvement. The scope and number of reviews, if any, will depend on several factors including the project's hardware level, applicant (or hardware developer) experience and history, service difficulty history, designee support, and other factors.

Chapter 3. Reserved

Chapter 4. Clarifying RTCA/DO-254 Topics Applicable to Both SEH and CEH

1. What to Tell Applicants. In this chapter we clarify and expand on selected RTCA/DO-254 guidance applicable to both SEH and CEH so you'll be able to tell applicants what they need to do to gain approvals.

2. Modifiable Custom Micro-Coded Components.

a. RTCA/DO-254 doesn't explicitly cover the possibility that certain aspects of SEH/CEH could be modified by someone other than the component developer, after it was designed and manufactured. We must advise applicants that when logic embedded in SEH or CEH is modified this way, in addition to RTCA-DO-254, they must either follow RTCA/DO-178B/C, *Software Considerations in Airborne Systems and Equipment Certification*, Sections 2.4 and 2.5 for DO-178B or paragraphs 2.5.2, 2.5.4, and 2.5.5 for DO-178C concerning user-modifiable software, option-selectable software and field-loadable software as applicable. Or, they can demonstrate an equivalent level of safety.

b. We also should be familiar with Order 8110.49 Change 1 or latest version, *Software Approval Guidelines*, Chapters 5, 6, and 7,which cover software that can be modified by the user after the software has been approved.

3. Planning for Hardware Aspects of Certification.

a. RTCA/DO-254 Section 10.1.1 discusses the plan for hardware aspects of certification (PHAC). However, when aircraft or engine systems use multiple pieces of equipment with multiple software and hardware components, we may need a higher-level certification plan to describe the overall development, integration, and compliance approach. A plan is essential to determine our level of FAA involvement, reduce the risk of misunderstandings, ensure that the design assurance activities are appropriate and support the system safety assessment, and agree on any alternative methods that the applicant or their hardware developer proposes.

b. We can permit applicants to package the plans for electronic hardware in different ways. Examples include:

(1) Each electronic hardware component could have its own stand-alone document (PHAC) to support its reuse in multiple systems,

(2) All electronic hardware components of a system could be combined into a stand-alone PHAC to support maintenance and changes to that system's electronic hardware, or

(3) Combining the PHAC content with other planning data for the aircraft or system (a project specific certification plan (PSCP). The plan should cover custom micro-coded components, and their integration with software and other system hardware components.

c. In addition to the information for a PHAC in RTCA/DO-254 Section 10.1.1, the system certification plan or PHAC for all electronic hardware components should include:

(1) A list of each SEH and CEH, with failure condition classifications, and a functional description of each component.

(2) A proposed means of compliance for each component (e.g., RTCA/DO-254 or alternative means).

(3) A proposed design assurance level and justification.

(4) References to appropriate hardware plans and standards.

(5) A list of certification data to be delivered and/or to be made available to the FAA.

(6) If proposing alternative methods to those in RTCA/DO-254, then the applicant has to explain how they interpret the basic objectives and guidelines, describe the alternative methods, and present their compliance justification early in the project.

(7) If proposing to reverse engineer a component, then applicants must justify the proposal.

(8) For SEH, it's important that we understand the applicant's approach for "simple" devices during certification planning. See paragraph 5-2 of this order for detailed guidance.

4. Validation Processes. Make sure that applicants validate *derived* requirements. RTCA/DO-254, Section 6.1 covers validation.

a. Expect applicants to identify and validate hardware derived requirements. A review, analysis, simulation, testing, or combination of these may satisfy the validation of derived requirements against the system requirements allocated to the hardware. Applicants should base the completion of the validation processes on defined criteria as further explained in RTCA/DO-254 Section 6.1.2.

b. Expect applicants to comply with RTCA/DO-254 Appendix A, documenting the validation processes as specified by the hardware design assurance level and control category. See paragraph 5-2.d(5) of this order for required SEH documentation.

5. Configuration Management. RTCA/DO-254, Section 7.0 talks about configuration management and problem reporting. Ensure that applicants start documenting change control and reporting problems early in the project when configuration identification (defined in RTCA/DO-254) begins. Ensure that applicants identify a baseline for the hardware before any reviews occur. Configuration management and problem processes also need to be in place before any review. For changes to a previously approved design, applicants should implement change control and report problems from the baseline from which they're claiming certification credit.

a. Although RTCA/DO-254 doesn't clearly require a hardware configuration index (HCI), both SAE International's Aerospace Recommended Practice (ARP) 4754A, *Guidelines for Development of Civil Aircraft and Systems* ,Section 5.6.1 and RTCA/DO-178B/C Sections 9.3 and 11.16 say that applicants should submit either a system or software configuration index to their certification authorities. RTCA/DO-254 Section 10.3.2.2.1 describes a top-level drawing that uniquely identifies the hardware item and defining documentation. However, it's not clear if a top-level drawing will include enough information to identify the hardware configuration and the embedded logic for a specific SEH or CEH. Have applicants submit appropriate configuration documentation, either in the top-level drawing or an HCI, to identify completely both the hardware configuration and the embedded logic.

b. You also need to make sure that the applicant has a hardware life cycle environment configuration index (HECI) or equivalent that identifies the configuration of the hardware life cycle environment for the hardware and embedded logic and is available for review. Similar to the software life-cycle environment configuration index described in RTCA/DO-178B/C Section 11.15, the HECI helps an applicant reproduce the hardware and embedded logic life cycle environment, regenerate the embedded logic, and re-verify or modify the embedded logic.

6. Tool Assessment and Qualification.

a. Sometimes applicants misinterpret RTCA/DO-254, Section 11.4 and Figure 11.1, deciding that if there is relevant tool service history (Box 5 in Figure 11.1), then they don't need any further qualification activities. But RTCA/DO-254 Section 11.4.1, bullet 5, explains that there should be data to support the relevance and credibility of the tool's service history. Applicants should show that the tool history proves that the tool produces acceptable results, and that previous tool use is relevant to the applicant's proposed tool use.

b. If applicants do claim for credit of relevant tool history, then we should expect them to justify it early in the project, and document it in the certification plan or PHAC.

7. Approving Hardware Changes in Legacy Systems Using RTCA/DO-254.

a. Before RTCA/DO-254 was published (April 2000), we approved many airborne systems, including the simple and complex electronic hardware in them. We may have also approved these systems by a TSO authorization (TSOA), whose minimum performance standards (MPS) didn't require compliance to RTCA/DO-254. Applicants may have used a design assurance process for the SEH/CEH in some of these systems. For example, they may have adapted RTCA/DO-178B (or a previous version) to hardware design assurance. In other systems, applicants may not have used any specific standard, and we approved the design assurance aspects of any SEH/CEH in those systems at the system level. After RTCA/DO-254 was published, but before we published AC 20-152 (June 2005), some applicants may have used RTCA/DO-254 to gain approval of some systems.

b. We will call SEH/CEH, approved (or plans for which were approved) before AC 20-152, previously developed hardware (PDH). We will call systems approved (or plans for which were approved) before AC 20-152 "legacy" systems.

c. In today's programs, some applicants and/or hardware developers intend to reuse PDH components from legacy systems in newly-designed or updated airborne electronic systems. In even more ambitious programs, applicants may want to install the entire airborne system or equipment, originally certified on a particular aircraft or engine, into a different or updated aircraft or engine.

d. We have established that we need to use RTCA/DO-254 Section 11.1 and subordinate paragraphs when an applicant and/or hardware developer proposes to reuse PDH. We require applicants to submit the assessments and analysis of Section 11.1.

e. The intent of these assessments and analysis is to ensure that using the PDH is valid, and that the compliance shown by the previous aircraft or engine type certificate or TSOA wasn't compromised by a:

(1) Modification to the PDH for the new application,

(2) Change to the function, use, or failure condition classification of the PDH in the new application, or

(3) Change to the design environment of the PDH.

f. *Any* of these can invalidate the original design assurance of the PDH. Therefore, we must assess these changes using the RTCA/DO-254 Section 11.1 and subordinate paragraphs.

8. Acknowledging Compliance to RTCA/DO-254 for TSOs That Don't Reference It.

a. We allow TSO applicants for any electronic equipment or system with electronic components, including SEH or CEH, to use RTCA/DO-254, even though the TSO MPS don't require compliance to RTCA/DO-254. If the TSO applicant complies with RTCA/DO-254 by AC 20-152, then we should write in the TSO authorization (TSOA) letter that the TSOA includes compliance to RTCA/DO-254. This is true for both newly design electronic components in addition to modified PDH.

b. Most TSO MPS don't require compliance to RTCA/DO-254, because RTCA/DO-254 didn't exist when the TSOs were published. However, all newly certified aircraft, engines, and airborne systems require compliance to RTCA/DO-254 (or some other acceptable means of compliance) as part of their current installation requirements for electronic systems. Trying to show compliance to RTCA/DO-254 for a component with TSOA at the time of installation may be very difficult, because the design and verification of the component is already complete. However, if the TSOA letter for that article plainly states that the component complies with RTCA/DO-254, then that aspect of the installation becomes easier. Because of this, we must strongly encourage applicants for all TSO applications to include compliance to RTCA/DO-254 by AC 20-152 as part of their data package.

9. COTS Intellectual Property (IP).

a. COTS Components Limited to IP. Though AC 20-152 recognized RTCA/DO-254 as an acceptable means to gain FAA approval of complex custom micro-coded components, the AC doesn't recognize RTCA/DO-254 as an acceptable means to gain design assurance for COTS components.

(1) RTCA/DO-254, Appendix C, defines a COTS component this way: Component, integrated circuit, or subsystem developed by a supplier for multiple customers, whose design and configuration is controlled by the supplier's or an industry specification.

(2) In this order, we limit the discussion of COTS components to COTS IP. COTS IP means commercially available functional logic blocks (including libraries) used to design and implement part or complete custom micro-coded components such as PLDs, FPGAs, or similar programmable components. COTS IP may be provided with or without the custom micro-coded component.

b. Using COTS IP in Airborne Systems. While RTCA/DO-254, Section 11.2 covers using COTS components, the information is targeted at the actual COTS hardware, and not the IP that can be used to program other COTS hardware (e.g., an FPGA). Therefore, although Section 11.2 is valuable, it doesn't say enough about issues with using COTS IP in airborne systems or equipment.

(1) COTS components, including IP, are developed by a company other than the applicant and hardware developer. Intended to provide specific functions or abilities in many different applications, COTS components may or may not have been developed using a rigorous design assurance method (e.g., RTCA/DO-254). Given this, we must ensure that the applicant and hardware developer show that using COTS IP complies with the applicable airworthiness requirements, regulations, policy, and guidance for that project.

(2) Availability of COTS IP doesn't automatically guarantee that it can be used in a manner that complies with airworthiness requirements, regulations, policy and guidance. Depending on the complexity of the COTS IP and the availability of IP documentation, applicants and/or hardware developers may have significant work to show compliance for the system or equipment.

Note: COTS IP cores that come as a netlist only and COTS processor cores (soft or hard) may not have the available documentation to show compliance.

(3) Using a COTS IP in a SEH/CEH that's installed in airborne systems or equipment should satisfy applicable functional and safety-related requirements. RTCA/DO-254 Section 11.2 may not be sufficient for design assurance of a COTS IP implemented in a SEH/CEH that supports level A and B aircraft, and other safety critical, functions. As a result, applicants may need to develop or augment system architectural mitigation, component verification, testing, analysis, and other life cycle data of a COTS IP. All this is needed to demonstrate its intended function, show that it is free from anomalous behavior, satisfies applicable regulations, and meets airworthiness requirements.

(4) Applicants can use methods to help establish compliance to the airworthiness requirements, regulations, policy, and guidance for an airborne system or equipment that use COTS IP. Some methods include (but aren't limited to):

(a) Reverse engineering the required life cycle data from known information about the COTS IP functionality and design.

(b) Extensive COTS IP testing and analysis, so that the applicant and system developer gain detailed information about the functionality, plus how it operates during boundary and failure conditions. This should include testing and analysis of any functionality from the

COTS IP that will not be used or activated in the specific application. Refer applicants to RTCA/DO-254, Appendix B, for advance methods and techniques.

(c) Architectural mitigations at the device, board, LRU, or system level that will detect and/or mitigate unforeseen or undesirable CEH/SEH operation in which the COTS IP is installed. This includes mitigating any functionality from the COTS IP that will not be used or activated in the specific application. Applicants have to design architectural mitigations, if required for compliance, to the appropriate design assurance level to satisfy the system safety assessment.

(d) Product service experience, per RTCA/DO-254, Section 11.3 and subordinate paragraphs. Applicants should use documented evidence to support any argument for using product service experience to gain certification credit. We will not accept unsubstantiated statements of compliance.

Chapter 5. Clarifying RTCA/DO-254 Topics Applicable Only to SEH

1. How Applicants Gain Approval. In this chapter we'll clarify and expand on selected RTCA/DO-254 guidance applicable only to SEH so you'll be able to tell applicants what they need to do to gain approvals.

2. Verification Processes. While we earlier acknowledged that RTCA/DO-254 is an acceptable means of compliance for simple electronic hardware components, RTCA/DO-254 doesn't clearly show readers how they can achieve comprehensive testing and/or analysis of simple hardware items. This paragraph clarifies what we should tell applicants about SEH verification.

a. Varying Levels of Testing.

(1) Given RTCA/DO-254's definition for a simple hardware item (reproduced in paragraph 4 of this order), many applicants have been confused about what is a "comprehensive combination of deterministic tests and analyses," and more specifically, the word "comprehensive" when applied to a simple hardware item. RTCA/DO-254 Section 1.6 offers no extra guidance on how to choose which specific deterministic tests and analyses are appropriate for a level A simple hardware item, as opposed to a level D item. But if we vary the rigor of verification coverage based on the assigned design assurance level of a simple hardware item, then this is consistent with RTCA/DO-254 guidance for complex hardware items of different design assurance levels.

(2) See RTCA/DO-254, Appendix A, Modulation of Hardware Life Cycle Data Based on Hardware Design Assurance Level, and Appendix B, Design Assurance Considerations for Levels A and B Functions, to see the different requirements for the different levels of airborne hardware. This difference of rigor between the various assurance levels is similar to the guidance for software design assurance. For example, there are different structural coverage criteria for software levels A, B, C and D based on the potential failure conditions that the software could cause or contribute to, as determined by a system safety assessment.

b. Two Design Assurance Approaches in RTCA/DO-254.

(1) RTCA/DO-254 offers two different ways to show compliance:

(a) Rely on a comprehensive combination of deterministic testing and analysis for simple hardware items.

(b) Rely on a disciplined hardware design assurance process--that is, satisfy the objectives of RTCA/DO-254, Sections 2 through 9.

(2) Testing custom micro-coded components or programmed electronic hardware components often can't show that the component has no design defects and errors. The component is too complex for comprehensive and deterministic test and analysis to remain a practical approach. So RTCA/DO-254 specifies a disciplined, structured design assurance approach for complex hardware items. However, simple hardware items can be

comprehensively tested and/or analyzed appropriate to the design assurance level. This testing and analysis can comprehensively demonstrate that the component performs its intended function, has no design errors, and shows no anomalous behavior. In other words, if applicants don't use a *structured* design assurance approach, then they must rely on a comprehensive combination of testing and analysis to ensure correct function without design errors or unexpected behavior.

(3) Hidden in the two approaches for design assurance listed above, and in RTCA/DO-254, is a risk for certification programs: the decision whether to treat a component as simple or complex has to be both correct *and* be made early in the program. Early on, an applicant could classify a component as simple, even though they might not be sure that they can demonstrate correct functional performance with no anomalous behavior through testing and analysis alone. If, later in the program, the applicant finds that indeed, it isn't possible or practical (or within the program schedule), then they have to reclassify the component as complex.

(4) Reclassifying the component after starting the project can cause many problems, as the design assurance process of DO-254 may not have been used at the beginning of the program. Reclassification will likely require that applicants repeat the development activities for the device to produce the necessary life cycle data, demonstrating that they followed a disciplined and structured design assurance approach required by RTCA/DO-254 for complex hardware items. So, if an applicant classifies a component as simple, then *you* must ensure that they can demonstrate the feasibility of the required verification coverage in the hardware plans. Discuss the applicant's proposed approach with them. Ensure that they understand the potential risks to the certification program.

c. Clarifying RTCA/DO-254 for SEH.

(1) Although it's generally accepted that most modern custom micro-coded components like PLDs, FPGAs (with thousands of configurable logic cells supporting many functions at the airborne system level) and ASICs are complex electronic components, some applicants have proposed their FPGAs as SEH. RTCA/DO-254 says little about how to demonstrate that simple hardware items comply with the applicable certification requirements. The following clarification on SEH will give you a more standardized approach to assess compliance when an applicant implements SEH in airborne systems.

(2) More than once in the next paragraphs we'll use the phrase "comprehensive combination of deterministic testing and analysis." The meaning of "comprehensive" depends on the assessed design assurance level (DAL) for SEH. Because the need for correct operation increases as a component's hazard classification increases, you have to be more thorough and rigorous when testing a DAL A or B device than a DAL C or D. This direct proportion is like the increasingly rigorous design assurance processes in RTCA/DO-178B/C for airborne software and in RTCA/DO-254 for complex hardware items.

d. Things Applicants Proposing SEH Should Address.

(1) DAL A and B: SEH with functions whose failure or malfunction could cause a *catastrophic*, or *hazardous/severe-major* failure condition as determined by the system safety assessment process, should have the following:

(a) A comprehensive combination of deterministic tests and analysis that demonstrates correct operation under all possible combinations, permutations, and concurrence of conditions across all primary inputs, internal elements, nodes, registers, latches, logic components, and gates within the component, with no anomalous behavior. Comprehensive testing and analysis for SEH should also consider a dynamic view of the component and include input parameters/characteristics like input set-up and hold time. If the inputs of some specific gates, nodes, and so forth can't be sufficiently controlled using external component inputs to create all required transitions, then applicants should augment the testing with techniques for acceptable component stimulation. If the outputs of some specific gates and nodes can't be sufficiently observed using external device outputs to detect correct operation, then applicants should augment the testing with more observation techniques.

(b) A coverage analysis that ensures that the testing and analyses satisfy the specified criteria and are complete. Test coverage analysis should confirm that all logical gate/nodes within the component, plus the interconnections between these gates/nodes, have indeed been exercised to demonstrate the proper operation of the elements within the component (e.g., applicants should test an "OR" gate to show that it truly operates as an "OR" gate). Plus, applicants should test all possible states of a sequential state machine and if applicable, all combinations of possible states of multiple state machines. If concurrency is present in the component, then all possible concurrency conditions should be tested. Concurrency will be present any time a component has multiple independent data streams that interact together in some way through shared resources, arbiters, and multiple interacting state machines.

(c) Timing analysis that covers best-case and worst-case timing conditions, potential clock drift, and other timing issues that may prevent a component's correct operation. Tell applicants that they should consider adverse environmental conditions, like temperature, in this timing analysis.

(2) DAL C: SEH with functions whose failure or malfunction could cause a *major* failure condition as determined by the system safety assessment should have a comprehensive combination of deterministic testing and analysis that demonstrates correct operation under all possible combinations and permutations of conditions of the inputs at the pins of the component (i.e., those inputs available outside the component packaging). Applicants must test all possible states of any sequential state machines. We should ensure that, when they comprehensively test and analyze SEH, applicants also take a dynamic view of the component and include input parameters/characteristics, like input set-up time and input hold time.

(3) DAL D: we don't require specific component level testing of level D SEH but if applicants don't perform component level testing, then they should test at the board, LRU, or other unit level to show that level D SEH satisfies the component level requirements.

(4) Testing Environment: when testing SEH in its operational environment isn't feasible, applicants have to offer, and justify, other verification means.

(5) Documentation: see paragraph 1.b of this order, for level D components. To clarify and support requirements for SEH documentation in RTCA/DO-254 Section 1.6, advise applicants to submit the following:

(a) A plan for hardware aspects of certification (PHAC) (RTCA/DO-254, Section 10.1.1).

(b) A hardware verification plan (RTCA/DO-254, Section 10.1.4).

(c) A hardware configuration index (paragraph 4-5.a, this order), and

(d) A hardware accomplishment summary (RTCA/DO-254, Section 10.9).

(6) Combine the Documentation: tell applicants that they can combine the SEH documentation with other documentation when using RTCA/DO-254. For example, they can submit a single PHAC for both SEH and CEH to you. Also, they should document test cases or procedures, test, results and test coverage analyses for SEH and retain it all as life cycle data, which is subject to your review.

3. Traceability. RTCA/DO-254 Sections 5.1.1, 5.1.2, 6.1, 6.1.2, 6.2.1, 6.2.2, 6.3.2, 6.3.3, and 10.4.1 talk about traceability. Though RTCA/DO-254 requires that the verification process be performed and documented for a simple hardware item, it doesn't require extensive documentation. In this paragraph, we clarify traceability for SEH:

a. In the absence of system requirements allocated to hardware, applicants may identify all requirements as derived. Clarifications in paragraph 4-4 of this order apply.

b. If hardware requirements do exist, then clarifications in paragraph 6-3 of this order apply. See paragraph 5-2.d of this order for the required SEH documentation.

Chapter 6. Clarifying RTCA/DO-254 Topics Applicable Only to CEH

1. Expanding on CEH Guidance. In this chapter, we'll clarify and expand on selected RTCA/DO-254 guidance applicable only to CEH so you'll be able to tell applicants what they need to do to gain approvals.

2. Verification Processes. RTCA/DO-254 Section 6.2 talks about verification. Section 6.3 covers verification methods in more detail. Here are some particular clarifications:

a. Hardware description language (HDL). HDLs, defined in RTCA/DO-254 Appendix C, have attributes similar to software programming languages. RTCA/DO-254 doesn't explicitly address these attributes. To prevent potentially unsafe attributes of HDLs from leading to unsafe features of the components, we must expect that, if they use an HDL, applicants define the coding standards for this language consistent with the system safety objectives, and establish conformance to those standards by HDL code reviews. Reviews should also include assessing the HDL (detailed design) with respect to the requirement for completeness, correctness, consistency, verifiability, and traceability.

Note: For levels C and D, the applicant need show only the traceability data from requirements to test (see RTCA/DO-254, Table A-1, Note 6.).

b. Testing.

(1) RTCA/DO-254 Section 6.3.1 says that testing confirms that the hardware item correctly responds to a stimulus or series of stimuli. RTCA/DO-254 doesn't explicitly address robustness testing, but the note in Section 5.1.2(4) calls for safety-related derived requirements to address abnormal (worst case) and boundary conditions on input data range, state machines, power-supply, and electrical signals.

(2) To make sure that applicants consistently capture and verify derived requirements per Section 5.1.2(4), we expect them to capture abnormal operating conditions as derived requirements, and address them in the tests. In addition to normal range testing and to demonstrate robustness, applicants should define requirements-based testing to cover normal and abnormal operating conditions. And where necessary and appropriate, applicants may have to do more verification (e.g., analysis and review) to address robustness.

c. Test case and procedure review: emphasize to applicants that, according to RTCA/DO-254 Section 6.2.2(4b), they have to review test cases or procedures to confirm that they are appropriate for the requirements to which they trace and are intended to verify.

d. Verification completion criteria: RTCA/DO-254 Section 6.2.2 (4) requires applicants to analyze the verification coverage and determine that the verification process is complete. This is consistent with verification objectives 1 and 2 in Section 6.2.1. It means that applicants have to verify each requirement and explain discrepancies between expected and actual results, especially safety-related requirements. RTCA/DO-254 Section 6.3.1 says that when testing the hardware item in its intended operational environment is not feasible, applicants have to offer, and justify, other verification means. So we should expect their PHAC and/or hardware verification plan to state and justify the level of verification coverage of the requirements achieved by test. We support RTCA/DO-254 when we require applicants to:

(1) Measure and record the verification coverage of the requirements achieved by test on the component itself in its operational environment, and

(2) Propose and justify an alternate verification means if we accept applicant's justification for not verifying specific requirements by test.

e. In addition to complete verification coverage of the requirements, RTCA/DO-254 Section 2.3.4 also requires that applicants apply advanced design assurance strategies (listed in RTCA/DO-254 Appendix B) for levels A and B functions. According to the description for item 4 in Figure 2-3, a single Appendix B approach may not be sufficient to ensure complete mitigation of potential failures and anomalous behavior for level A functional failure paths. But RTCA/DO-254 doesn't explicitly identify completion criteria for these advanced design assurance activities. Appendix B discusses using elemental analysis, which may be applied to determine completion criteria. Appendix B also covers other advanced verification methods, (e.g., safety-specific analysis and formal methods).

f. Regardless of the approach methods and approaches they propose, applicants should document the completion criteria of design assurance methods for level A and B functions in the PHAC. In particular, for components with design assurance levels A or B, applicants should adhere to RTCA/DO-254 guidelines:

(1) Define and justify a target level of verification coverage of the internal structure of the design implementation using verification procedures that achieve the verification objectives of RTCA/DO-254 Section 6.2.

(2) Justify an inability to generate correct and acceptable assurance data showing complete coverage of the internal structure of the design implementation. Applicants should use more advanced design assurance methods to mitigate against potential hardware failures and anomalous behaviors.

(3) Satisfy verification processes with independence (refer applicants to RTCA/DO-254 Appendix A and Table A-1).

Note: Branch and decision coverage is an example of an additional advanced design assurance strategy for level A.

g. Finally, we can't assume partitioning (separating or isolating functions or circuits) within the hardware component. If they use partitioning to justify combining different design assurance levels within a component, then applicants should demonstrate, verify, and document partition integrity.

3. Traceability. Many RTCA/DO-254 sections talk about traceability, including Sections 5.1.1, 5.1.2, 6.1, 6.1.2, 6.2.1, 6.2.2, 6.3.2, 6.3.3, and 10.4.1. In this paragraph, we clarify two areas for levels A and B, and one area for levels C and D:

a. Applicants should ensure traceability between the hardware requirements, the conceptual design, the detailed design, and the implementation.

b. Applicants should ensure both the traceability between the requirements and design data covered in paragraph 6-3a in this order and the corresponding verification and validation results.

c. For levels C and D, applicants need to ensure only the traceability from requirements to test (see RTCA/DO-254, Table A-1, Note 6).

Appendix A. Administrative Information

1. Distribution. Distribute this order to the branch level in Washington headquarters Aircraft Certification Service, section level in all aircraft certification directorates, all chief scientific and technical advisors (CSTA), all aircraft certification offices (ACO), all manufacturing inspection offices (MIO), all manufacturing inspection district or satellite offices (MIDO/MISO), all flight standards district offices (FSDO), and the FAA Academy.

2. Forms and Reports. Find the Directives Feedback Information Form 1320-19 in Appendix D or at https://employees.faa.gov/tools_resources/forms/.

3. Related Publications

a. Code of Federal Regulations. Title 14 of the Code of Federal Regulations (14 CFR) part 21, *Certification Procedures for Products and Parts*.

b. FAA Orders and Advisory Circulars (AC). View and download the following orders and ACs from the FAA website at http://rgl.faa.gov.

- Order 8040.4, *Safety Risk Management Policy*
- Order8100.8, *Designee Management Handbook*
- Order 8100.15, *Organization Designation Authorization Procedures*
- Order 8110.37, *Designated Engineering Representative (DER) Handboo*k
- Order 8110.42, *Parts Manufacturer Approval Procedures*
- Order 8110.49, *Software Approval Guidelines*
- AC 20-152, *RTCA, Inc. Document RTCA/DO-254 Design Assurance Guidance for Airborne Electronic Hardware*

c. RTCA, Inc. Documents. Order copies of RTCA documents from RTCA, Inc., 1150 18th Street, NW, Suite 910, Washington, DC 20036. You can also order copies online at http://www.rtca.org. RTCA documents referenced in this order are:

- RTCA/DO-160(), *Environmental Conditions and Test Procedures for Airborne Equipment*
- RTCA/DO-254, *Design Assurance Guidance for Airborne Electronic Hardware*
- RTCA/DO-178B, *Software Considerations in Airborne Systems and Equipment Certification*
- RTCA/DO-178C, *Software Considerations in Airborne Systems and Equipment Certification.*

d. SAE International Documents. Order SAE documents from SAE International, 400 Commonwealth Drive, Warrendale, Pennsylvania, 15096-0001. You can also order copies online at http://www.sae.org/servlets/index. The SAE document referenced in this order is SAE ARP 4754A, *Guidelines for Development of Civil Aircraft and Systems.*

Appendix B. Acronyms

AC	Advisory Circular
ACO	Aircraft Certification Office
AIR	Aircraft Certification Service
ASE	Aviation Safety Engineer
ASIC	Application Specific Integrated Circuit
CEH	Complex Electronic Hardware
CFR	Code of Federal Regulations
COTS	Commercial Off The Shelf
CSTA	Chief Scientific And Technical Advisor
DAL	Design Assurance Level
DER	Designated Engineering Representative
FAA	Federal Aviation Administration
FPGA	Field Programmable Gate Array
FSDO	Flight Standards District Office
HAS	Hardware Accomplishment Summary
HCI	Hardware Configuration Index
HDL	Hardware Description Language
HECI	Hardware life cycle Environment Configuration Index
IP	Intellectual Property
LRU	Line Replaceable Unit
MIDO	Manufacturing Inspection District Office
MIO	Manufacturing Inspection Office
MISO	Manufacturing Inspection Satellite Office
MPS	Minimum Performance Standards
PDH	Previously Developed Hardware
PHAC	Plan For Hardware Aspects of Certification
PLD	Programmable Logic Device
PSCP	Project Specific Certification Plan
RGL	Regulatory and Guidance Library
SEH	Simple Electronic Hardware
SRAM	Static Random Access Memory-based
TSO	Technical Standard Order
TSOA	Technical Standard Order Authorization
V&V	Validation and Verification

Appendix C. Level of Involvement Worksheets

Appendix C contains three worksheets that may be used to help the certification authority or designee determine an appropriate level of involvement in hardware projects. The worksheets are provided as examples only and their use, individually or in combination, is not mandatory. Worksheet 1 indicates a level of involvement based on the hardware level of the project. Worksheet 2 allows for additional refinement of involvement based on more specific criteria. Worksheet 3 uses the total score result from Worksheet 2 to indicate a level of involvement.

Worksheet 1: Level of Involvement Based on Hardware Level

RTCA/DO-254 Hardware Level	Level of Involvement
A	MEDIUM or HIGH
B	MEDIUM or HIGH
C	LOW or MEDIUM
D	LOW

Worksheet 2: Level of Involvement Based on Other Relevant Project Criteria

	Criteria	Scale	MIN.		MAX.	Score
1.	**Applicant/Developer Hardware Certification Experience**					
1.1	Experience with civil aircraft or engine certification.	Scale: # projects:	0 0	5 3-5	10 6+	
1.2	Experience with RTCA/DO-254.	Scale: # projects:	0 0	5 2-4	10 5+	
1.3	Experience with other process assurance standards (other than RTCA/DO-254).	Scale: # projects:	0 0	2 4-6	4 7+	
2.	**Applicant/Developer Demonstrated Hardware Development Capability**					
2.1	Ability to consistently produce RTCA/DO-254 hardware items.	Scale: Ability:	0 Low	5 Med	10 High	
2.2	Cooperation, openness, and resource commitments.	Scale: Ability:	0 Low	5 Med	10 High	
2.3	Ability to manage hardware development and sub-contractors.	Scale: Ability:	0 Low	5 Med	10 High	
2.4	Capability assessments	Scale: Ability:	0 Low	2 Med	4 High	
2.5	Development team average based on relevant hardware development experience.	Scale: Experience:	0 < 2 yrs	5 2-4 yrs	10 > 4 yrs	
3.	**Applicant/Developer Hardware Service History**					
3.1	Incidents of hardware-related problems (as a % of affected hardware items).	Scale: Incidents:	0 > 25%	5 > 10%	10 None	
3.2	Company management's support of designees.	Scale: Quality:	0 Weak	5 Med	10 Strong	
3.3	Company hardware process assurance organization and configuration management process.	Scale: Quality:	0 Low	5 Med	10 High	
3.4	Company stability and commitment to safety.	Scale: Stability:	0 Weak	3 Med	6 Strong	
3.5	Success of past company certification efforts.	Scale: Success:	0 None	3 > 50%	6 All	
4.	**The Current System and Hardware Application**					
4.1	Complexity of the system architecture, functions, and interfaces.	Scale: Complex:	0 High	5 Med	10 Low	
4.2	Complexity and size of the hardware and safety features.	Scale: Complex:	0 High	5 Med	10 Low	
4.3	Novelty of design and use of new technology.	Scale: Newness:	0 Much	5 Some	10 None	
4.4	Hardware development and verification environment.	Scale: Environ:	0 None	3 Old	6 Modern	

	Criteria	Scale	MIN.		MAX.	Score
4.5	Use of alternative methods or additional considerations.	Scale: Standard:	0 Many	3 Few	6 None	______
5.	**Designee Capabilities**					
5.1	Experience of designee(s) with RTCA/DO-254.	Scale: Projects:	0 < 5	5 5-10	10 > 10	______
5.2	Designee authority, autonomy, and independence.	Scale: Autonomy:	0 Little	5 Some	10 Full	______
5.3	Designee cooperation, openness, and issue resolution effectiveness.	Scale: Effectiveness:	0 Non-Responsive	5 Responsive	10 Cooperative	______
5.4	Relevance of assigned designees' experience.	Scale: Related:	0 None	5 Somewhat	10 Exact	______
5.5	Designees' current workload.	Scale: Workload:	0 High	5 Medium	10 Low	______
5.6	Experience of designees with other process assurance standards (other than RTCA/DO-254).	Scale: Projects:	0 < 5	3 5-10	5 > 10	______

Total Score Result (TSR): _______

Worksheet 3: Level of Involvement Combining Results of Worksheet 2 with Hardware Level

Total Score Result	**Level A**	**Level B**	**Level C**	**Level D**
TSR < 80	HIGH	HIGH	MEDIUM	LOW
80 $\leq$ TSR $\leq$ 130	HIGH	MEDIUM	MEDIUM	LOW
130 < TSR	MEDIUM	MEDIUM	LOW	LOW

Appendix D. Directive Feedback Information

FAA Form 1320-19, Directive Feedback Information

Please submit any written comments or recommendations for improving this directive, or suggest new items or subjects to be added to it. Also, if you find an error, please tell us about it.

Subject: FAA Order 8110.105A, Simple and Complex Electronic Hardware Approval Guidance

To: Directive Management Officer at 9-AWA-AVS-AIR-DMO@faa.gov or
complete the form online at https://ksn2.faa.gov/avs/dfs/Pages/Home.aspx

(Please check all appropriate line items)

☐ An error (procedural or typographical) has been noted in paragraph ____________ on page ________.

☐ Recommend paragraph ____on page __________ be changed as follows:
(attach separate sheet if necessary)

☐ In a future change to this directive, please include coverage on the following subject *(briefly describe what you want added):*

☐ Other comments:

☐ I would like to discuss the above. Please contact me.

Submitted by: ____ Date: _______________

FTS Telephone Number: ____________________ Routing Symbol: _________________

FAA Form 1320-19 (8-89)