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(R) Constructing a Development Assurance Plan for Integrated Systems

RATIONALE

With the recent approval of ARP4754B/ED-79B and ARP4761A/ED-135, this document required a minor revision to maintain consistency. The changes bring references and terminology in this document in alignment with the updated ARPs/EDs, as well as clarifying several topics addressed in ARP4754B/ED-79B with added insight for integrated systems.

FOREWORD

This SAE Aerospace Information Report presents a collection of lessons learned for constructing development assurance plans for integrated systems based on past certification programs. This report has been revised to align with, and may be used as a supplement to, the guidelines on Development Assurance Planning and Aircraft/System Integration in ARP4754B/ED-79B.

Integrated aircraft/system architectures have flourished in civil aircraft development since the 1990s, and the use of such architectures will likely accelerate in future design practices. To date, the industry standards (and regulatory guidance) on integrated systems have not progressed much further than a firm acknowledgment of the rapid integrated systems growth trend, and a recognition of potential safety risks if development errors are not identified and corrected during the development process. Section 4 of ARP4754B/ED-79B recognizes this issue and states, "Complex systems and integrated aircraft-level functions present greater risk of development error and undesirable, unintended behavior."

In today's practices, development assurance plans for integrated systems are predominantly based on the tried-and-true concept of separation of responsibilities between various disciplines. This is incongruent with the demands of integrated aircraft/system architectures. While system separation, fault isolation, or error containment will continue to be effective risk management practices that must not be compromised or overlooked, a different approach for constructing a development assurance plan for integrated systems is needed to cope with the reality of system design trends.

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1. SCOPE

This SAE Aerospace Information Report (AIR) supplements ARP4754B/ED-79B by identifying the crucial elements to be considered when constructing the development assurance plans described in Section 3 (Development Assurance Planning) of ARP4754B/ED-79B for integrated systems. Section 4.6.4 of ARP4754B/ED-79B expands the aircraft/system integration and verification activities by emphasizing testing during integration to investigate for unintended behaviors. However, guidelines are needed for planning that are specifically aimed at the aircraft level and at integrating across system functions and boundaries. Until such guidelines are more comprehensively provided, this AIR presents a collection of lessons learned from past certification programs involving integrated systems, and as such it may be considered in conjunction with Sections 3 and 4 of ARP4754B/ED-79B.

ARP4761A/ED-135 elaborates the safety activities by adding processes and methods such as the Aircraft or System Functional Hazard Assessment (AFHA/SFHA) and Preliminary Aircraft or System Safety Assessment (PASA/PSSA). These safety activities can contribute to the overall plans for the integration phase of development at the aircraft or system level, including the identification of areas that could lead to cascading failures or unintended behaviors.

This AIR is not guidance for system integration technologies.

2. APPLICABLE DOCUMENTS

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 1-877-606-7323 (U.S. and Canada only) or 1-724-776-4970 (outside U.S. and Canada), www.sae.org.

ARP4754B Guidelines for Development of Civil Aircraft and Systems

ARP4761A Guidelines for Conducting the Safety Assessment Process on Civil Aircraft, Systems, and Equipment

Beland, S. and Miller, A., "Assuring a Complex Safety-Critical Systems of Systems," SAE Technical Paper 2007-01-3872, 2007, <https://doi.org/10.4271/2007-01-3872>.

2.2 RTCA Publications

Available from RTCA, Inc., 1150 18th Street NW, Suite 910, Washington, DC 20036, Tel: 202-833-9339, www.rtca.org.

DO-178C Software Considerations in Airborne Systems and Equipment Certification

DO-254 Design Assurance Guidance for Airborne Electronic Hardware

2.3 EUROCAE Publications

Available from EUROCAE, The MINT Building, 2 Avenue François Mitterrand, 93200 Saint-Denis, France, Tel: +33 1 40 92 79 30, www.eurocae.net.

ED-79B Guidelines for Development of Civil Aircraft and Systems

ED-135 Guidelines for Conducting the Safety Assessment Process on Civil Aircraft, Systems, and Equipment

3. DEVELOPMENT ASSURANCE PLANNING

Development assurance involves all of those planned and systematic actions used to substantiate, at an adequate level of confidence, that errors in requirements, design, and implementation have been identified and corrected such that the system satisfies the applicable safety objectives. Section 3 of ARP4754B/ED-79B provides a general planning process to address development assurance. This general process involves a number of development planning elements, repeated in Table 1:

Table 1 - Development planning elements

Planning Elements	Planning Element Description
Development	Establish the process and methods to be used to provide the framework for the aircraft/system development, integration, and implementation.
Safety Program	Establish scope and content of the safety activities related to the development of the aircraft or system.
Requirements Capture	Identify and describe how the requirements are captured and managed. Sometimes the requirements capture planning elements are included in conjunction with the requirements validation planning elements.
Requirement Validation	Describe how the requirements will be shown to be complete and correct, and how the assumptions will be managed.
Implementation Verification	Define the processes and criteria to be applied when showing how the implementation satisfies its requirements.
Configuration Management	Describe the key development-related configuration items and how they will be managed.
Process Assurance	Describe the means to assure the practices and procedures to be applied during system development are followed.

The various planning data described in ARP4754B/ED-79B is reproduced graphically in Figure 1 using the traditional development “V” diagram. This graphic conveys a potential for gaps in conventional system development planning to occur (i.e., the white space in between the aircraft plans and the system plans). An integrated system may, therefore, have these same plan disconnects as well as additional system implementation strategy-induced shortfalls. Although ARP4754B/ED-79B comprehensively describes a general development process and life cycle, it does not focus on the development assurance activities that are unique to integrated systems. While the number of total system items increases at the integrated aircraft level, the unique challenge is that many of them are shared resources for multiple systems and the number of interactions between system items increases exponentially. To begin this discussion, a common understanding of terms and concepts needs to be established; this AIR focuses on the following fundamental questions:

1. What is an “integrated system”?

In the context of this AIR, an “integrated system” is the set or arrangement of interdependent systems that have complex relationships or connections to accomplish aircraft functions. Shared system resources, especially computers and communication networks, enable the implementation of functions more complex than can be provided by an individual system. However, integrated system architectures can introduce complex mechanisms for cascading failures or other unintended behaviors.

2. How is the Development Assurance Plan for Integrated Systems (DAPIS) different from the plan elements shown in Table 1 and Figure 1?

The planning elements shown in Table 1 and Figure 1 reflect practices commonly associated with the development of systems. While the concept they represent is generally applicable to any system arrangement, DAPIS focuses on the interrelationships between those elements to help answer lingering concerns that something may be missing or overlooked when integrated systems are developed and certified. The integrated system plan must contemplate the larger number of multi-dimensional interactions between functions, systems, and the organizations who work on them, to minimize the risk of missing something important. This AIR provides a hands-on set of elements based on lessons learned from past certification programs.

Because a plan is tailored to the needs of the individual project, the elements discussed in Section 4 are not intended to be a general template. Rather, they provide insights on issues that experience has shown may not always be obvious (and thus might be missed) when the development assurance activities of ARP4754B/ED-79B are planned or executed.

4. DEVELOPMENT ASSURANCE PLANNING FOR INTEGRATED SYSTEMS (DAPIs)

The classic planning considerations prescribed in ARP4754B/ED-79B provide for nominal integration of systems with considerations for the physical interfaces between electrical systems, interfaces between electrical systems and mechanical systems, or logical interfaces between hardware and software. These considerations may be expanded upon to assure the development of integrated systems.

The planning elements for integrated systems should also be considered when executing the planning process described in ARP4754B/ED-79B. DAPIs effects on the overall planning process should cover some or all of the following: design, verification, manufacturing, maintenance, and allowances for follow-on product improvement.

Considerations for system integration begin during the early development stages when performing system architecture definition as well as requirement capture and validation. This includes considerations for interface definition at both the system and item levels. Assumptions made during architecture definition and requirement decomposition are later confirmed during detailed design and eventual system implementation verification. System integration typically starts with analysis and progresses to prototypes or lab test articles, then to complete system implementation verification against the system requirements. Confirming the validity of assumptions and evaluation of interfaces and interactions between items as early as possible is a basic goal of the integration process. Although integration facilitates the eventual system implementation verification, it is not solely related to verification.

The inherent complexity of integrated systems drives the need for rigorous processes to expose potential unintended behaviors. These unintended behaviors can arise from areas such as (but not limited to):

- Item or system level requirements gaps
- Unanticipated interactions between functional elements/items when operating in an integrated environment

Integration affords the opportunity to identify and address the unintended behaviors.

The integrated systems effects on the ARP4754B/ED-79B plans that are discussed in the following sub-sections should be contemplated.

NOTE: As the following information is a collection of “lessons learned,” readers should assess them for applicability to their projects and the equivalency of their existing methods and tools.

Figure 2 presents the additional planning and implementation relationships for integrated systems. The magenta highlighted integration planning gains importance when the development objective is an integrated system. Mechanisms for interface coordination, as shown in Figure 2, also increase the interactions between activities and enhance communication for the integrated system. The associated sections in ARP4754B/ED-79B are listed for reference.

Note that in both Figures 1 and 2, sub-system levels may apply in between the system and item levels.