

Planning for the Application of ARP4754A for New and Modified Aircraft Projects with New, Simple, and Reused Systems

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ABSTRACT

Aerospace Recommended Practice (ARP) 4754 Revision A (ARP4754A), "Guidelines for Development of Civil Aircraft and Systems," [1] is recognized through Advisory Circular (AC) 20-174 (AC 20-174) [2] as a way (but not the only way) to provide development assurance for aircraft and systems to minimize the possibility of development errors. ARP4754A and its companion, Aerospace Information Report (AIR) 6110, "Contiguous Aircraft/System Development Process Example," [3] primarily describe development processes for an all new, complex and highly integrated aircraft without strong consideration for reused systems or simple systems. While ARP4754A section 5 mentions reuse, similarity, and complexity, and section 6 is intended to cover modification programs, the descriptions in these sections can be unclear and inconsistent.

The majority of aircraft projects are not completely new Products nor are they entirely comprised of complex and highly integrated systems. Due to the lack of focus of ARP4754A on these conventional types of projects, planning for the use of the ARP4754A processes becomes difficult. Further complicating such planning is a redundancy with conventional systems certification, which processes such DO-178C [4] and DO-254 [5] do not face. Regulatory guidance involving ARP4754A (i.e., AC20-174, AC23-1309-1C [6], Part 23 ARC [7], and Order 8110.4C [8]) can also be vague and in some cases conflict.

This work describes a recommended methodology for properly scoping the application of ARP4754A for an aircraft project with new complex and highly integrated systems along with reused and simple systems. This planning methodology can also be applied on modification projects allowing for "traditional techniques" where applicable. This work also provides a path forward for potential changes to sections 5 and 6 in the next revision of ARP4754 to provide clarity and consistency.

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INTRODUCTION

Aircraft development programs take many forms. While the latest technology or extreme aircraft designs grab the headlines, the majority of programs focus on the routine development of variations to existing designs. "Blank sheet" designs are exciting, because they are rare. This story is told in the Federal Aviation Administration's (FAA) Type Certification Data Sheets (TCDS) database [9]. In this database only 1227 TCDSs are used to define the 3403 aircraft models, categorized under the large, small, large/small, and rotorcraft aircraft categories. Revision after revision has added model numbers to each sheet, documenting decades of design reuse and modification. These TCDSs do not include the additional thousands of Supplemental Type Certificates (STCs) which embody programs based on system reuse and aircraft modifications. In many cases, these STCs cross-pollinate legacy system between aircraft families and companies. From modifications to existing aircraft designs to new designs which reuse systems from legacy aircraft, the majority of aircraft development programs focus on leveraging a company's traditional systems and techniques to take advantage of their proven methods.

While a few manufacturers investigate the leading edge of technology with new, complex and highly integrated systems, aircraft development in the rest of the industry rarely implements leading edge technologies in a wholesale approach. This conventionality is based on practicality. As discussed in "Small Airplane Considerations for the Guidelines for Development of Civil Aircraft and Systems," [10] not all advanced technologies scale down. In small aircraft, the size of hydraulic actuation systems does not beat the design efficiency of their pure mechanical counterparts. Flight control of small airplanes, including smaller Part 25 airplanes, can easily leverage the average pilot's strength with simple, cable operated systems. It is recognized that as technology in the personal computing world shrinks, so too does the technology in aviation, but the pace within aviation is much slower.

The glass cockpit revolution for commercial aircraft began in the 1980's. A "glass cockpit" features digital flight information on integrated, multi-function displays rather than traditional analog information presented on discrete gauges. Many of these aircraft utilized a combination of complex integrated avionics with a set of

simpler, federated primary systems - flight controls, landing gear, environmental controls, etc. Examples of aircraft that have been developed with glass cockpits and conventional systems include the Boeing 737-500, 737 Next Generation (NG), 757, 767, and 747-400. Yet, it wouldn't be until the 2000's when similar platforms would become available for the general aviation community.

The development of glass cockpit aircraft was a significant feat and occurred without the more structured techniques offered by standards such as ARP4754A - and in some cases, before the original publication of the ARP. Evidence of the safety of these aircraft can be inferred from the "Statistical Summary of Commercial jet Airplane Accidents, Worldwide Operations 1959-2013" [11] and the "Commercial Aviation Accidents 1958 - 2013: A Statistical Analysis" [12] issued by Airbus. In this report, glass cockpit aircraft which precede fly-by-wire systems are considered "third generation aircraft" and have accident trends more similar to the "fourth generation aircraft" (fly-by-wire aircraft) than to their predecessors. Many of these glass cockpit aircraft are still in-service today as shown in [Table 1](#) with remarkable safety records with few examples of development errors. We should also not discount the fact that a significant portion of the larger aircraft population operating today in commercial aviation are still of that 1980's revolution and use a similar mix of conventional systems and targeted advanced technologies as general aviation. Further, fourth generation aircraft such as the Boeing 777 have had exceptional safety records while being designed before the publication of the original revision of ARP4754.

Table 1. "Glass Cockpit" Aircraft Developed without the More Structured Techniques of ARP4754

Aircraft	Entered Service	Delivered (Approx) [13]	In-service (Approx)[14]
767	1982	1,069 as of January 2015	Over 750
757	1983	1,050 as of October 2004 (when production ceased)	Over 750
737-500 and 737NG	1987 for 737-500, 1998 for 737NG	Over 5,600 as of Feb 2015	Over 4,500
747-400	1989	694 as of 2009 (when production ceased)	Over 450

Today the philosophy of third generation types of programs is alive and well. In general aviation, avionics "glass cockpit" packages are a standard feature of some smaller aircraft designs. These developers are often integrating "off the shelf" packages onto their conventional systems architectures - more similar to the start of the commercial integration in the 1980's than the highly integrated fly-by-wire systems in commercial aircraft.

When guidance is developed for a small portion of the aviation community, complex and highly integrated aircraft, great care must be taken to not forget the mundane reality of the majority of aircraft development programs

Regulatory Concerns about Systems Development

While the majority of aviation programs continue to leverage conventional designs, regulators have become increasingly concerned with the future growth of complexity seen on a few aircraft programs. For certain, the development of these complex and highly integrated aircraft pose potentially greater risk of generating errors in design than conventional aircraft. This advanced technology possesses a level of uncertainty that can be masked through the development process, unlike their predecessors. Where testing and increasingly capable analysis tools are able to tease out such faults in more conventional systems, the fear of the unknown is a feasible concern for these complicated and highly integrated systems. In 2011, AC 20-174 identified ARP4754A as a way (but not the only way) to provide development assurance for aircraft and systems to minimize the possibility of development errors. AC 20-174 stated its intent to address "the concern of possible development errors due to the ever increasing complexity of modern aircraft and systems." This sentiment is repeated in ARP4754A, section 1.2, "While there can be considerable value gained when integrating systems with other systems, the increased complexity yields increased possibilities for errors, particularly with functions that are performed jointly across multiple systems."

Industry Concerns about Regulatory Conflicts

ARP4754A and its companion, AIR6110, "Contiguous Aircraft/ System Development Process Example," primarily describe development processes for an all new, complex and highly integrated aircraft without strong consideration for reused systems or simple systems despite the prevalence of such systems in the industry. While ARP4754A discusses sections that are essential to planning of ordinary programs such as reuse (sections 5.3.1.5 and 6.6.3), similarity (sections 5.4.6 e, 5.5.5.5, and 6), simplicity (section 5.2.3.3 and 5.4), and modifications to existing aircraft (section 6) these discussions are approached piecemeal, or, in the case of section 6, inconsistently with the remainder of the ARP. Even though a planning section, section 3, exists and includes many elements of the processes which are covered later in the document, it does not discuss a complete planning concept that aligns with the reality of most aircraft programs. This work proposed a method to comprehensively approach these topics as part of program development planning which could be used on any program type. The proposed method would be part of the planning section of ARP4754A and provide coverage adequate to meet the objectives of sections 3, 4, and 5. Section 6 would be removed, but the intent of this section will be covered in the methodology. The proposed methodology could be viewed as the development assurance applicable elements of section 6.2, "Modification Management Process," which should be equivalent to section 3, "Planning."

For the majority of aircraft programs, these topics are the keys to understanding how to appropriately plan for the application of the process to give development assurance coverage where it will provide a benefit. A planning method which includes these considerations is urgently need in the near term to both provide comprehensive coverage for complex and highly integrated systems, and not burden the development of simpler aircraft or reused systems (particularly, previously Type Certificated (TC) Engines and Technical Standard

Order (TSO) Avionics). The urgency for this planning method is particularly pressing for smaller aircraft. Since the FAA identified Part 23 regulations as being applicable in the AC, a conflict is imminent between the drive for use of the AC 20-174 and the simplified regulatory concepts of the Part 23 Aviation Rulemaking Committee (ARC).

A RECOMMENDED PLANNING METHOD

Central to all aircraft development preparation is the certification planning of the Product. As discussed, the majority of projects are those that are implementing new systems along with systems which are reused or not complex and highly integrated. When planning for the use of ARP4754A, considerations of legacy systems, complexity, and certification basis must be taken into account as allowed by the ARP and AC20-174. To do this, a consistent evaluation method of the program should be conducted to determine if all processes of ARP4754A are applicable. If a system to be developed by a means other than that defined by ARP4754A, the requirements of that “traditional technique” must be established. This work will first evaluate the requirements of acceptable “traditional techniques” in comparison to ARP4754A, and then discuss the evaluation method which may be conducted to decide to use them.

Defining “Traditional Techniques”

Foundationally, one must identify a common technique that allows ARP4754A to interface with systems developed under the conventional means of Type Certification for projects such as amended TC's, STCs, or reuse of systems from Type Certificated Products. Unlike processes as defined by DO-178 and DO-254, ARP4754A works at a level of detail, aircraft and system, for which there already exists a process to demonstrate the compliance of a significant number of regulatory requirements. Systems level regulations can be found to define a variety of system aspects including functions, performance, pilot interfaces, and even lever shapes. Because of this, certification plans and compliance reports regarding systems have an unmistakable similarity to ARP4754A's requirements documents and accomplishment summaries. When considering the Type Certification process further, it is easy to see that it covers many of the foundational processes of ARP4754A including: planning, requirements management, validation, verification, configuration management, and process assurance. These processes are already present in all Type Certification projects as required by regulatory authorities, though these processes are not as structured as those defined in ARP4754A. The processes are discussed, though not necessarily by name through documents such as FAA Order 8110.4C. The following are a few common concepts shared between the ARP and Type Certification process:

- All Type Certification projects require certification planning to describe how the Product will demonstrate it complies with regulatory requirements.
(Order 8110.4C sections 1-6 & 2-3 (d) Certification Plan)
- Certification plans document the regulatory requirements for the project. These requirements include the required definition of functions. For decades, more conventional means of compliance

have been adequate to mitigate design errors for systems which were not complex and highly integrated.

(Order 8110.4C sections 1-6 & 2-3 (d) Certification Plan)

- The demonstration of compliance relies on a validation that the proposed means of compliance per regulatory requirement is appropriate. Further, a traceable path from the requirements source (airworthiness regulations), to verification artifacts (analysis, test, etc.), aircraft configuration, and finally to accomplishment summaries (compliance reports) - similar to ARP4754A tracing of requirements to their verification activity.
(Order 8110.4C sections 2-5. a. FAA Involvement, & 2-6. m. Compliance Reports)
- All Type Certification is based on a verification that the aircraft design complies with the regulatory requirements, similar to ARP4754A.
(Order 8110.4C section 2-6. J. Compliance Substantiation)
- To enable the processes described above, Type Certification also necessitates a level of configuration management to execute these processes. An applicant must describe how documentation is to be controlled and maintained.
(Order 8110.4C sections 2-6. b. Conformity Inspections, g. Analysis, 2-7. F. Data Retention)
- Most foundationally, Type Certification relies on a level of process assurance - a critical process for ARP4754A - in the form of requiring a qualified individual to make a finding of compliance, which is involved in the review and approval of the artifacts described above against specific criterion.
(Order 8110.4C 2-5. b. Oversight and Delegation, and 2-6. c. Applicant Test Plan and FAA Approval, d. Before Witnessing, and g. Analysis)

Therefore, conventional Type Certification inherently provides a set of traditional techniques which align with the more structured techniques of ARP4754A. Since, the ARP4754A modifications, derivatives, and reuse cases will likely involve systems that were not developed with the structured processes of the ARP, the ARP can leverage the Type Certification process itself as a development assurance process, though less structured.

This similarity between the ARP and the Type Certification process models -especially as described in Order 8110.4C-is particularly relevant for simpler systems which do not implement a large number of functions. Should the ARP4754A process be used as the certification method, or conversely can the certification process be used as another means of development assurance for these simpler systems? Based on AC20-174, ARP4754A is only intended to cover the 2X.1301 and 2X.1309 regulations, though in multiple Parts - the AC never mentions Part 21. However, the AC does mention the use of “traditional techniques” which are not the same as the “more structured techniques described in ARP4754A.” Not only would such certification data have to be available on modification programs and programs with reused systems, but the processes used to achieve Type Certification would also be present in new programs with systems that are not complex and highly integrated or with previously Type Certificated engines.

