

The Research and Practice of ARP 4754A Process Assurance Method in Civil Aircraft Development

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ABSTRACT.

CCAR25.1309 clause is a programmatic certification requirement for the civil aircraft and system safety, which is one of the most comprehensive and complex airworthiness clauses for the civil aircraft[1]. The process assurance method based on ARP 4754A is an effective means to develop a civil aircraft or a system in a top-down mode which comply with the CCAR25.1309 clause. The research and practice on how to promote and implement the 4754A process assurance method in the TC certification process of civil aircraft is conducted. The study of the requirements realization process, safety assessment process, and development assurance level assignment of the 4754A development assurance process is performed. The process assurance concept, requirements, objectives, and methods are introduced. The key points that need to be paid attention to in process assurance, activities, checklist are defined and introduced to ensure that the 4754A process assurance method can be followed and implemented in the development of civil aircraft models. It shows it is effective to support the review of complex comprehensive airworthiness clauses by the authorities.

Keywords: 4754A; Process Assurance; Development Assurance Process; Development Assurance Level

1. RESEARCH BACKGROUND AND PURPOSE

1.1 Research Background

In a civil aircraft TC certification process, it is required that the aircraft and its systems shall meet the requirements of CCAR 25.1301 and CCAR 25.1309. Especially, CCAR 25.1309 (b) requires that the design of aircraft systems and related components shall comply with the following requirements:

- (1) The probability of any failure state that hinders the continued safe flight and landing of the aircraft is highly unlikely.
- (2) The probability of any other failure state that reduces the aircraft's ability or the crew's ability to handle adverse operating conditions is unlikely.

The current trend in system design is to continuously improve the level of integration between aircraft functions and system for executing functions. Although significant benefits can be achieved through integration between the system and other systems, the increased complexity also increases the likelihood of errors, especially for functions executed jointly by multiple systems. The traditional approach to detecting and correcting errors in design and system development is to conduct thorough testing, on board inspections, and other direct verification methods on the system and its components. However, due to the highly comprehensive and complex characteristics of modern aircraft systems, the authorities are extremely concerned about the possibility of aircraft failure caused or caused by development errors. To address these issues, there is a need for a method that can reduce development errors. The compliance of such systems can be demonstrated through the "Development Assurance" method provided by SAE ARP 4754A.

1.2 Research Purpose

In 2011, FAA recognized the industrial standard SAE ARP 4754A through AC 20-174 as an acceptable guidance method for the development assurance process of civil aircraft and systems. Implementing the development assurance approach and methods as defined in ARP 4754A requires a process to establish confidence, which minimizes development errors that can lead to or cause confirmed failure states with appropriate rigor. This process is called the development assurance process. An important process element in the development assurance process is "process assurance", which should form a process assurance plan and describe activities and methods to ensure that the rules and procedures used in the aircraft or system development process are followed. Considering the requirements of ARP 4754A together with requirements management and safety assessment, it is essential to generate the aircraft process assurance plan document to define how

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to perform the process assurance to ensure all the requirement capture and allocation, validation and verification, safety assessment, configuration management etc. are performed properly. The process assurance plan is the key deliverable which the authorities concern a lot to confirm ARP 4754A has been effectively implemented in the aircraft project.

2. 4754A PROCESS ASSURANCE METHOD RESEARCH

2.1 Aircraft/System Development Process Model

4754A provides a typical aircraft/system development process model[2] as seen in Figure 1, which interprets the plans required for the aircraft development planning process thereby to control the process of aircraft/system from function determination, function allocation, system architecture design to system implementation. Process assurance plays an important role in it, used to supervise and ensure that other processes follow the established methods to carry out development work.

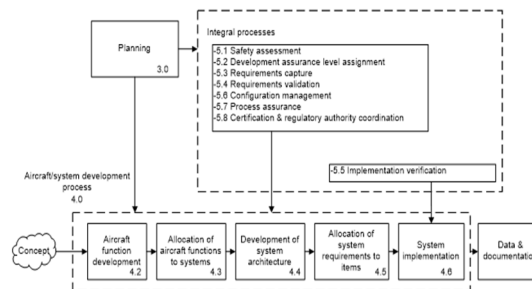


Figure. 1 Aircraft/System Development Process Model

2.2 4754A Requirement Implementation and Security Assessment Process

2.2.1 Requirements Implementation Process

The airworthiness regulation is one of the most important customers requirements. Therefore, it is essential and necessary to understanding the regulation requirements and to transform the airworthiness requirements into aircraft/system level requirements. The requirement based design and verification process runs through the aircraft level, system level, and component level, development and requirement design are processes of step-by-step allocation and mutual iterative optimization[3] which lays a solid foundation for aircraft/system development. According to the five step requirements of "complete requirement capture, comprehensive scenario analysis, accurate functional definition, reasonable layer by layer allocation, and effective confirmation and verification" to understand the requirements. A process for requirement implementation is define as pictured in Figure 2 to ensure that all levels of requirements can be achieved in model development.

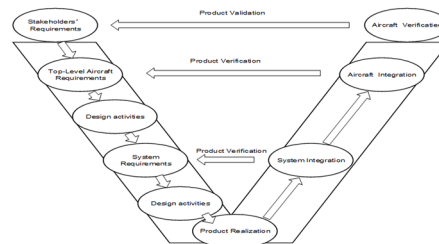


Figure. 2 Requirements Implementation Process

2.2.2 Safety assessment process

The aircraft safety assessment is coordinated with the aircraft development plan. The safety requirements capture and definition are closely related to the aircraft/system functions and requirements. It is formed based on aircraft functional hazard assessment analysis (FHA). The relationship between the safety assessment process and the system development process is shown in Figure 3.

2.3 Development Assurance Level Allocation

The development assurance level is a new defined concept introduced by 4754A development assurance, which qualitatively determines whether the development errors of highly complex and comprehensive systems are at an acceptable level of safety. In ARP 4754A, it proposes general guidelines of DAL assignment for aircraft and system[4]. The allocation of development assurance levels is based on the severity level of the failure state, and the results of

preliminary common mode analysis. According to the functions and items, the functional development assurance level (FDAL) and item development assurance level (IDAL) are determined and allocated. The allocation process is shown in Figure 4.

The allocation of development assurance level should be based on the safety assessment process, which is a top-down process[5]. Process assurance needs to focus on checking the allocation process of development assurance levels and their subsequent implementation and application.

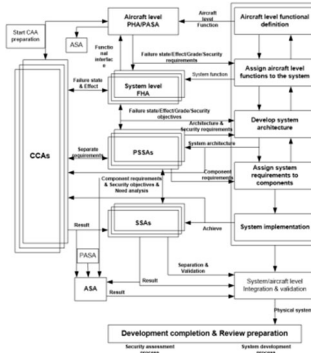


Figure. 3 Safety Assessment Process and System Development Process

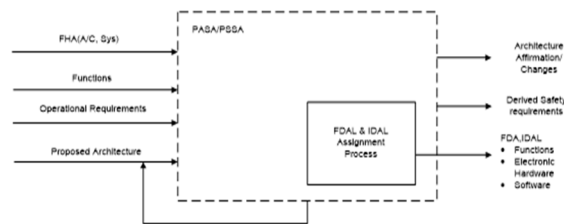


Figure. 4 FDAL/IDAL allocation process

2.4 Process assurance methods

The process assurance activities covers the whole aircraft or system lifecycle which includes product concept, design, production, operation, and maintenance stages[6], in order to ensure that development assurance work is maintained and tracked, and its work objectives can be achieved:

- (1) To ensure that all necessary plans are developed and maintained properly for the aircraft, systems, and subsystem in the aircraft development;
- (2) To ensure that development work and processes are carried out according to the corresponding plans;
- (3) To provide evidence to demonstrate that the work and process were strictly carried out according to their corresponding plans.

Particularly, the process assurance process shall be performed with a certain degree of independence compared to other processes. Meanwhile, the process assurance plan is coordinated with other process plans. The process assurance can provide a supervision ensures that it is executed according to the prescribed procedures and methods. The relationship between process assurance process and other processes is shown in Figure 5.

3. APPLICATION OF PROCESS ASSURANCE METHOD IN THE AIRCRAFT PROGRAM

3.1 Process assurance activity promotion ideas

The aircraft development lifecycle model is the essential basis for the planning process. Typically, there are four phases, i.e. feasibility demonstration, preliminary design, detail design, production and test, in the aircraft development lifecycle. The activities to be performed together with their outputs in each phase shall be clearly defined in the aircraft development

plan. In order to ensure all the activities in each development phase, four process assurance audits reviews are defined according to the aircraft development milestones, as shown in Figure 6.

In the planning phase, all the plans mentioned in ARP 4754A shall be defined. These plans clearly define all the activities and required deliverables for each phase and will be used as the criterion for the process assurance. The DAR1 is carried out to inspect if all the plans are defined properly. DAR2 focuses on the requirements validation while the DAR3 lay attention on the verification. All the DARs review generate a lot of evidence which shall be recorded properly. The whole process assurance summary is performed at the DAR4.

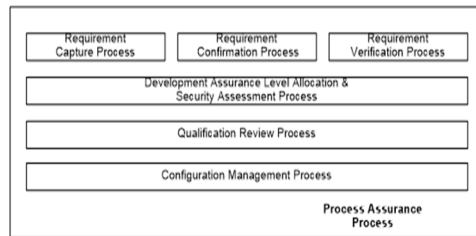


Figure. 5 Relationship between Process Assurance and Other Processes

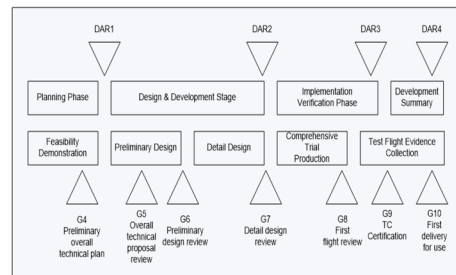


Figure. 6 Correspondence between the development stages and development assurance process stages of the civil aircraft project

3.2 Process Assurance Plan Documents

According to the work objectives and requirements of process assurance, it is necessary to prepare process assurance plan documents to clarify the quality control of the development process. The process assurance plan specifies the resources and institutional functions required for process assurance, tools, techniques, and methods for process assurance activities, review requirements and records at each stage, Problem report management requirements, etc.

According to the requirements for development assurance levels, the corresponding development assurance levels for each process activity plan document are shown in Table 1.

Table 1 Method for Different Development Assurance Levels of Process Plan Documents

Process Program File	Development Assurance Levels A and B	Development Assurance Levels C	Development Assurance Levels D	Development Assurance Levels E
Certification Plan	R	R	R	R
Execution of the Safety Program Plan	R	R	R	N
Development Plan	R	R	R	N
validation plan	R	R	A	N
Verification Plan	R	R	A	N
ConFigureuration Management Plan	R	R	R	A
Process Assurance Plan	R	R	R	N

Process Program File	Development Assurance Levels A and B	Development Assurance Levels C	Development Assurance Levels D	Development Assurance Levels E
Notes: R-Certification recommended,A-As negotiated for certification,N-Not required for certification				

3.3. Implementation of process assurance activities

The process assurance activities of the aircraft project are implemented in accordance with the work content and requirements determined in Table 2. The checklist is used as the review or inspection methods[7].

Table 2 Implementation Requirements for the Four Stage Process Assurance

Process phases	Main Task/Deliverable Items		Review Requires	Forming Records
	aircraft-level	system level		
Planning phase(DA R1)	1.development plan; 2.safety plan; 3.Requirements validation plan; 4.Requirements Verification plan; 5.ConFigureuration Management Plan; 6.Process Assurance Plan; 7.Certification plan.	1.development plan; 2.Requirements validation plan; 3.Requirements Verification plan; 4.ConFigureuration Management Plan; 5.Certification plan.	1.Whether the content of each process plan meets the requirements of 4754A; 2.Whether the process plan documents are signed and published; 3.Whether there are checklists, procedures, communication mechanisms etc. That support activities of the third development process have been defined	1.planning documents checklists; 2.Review reports(review suggestions included).
Design phase(DA R2)	1.Finish the identification, capture and assignment of aircraft-level needs; 2.Release aircraft-level requirement documents; 3.Formation of a demand confirmation matrix; 4.Publish the summary report of demand confirmation; 5.Complete aircraft-level AFHA, PASA, ZSA and other safety work; 6.Establish a baseline of conFigureuration and function, etc.	1.Finish the identification, capture and assignment of system-level needs; 2.Release system-level requirement documents(SRD), system-level description documents(SDD); 3.Formation of a demand confirmation matrix; 4.Publish the summary report of demand confirmation; 5.Complete system-level SFHA, PSSA and other safety analysis; 6.Establish conFigureuration assignment baselines, etc.	1.whether the activities in the design and development phase are in accordance with the developed process plan documents; 2.whether the company's design specifications are translated into requirements within the DOORS; 3.whether the established requirements confirmation matrix is traceable; 4.Approval of the Requirements Confirmation Matrix; 5.whether a summary of requirements confirmation has been formed; 6.Whether the confirmation methods and data used by the system meet the corresponding requirements of the development guarantee level; 7.ConFigureuration management of requirements within DOMS; 8.whether the aircraft and systems safety analysis and assessment work has been completed; 9.List of action items for project review/review activities, etc.	1.Requirements Confirmation Checklist; a) Safety analysis and evaluation checklist; 2.Review report (including review opinions/suggestions); 3.Engineering evaluation report.

Process phases	Main Task/Deliverable Items		Review Requires	Forming Records
	aircraft-level	system level		
Implementation validation phase(DAR3)	1. Formation of a requirements verification matrix; 2. Publish a summary of the aircraft-level requirements verification; 3. Report on compliance with airworthiness clauses; 4. Complete safety analysis and evaluation of aircraft-grade ASA.	1. Formation of system/equipment DDP; 2. the formation of a requirements verification matrix; 3. Publish the requirements verification summary report; 4. Complete system-level SSA and other security analysis; 5. Airworthiness clause compliance report; 6. Establish a baseline of configuration products, etc.	1. whether the activities of the implementation validation phase are in accordance with the process plan document developed; 2. whether a requirements validation matrix has been formed; 3. Approve the requirements validation summary; 4. Whether the verification methods and data used in the system meet the corresponding requirements of the development guarantee level; 5. whether the aircraft and system safety analysis and assessment work has been completed; 6. List of action items for project review/review activities, etc.	1. Requirements Verification Checklist; 2. Safety analysis and evaluation checklist; 3. Review report (including review opinions/suggestions); 4. Engineering evaluation report.
Development summary stage(DAR4)	1. Formation of an aircraft-grade functional compliance review; 2. Overview of aircraft validation; 3. Configuration index files; 4. Each process plan work summary, etc.	1. a review of the functional compliance of the three key systems; 2. a review of the validation of the three key systems; 3. Summary of each system, process assurance, activities, etc.	1. whether all process activities are consistent with the process specified in the planning process; 2. consistency between the configuration index file and the configuration; 3. the requirement to confirm and verify the data integrity of the data; 4. Process assurance records and related evidence; 5. All change requests and problem reports are recorded and traceable; 6. List of action items for project review/review activities, etc.	1. Process summary (consistency, etc.) checklist; 2. Review report (including review opinions/suggestions); 3. Engineering evaluation report.

3.4 Problem Report

In order to standardize the management of aircraft development and design process issues, the problem report process is defined to record various issues in the aircraft development such as test issues, flight test issues, route operation issues, demand issues, and continuing airworthiness events. The problem report process document clarifies the responsibilities of relevant parties and requirements for root cause analysis and capability transformation. The requirements for problem reporting in 4754A are related to configuration changes. In order to implement this requirement, a "Development Process Problem Record Control Form" has been developed and the requirements for preparing development process problem reports have been clarified to meet the requirements of the authority for the special review of the aircraft 4754A implementation.

3.5. Process Assurance Summary

According to the aircraft program plans, The process assurance summary report is generated after all process assurance activities at DAR4. The "Compilation Requirements for Aircraft Process Assurance Summary" has been formulated to standardize and guide the preparation of process assurance summary reports for aircraft and key propulsion systems.

4. 4754A PROCESS ASSURANCE CONCEPT AND MODEL DEVELOPMENT CONTROL INTEGRATION

According to ARP 4754A development assurance requirements, the process assurance is performed throughout the whole aircraft development. It found that the emphasis shall be laid on the requirements definition and implementation[8]. The following experience and suggestions shall be considered in the process assurance implementation :

- (1) Integrate into the quality system: Sort out and improve the 4754A development assurance process documents, incorporate them into the quality system documents, and promote the implementation of development assurance.
- (2) Incorporating model documents: Highlighting the deliverable control and review requirements for aircraft system functions and requirements in access control management requirements and model development procedures, paying attention to the requirements for development assurance levels, and strengthening demand driven forward design.
- (3) Solidification process assurance: Develop the "Model Development Process Assurance Method Standard" to guide the preparation of process assurance plan documents, with a focus on controlling the requirement realization process and safety assessment process.
- (4) Solidification engineering review: Form the "Model Development Assurance Process Engineering Review Procedure", using the tools of requirement capture, requirement confirmation, and requirement verification review checklist, and conduct strict engineering review activities separately to distinguish them from transition review activities and implement the requirement realization process.

5. CONCLUSION

The ARP 4754A development assurance process is increasingly recognized by civil aviation as a formal aircraft or system development approach. The process assurance, one of the ARP 4754A processes, is studied and introduced. The activities in the process assurance are described separately. The process assurance checklist is defined according to the ARP 4754A objectives. The main deliverables, including the process assurance plan, problem reports, summary are introduced. The four Development Assurance Reviews (DAR) in the whole aircraft development are defined. It is found that the requirement definition and realization process, and the safety assessment process are the key processes in the ARP 4754A. It is also shows that the process assurance is very important process to ensure the ARP 4754A which can effectively obtain the approval of the reviewers for the internal control of development assurance. This provides strong support for ensuring the compliance of CCAR 25.1309 (b) through review.

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