# Research on Airworthiness Requirements for Function and Reliability Flight Test of Civil Aircraft

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**Abstract:** Function and reliability flight testing is an important trial for civil aircraft airworthiness certification, and is a part of the qualified acceptance flight tests that confirm that the aircraft, components, and equipment are reliable and functioning properly. This article studies the airworthiness requirements for function and reliability flight testing in CCAR21 and Appendix B of AC25-7D, and combines practical experience with civil aircraft models to analyze the requirements for flight testing time, configurations, procedures, and problem requirements, and provide recommendations for civil aircraft function and reliability flight testing.

**Keywords:** Function and reliability; Flight Testing；CCAR21; AC25-7D; Airworthiness.

## 1. Introduction

The C919 aircraft completed function and reliability test flights in strict accordance with airworthiness regulations in August 2022, further exploring and mastering civil aircraft function and reliability test flight technology and airworthiness requirements in China, providing reference and guidance for subsequent function and reliability test flights of other models. This article conducts research on the airworthiness requirements for function and reliability flight tests in CCAR21, and analyzes the impact of these airworthiness requirements on the function and reliability flight tests and airworthiness certification work of civil aircraft, in conjunction with Appendix B of AC25-7D. The aim is to provide reference for subsequent function and reliability flight tests of civil aircraft.

## 2. Airworthiness Terms

### 2.1 Function and Reliability Airworthiness Requirements in CCAR21

Before obtaining the type certificate, civil aircraft must complete function and reliability test flights. The main airworthiness terms for function and reliability test flight verification are as follows:

CCAR21.35 (II) (2): Upon showing accomplice with paragraph(I) of this section, for aircraft to be certificated under airworthiness regulations, the applicant must make all flight tests that the CAAC finds necessary to determine whether there is reasonable assurance that the aircraft, its components, and its equipment are reliable and function properly.

CCAR21.35 (VI) (1): For aircraft incorporating turbine engines of a type not previously used in a type certificated aircraft, at least 300 hours of operation with a full complement of engines that conform to a type certificate [1].

### 2.2 Function and Reliability Airworthiness Requirements in AC25-7D

On April 5, 2018, FAA released AC25-7D Flight Test Guide for Certification of Transport Category Airplanes, in which the content of the "APPENDIX B. FUCTION AND RELIABILITY (F&R) Tests" section was changed compared to AC25-7C.

2.2.1 Explanation section

Appendix B of AC25-7D provides explanations, test procedures, test time requirements, test aircraft requirements, reporting and recording requirements for function and reliability testing. The

FAA believes that it is necessary for applicants applying for a type certificate (including an amended type certificate or a supplemental type certificate) to conduct function and reliability tests, to determine whether there is assurance that the aircraft, its components, and its equipment function properly (i.e., perform their intended function without introducing safety hazards) and are reliable (i.e., will continue to function properly in service) [2].

2.2.2 Program section

For turbojet powered aircraft, if the engine has not previously obtained a certificate of conformity on an aircraft used for a certain type certification, a function reliability test is required for at least 300 hours. Although some function and reliability tests can be completed together with certification flight tests, at least 150 hours of test flight, also known as dedicated function and reliability test, must be completed on one production configuration aircraft to simulate route operation mode. The remaining part can be completed in conjunction with certification flight tests, also known as non-dedicated flight tests. In order to achieve the required reliability verification, the applicant must conduct at least 300 hours of aircraft testing using an identical and compliant engine, with a dedicated test flight time of no less than 150 hours.

## 3. Analysis of Airworthiness Requirements

AC25-7D was upgraded and released in 2018, with significant changes in some content descriptions compared to AC25-7C, as well as some changes in the main meaning of guiding test flights. Especially in the section "B.1 Explanation", AC25-7D completely changed the description in AC25-7C, highlighting and emphasizing the purpose of conducting function and reliability test flights, as well as the scope of application of the terms [3]. Appendix B of AC25-7D, "Function and Reliability (F&R) Tests," provides a more comprehensive and detailed description of the requirements for function and reliability flight testing, with clear requirements for aircraft configuration control, aircraft status maintenance during flight testing, and handling of flight testing issues. Overall, the differences between AC25-7D and AC25-7C in terms of function and reliability testing have had a certain impact on the development of civil aircraft function and reliability flight testing work, but there have been no changes in testing procedures, non specialized flight time statistics and conversion ratios, reports and records requirements, and achievement criteria.

### 3.1 Flight Test Time

3.1.1 Test flight time requirements

Flight test time is a key requirement in the airworthiness regulations for function and reliability flight tests, and is a key indicator for determining the success of function and reliability flight tests. The test flight time for function and reliability has different requirements for different types of aircraft for certification. Based on a thorough understanding and analysis of airworthiness clauses and advisory notices, it is necessary to establish principles for the development of civil aircraft function and reliability test flight time by studying international advanced model test flight experience and conducting detailed discussions with the civil aviation administration.

According to CAAR21 regulations, the function and reliability test flight time for aircraft equipped with a certain type of turbine engine that has not been used on aircraft with existing model qualification certificates or design approvals shall be at least 300 hours. AC25-7D provides clear requirements that function and reliability test flights require at least 300 hours, with no less than 150 hours for dedicated function and reliability tests. AC25-7D also provides time requirements and conversion statistics for non-dedicated flight tests. Based on the experience of large civil aircraft models, the optimal time allocation ratio for function and reliability test flights is: more than 150 hours for non-dedicated test flights and more than 150 hours for dedicated test flights.

3.1.2 Design changes to aircraft test flight time requirements

Two new requirements regarding test flight time have been added to AC25-7D, clarifying the

determination of function reliability test flight time for aircraft with design changes, a new definition has been provided for the conversion of flight time between compliance test flight and function reliability test flight. For aircraft with design changes, FAA can give full or partial trust to the function and reliability tests previously conducted on aircraft with sufficiently similar configurations. The FAA will require a certain amount of dedicated function and reliability tests, which are related to the level of aircraft design changes, the potential impact of aircraft function and reliability changes, the workload of flight tests indicating compliance based on airworthiness requirements, and the configuration of flight tests indicating compliance based on airworthiness requirements. If changes to the aircraft and potential impact areas are confirmed to be production configurations, and the testing activities are consistent with the purpose of function and reliability testing required by design changes, FAA may reduce dedicated testing time.

At the same time, FAA can provide applicants with a conversion of the compliance test flight indicated in § 21.35 (b) (1) and the function and reliability test flight time indicated in § 21.35 (b) (2) in the following situations:

a) The changed and potentially affected areas of the airplane conform to the production configuration, and

b) The test activities are consistent with the intent of the function and reliability testing required for the design change.

The above requirements in AC25-7D are beneficial for the statistical analysis of the function and reliability test flight time of civil aircraft. If a certain type of certification aircraft is a design modification of another aircraft, the applicant can convince the civil aviation administration through data analysis that the potential impact of design modification, functionality, and reliability modification on the certification aircraft and similar configuration aircraft is acceptable. This can give trust to the function and reliability testing of similar configuration aircraft, which can greatly reduce the time for dedicated and non-dedicated function and reliability testing of the certification aircraft.

### 3.2 Test Flight Configuration

3.2.1 Test flight configuration requirements

The AC25-7D specifies that the function and reliability test flight configuration requirements are all production delivery configurations. The test aircraft participating in the function and reliability dedicated test flight do not require special testing and modification. The dedicated test flight requires that the engine, APU, fuel, flight control, hydraulic, air conditioning, air source, oxygen, landing gear, fire prevention, avionics and other related system configurations of the entire aircraft meet the requirements of certification flight. If there is a configuration deviation (such as difficult to implement structural design changes), it can exist without affecting aircraft safety and flight test results, but the configuration needs to be evaluated to prove that the deviation does not affect function and reliability flight test results, and is recognized by the authorities.

The non-dedicated flight test requirements for function and reliability require the aircraft configuration and the added test modifications to meet the configuration requirements of each subject. According to the requirements of AC25-7D for function and reliability test aircraft, function and reliability dedicated test flights should be conducted on one production configuration or equivalent aircraft, while non-dedicated test flights can be conducted on another (or multiple) aircraft. Therefore, the applicant can choose one or more aircraft to conduct function and reliability non-dedicated flight tests based on the requirements of the terms and the guidance methods provided in the Advisory Circular, and considering factors such as the needs of non-specific flight tests, the situation of participating aircraft, and the coordination of workload.

3.2.2 Engine configuration requirements

In the section “B.2.1 Test Time” of AC25-7D, a requirement for engine configuration has been added to the time requirements for function and reliability test flights, specifying that the minimum

300 hours of test flight time required for function reliability test flights is "on a full complement of engines installed on the airplane that fully conform to the production configuration", and that the engines must be "the same set of conforming engines" during these 300 hours of testing. However, there is no description of such requirements in AC25-7C. In the requirements section of the test time, it is emphasized again that the engine must fully comply with the production configuration.

### 3.3 Flight Test Procedure

3.3.1 Simulate route operation

According to the requirements of AC25-7D, the function and reliability dedicated test flight is conducted in the form of the routine-type tests. during the test flight process, various system functions of the aircraft are checked, verified, and recorded in combination with ground inspection, taxiing, flight, approach, and landing stages. Information on problems and defects in the aircraft system, components, and equipment is recorded and statistically analyzed.

When conducting function reliability test flights, the test flights should be conducted under all foreseeable operating conditions during actual aircraft use. Typical airports, representative short range, medium range, and long range routes, and common weather conditions may be considered for the test flights, but it’s not required to conduct the test flights under the most severe conditions.

3.3.2 Simulating fault conditions

Simulate the operational scenarios of aircraft equipment in the event of malfunctions in the air; Simulate the operation of aircraft dispatch after discovering that certain equipment is not working during pre flight inspection.

3.3.3 Ground inspection

AC25-7D requires ground inspections and maintenance of aircraft at appropriate intervals. This requires maintenance personnel to truthfully record the inspection frequency, inspection results, and problems related to the project according to daily maintenance work.

### 3.4 Flight Test Issues

Compared to AC25-7C, AC25-7D emphasizes that when the applicant discovers items that do not meet the requirements that may render future test data meaningless or pose unnecessary risks to continuing the test, the applicant must interrupt the function and reliability test flight until appropriate corrective measures are taken. The applicant must handle any issues that do not comply with the function and reliability terms, as well as any unsafe features or characteristics identified during the trial. These requirements are worth paying attention to, and the applicant should clarify with the civil aviation administration the scope of items or issues that do not meet the requirements, in order to reduce unnecessary interruptions in test flights.

## 4. Measures for Civil Aircraft F&R testing

The function and reliability test flight involves a wide range of aircraft systems, numerous inspection items, and takes a long time, posing great challenges to the organization and support of the test flight. It is difficult to implement and carry out, and is one of the important special test flights in civil aircraft certification flight. Based on the above airworthiness requirements analysis and type practice experience, the following measures can be taken to promote the safe and implementation of function and reliability test flights.

### 4.1 Clarify in Advance the Requirements for Non-dedicated test time statistics

The non-dedicated test time for function and reliability is based on the conversion of the certification flight time and the compliance flight time [4]. Because the configuration of the test aircraft is gradually in place, and different test subjects in the execution of the configuration is not the same, the applicant shall, on the premise of safety and the realization of expected functions,

evaluate the impact of functional loss or deviation of relevant systems on the functional realization of the cross-linked system, discuss with the civil aviation administration in advance which specific subjects of the test flight time can be counted, and clarify the configuration requirements and time statistical requirements of non-dedicated test before the launch of the dedicated test.

According to the test experience of ARJ21-700 aircraft, the non-dedicated function and reliability test is only counted based on the time of the certification flights. According to the new requirements in AC25-7D, the time for compliance flights can also be included in the non-dedicated flight time, which requires the applicant to communicate and clarify with the authorities in advance. In the practice of latest types, the time for function and reliability test is prioritized for non-dedicated test. For those compliance flights that meet the configuration requirements, the time for function and reliability test can also be counted together, with converting into function and reliability test flight time at a ratio of 5:1.

### 4.2 Clarify Review Methods for Engine Configuration Requirements

AC25-7D has added requirements for engine configuration, specifying that the engine must be identical during a 300 hour function and reliability test flight. The civil aircraft used for certification may be designed into different types due to range and commercial considerations. For example, the C919 aircraft is divided into standard range (STD) and extended range (ER), with differences in engine thrust levels between the two types. In this case, the applicant needs to communicate with the civil aviation administration in advance to determine the function and reliability test review methods for aircraft with different engine configurations [5]. If different configurations of aircraft undergo function and reliability test flights separately, the applicant will need to pay double time and cost. If analysis reports can be provided to the civil aviation administration to verify the compliance of the aircraft with function and reliability terms by selecting aircraft configurations with more critical reliability indicators for testing, this can reduce the applicant's test flight time and cost.

### 4.3 Closing Flight Test issues

The applicant should try to close the accumulated test flight issues during the early test flight period as much as possible. The closure rate of test flight issues is one of the indicators of the aircraft's status and configuration, and is a key focus of the authority's agreement to carry out function and reliability test flights.

Also, the applicant should improve the efficiency of handling issues during the function and reliability test flight, in order to improve the efficiency of the function and reliability test flight. The applicant should complete the aircraft maintenance manual and flight manual as soon as possible. When dealing with test flight issues during function and reliability test flights, priority should be given to simulating route operations and using the aircraft manual to handle test flight issues [6]. For issues that cannot be covered by the manual, a problem handling process should be set up in advance.

### 4.4 Flight crew briefing

Since the dedicated function and reliability test flight is to simulate the normal operation of the route,,involving multiple airports, different routes, complex environments, and weather conditions, it is necessary to consider the risks that may be caused by insufficient briefing to the crew about the airport environment, test flight routes and test flight restrictions before thed edicated test flight. The applicant should provide relevant training and technical briefing to the test flight crew (including the authority's crew) in advance, so that they can understand and master the latest station equipment, facilities, command and support, and air traffic control requirements of the relevant civil aviation airport, and be familiar with the route and test flight restrictions.

### 4.5 Establishing a Special Flight Test Team

The function and reliability test flight is different from the applicant's test flight and the certification test flight, which only complete the test flight tasks at individual test flight airport. The function and reliability test flight will operate in a simulated route manner at more than ten airports, involving flight planning, flight declaration, military and civil aviation coordination, accessory support, stopover support, and many other tasks. It is necessary to consider in advance the risks that may arise from multi airport coordination and test flight organization management changes. The applicant should establish a special flight test organization and management team to coordinate various issues during the flight test, remove obstacles in the progress of the flight test, and improve the efficiency of the flight test.

## 5. Summary

Function and reliability test flight is one of the important tests for civil aircraft certification flights. This article is based on the function and reliability testing guidance in CCAR21 and Appendix B of AC25-7D, and studies the requirements for aircraft configuration, test flight time, and test flight procedures in function and reliability testing. At the same time, from the perspective of the applicant, it analyzes the risks of function and reliability testing and provides suggestions and measures, which can provide certain reference for civil aircraft function and reliability testing.

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