Journal of Electronic Research and Application, 2025, Volume 9, Issue 3
http://ojs.bbwpublisher.com/index.php/JERA
ISSN Online: 2208-3510
ISSN Print: 2208-3502

Research on Compliance Flight Test Technology of Integrated Modular Avionics (IMA) System

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Abstract: Based on the analysis and research of the airworthiness objective of integrated modular avionics system (IMA), and the characteristics of IMA system's comprehensive and complex cross-linking with other airborne systems, the extraction strategy of IMA system's compliance flight test subjects and the selection method of IMA system's compliance flight test parameters are proposed. The data analysis method based on the abnormal probability matrix of the IMA system is proposed for the first time, and the abnormal state information of the IMA system can be quickly identified. The compliance flight test of the IMA system is completed with limited flight test resources, which achieves the purpose of saving flight test sorties and improving flight test efficiency. This research has been successfully applied to the airworthiness certification flight test of a certain civil transport aircraft in China, and can provide technical support for the subsequent type flight test.

Keywords: Integrated modular avionics; Flight test; Compliance; Abnormal probability

Online publication: 29 May, 2025

1. Introduction

With the development of airborne avionics systems, the architecture of the integrated modular avionics system is more and more widely used. Compared with the traditional joint avionics system architecture, the integrated modular avionics system architecture has a high degree of integration. It connects the general modular avionics processing platform, network switch, and remote data interface unit through the A664 network. Jointly provide data calculation, data transmission, data transformation, and other functions for each airborne user system. In addition, the avionics core processing system provides a software resident platform, and each airborne user system can realize the functions of each system through the form of a resident application.

In the relevant airworthiness documents that have been published, only DO297 requires the development and verification process of the avionics core processing system. At present, there is no guidance on the flight test method of IMA system compliance verification at home and abroad. This study analyzed the existing airworthiness system documents of the avionics core processing system, clarified the airworthiness objectives, proposed an extraction strategy of IMA conformity flight test subjects and a method of selecting test flight parameters, and helped analyze its conformity by calculating the abnormal probability matrix of IMA system. Combined with the actual flight test of a civil transport aircraft, this research has been successfully applied to the airworthiness certification flight test of a civil transport aircraft.

2. The airworthiness analysis of the IMA system

Part CCAR25, as the basis of airworthiness certification, has no provisions for the IMA system, but only specifies the general provisions [1], which mainly include:

(1) 25.1301(a)(4), functions normally after installation;

(2) 25.1309(a), equipment, systems, and installations whose functions are required by aircraft airworthiness standards must be designed to perform their intended functions under a variety of predictable operating conditions;

(3) 25.1431(c), that radio and electronic equipment, controls, and conductors must be installed in the operation of any part or system without adversely affecting the simultaneous operation of any other radio and electronic part or system as required by the Regulations of Civil Aviation of China;

(4) 25.1431(d), electronic equipment must be designed and installed in such a way that a critical load will not be inactivated when transients due to power supply transients or other causes occur.

The TSO-C153 standard specifies the hardware elements of IMA systems, and AC20-145 guides the integration, certification, installation, and continuous airworthiness of IMA hardware elements, both of which are limited to hardware guidance and requirements [2]. The comprehensive verification of the IMA system, especially the flight test verification, has no direct guiding significance.

RTCA/DO-297 provides ideas for the development guidelines and certification of IMA systems for the first time, and it defines the compliance verification activities of IMA systems into four categories according to the system hierarchy [3]:

(1) Validation of modules or platforms: Verify that the function of a single module meets its functional performance requirements, including the ability and means of platform configuration, such as network service, data communication, fault management, health detection, resource management, etc.

(2) Resident application validation: Verify that the resident application can correctly meet the resource requirements of the user system in the target module and platform resources.

(3) IMA system-level verification: Comprehensive integration verification of the entire IMA system under non-installed conditions. Focus on the verification of the interface and interaction between modules and the allocation and use of resources, and examine the behavior response of the IMA system in normal and abnormal modes.

(4) Aircraft-level IMA system validation: Under the condition of cross-linking with the aircraft platform, the interface and interaction with the IMA system are verified through necessary ground tests or flight tests, and the function of the IMA system is normal and can meet the functional, performance, and safety requirements of the aircraft platform.

In summary, the test flight of IMA system conformity verification should mainly focus on the general terms requirements in CCAR25 and the aircraft-level IMA system verification requirements in RTCA/DO-297.

3. Compliance flight test verification technology of IMA system

3.1. Validation strategy

Given the requirements and verification objectives, the IMA system compliance method includes two parts. The first part is the resident application and resident function compliance flight test conducted by the cross-linked system to prove that the resident application/function can achieve the expected function, and indirectly verify the normal function of the avionics core processing system resources. In the second part, the IMA system test data collected during the cross-linked system's compliance flight test course is analyzed to confirm that the IMA system runs as expected and the interface interaction between IMA and the other airborne system is stable and reliable during the test. The first part mainly quotes the test flight conclusion of the relevant resident application system, and the following part mainly discusses the content of the second part.

3.2. Subject selection

Although the aircraft functions verified by the flight tests of each system are different, the IMA system follows the same design and allocation principles for the same type of resource functions. For example, the use of IMA system resources in some systems of a civil transport aircraft is shown in **Table 1**.

Table 1. Some systems use IMA resources

Serial number	Resident application	Data compute	Data transmission	Data conversion
1	Air conditioner	–	√	√
2	Communication	√	√	√
3	Power supply system	√	√	√
4	Flight management system	√	√	√
5	Passenger cabin	–	√	√
6	Information system	–	√	√

The IMA system has a large number of user systems, and it is neither efficient nor practical to verify all the flight test system functions. To ensure that the analysis results have sufficient confidence, the selected subject needs to validate sufficient resources and cover critical systems. Based on the above objectives, the selection of test flight subjects should follow the following principles:

(1) All flight test subjects related to resident applications;

(2) The flight test items related to non-resident applications should be selected from aircraft critical systems with functional failure status impact Class I;

(3) All subjects selected from a system should cover the validation of the various resources assigned to the system [4–6], including computing, A664, A429, A825, analog, discrete, and embedded functions.

3.3. Parameter selection

The application environment of IMA covers the whole flight process, such as taxiing, take-off, climb, descent, approach, and landing. During the flight test of each test flight subject, IMA flight test data should be sampled during the whole flight process. However, with all the A664 data running in the IMA system, including tens of thousands of parameters, it is difficult to analyze all the IMA flight test data for each flight under the current technical conditions.

The objectives of the verification activities for the aircraft level IMA system in DO-297 are focused on the interface interaction and the functionality and security of the entire IMA system platform [7,8]. The rest of the verification content should be proved theoretically or verified by laboratory tests during the design and development.

In the conformance flight test verification activities, only the alarm and status information inside the IMA system can be analyzed, such as the status and alarm information of RDIU, ARS, GPM, etc. Thus, more than 1,000 system status information points can be analyzed, which improves the implementation of the flight test.

4. Flight test data analysis method

A probability matrix is introduced according to selected flight test subjects and parameters. Define a=1... n indicates the test flight course. For example, a=1 indicates the VHF POA AOC data link communication course, and a=2 indicates the high frequency voice communication flight test course. Define b=1... N indicates the status parameter of the b IMA system. For example, b=1 indicates the LA status alarm of the built-in switch of HM_L1, and b=2 indicates the LB status alarm of the built-in switch of HM_L1. It is defined as the exception probability of the b parameter of flight test course a; then there is the entire IMA system exception probability matrix:

$$I = \begin{bmatrix} p_{11} & \cdots & p_{1n} \\ \cdots & p_{ab} & \cdots \\ p_{N1} & \cdots & p_{N1} \end{bmatrix} \quad (1)$$

$$p_{ab} = \frac{m_x}{m_y} \quad (2)$$

Where is the number of outliers of the b parameter of flight test subject a, and is the total sampling number of the b parameter of flight test subject a?

The IMA system anomaly probability matrix I can be obtained through the calculation process shown in **Figure 1**.

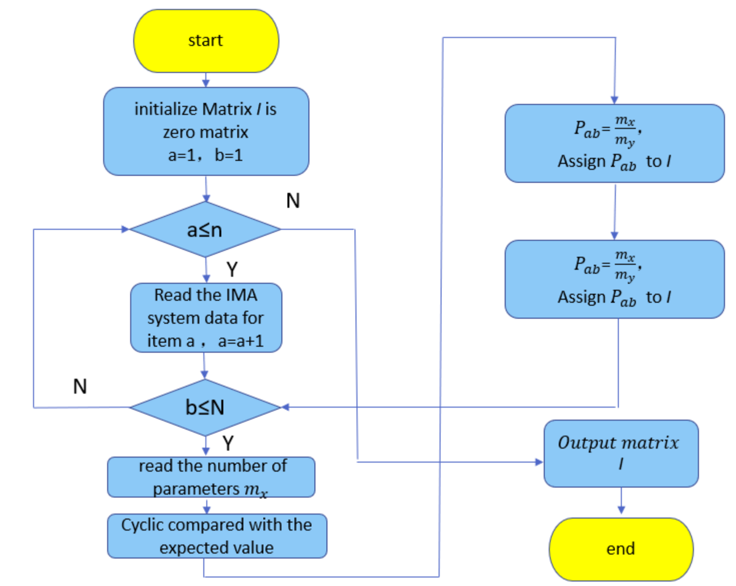

Figure 1. IMA system exception probability matrix calculation flow

The flight test exception probability matrix I is used to represent the conformity test results of the IMA system. If the I matrix is a zero matrix, it indicates that there is no abnormal operation during the whole test flight of the IMA system, and the function and operation state of the IMA system meet the expectations. If the matrix I is nonzero, the items and parameters in the abnormal state can be quickly located, and the logic of the operating state of the positioning system can be further analyzed. If the abnormal state is not caused by the IMA system after analysis, it indicates that the function and operating state of the IMA system meet the expectations.

5. Flight test verification

For all selected flight test subjects, IMA system state parameter data from 5 minutes before takeoff to 5 minutes after landing were extracted, and the internal operating state of the IMA system during the operation of each user system was analyzed and compared. Some flight test results are shown in **Table 2**.

Table 2. Flight test results of some subjects

Serial number	Subject	Abnormal state parameter	Anomaly probability
1	High-frequency voice communication	IBIT suppression status	0.29%
2	Display and control	–	–
3	Flight management system hold mode	IBIT suppression status	0.20%
4	Airborne maintenance system	IBIT suppression status	0.17%
5	Flight crew alarm	–	–

Based on the test flight results of the middle sub-subjects in **Table 2**, the operation state logic of each system is further analyzed for the abnormal probability of IMA system state parameters in some subjects that are not zero. The process of system running state logic analysis is not the focus of this paper and will not be described here.

After analysis, the nonzero probability of IBIT suppression state anomaly in some subjects is not caused by the IMA system, which still indicates that the function and operating state of the IMA system meet the expectations.

6. Conclusion

IMA system compliance flight test technology research is summarized as follows:

(1) The IMA system flight test verification strategy, subject selection method, and parameter extraction method determined in this study can meet the requirements of IMA system conformity flight test verification and improve the test flight efficiency of IMA system.

(2) The abnormal probability matrix of the IMA system and its calculation process method introduced in this study can realize the quantitative evaluation or fault location of the IMA system.

Disclosure statement

The author declares no conflict of interest.

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