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Research on Aircraft-level Physical Integration Verification Test Technology

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Abstract

In this paper, the positioning and objectives of the aircraft-level physical integration verification test are proposed. Based on the captured test requirements, technical solutions are also presented. The related key technologies are discussed to improve the maturity of aircraft-level integration verification and the verification rate of requirement confirmation and reduce the gap between laboratory test and flight/operational test.

Keywords: Aircraft Level, Physical Integration, Scenario Based Test, Fidelity

1. Introduction

Large-scale integrated design is currently adopted in the new large-scale passenger aircraft. The complexity of the highly-integrated aircraft system puts forward higher requirements and challenges to integrated verification. Each OEM is looking for an appropriate integrated verification method for the whole aircraft system-in-loop to improve the integration maturity, meet the MOC4/MOC8 compliance verification test requirements, and avoid the problem and error passed to the flight test stage. According to APR4554 A[1], INCOSE system engineering manual[2], SAE 6218[3], and other standards, the aircraft-level test of the whole system-in-loop is the most critical part of the verification phase. Test planning and implementation should be constructed according to the principle of meeting the real flight mode test.

2. Positioning and Objectives of Aircraft-level Physical Integration Verification Test

2.1 Positioning

The Aircraft-level physical integration verification test is aimed at aircraft-level function, interface, safety, man-machine interface and other aircraft-level requirements. When designing the system and formulating the system test scheme, the testing configuration of the relevant system is comprehensively considered, which is both beneficial to the individual test of each relevant system and to the multi-system synthesis and cross-linking test[4]. It breaks through the test concept of ' fragmented ' in the traditional test method, and forms the test idea of 'systematic integration '. The physical integration verification and scenario test of the whole aircraft system are carried out to improve the adequacy of the ground simulation test of the aircraft system and enhance the credibility of the test results[5]. Moreover, the conformity is shown to the authorities via the whole aircraft, and the gap between laboratory test and flight/operation test is reduced. Just as shown in Figure 1, the Aircraft-level integration and verification test platform, also called Aircraft 0, is mainly used on the engineering and product development phase along with the aircraft lifecycle.

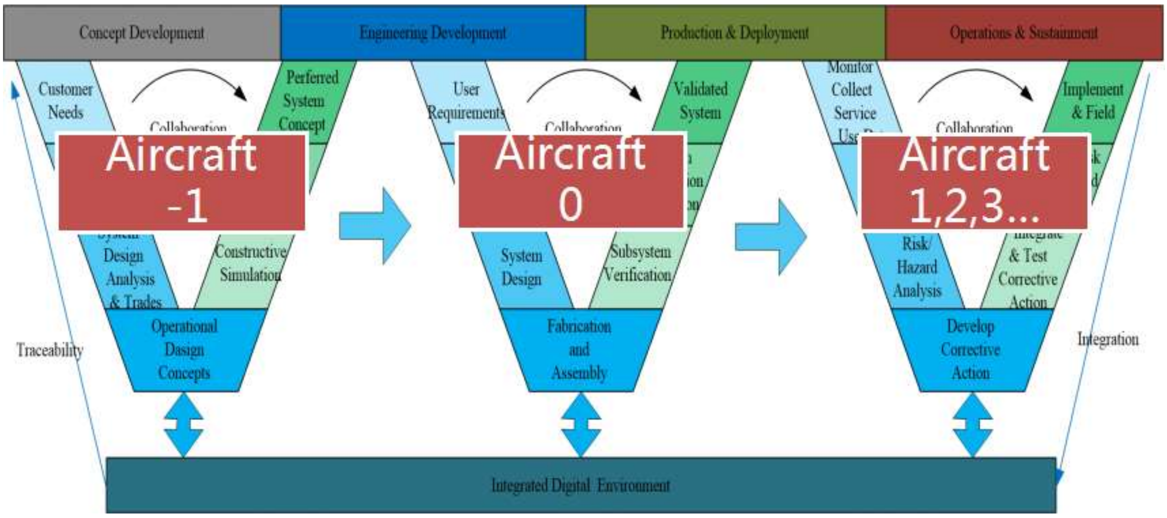

Figure 1 Position of aircraft-level physical integration verification platform

2.2 Objectives

The planning aircraft-level integrated verification platform needs to achieve the following objectives :

a. Improving the laboratory integration level, simulating the real aircraft configuration, and improving the laboratory integrated verification test scope and test results confidence level;

b. Complying with airworthiness requirements and activities and conducting practical airworthiness certification tests of aircraft systems so as to provide sufficient evidence to demonstrate to the authorities in the form of integrated verification of the whole aircraft system for airworthiness certification;

c. Integrating the results (models, test cases, tools) of the previous virtual integration test and the data of the later flight test to support the ground test, flight test and operation test in order to reduce the verification cost, shorten the development cycle, and enhance the confidence of Archiving.

3. Aircraft-level Physical Integration Verification Test Requirements

Aircraft development generally captures aircraft-level functional requirements and non-functional requirements according to expected operating scenarios, market objectives, design objectives and requirements. The functional requirement (including aircraft-level functional requirements and safety requirements) verification matrix with the verification method of text is the main source of aircraft-level integrated verification test requirements. In order to meet the above test requirements, the aircraft-level physical integration verification test platform needs to possess the following capabilities :

a. Providing aircraft-level functional requirements confirmation and verification capabilities (including control laws);

b. Providing aircraft-level safety requirements confirmation and verification capabilities;

c. Providing pilots-in-loop flight simulation verification test capabilities;

d. Providing training and test capabilities for the flight crew of the first flight;

e. Providing support for MOC4/MOC8 airworthiness verification test capabilities;

f. Providing support for OATP, on-board ground and flight test capabilities;

g. Providing fault location and troubleshooting capabilities during flight test and operation;

h. Providing test data playback function, including simulator test data, system test bench data, flight test data, and operation data.

4. Aircraft-level Physical Integration Verification Test Platform Scheme

The construction of the aircraft-level physical integration verification test platform is based on the aircraft-level system comprehensive verification test requirements. It can meet each related system's test and carry out multi-system synthesis and cross-linking tests to improve the adequacy of the ground simulation test of aircraft system and enhance test results' credibility.

4.1 Test platform scheme

The aircraft-level physical integration verification test platform is based on the Iron Bird platform and the engineering cockpit[6]. It integrates the complete system test pieces (including flight control, landing gear, hydraulic, avionics, power, etc.) and system Mini-rig platform (such as power, environmental control, fire protection). The overall architecture of the platform is shown in Figure 2. The test bench should be built according to the 1:1 ratio of the aircraft, including system test pieces, structural test pieces, pipeline test pieces, cable test pieces, etc. The test environment should simulate the real operation and test environment of the aircraft, containing flight atmospheric environment simulation, aerodynamic simulation, rudder load simulation, ground effect simulation, mode switching, data acquisition, test management, etc. At the same time, At the same time, the switching between the real parts of each airborne system and the simulation model, and the switching between the ground simulation power supply and the real power supply system can be supported.

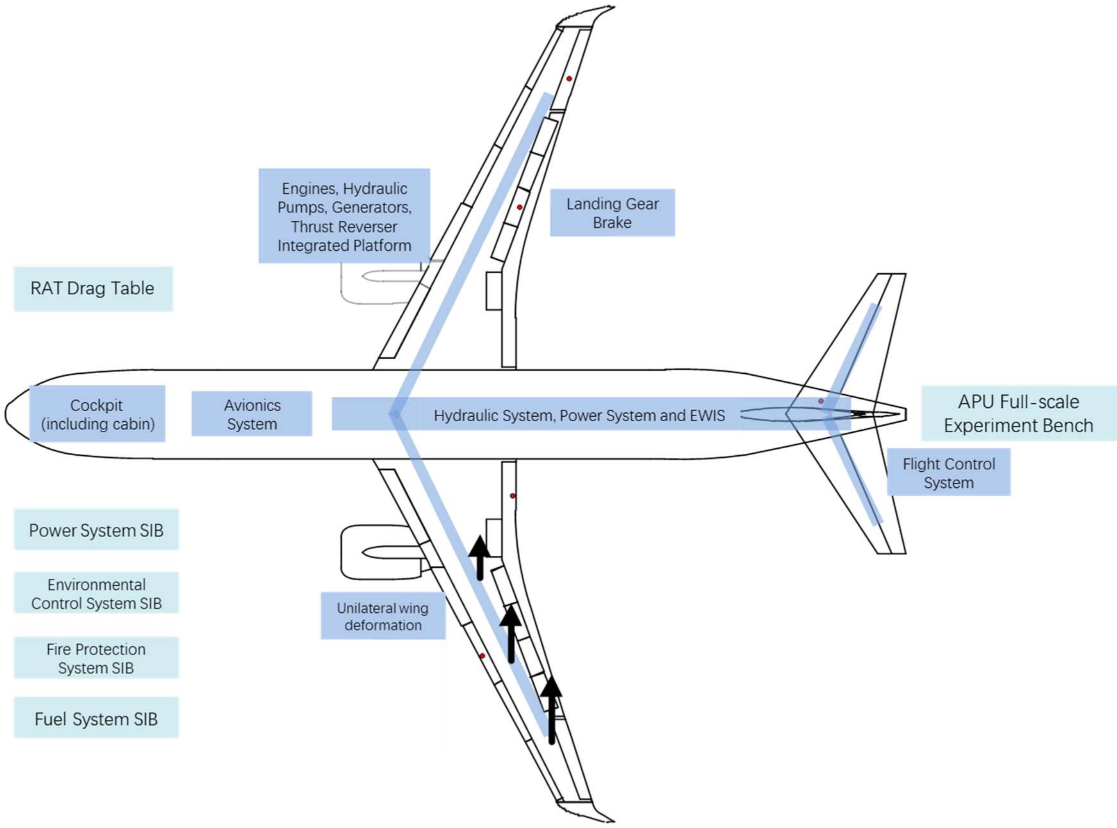

Figure 2 Overall architecture of aircraft-level physical integration verification platform

4.2 Test environment requirements

Test pieces of the aircraft-level physical integration verification test platform should include system test pieces, structural test pieces, simulation models and test equipment, and:

a. Real and complete control components of avionics, flight control, hydraulics, landing gear, brake system, electrical system, cockpit;

b. Real Mini-Rig platform composed of engine control, environmental control, fuel inerting control, hatch control, water and wastewater control, APU control, lighting control and other control units;

c. Real cables;

d. Real pipelines;

e. Test pieces of real supporting structure;

f. Real activity surface;

g. Unilateral real wing (on demand);

h. Flight test equipment (FTE).

5. Key Technology of Aircraft-level Physical Integration Verification Test

5.1 Scenario-based verification technology

As shown in Figure 3, scenario-based verification is not used to verify a particular requirement or a group of requirements but to take aircraft products as the object to verify that all systems related to aircraft function and operation have been correctly integrated, meeting the expectations task requirements. The focus is to check the unexpected function and influence under normal and severe conditions (robustness). In aircraft test verification, customer scenarios are taken into account to identify and solve problems in advance to avoid the exposure of problems in flight test and operation and improve the coverage and maturity of system integration and ground verification[7]. The scenario verification matrix is used to connect scenarios, functions, tests, and reporting. Moreover, automated testing also helps to improve test coverage and efficiency.

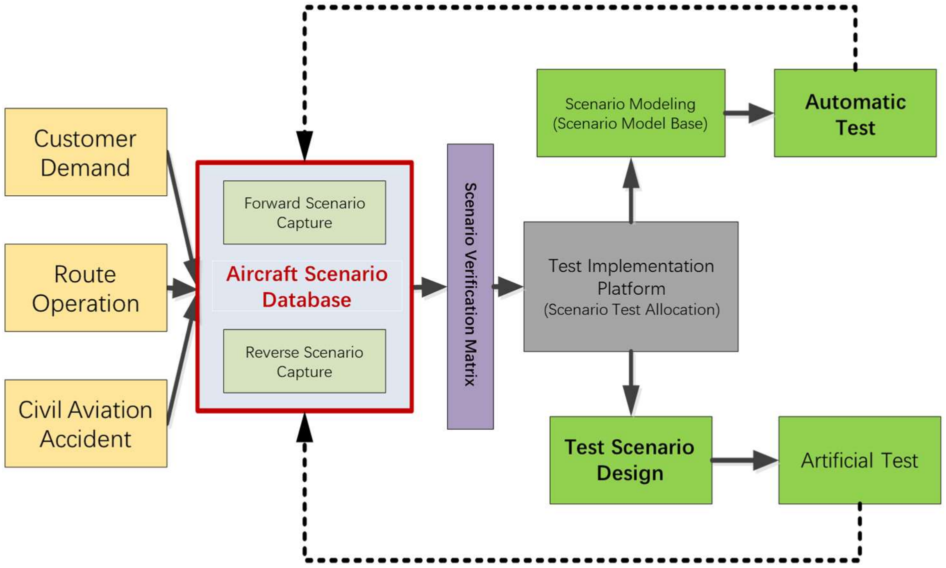

Figure 3 Scenario-based verification technology diagram

The scenario verification process of the aircraft physical integration test platform is shown in Figure 4. The initial stage of virtual integration is to map the operation scenarios and requirements to form a scenario verification matrix, and provide input for scenario verification. Secondly, based on the modelling language SysML, the aircraft operation scenario is constructed, including normal scenario, abnormal scenario and emergency scenario. Then, a dynamic model of the aircraft's ontology, airborne system and environment is established via Simulink. The scenario-based automatic test technology is realized by SysML and Simulink co-simulation. Finally, the test results are displayed on the visualization terminal to identify unexpected functions, discover and solve problems in advance. Under the physical integration stage, the aircraft-level physical integration verification test platform after multi-system-in-loop and simulation model verification is re-confirmed and verified for the typical scenarios extracted from the previous virtual integration, which is able to improve the maturity and effect of aircraft-level integration verification.

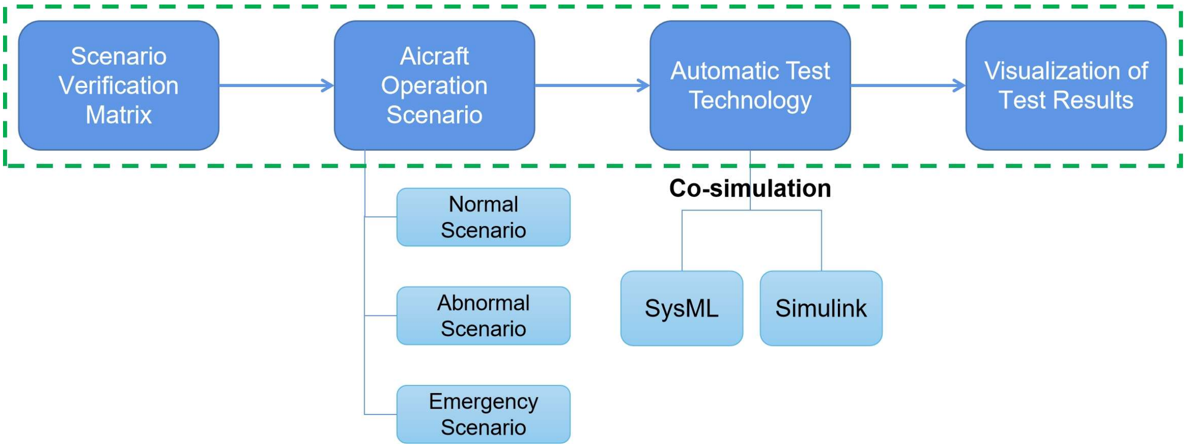

Figure 4 Technical path based on scenario verification

5.2 Configuration management and switching of the test platform

The aircraft-level physical integration verification platform adopts a bottom-up verification method to meet the test requirements, as shown in Figure 5. The model iteration covers all the processes of model-in-loop, hardware-in-loop, system-in-loop and aircraft-in-loop, thus realizing the conversion from virtual integration verification to physical integration verification, from single system integration verification to aircraft-level integration verification, and from virtual integration to physical integration[7]. Finally, a perfect aircraft-level integration verification test environment is formed, which can further support OATP & AIL, MOC5, MOC6 and MOC8 tests.

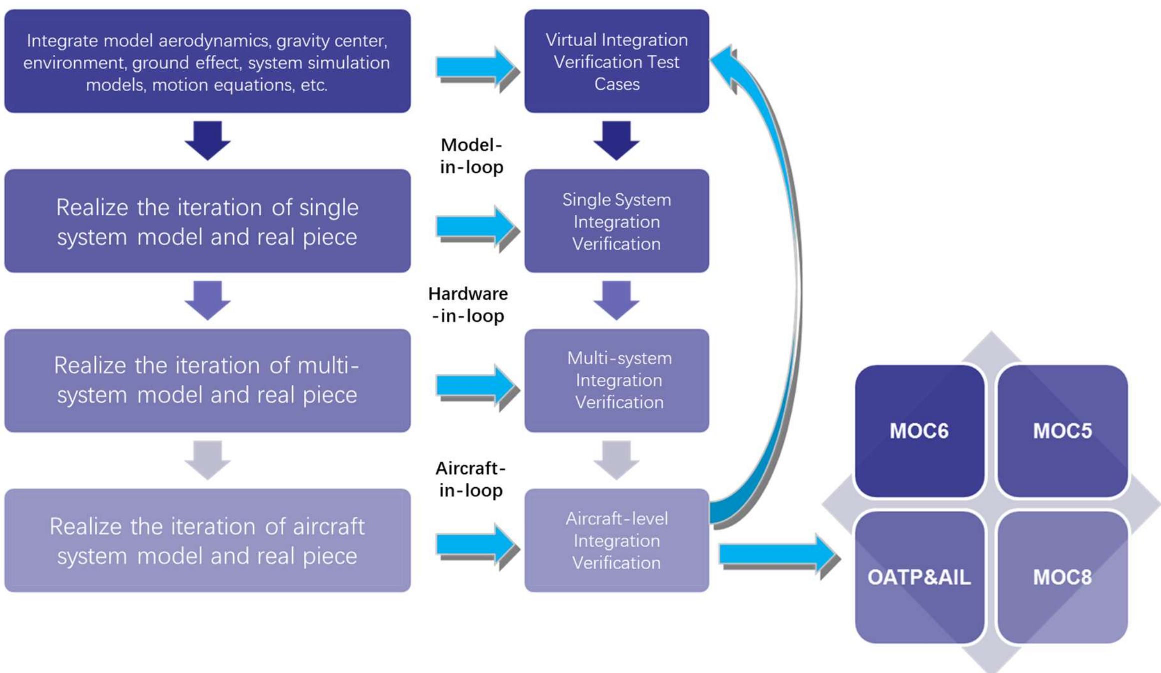

Figure 5 Aircraft 0 test platform configuration switching requirements

The integration process of the test platform involves a large number of test pieces, simulation pieces, simulation models, test equipment, etc. To meet the requirements of a single test and multi-system collaborative test, the test platform needs to have test configuration and test process control capabilities. Firstly, based on different test scenarios and test requirements at the aircraft/system level, the configuration required for the test can be generated and automatically switched through the program. Then, the whole test process, comprising the test preparation, pre-test inspection, test implementation and monitoring, can be centralized control through the integrated console. The control signal between the integrated console and different devices can be electrical signals, light signals or 5G signals.

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7. Copyright Statement

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