THE DESIGN FOR TESTABILITY OF CIVIL AIRCRAFT AVIONICS SYSTEMS

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Abstract

The comprehensive testability design of avionics systems can ensure that the equipment has good state monitoring, fault detection, and fault isolation capabilities, achieving detection and isolation, fault tolerance, and fault response for faults that affect safety, to support the crew and ground personnel in taking preventive measures and rapid maintenance afterwards.This paper discusses the requirements, system architecture, design process, and implementation methods for testability design of civil aircraft airborne avionics systems.

Keywords: testability design,avionics systems

1. Introduction

The civil aircraft avionics system is an important guarantee for aircraft safety, economy, comfort, and airworthiness. In order to ensure the safe and reliable operation of avionics equipment, and to detect and eliminate faults in a timely manner, sound testability design has become particularly important.

The comprehensive testability design of avionics equipment can ensure that the equipment has good state monitoring, fault detection, and fault isolation capabilities, achieving detection and isolation, fault tolerance, and fault response for faults that affect safety, to support the crew and ground personnel in taking preventive measures and rapid maintenance afterwards.

At present, the testability design of civil aircraft airborne avionics systems has developed into a comprehensive test management system with health management as the core. This paper discusses the requirements, system architecture, design process, and implementation methods for testability design of civil aircraft airborne avionics systems.

2. Avionics System Architecture

Typically, the civil aircraft avionics systems include the following components[1]:

a. Flight control system with fly-by-wire as the core;

b. Engine control system with full authority digital engine control(FADEC) as the core;

c. A flight management system that integrates multiple sensor inputs to complete aircraft flight control and engine control, with a flight management computer as the core.

Its composition is shown in Figure 1 below.

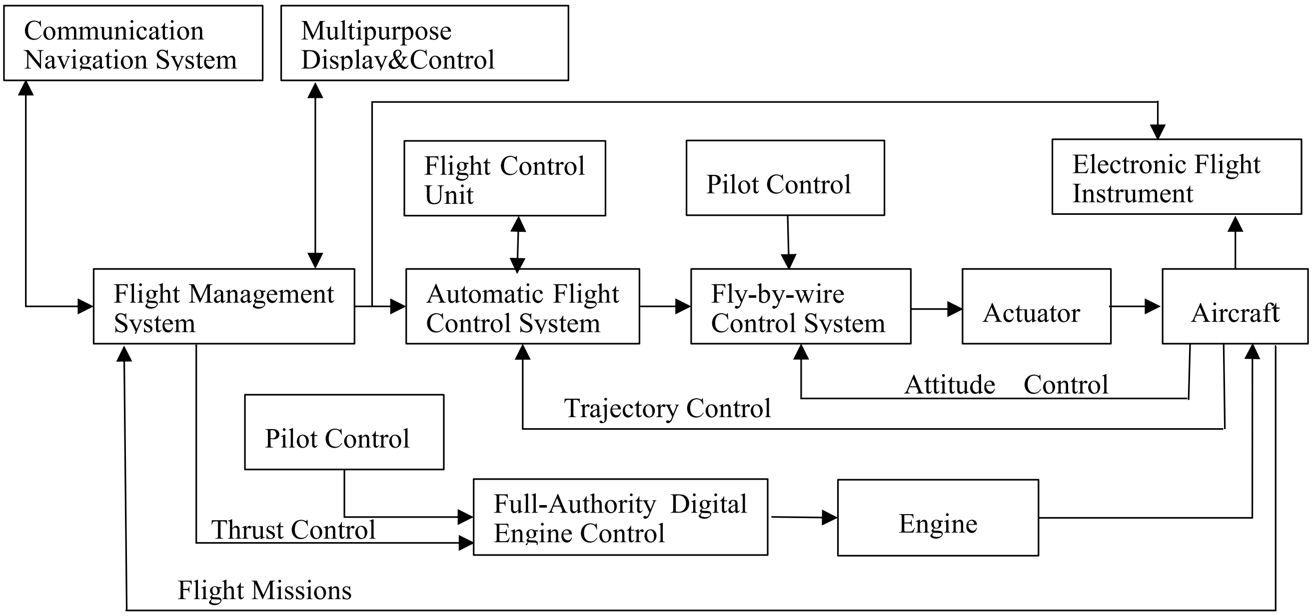

Figure 1 - The composition of civil aircraft avionics systems

Considering various factors such as safety and reliability, these three systems are independent of each other, but their information is interconnected. With the improvement of the automation level of civil aircraft, the interconnection relationship between the three has become closer, and the flight management system has become the front-end of the other two systems[2]. The interconnection relationship of civil aircraft avionics systems with flight management systems as the core is shown in Figure 2.

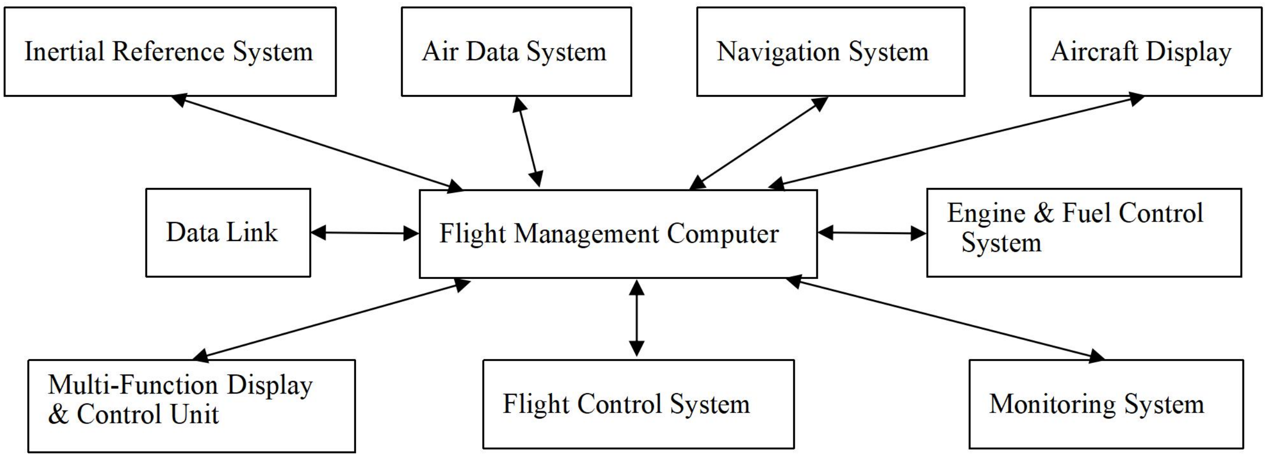

Figure 2 - Cross link relationship of flight management system

The current civil aircraft avionics system usually refers to the integrated modular avionics system, which includes not only the traditional avionics system mentioned above, but also other aircraft systems, and is an integrated system of the entire aircraft. Its characteristics are:

a. Based on line replaceable modules and application software modules for various processing;

b. Using high-speed communication bus as a link;

c. Utilize various sensor information and corresponding actuators to achieve various functional integration of avionics systems.

Its biggest feature is resource sharing, which means the ability to share variable, reusable, and interoperable hardware and software resources.

From the above description, it can be seen that the avionics system is not only an important guarantee for various functions of the aircraft, but also an important guarantee for aircraft safety. Therefore, timely health diagnosis, prediction, and fault elimination of aircraft have become particularly important to ensure healthy flight and improve safety. At the same time, good health monitoring and condition monitoring facilitate immediate maintenance and repair, shorten aircraft repair time, and improve the attendance rate of aircraft.

3. System Testability Design Requirements

In avionics systems, the testability design of safety equipment is more important, and the fault detection mode must be 100% covered. When the equipment is powered on, safety related testing items must be run to ensure the equipment is safe and controllable. Once the device detects a hardware failure that generates dangerous or false alarm information, it can automatically shut down relevant functions and devices that affect safety. Safety critical equipment must have fault tolerance capability, switch to backup and report through redundancy management when a fault is detected, timely cut off the propagation of the fault, and eliminate the impact of the fault. Safety critical equipment must have complete and clear fault response measures after a fault occurs, and have the ability to merge, log, isolate, and report faults to support aircraft health management and ensure flight safety.

Testable design should specifically implement requirements for failure detection, fault diagnosis, fault prediction, and acquisition, transmission, and processing of status monitoring data during the product design process. The details are as follows:

a. The testability design of the product should be able to provide sufficient basic testing resources, good inherent testability design, and provide basic detection information for the system status monitoring indication and alarm required for aircraft safety;

b. The testability design of the product should be able to provide sufficient capabilities for failure detection, condition monitoring, and fault detection, providing detection capabilities and data support for the implementation of condition based maintenance and predictive maintenance of the aircraft;

c. The testability design of the product should be able to provide fault detection and functional testing methods corresponding to the product's fault mode (including various airborne and ground, automated and manual methods), fault isolation logic, and troubleshooting procedures to support the troubleshooting activities of the aircraft system.

4. Design Process for Testability of Avionics Systems

The testability design of avionics systems is a process that synchronizes with its functional design. It is divided into requirement definition stage, preliminary design stage, and critical design stage. During the requirement definition stage, the development requirements and overall testability solution are determined, and a testability work plan and testability design criteria are formulated. During the preliminary design stage , conduct testability analysis, establish a simulation model, and complete requirement confirmation. During the critical design stage , testability design is implemented, testing experiments are conducted, and requirements verification is completed. The task status of each design stage is described below.

The design objectives and technical status of the requirement definition stage are as follows:

a. Work objective: Determine solution and requirements, develop work plans and design criteria;
b. Design input: project development demands, relevant airworthiness regulations and specifications, etc;
c. Design output: Testable design requirements, preliminary diagnostic plans, testing work items, testing work plans, testing verification plans, and testing design criteria.

The above work has been reviewed and approved, relevant documents have been signed and released, and the baseline has been established.

The design objectives and technical status of the preliminary design stage are as follows:

a. Work objective: Simulation design, requirement validation;
b. Design input: Relevant outputs from the requirement definition stage;
c. Design output: Complete the preliminary design for inherent testability, create a simulation model, complete testability allocation, and analyze the results to meet the design requirements.

The above work has been reviewed and approved, relevant documents have been signed and released, and the baseline has been established.

The design objectives and technical status of the critical design stage are as follows:

a. Work objectives: design implementation, requirement verification;

b. Design input: Relevant outputs from the preliminary design stage;

c. Design output: Complete the inherent testability detailed design, diagnostic design, and complete experimental verification. The verification results meet the testability design criteria and meet the design technical requirements.

The above work has been reviewed and approved, relevant documents have been signed and released, and the baseline has been established.

Based on the above design stage, work tasks, and testability design process are shown in Figure 3.

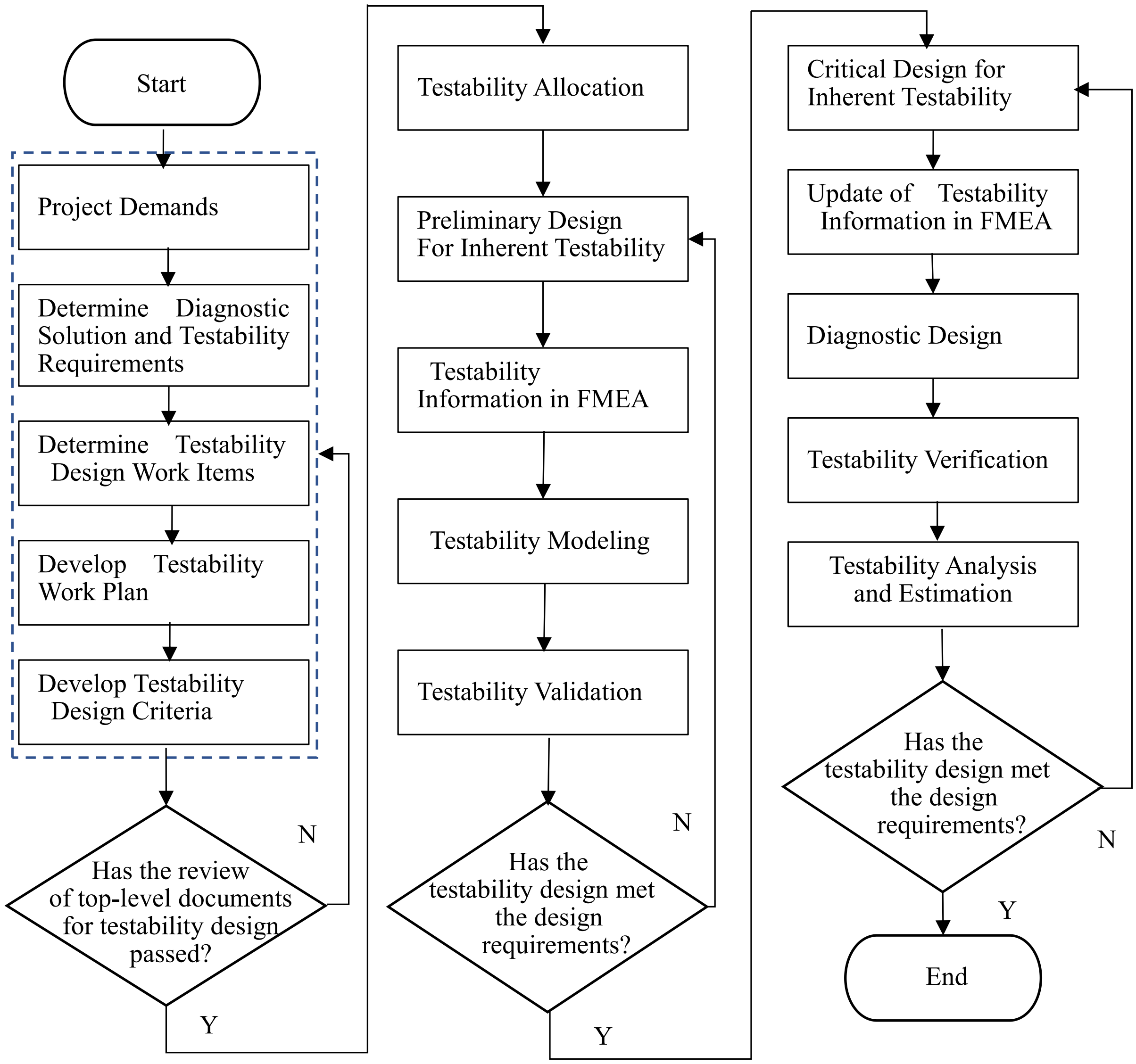

Figure 3 - Testability design process

5. Implementation of Testability Design for Avionics Systems

Testability design technology mainly includes technologies and methods such as inherent testability, build in test(BIT), external automatic testing, manual testing, comprehensive diagnosis, and health management. The design of an airborne health management system is based on the analysis of fault modes and impacts of the airborne system, and then arranging a multi-sensor network for key feature information detection, and conducting status monitoring, fault diagnosis/prediction, fault handling, comprehensive evaluation, maintenance support decision-making, etc. It is a design form that comprehensively considers internal and external testing, including the airborne system and ground system.

5.1 Overall Architecture Design for Testability of Avionics Systems

The airborne avionics systems support airborne fault detection and health status monitoring, and provides sufficient basic conditions and data for ground systems to meet the needs of ground fault diagnosis and health management. The onboard function of aircraft health management is coordinated with the ground prognostics and health management(PHM) system to jointly achieve aircraft fault prediction and health management. Airborne systems mainly refer to onboard systems or equipment units related to PHM systems, including onboard maintenance systems(OMS), information systems(IS), and communication systems. Their composition is designed as shown in Figure 4.

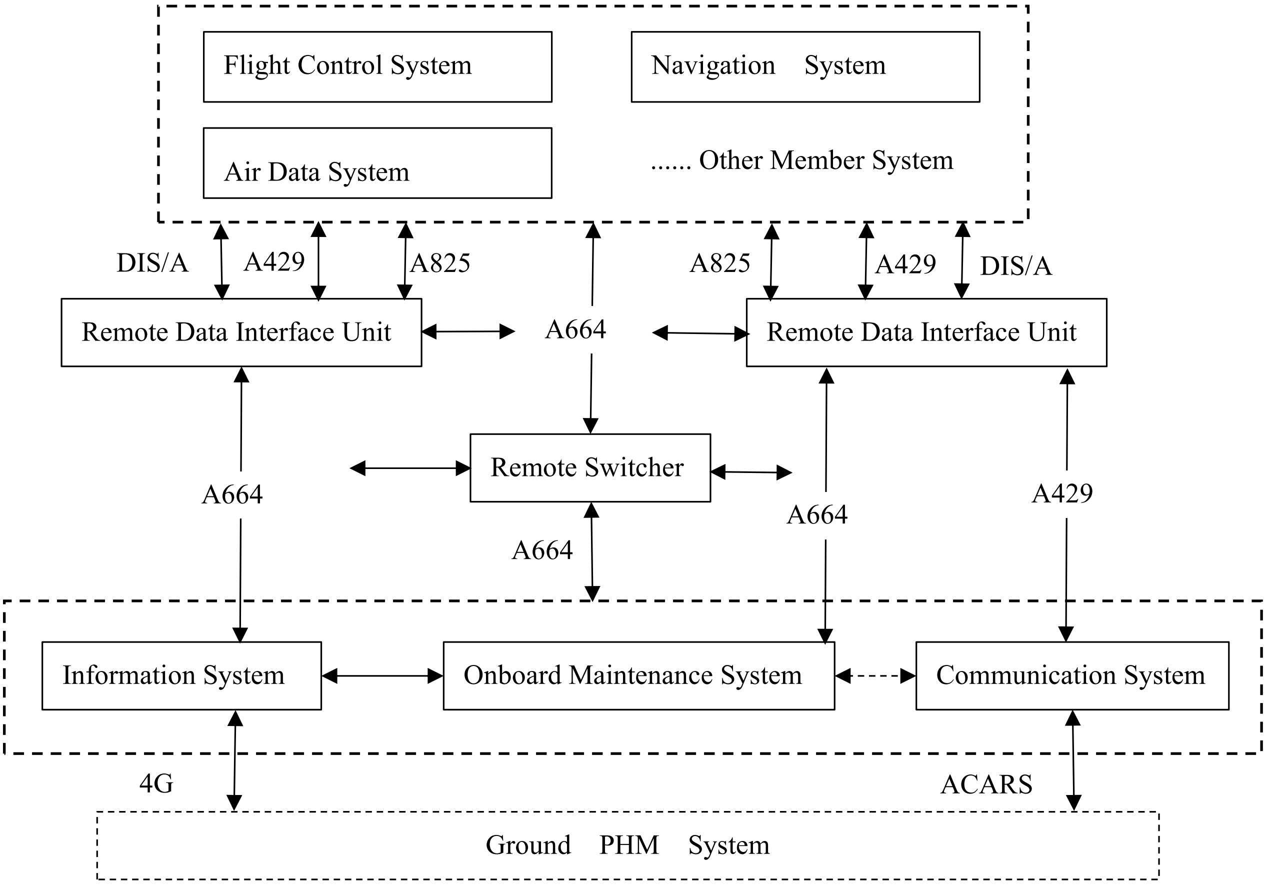

Figure 4 - Overall architecture of airborne systems

a. Airborne maintenance system: mainly monitors the failure status of each member system of the aircraft, detects, receives, and stores fault data reported from each member system, judges and confirms the fault status of each member system, and isolates the fault status to a single LRU. At the same time, the system will transmit the detected faults and other information to the ground PHM system in real-time through the Aircraft Communication Addressing and Reporting System(ACARS)link. In addition, the onboard maintenance system also sends all parameter data, messages, and processing results collected by itself to the information system for storage and import into the PHM ground system for use by ground maintenance personnel.

b. Information system:the information system mainly collects status parameters, analog parameters, discrete parameters, fault information and other data sent by each subsystem, and stores them in a certain format for import into the ground system after flight. At the same time, the information system provides support for real-time ground monitoring based on air ground broadband in the future, as well as expansion of onboard fault prediction and health management functions.

c. Communication system: the communication system is mainly responsible for transmitting fault parameter and other messages generated by OMS and other systems to the ground PHM system according to the air to ground data transmission specifications. At the same time, the communication system also transmits some of its own generated messages in real-time to the ground PHM system for the application of ground real-time monitoring function.

5.2 Implementation of BIT design for Testability of Avionics Systems

BIT is an automatic testing capability provided within the avionics system for detecting and isolating faults. According to the scale of BIT, the ways to achieve BIT are divided into BITE and BITS. Among them, BITE refers to the equipment that implements BIT functions (including BIT specific and shared hardware and systems with system functions), and BITs refer to testing systems composed of multiple BITEs. BIT design includes system functional design, system working mode design, system structural layout design, and system information processing design, as detailed below.

a. The system functional design includes:

- Status monitoring function
- Fault detection function
- Fault isolation function
- Fault prediction function

b. The design of the system working mode includes：

- Power on BIT

- Continuous BIT
- Maintenance BIT

c. The system structure layout design includes

- System level BIT design
- Subsystem BIT design
- LRU level BIT/LRM level BIT design
- SRU level BIT/SRM level BIT design
- Component level BIT design

The onboard system collects the original status information of the avionics system through sensors or BITE, transmits the data to the onboard maintenance system through the onboard communication network, processes the original status information through the onboard maintenance system, preliminarily diagnoses the fault status of the avionics system, and timely processes the faults that have occurred to prevent fault propagation.

6. Summary

This paper provides a brief description of the testability design process for civil aircraft avionics systems. After years of development, testability design technology has gradually evolved from component/system level monitoring technology to aircraft level comprehensive health management technology today. At present, a monitoring and health management system based on air ground bidirectional data communication system has been established, which collects real-time status information of the aircraft, obtains real-time health status of the aircraft, and effectively manages the health status of the entire life cycle of the aircraft. Through the integration of artificial intelligence, advanced sensors, advanced communication technology, etc., the health management system of advanced civil aircraft is developing in a direction beyond integration, standardization, and intelligence. The International Organization for Standardization has also released relevant standards. With the continuous advancement of technology, the future testing system of aircraft should be led by system level integrated applications, improving the accuracy of fault diagnosis and prediction, and integrating information across components, systems, and aircraft.

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8. Copyright Statement

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