# Research on Fault Diagnosis of Complex Avionics Systems in Civil Aircraft

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**Abstract.** In order to ensure the rapid development of the aerospace industry and promote the safe navigation of civil aircraft, the country has summarized its past fault experience and developed relevant fault isolation manuals. Under the guidance of the above manual, some minor faults in the avionics system can be immediately eliminated. However, there are still some complex system faults that are difficult to solve through manuals. For such faults, it is necessary to apply other diagnostic methods to ensure accurate diagnostic results.

**Keywords:** civil aircraft; avionics systems; fault diagnosis

## 1 Introduction

Avionics systems, also known as "avionics systems". It refers to a comprehensive system that uses distributed computers to link various airborne electronic subsystems together through multiple transmission data buses. It combines existing single functional decentralized systems, such as communication radios, radars, navigation equipment, etc., and integrates them into a multifunctional comprehensive system. Capable of measuring, collecting, transmitting, processing, monitoring, and displaying information, and completing tasks such as flight control, engine control, navigation, and performance management. This system is generally divided into sensor systems (inertial navigation systems, atmospheric data computers, radars, various radio navigation receivers, etc.), control systems (flight control systems, engine control systems, etc.), and comprehensive electronic display systems as human-machine interfaces.

The highly integrated and electronic avionics system leads to complex fault modes, so it is difficult to locate the fault unit with a single fault phenomenon. [1] Once a malfunction occurs without timely understanding, it can easily affect the safety of passengers and even crew members, posing a threat to national property. In order to maximize the operational safety of avionics systems and ensure the safety of aircraft flight, it is necessary to conduct complex avionics system fault diagnosis to ensure that faults can be detected and resolved in the first time.


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# 2 Overview of Fault Diagnosis

The so-called fault diagnosis refers to a method of monitoring the flight conditions of civil aircraft and evaluating the performance of software and hardware to determine whether the aircraft is in normal condition. The fault classification of complex avionics systems in civil aircraft is shown in Table 1. System faults include communication faults, Navigation faults, etc.

**Table 1.** Fault classification of complex avionics systems in civil aircraft

| | |
|---|---|
| Communication failure | including issues such as inability to establish communication, communication interruption, and poor communication quality; |
| Navigation faults | including position deviation, navigation system failure, reduced accuracy, and other issues; |
| Control faults | including control surface failure, incorrect cockpit display, flight indicator error, and other issues |

## 2.1 Fault diagnosis content

The diagnosis of civil aircraft faults includes various contents, as follows:

(1) Detection process: The key to diagnosing a fault is to determine that the fault has already occurred. If there are no faults, there is no diagnosis. Therefore, before diagnosis, it is necessary to first detect the fault. At this point, staff usually use information systems to read feedback signals by sending signals, and complete the detection process by comparing the reading results.

(2) Type analysis: There are many types of faults in civil aircraft avionics systems, but different types have different manifestations of faults. Therefore, in fault detection, if it is found that the fault does exist, it is necessary to judge its type based on its manifestation and the location of the occurrence.

(3) Fault recovery: according to the cause of the fault, different measures are taken to troubleshoot the system.[2]

## 2.2 Common Fault Analysis

The common types of faults in avionics systems are mainly line faults, system faults, software faults, etc. Different faults have different manifestations. Analyzing it is beneficial for better identification in the future and early troubleshooting. The cockpit of the Airbus A380 flight control system is shown in Figure 1. Specifically, the common types of faults are as follows:

**Fig. 1.** Airbus A380 Flight Control System Cockpit

From the above figure, you can see the overview of the aircraft cockpit, where the pilot controls the aircraft through the control system.

(1) Line: The operation of the avionics system requires a large amount of power resources as support, and the line is the main carrier of power resource transmission. Once the circuit malfunctions, it will cause the system to stop running. The fault of the circuit has the characteristic of strong concealment. Common problems are reflected in the damage of the insulation layer. The above situation, if not handled in a timely manner, can easily lead to short circuits and even affect the safety of civil aircraft navigation.

(2) System: After a malfunction occurs in the avionics system, it generally manifests as an abnormal performance of a certain hardware device that cannot operate. Therefore, once the above fault phenomenon is found, the possibility of system failure should be considered.

(3) Software: Avionics systems are not solely composed of hardware, but contain a large amount of software. The function of the software is to monitor and adjust the operating status of the system. Once a malfunction occurs, it will cause the system to crash. The above faults often manifest as signal transmission failure. When staff discover the above fault symptoms, they can first troubleshoot the software.

(4) Other: In addition to the inherent reasons of the avionics system, other external factors can also lead to the occurrence of faults. The above factors, with uncontrollable and preventive characteristics, require civil aircraft personnel to summarize their experience and develop risk emergency measures

## 3 Diagnosis of complex avionics system faults

### 3.1 Failure diagnosis method

In the process of diagnosing avionics system faults, the targeted use of various methods is the key to ensuring the effectiveness of fault resolution. For the application of diagnostic methods, it is necessary to follow the process. Firstly, an analytical model needs to be established, followed by signal processing and identifying the type of fault based on the processing effect, in order to propose solutions. The specific methods are as follows:

(1) Establishing an analytical model

During the diagnosis of avionics system faults, staff should first establish an analytical model, which should include all information related to the fault. Including the occurrence time, performance, and specific location of the fault. The fault information record table is shown in Table 2. After establishing the model, it can be run to ultimately determine the fault. The advantage of the above method is that it can achieve real-time monitoring of faults, but it also has the drawback that there may be slight differences in the occurrence of faults between the model and the actual situation.

**Table 2.** Fault information record table

| | | | | | |
|---|---|---|---|---|---|
| Aircraft Sorties | XXX | Test date | XXX | Flight test unit | XXX |
| Question name | XXX | | | | |
| Problem description | XXX | | | | |
| Flight stage | XXX | Flight altitude | XXX | Flight speed | XXX |
| Flight test subjects | XXX | | | | |
| Unit operation | XXX | | | | |
| System anomaly | XXX | | | | |
| Manual description | XXX | | | | |

(2) Emphasis on signal processing

The diagnosis of avionics system faults also requires attention to signal processing. During the operation of the avionics system, in order to monitor the system's condition, staff need to obtain real-time operating signals. After different faults occur in the system, the signals will also exhibit different states. Staff can diagnose faults based on the characteristics of the signal. [3]

## 3.2 Implementation of fault diagnosis

(1) Implementation of Out of Position Inspection

Out of position inspection is one of the main methods for diagnosing avionics system faults. As the name suggests, it refers to the inspection performed after removing the suspected faulty equipment from its original position. [4] The above inspection methods are conducive to accurate diagnosis of faults and have certain advantages. Therefore, staff can diagnose faults through out of position inspection. For example, when a hardware malfunction occurs, it can be removed from its original location and detected to see if the hardware can operate. The advantage of the above method lies in its strong targeting, while the disadvantage lies in the process of removing hardware, which must be precise, otherwise it may affect the performance of its normal operation parts.

(2) Implementation of equipment testing

This type of detection is a testing system centered on computer-aided testing, mainly composed of subroutines such as data acquisition, processing, analysis, judgment, estimation, input, output, fault tolerance, self inspection, alarm, etc. It is mainly used for fault detection and troubleshooting of bus data transmission equipment. During the detection process, relevant personnel can use sensors and other devices to collect fault data and transmit the data to the system for processing and analysis. [5] After analysis, the system will evaluate the fault and form the final diagnostic result through input and output methods. Avoiding fault diagnosis errors through fault tolerance and self inspection. Remind staff to handle faults through alarms.

For example, the B737-CL once experienced a VHF communication system malfunction: Symptom: The crew reacted, sometimes unable to communicate with the tower in the air, and the tower also responded. This aircraft sometimes remained in a speaking state, full of noise, interfering with the tower, and sometimes normal. The avionics maintenance personnel did not find any faults during ground inspection, and the system function was normal. Therefore, the aircraft was released for flight execution. Subsequent flight faults still frequently occurred, affecting the tower's inability to work and flight safety. The tower notified the aircraft that the fault was not resolved and could not be flown. This fault sometimes occurs in the air and works normally on the ground, making it difficult to troubleshoot (if the fault persists, it will be very easy to determine the cause of the fault). We have temporarily organized experienced avionics personnel and established a team to organize relevant information. We have consulted AMM (Aircraft Maintenance Manual), SSM (System Schematic Diagram), WDM (System Circuit Diagram), IPC (Aircraft Illustrated Component Catalog Manual) and other materials, Then a special meeting was held for analysis and discussion, and a set of troubleshooting plans was developed: after the above work, no problems were found or solved. We held a meeting again to discuss and carefully review any omissions. Later, we realized that only crew earphones are usually used for communication between the crew and the tower, and the functions of handheld microphones and oxygen mask microphones in the cockpit have not been checked. This aircraft is not equipped with a handheld microphone. After receiving the microphone from the warehouse, we tested it and found that the co pilot's side jack was not working properly. After destructive removal of the microphone jack, we found a copper fragment of a broken microphone plug inside (a previously broken handheld microphone plug was left inside). This fragment can move inside the jack as the aircraft's attitude changes, sometimes forming a short circuit in the jack's wiring, causing radio communication transmission and interfering with the tower. At this point, the cause of the malfunction has been confirmed.

## 4 Fault diagnosis technology

In the process of diagnosing faults in civil aircraft avionics systems, there are many diagnostic technologies that can be utilized, and the above technologies are feasible and have good application effects obtained by the aviation industry based on continuous experience summarization. This section mainly summarizes specific fault diagnosis techniques from two aspects: fault tree and inference method:

### 4.1 Fault Tree

This is a method of analyzing from top to bottom, from the upper system to the components, and then to the component functions. It can be used to analyze the impact of component, component, or subsystem failures on system failures, including human factors and environmental conditions. System faults can be analyzed not only qualitatively but also quantitatively; Not only can system faults caused by a single component be analyzed, but also system faults caused by different modes of faults of multiple components can be analyzed.

### 4.2 Reasoning method

The process of deriving an unknown conclusion from one or several known judgments (premises) using symptom inference analysis. Its function is to use logical proof or mathematical operations to derive general concepts, principles, or conclusions from known phenomena and knowledge.

## 5 Conclusion

In summary, the research on fault diagnosis of complex avionics systems in civil aircraft in this article is beneficial for reducing the occurrence rate of faults, improving the safety of civil aircraft navigation, extending the lifespan of avionics systems, and reducing operation and maintenance costs. In the future, relevant fields need to strengthen attention to fault diagnosis issues, continuously introduce advanced technology, strictly follow the process of testing, determine detection methods based on actual situations, improve the accuracy of fault diagnosis, and provide guarantees for the safety of civil aircraft navigation and passenger safety.

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