

# The Function of Software in Satellite System and Its Reliability Analysis

Cheng Jia

Swinburne College, Shandong University of Science and Technology, Jinan 250031, China

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**Abstract:** This paper aims to discuss the function of software in satellite system and the reliability analysis of satellite software. Firstly, the overview of satellite system and the importance of software in it are introduced. Then, the concept of reliability, reliability evaluation method and factors affecting reliability of satellite software are expounded in detail. Then, the strategy to improve the reliability of satellite software is discussed. Finally, the article looks forward to the future development trend of satellite software reliability, including the application of artificial intelligence, machine learning, and distributed ledger technology. These new technologies are expected to further improve the reliability of satellite pieces and provide a solid guarantee for the safety of satellite communication.

**Keywords:** Software reliability testing; Satellite system; Safety-critical software; Application of new technologies; Reliability assessment.

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## 1. Introduction

### 1.1. Background introduction:

#### 1.1.1. Overview of Satellite System

In 1970, China successfully launched the first "Dongfanghong" artificial satellite, which achieved a great leap from experiment to application, from earth to sounding, and from unmanned to manned. Because the satellite has the characteristics of complex system, many new technologies, great influence on space environment, difficult on-orbit maintenance, high risk and high investment, it is necessary to carry out sufficient reliability design and verification to ensure the high reliability and long-term stable operation of the satellite in orbit [1]. Reliability technology is an important professional technology in satellite development, including reliability design, reliability analysis, reliability test and reliability evaluation technology. Satellite reliability engineering is a reliability technical activity and reliability management activity aiming at ensuring and improving satellite reliability, and correcting and controlling all kinds of accidental failures and preventing and eliminating all kinds of inevitable failures to the greatest extent during the whole life cycle of satellites [2]. Satellite reliability engineering involves the reliability design, analysis, test, evaluation, process control management and other aspects of products from the beginning of satellite development to the end of life, from single machine to the whole satellite [1].

#### 1.1.2. The function of software in satellite system

Software plays a key role in the satellite system. It is not only an important part of the satellite system, but also has an important impact on its performance, reliability and efficiency [3].

First of all, one of the main functions of software in satellite system is to control and manage all parts of the satellite system. For example, the software can control the attitude, orbit, communication and data transmission of the satellite system [4]. In addition, the software can also manage various sensors and equipment of the satellite system, ensure their normal operation and collect data in time.

Secondly, another important function of software in

satellite system is to process and analyze the collected data. For example, the software can process and analyze images, sounds and other data collected by satellite systems in order to extract useful information [3]. In addition, the software can also help the satellite system to realize automation and intelligence, thus improving the working efficiency and reliability of the satellite system.

In addition, the software also helps to improve the reliability of the satellite system. For example, the software can realize fault diagnosis and prediction, and find and solve potential problems in time. In addition, the software can also achieve fault tolerance and redundancy, thus improving the fault tolerance and reliability of the satellite system.

#### 1.1.3. The importance of software reliability engineering

With the improvement of the complexity and intelligence level of satellite system, the role of satellite software in the system is becoming more and more important, and its reliability design is becoming more and more critical. Safety-critical software refers to the software that is considered as critical in aerospace and other important fields because its failure may lead to serious consequences, such as endangering human life and health or causing huge property losses [5][6]. In the software design of satellite system, reliability design is an essential part. Software reliability engineering is an important branch of software engineering, which covers software reliability modeling, reliability index allocation and prediction, reliability design, reliability analysis, reliability testing and reliability evaluation [1].

## 1.2. Research significance

In today's era of rapid development of information and high technology, satellite system, as a key infrastructure for global communication, navigation, earth observation and scientific exploration, plays an irreplaceable role in social life and national security. With the continuous progress of technology, the application of software in satellite system has become more and more extensive, and its role has become increasingly important [7]. Moreover, as an important national strategic resource, the reliability of satellite system is directly related to national security and economic development. Satellite software plays a key role in the

satellite system, and its reliability directly affects the operating efficiency and stability of the satellite system [8]. Therefore, the research on the reliability of satellite software is helpful to improve the reliability of satellite system, reduce the risk caused by software failure, and ensure national security and economic development.

## 2. Software architecture of satellite system

### 2.1. Satellite system components

Satellite system is an important part of modern communication, navigation, remote sensing and other high-tech fields. Its seven main components cooperate with each other to form the basic framework of the satellite system, which provides necessary support and guarantee for the operation of the satellite system [1].

**Table 1.** List of functional description of the satellite system

System Name	Functional Description
Load	An instrument, equipment or load carried on a satellite to complete a specific task or measure data. The type and performance directly affect the working effect and data quality of satellites.
Platform	The mechanical structure on the satellite supports and protects the load and provides motion and attitude control. Design and manufacture should consider the operating environment and task requirements to ensure stable operation.
Communication system	The communication between satellite and ground station is realized, including antenna, transceiver and modem. Performance affects the quality and speed of data transmission.
Control System	Control the attitude, orbit and other motion parameters of the satellite, including computers, controllers and actuators. The design needs to consider the operation environment and task requirements to ensure the operation according to the expected trajectory and speed.
Telemetry System	Equipment for collecting and transmitting satellite status and data, including sensors, data collectors and data processors. Performance affects data quality and accuracy.
Data Processing Storage System	Processing and storing data collected by satellites, including computers, memories and databases. Performance affects processing speed and storage capacity.
Software System	Software programs to realize various functions and tasks of satellite system, including operating system, application software and tool software. Reliability and performance affect work efficiency and data quality.

## 3. Reliability analysis of satellite software

### 3.1. Software reliability concept:

Software reliability means that the software can run continuously and stably according to the expected function, performance and quality requirements under specified conditions [3]. The reliability of software is mainly manifested in the following aspects:

**Table 2.** List of Factors affecting software reliability

Factors Affecting Software Reliability	Describe
External environmental factors	Temperature, humidity, vibration, electromagnetic interference, etc. may cause the software to run incorrectly or crash.
Internal structural factors	Unreasonable, nonstandard or insufficient software design, implementation and testing will lead to the decline of reliability.
Use and maintenance factors	The harsh environment of software use and the low skill level of maintenance personnel may lead to the decrease of software reliability.

### 3.2. Software reliability evaluation method:

Commonly used software reliability evaluation methods include failure mode and effect analysis (FMEA), fault tree analysis (FTA), event tree analysis (ETA), reliability block model (RBD), Bayesian network analysis (BN) and so on. These methods can help to evaluate the reliability of software, find potential problems and propose improvement schemes.

### 3.3. Factors affecting software reliability:

The factors that affect the reliability of satellite software mainly include the following aspects:

**Rationality of software design:** Whether the software design conforms to the specifications and whether the actual situation and use environment are fully considered will affect the reliability of the software.

**Normality of software implementation:** Whether the software implementation conforms to the specifications and whether it has been fully tested and verified will affect the reliability of the software.

**Software use environment:** Whether the software use environment is bad, whether there is interference or destruction will affect the reliability of the software.

**Skill level of software maintenance:** Whether the software maintainers have enough skill level and can find and solve

problems in time will affect the reliability of the software.

Software reliability is an important factor that must be considered in the design and development of satellite software [9]. Only through reasonable design and standard implementation can the reliability of the software be guaranteed, thus improving the reliability and stability of the satellite system [10].

#### 4. Strategies to improve the reliability of satellite software

In the aspect of satellite software reliability design, it is necessary to do a good job in the reliability design of satellite software system first, which is a top-level design and has a key impact on the reliability of the whole satellite [11]. Then, the demand analysis of software reliability is carried out as the basis of software reliability bit design: on this basis, the reliability design of key software functions, conventional software reliability design and robustness design, FPGA anti-single particle design and so on are well done [12].

(1) Reliability design: In the design stage of satellite software, the reliability of the software should be fully considered, and the reliability design method should be adopted to carry out a comprehensive reliability design from the aspects of the overall architecture, module design and algorithm design of the software to ensure the reliability of the software.

(2) Requirement analysis: Before software design, it is necessary to analyze the requirements of the software, make clear the functions and performance requirements of the software, and all kinds of problems and risks that may be encountered [13]. This can provide a basis for software design and ensure the reliability of the software.

(3) Reliability testing: In the process of software development, comprehensive reliability testing is needed, including unit testing, integration testing and system testing [14]. Through testing, the problems and defects in the software are found, and they are repaired and adjusted in time to improve the reliability of the software.

(4) Robustness design: In order to ensure the stability and reliability of software under various abnormal conditions, it is necessary to carry out robustness design. This includes fault-tolerant design and exception handling design of the software to ensure that the software can still run normally under abnormal conditions.

(5) Anti-single event design: There are a lot of single event interference in satellite system, which has a great impact on the reliability of software. In order to improve the reliability of the software, it is necessary to carry out anti-single event design and adopt some special technologies, such as FPGA anti-single event design, to resist single event interference [1].

(6) Continuous integration and continuous deployment: In order to ensure the reliability of software, it is necessary to develop and deploy by means of continuous integration and continuous deployment. This can help to find and solve problems in the software as early as possible and improve the reliability of the software.

(7) Periodic audit and life cycle management: In order to ensure the reliability of software, periodic audit and life cycle management are needed. This includes regular inspection and evaluation of the software, as well as updating and maintaining the software to ensure the reliability of the software.

Through the implementation of these strategies, the

reliability of satellite software can be greatly improved and the stable operation and effective work of satellite system can be guaranteed.

#### 5. Future trend of satellite software reliability

With the rapid development of science and technology, the reliability of satellite software is expected to be strengthened by artificial intelligence (AI) and machine learning (ML) in the future, so as to realize real-time monitoring and early warning and improve adaptive ability. At the same time, the trend of autonomy will promote the development of self-repairing system and ensure that the software can respond quickly and maintain normal operation when faced with errors [15]. In addition, distributed ledger technologies such as blockchain will play an important role in protecting satellite communications from unauthorized access or tampering, and it is also expected to optimize network management efficiency.

(1) Application of Artificial Intelligence and Machine Learning

With the development of artificial intelligence technology, the reliability of satellite software will be better guaranteed. Artificial intelligence can be used for automatic diagnosis and prediction of satellite software. By analyzing and processing the data in the process of software operation, problems can be found and solved in time, and the stability and reliability of software operation can be improved [16].

(2) Development of adaptive and self-repairing system

Another important trend of satellite software reliability is the development of adaptive and self-repairing systems. This kind of system can monitor the running state of satellite software in real time, and automatically adjust the software parameters according to the monitoring results to ensure the normal operation and fault repair of the software [17]. This adaptive and self-repairing ability can greatly improve the reliability and stability of satellite software.

(3) Application of Distributed Account Book Technology in Satellite Security

With the development of distributed ledger technology, the means to ensure the reliability of satellite software will be more diversified. Distributed account book technology can record and verify the data and operations in the running process of satellite software openly and transparently [18], thus effectively preventing malicious attacks and data tampering and improving the security and reliability of satellite software.

#### 6. Conclusion

This paper discusses the core function of software in satellite system and the importance of reliability analysis. From the overview of satellite system and the function of software, to the detailed discussion of various factors affecting software reliability and evaluation methods, this paper reveals the key position of software design in ensuring the stable operation of satellite system [1]. Satellite software is not only responsible for effective data processing and analysis, but also plays a vital role in controlling satellite attitude, orbit adjustment and communication. Therefore, its reliability is directly related to the success of the satellite mission, and even affects the life and efficiency of the spacecraft.

Through analysis, we recognize the influence of external

environment, internal software errors, human operation errors and other factors on software reliability, and put forward promotion strategies including reliability design, requirements analysis, reliability testing, robustness design, etc., aiming at improving the reliability of satellite software through these strategies and ensuring that satellite systems can support space tasks efficiently and stably.

In the future, with the development of artificial intelligence, machine learning, and distributed ledger technology, the field of satellite software reliability is expected to undergo changes. The integration of these technologies is expected to improve the reliability of software as never before, provide a solid guarantee for the safety of satellite communication, and promote the development of self-repair system and adaptive technology. However, the challenges brought by quantum computing can not be ignored, and targeted research is needed to ensure compatibility and security.

Satellite software and its reliability analysis are very important for the successful operation of modern satellite systems. In order to maintain technological advantages and meet future challenges, we must constantly explore and implement effective promotion strategies, and at the same time actively embrace new technologies and expand the depth and breadth of research. Future research can focus on how to apply emerging technologies to improve the reliability of satellite software more effectively, and how to optimize performance and resource utilization while ensuring reliability.

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