The Application Design of SOIS Electronic Data Sheets in Onboard Integrated Electronic System

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Abstract. This paper analyzes the concept and research status of SEDS (SOIS Electronic Data Sheets) in the field of Spacecraft Onboard Interface Services (SOIS) of Consultative Committee for Space Data Systems (CCSDS). In order to achieve fast integration and testing of the onboard software, this paper discusses how to apply the SEDS standard in the onboard integrated electronic system of Chinese spacecraft. This paper shows the structure of the onboard integrated electronic system, the stratification of the structure, and the functions, services, protocols, and components of each layer. Based on the architecture of the system, the top-level application design of SEDS in the process of the development of onboard integrated electronic systems is presented, Taking the remote sensing and acquisition function of spacecraft as an example, the design and application examples of SEDS and the subsequent expansion methods of SEDS are given. The SEDS is used as input in the development and testing of spacecraft integrated electronic system software. The results show that the application of SEDS is helpful to realize the standardization of onboard interface and promote the spaceborne integrated electronic system and even the whole spacecraft research through automatic code generation and electronic data reuse. Shorten the system cycle.

Keywords: SOIS · Electronic Data Sheets · CCSDS

1 Introduction

Founded in 1982, the Consultative Committee for Space Data Systems (CCSDS) is the most authoritative organization in the field of space data systems. At present, there are 11 member organizations and 32 observer organizations, mainly responsible for the development of international standards for space data systems. It includes six fields, such as satellite interface, space link, space Internet, task operation and information management, interactive support, system engineering, etc. Up to now, CCSDS series standards have been implemented and applied on more than 800 spacecrafts worldwide.

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Current work in the Spacecraft Onboard Interface Services (SOIS) field of CCSDS is focused on SEDS (SOIS Electronic Data Sheet). Aiming at the requirement of fast integration and testing of on-board software, SEDS can describe the device information and services interface information, and automatically generate on-board software, test cases and related documents by tools, the software, test cases and related documents are automatically generated by the tools, so that the integration, test and maintenance time of the software on board is reduced and the consistency of the data in each development stage is guaranteed. The implementation and application of this standard is beneficial to shorten the development cycle of Onboard Integrated Electronic System and reduce the development risk and cost. In this paper, the SEDS standard and foreign research and application status are analyzed, the Onboard Integrated Electronic System is studied and designed, and the application of SEDS is designed and verified based on this system.

2 Overview

In SOIS architecture, EDS (Electronic Data Sheet) is mainly used to describe device information and business interface information, called SEDS. It contains the following contents: the interface of bidirectional data exchange between SOIS protocol layers; the instructions and parameters that constitute the above interfaces; the component services that implement the mapping between two sets of interfaces; the state machine, variables, and behaviors that make up the components; and the types, variables, codes, and terminology that serve as the above references.

Besides describing the devices, SEDS can also be used to describe the interface of services, the connection relationship between services, the configuration parameters of services, and the configuration parameters of the system. In addition, SEDS has many other uses. For example, the ground operator can convert the SEDS of the device by tools, and automatically generate the task database, which is convenient to generate the control instructions for the device and to analyze the telemetry data of the device. For applications such as the space station, if astronauts connect a new device to the system network of the station, when the device stores its own SEDS inside the device, the device can be automatically identified and its data and SEDS information can be published in the space station by plug-and-play mechanism, and astronauts can subscribe to the device through a computer. Astronauts can subscribe to the device's data and SEDS through a notebook, through the SEDS parser tool to analyze the device's data, you can view the data in the interface.

Onboard software codes, test cases, interface control documents, telecontrol instructions, telemetry parsing files generated by SEDS can reduce the uncertainty and inconsistency of documents and avoid modifying a large number of documents when the requirements change. At present, the electronic data sheets used in ground test is described by CCSDS XTCE standard. It mainly focuses on telecontrol and telemetry data. After extending the description of onboard service interface to adopt SEDS standard, SEDS and XTCE can be converted by tools. The advantages of SEDS and XTCE are integrated to realize the electronic data sheets of the entire spacecraft interface software and documents.

3 Current Status of Foreign Research

At present, NASA and ESA are the first ones to launch SEDS in the international field. NASA's Goddard Flight Center implements SEDS applications in its cFE core flight software architecture; ESA is currently using JAVA development tools to support the generation and analysis of SEDS.

3.1 NASA Research Status

NASA core software system cFE has been used in many models to communicate messages between software components based on software bus, and a matching component configuration tool has been developed. Its source code is open, not only for spacecraft, but also for unmanned aerial vehicles and other systems. NASA plans to further refine the software architecture by referring to the interfaces defined by the SOIS architecture to suit the SOIS architecture. In NASA's cFE core flight software architecture, SEDS technology is used to automatically generate software configuration information to facilitate software on-demand configuration and assembly. SEDS can define the interface of the device, and can also define the interfaces of all software components. The SEDS is generated with the help of tool scanning header file. After modifying the SEDS, the new code can be regenerated. At the same time, the telecontrol instructions for testing can be generated by SEDS and the telemetry data can be parsed. NASA has developed a tool that takes software component SEDS and task configuration files as input and generates C header files. Header files contain message definitions and transformation of engineering units. At present, the tool is integrated in the cFS (core flight system) creation system, and is used by several NASA centers.

3.2 ESA Research Status

SCISYS from Europe has been researching EDS for many years and is developing tools to support SEDS generation and parsing. The tool is developed by JAVA and can automatically generate onboard software code according to SEDS. The generation and use of SEDS are as follows: in the early stage of development, the SEDS file is generated by the parameters of the device, and the relevant documents can be generated and verified by the SEDS file of the tool. At this time, the generated SEDS file can generate some onboard components, such as device drivers, and also generate input for simulation. In the process of project development, SEDS can be updated directly when the parameters of new device or device change; the model or data of the system can also generate SEDS; when the system data or device data changes, they can influence each other through EDS to modify the data, and the modified SEDS file automatically updates the document by tools. In comprehensive testing, EDS can be used directly as its input without documentation, because SEDS directly contains all its documentation data.

4 SEDS Application Design

4.1 Onboard Integrated Electronic System Architecture

The Onboard Integrated Electronic System architecture is a layered architecture [1] based on SOIS. Each layer contains a variety of services and protocols. In this architecture, on the one hand, the SOIS standard services and protocol are mapped into reusable software components, on the other hand, the software components are divided into middleware layer, and together with the operating system layer and application layer, the Onboard Integrated Electronic System software is composed. The core of the architecture is the middleware layer, which contains a variety of standard protocols of CCSDS and ECSS, and provides services to the application layer through standardized interfaces, as shown in Fig. 1.

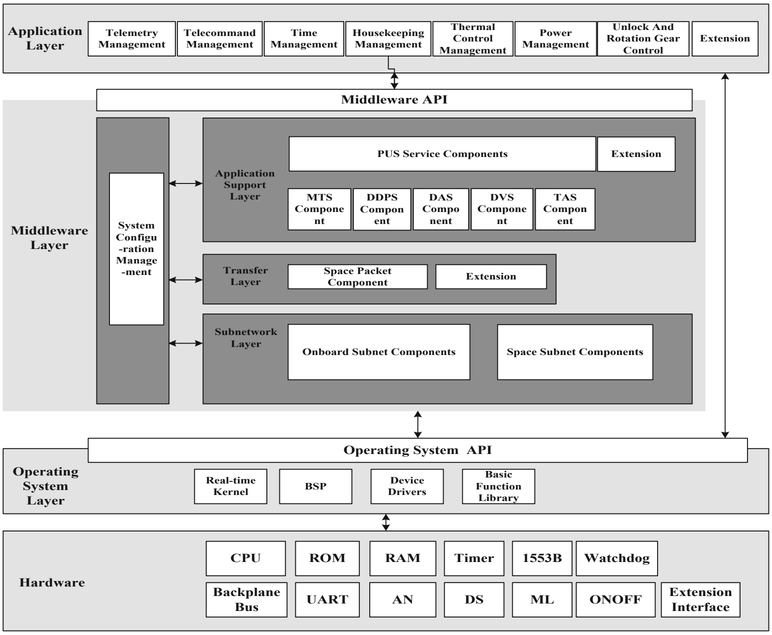

Fig. 1. Spacecraft onboard integrated electronic system architecture

(1) *Application Layer*

The application layer includes top-level functions such as telecontrol, telemetry, time management, housekeeping, thermal control management, energy management, load management and other extended applications. The services provided by the bottom layer can be used to generate different application processes by instantiating these services.

(2) *Application Support Layer*

The application support layer includes command and data acquisition service (including device access service, data pool service, device virtualization service), application programs accessing onboard devices, file and packet storage service for transferring files in the computer file systems within and between spacecraft, and time access service for acquisition. Spacecraft take time; message transfer service is used for message transfer between two applications on board the satellite; standard service defined by PUS basically covers the general functions of current Onboard Integrated Electronic System.

(3) *Transfer Layer*

Transfer/network layer is generally used only when there are multiple subnets and the applications between subnets need to communicate with each other. It provides end-to-end data transmission service between applications. In this paper, Space packet protocol is used for routing, and Space packet protocol is extended. Source/destination address information is added to its sub-header, which can support UDP/IP and other protocols extensively.

(4) *Subnetwork Layer*

Subnetwork layer includes space link and satellite link, providing a series of services for upper application support layer and transfer layer service call. Space link is mainly provided by uplink TC protocol, COP-1 protocol and downlink AOS protocol. The satellite link includes packet service, memory access service and synchronous service. In addition to the above standard services, it also provides a unified common bus interface services, in each link, through the corresponding aggregation protocol and data link layer protocol, it can support the standard services of the subnetwork, thus shielding the different underlying links from the upper. The current supporting links include 1553B bus, SpaceWire bus, serial port, ML interface, DS interface, etc.

(5) *Operating Systems and Hardware*

Hardware layer is the basis of software operation, including various hardware of satellite computer, mainly including CPU, RAM, ROM, EEPROM watchdog, timer, telemetry interface, telecontrol interface, serial port, bus interface, other interfaces.

The operating system layer encapsulates the interfaces of the operating system and provides a unified application programming interface. As long as any operating system supports a unified access interface in this structure, it can be applied in the Onboard Integrated Electronic System. Therefore, it can support the update of the operating system. Its composition includes real-time operating system, device driver, board-level support package (BSP), basic function library and so on.

4.2 SEDS Application Design

The application of SEDS can run through the lifecycle of Onboard Integrated Electronic System development, as shown in Fig. 2. In the software design and development stage, SEDS is generated by the designer; SEDS is divided into two types: one is the existing software component or model, which can be generated directly by the tool; the other is the new software component which can be generated by writing and can be used as the input of component model. In the software testing phase, these SEDS generated above can be read as the input of the simulation test through the tools to ensure the correctness while reducing the test configuration work; in the later test phase and the spacecraft flight ground control phase, these electronic data sheets can also be generated through the ground system tools database. The database can also be used for developer testing, third party testing, and on orbit testing. In short, once the electronic data sheets is formed, its application runs through all stages of project development and operation.

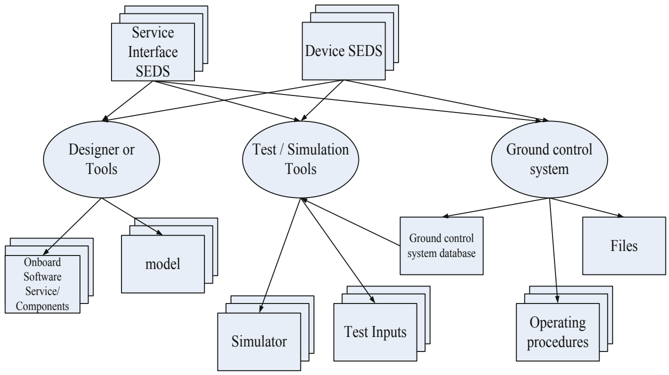

Fig. 2. Top level design for SEDS application

4.3 SEDS Application Example

Figure 3 is an example of telemetry acquisition in satellite software. sheets left to right, it corresponds to hardware, subnetwork layer, transfer layer, application support layer and application layer of satellite Onboard Integrated Electronic System in turn. The left D1, D2, D3 are different devices, D1, D2 are connected to RTU1 (remote unit) through RS422, CSB bus, RTU1 through 1553B and Onboard Integrated Electronic System central management unit (SUM); D2 is directly connected to SUM through 1553B. To collect the telemetry data of these devices, the telemetry acquisition and organization are completed by 1553B and serial port convergence protocol, and the spatial packet is formed. The packet is sent to the application support layer by the spatial packet protocol. The message transmission primitive of the message transmission service transmits the telemetry to the telemetry processing module of the application layer. Spread over the space link to the ground.

In this process, SEDS begins with the device. Because different devices support different data when describing device information, SEDS includes device access interface, device functional interface, device access protocol, device virtual control steps, and subnetwork layer usage information, such as SEDS1, SEDS2, SEDS3, etc. With the layering of Onboard Integrated Electronic System architecture, the higher the level of convergence, the less the number of SEDS devices, such as SEDS5, which aggregates the relevant information of SEDS1 and SEDS2, and then adds 1553B aggregated access interface. SEDS describes the services interface, mainly describes the two-way data exchange interface between services, including business/component parameters (can be input or output), commands, services primitives, the mapping relationship between the three and the state machine that represents the relationship between services.

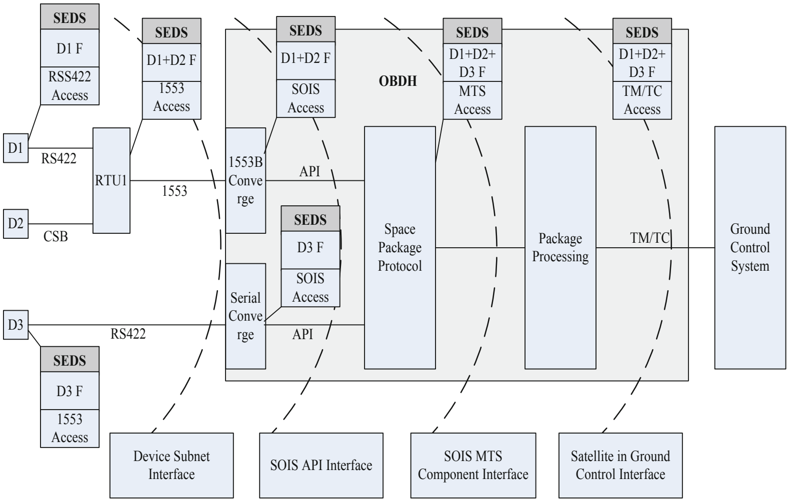

Fig. 3. SEDS describes the device, business interface

4.4 SEDS Application Extension

At present, the electronic data used in ground integrated test system, launching base data system and flight control center data system are described by CCSDS XTCE standard, mainly focusing on telecontrol and telemetry formats, and their applications are mainly for data annotation and Analysis on the ground. The description of the onboard services interface/device is based on SEDS standard, and the subsequent conversion between SEDS and XTCE can be done by the tool, as shown in Fig. 4. With the input of onboard service interface/device SEDS and task configuration file, XTCE standard database is generated, and different mission systems are provided to use the conversion to facilitate the connection between onboard data and ground data. SEDS can be used not only in the various life cycle of onboard software development, but also in ground system.

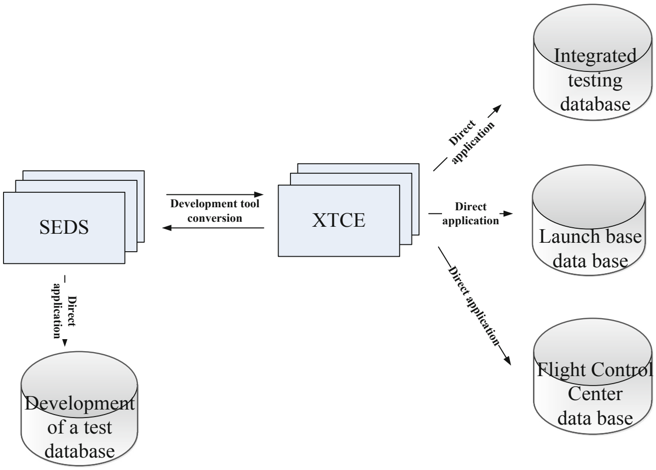

Fig. 4. Conversion of SEDS to XTCE

5 Design Verification

Based on 43 software components of SMU, which include CCSDS spatial link protocol, nine SOIS standard services and protocols, space Internet domain protocol, 1553B protocol, and 12 services, convergence protocol and driver in the PES protocol of ECSS, 43 SEDS of service interfaces are developed for devices with SMU interfaces. 15 SEDS of devices were developed. In the software development stage, debugging and testing stage, unit testing, assembly testing and confirmation testing stage, SEDS was used as the test input. According to statistics, in the development and testing phase of the Onboard Integrated Electronic System, the time is saved about 35%, and the automatic generation part of the integrated code accounts for 62%. At the same time, there is no inconsistent interface state caused by file problems. Through SEDS development, testing in the rapid integration, reusability, reliability has a prominent role, mainly reflected in:

(1) Rapid integration testing. Because SEDS describes the configuration parameters, interfaces, and connections between services, after selecting the relevant software components according to the requirements, the call relationships between these components can be described by SEDS, and the calling codes can be generated by the tools, which can realize the rapid integration within the Onboard Integrated Electronic System. Plug and play is realized through SEDS in the development and testing phase and the whole satellite testing phase, which greatly reduces the configuration work and shortens the testing period.
(2) Reusability. At present, the software components are all stored in the data base, and the SEDS corresponding to the interface is also stored in the data base. For the same component used in different fields, because its parameters, interfaces and invocation relations are fixed, the SEDS of the service interface can be reused. For the same device, when the communication protocol is fixed, the SEDS of the

device can be reused throughout the spacecraft development cycle. The higher the reuse, the higher the development efficiency.

(3) Reliability. The uncertainties and inconsistencies of the documents can be reduced by generating onboard software codes, test cases, interface control documents, telecontrol instructions, telemetry parsing files and so on through SEDS. The database of the tasks can be automatically generated after the conversion of SEDS by tools, which ensures the data of each stage of software development, integration and testing. This improves the reliability of data at all stages.

6 Summary

The device information and service interface information are described by SEDS, and the onboard software is generated automatically. The Onboard Integrated Electronic System can be quickly integrated and tested. Through SEDS, the onboard software code, test cases, interface control documents, telecontrol instructions, telemetry and parsing software can be automatically generated, which can reduce the uncertainty and inconsistency of documents and avoid modifying a large number of documents when the requirements change. At the same time, by extending the automatic conversion between SEDS and ground XTCE, flexible and reliable data exchange among software developers, integrated testing, flight control center and equipment producers can be realized. While SEDS achieves rapid integration and testing, its reusability and reliability help to improve development efficiency and shorten the entire spacecraft development cycle.

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