



# A Full Lifecycle-Oriented Flexible Method for Satellite Design

Yaohua Zhou<sup>1,2</sup>(✉), Cuina Liang<sup>1,2</sup>, and Jingquan Ji<sup>1,2</sup>

<sup>1</sup> China Academy of Space Technology, Beijing, China

<sup>2</sup> Institute of Telecommunication and Navigation Satellites, Beijing, China

**Abstract.** In the process of satellite development, user requirements may continue to change with the deepening of understanding. Due to the difficulty of satellite in-orbit maintenance, while considering the cost and time of satellite production, under the pressure of satellite batch production, this paper proposes a full life cycle-oriented navigation satellite flexible design, which can shorten the development cycle of the satellite when the requirements change, upgrade the software in the ground and in orbit flight stages, reduce the development cost of satellite and enhance the value of satellite.

**Keywords:** Flexible design · Satellites · Lifecycle

## 1 Introduction

The satellite design is carried out after the user's task requirements are specified. Mission requirements include mission definition, technical indicators and development cycle. The content of satellite design is to carry out mission analysis, put forward the whole satellite scheme and carry out the whole satellite design [1]. With the development of new technology and the extension of satellite life, users' requirements may change. The design of the satellite must be able to quickly meet the changes of user requirements, whether in the ground development stage or in orbit stage. The design of the satellite should reduce the development cycle and the increase in funds brought by the change as far as possible. Keeping the flexibility of design is always the goal of satellite designers.

In recent years, flexible, modular, plug and play, software redefinition and other concepts are gradually introduced into satellite design, such as flexible thermal control system [3], plug and play satellite [3–5], software-defined satellite [6, 7], etc. The above research only involves some functions of the satellite, and can not be carried out from the perspective of the satellite system. The design of the whole satellite shall be able to adapt to the changes of hardware and software caused by user requirements in the whole life cycle. This paper presents a full life cycle-oriented flexible method for satellite design, which solves the problems of long periods and high costs to realize the change.

## 2 Definition of Satellite Flexibility

Flexibility is defined as the ability to effectively handle environmental changes or uncertainty caused by the environment. Unlike other products, satellites have to experience complex and harsh space environments during launch and in orbit. The cost and risk of satellite in orbit maintenance are very high, even not repairable.

The flexibility of satellite should have the ability of in orbit maintenance and be able to upgrade its functions. Maintenance refers to the functional aspect of the software. A full lifecycle refers to two phases of satellite development on the ground and flight in orbit. In the ground development stage, the flexibility of the satellite means that it can be compatible or easy to complete modification when hardware products and software functions are changed. In orbit stage, the flexibility of the satellite means that it can be upgraded when the software function is changed.

The overall goal of satellite flexible design for the whole life cycle is to reduce the cost. It has two meanings:

- Shorten the increase in development cycle caused by the change, and reduce the cost of test and test caused by the change of equipment and the whole satellite;
- Improve the ability of in orbit software upgrade, enhance the value of satellites, and reduce the total cost of launching satellite again.

## 3 Methods Supporting the Design of Flexible for Full Lifecycle

A method is here defined as a tool that supports the designer in designing satellites in a systematic way, taking relevant parameters into account. Systematic in this context means the theory of system engineering. The requirements are decomposed into different parts of the satellite, and then integrated into the whole satellite, through system research and problem solving. The flexible design process, as well as the relevant parameters should be truly structured in such a method (Fig. 1).

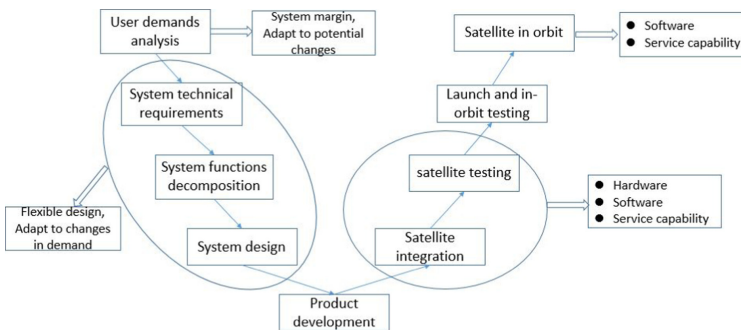


Fig. 1. Flexible design and implementation of satellites

How to develop a design that adapts to change? The core of the flexible design process is to adapt to changes. As shown in Fig. 2. When the design requirements are determined in phase 1, it is necessary to consider the impact of the external interface changes and the internal interface changes of the satellite on the whole satellite from the perspective of the system. In phase 2, the flexible design requirements should be considered from the satellite architecture, hardware and software. Architecture is the key to satellite flexible design, which ensures that changes will not have a disruptive impact on satellite design under the premise of given mission requirements. Hardware and software are the means to realize the flexible design.

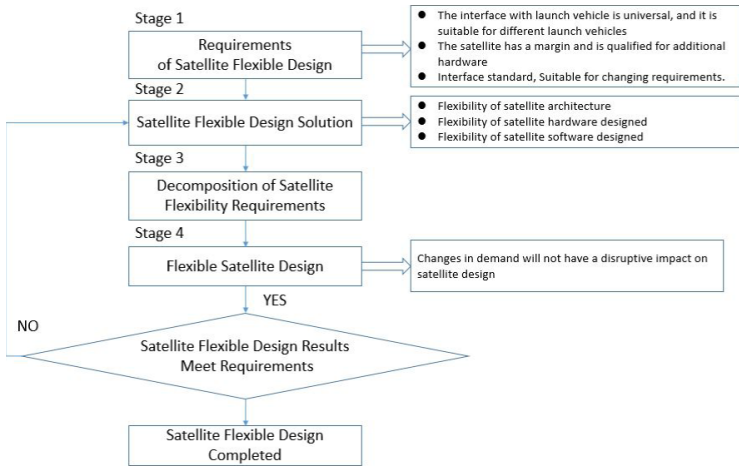


Fig. 2. Flexible designed process of satellites

### 4 Flexible Design of the Satellite

The flexible design of satellite starts with architecture design. For the efficient and reliable management and control requirements of on-board tasks such as attitude and orbit control, energy, thermal control, and load, there are centralized and distributed architectures. After comprehensive analysis and evaluation, the hierarchical distributed architecture is adopted, the onboard computer is the center, the interface unit is the middle layer, and the general module and standard interface are adopted. When the demand changes, the system flexibility is realized through the middle layer buffer.

- Hardware design such as electric heating interface and mechanical performance matching, which can adapt to the changes of external new equipment requirements, mainly in the ground development stage.
- The whole satellite operation software design, such as plug and play of equipment, independent health management, and independent operation ability of the whole satellite, adapts to the changes of internal and external software functions, mainly in the ground development stage and in orbit flight stage.

- The whole satellite application software design, such as in orbit reprogrammable digital signal generator [10, 12], realizes flexible navigation load and adapts to satellite value promotion, mainly in the ground development stage and in orbit flight stage (Fig. 3).

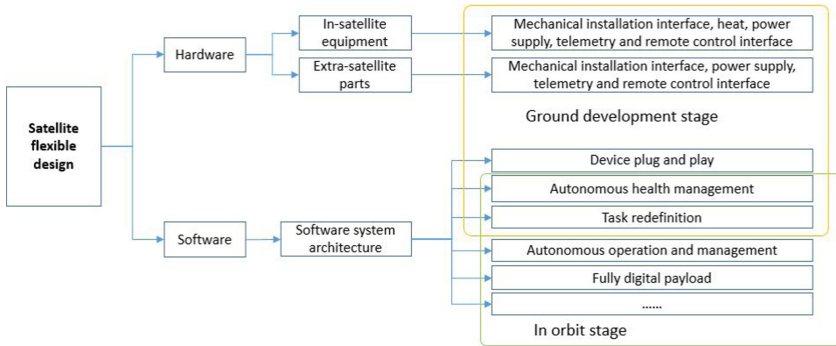


Fig. 3. Satellite flexible architecture

### 4.1 Flexibility of Satellite Hardware Designed

The hardware flexible design of the satellite realizes the installation of a single machine and the integration of the whole satellite. The flexible design is carried out from the following three aspects.

1. The flexible design is realized through the standard interface of the local cabin board. By adopting compatible, envelope and transfer designs on the cabin board, the installation requirements of new stand-alone products can be met. The compatibility and envelope design is carried out in the whole satellite design stage, and can be realized in the whole satellite production stage. The switching design has no impact on the whole satellite production, and can be carried out in the whole satellite design stage and development stage (Fig. 4).

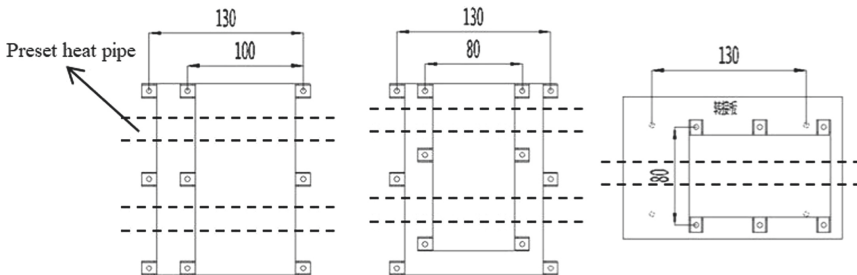
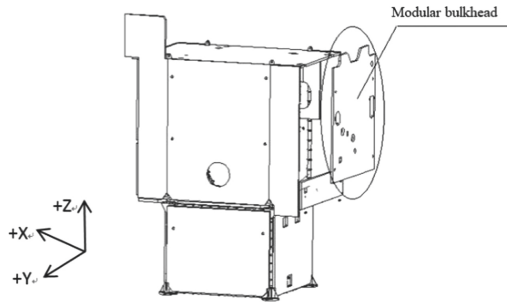


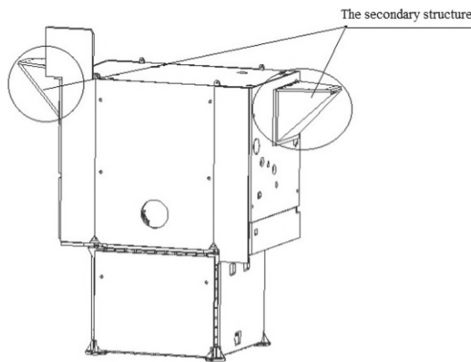
Fig. 4. Schematic diagram of compatibility, envelope and transfer design

2. The flexible design is realized through the standard interface of a modular independent cabin. The hatch adopts the standard interface with the hatch section. Different hatch plates can be carried out in the whole satellite design stage and development stage. The hatch plates shall be uniformly designed at the design stage, and two or more different hatch plates of the same type shall be produced when they are put into production. In the whole satellite development stage, the cabin plate is directly installed according to the needs of different products to realize the flexible configuration of products. Compared with the flexible design of partial bulkhead, the independent bulkhead is suitable for the replacement of a large number of equipment or the configuration of new functional equipment in the development stage (Fig. 5).



**Fig. 5.** Modular bulkheads, the interface of the bulkhead is universal

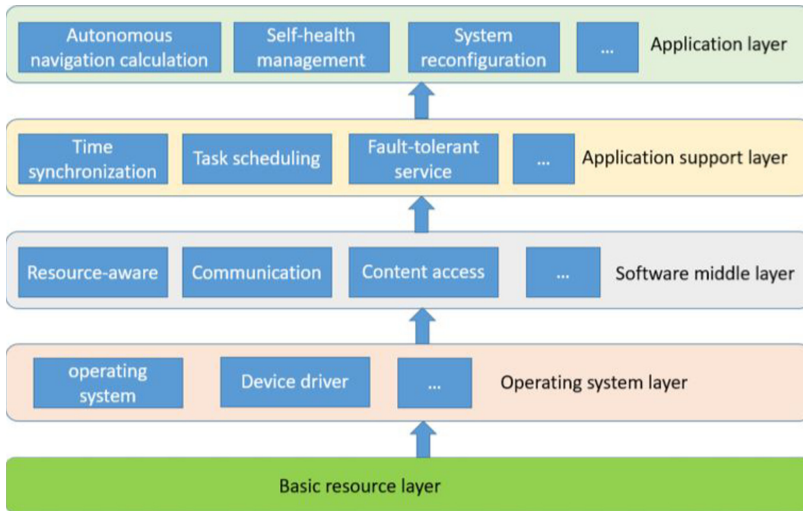
3. The hardware flexibility design is realized through the transfer of second intermediate structure. This design can realize the decoupling between the whole satellite and the load terminal design, and meet the development requirements of the whole satellite. The secondary structure is fixed on the main structure of the whole satellite, does not transfer the main load, and does not significantly affect the structure of the fundamental frequency and vibration mode of the whole satellite (Fig. 6).



**Fig. 6.** Add secondary intermediate structure

## 4.2 Flexibility of Satellite Software Designed

The flexible design of satellite software realizes the rapid upgrading of software functions. Software flexible design is based on the software hierarchical design of the integrated electronic system. Under the unified bottom hardware resources and operating system configuration, it supports the plug and play of equipment and the realization of various satellite application services (Fig. 7).



**Fig. 7.** Software hierarchical design of integrated electronic information system

In the ground development stage, plug-and-play technology is applied to realize the flexible design support of hardware. Plug and play technology can automatically identify access devices and conduct dynamic monitoring and configuration. After the equipment is installed, it is connected to the standard power supply and distribution, information, and other interfaces on the satellite, and can be found, identified, and configured independently on the satellite to meet the needs of task changes.

In orbit stage, digital load technology is used to realize the flexible design of service-oriented software. Taking the navigation satellite as an example, the digital load is to amplify and frequency transform the RF signal, digitize the broadband IF signal to its digital signal processing unit, and process the data onto the signal processing software to complete the corresponding different task functions.

According to the traditional whole satellite design, when the requirements change in the development stage, it is necessary to restart the interface coordination and satellite design, with a long iteration cycle. If the flexible design is adopted, interface coordination, overall design, and satellite development will be changed from serial to collaborative parallel, which can realize new or changed configurations at a small cost and shorten the development cycle.

## 5 Conclusion

With the improvement in user requirements, the satellite has a shorter and shorter period from contract signing to delivery, and the satellite life is longer and longer. Using flexible design can shorten the coordination iteration cycle at the initial stage of design and improve the value of in orbit satellites.

In the future, as the top-level guidance of design, flexible design theory and method need to further strengthen research, develop a new hardware flexible design system based on the modular cabin, modular cabin board and standardized single machine interface, and coordinate the relationship between modularity and system optimization;

The development cycle of new technologies is getting shorter and shorter, and the satellite life is getting longer and longer. Under the constraints of the limited resources of the whole satellite, improving the value of the whole satellite is the goal that users always pursue. Based on the uncertainty of future new technology prediction and the in-depth mining of satellite value, it will be an important development direction from the traditional fixed resources and fixed functions to the direction of flexibility and redefinition.

## References

1. Xu, F.: Satellite Engineering. China Aerospace Publishing House, Beijing (2002)
2. Ning, X., Wang, Y., Song, X., Zhang, B., Zhang, J.: Modular and flexible thermal control architecture of satellite platform. *Spacecraft Eng.* **21**(02), 50–55 (2012)
3. Wang, X.: Research progress of plug-and-play satellite system technology. *Satell. Netw.* (05), 70–74 (2014)
4. Wang, X., Dong, Y.: Research on plug and play modular satellite architecture. *Spacecraft Eng.* **21**(05), 124–129 (2012)
5. Zhang, S., Wang, B., Sun, Z.: The design method of micro-satellite flexible platform based on standardized function modules. *Aerosp. Stand.* (02), 1–6 (2009)
6. Chen, J., Wang, C., Liang, X.: Progress in foreign software-defined satellite technology. *Satell. Netw.* (04), 50–53 (2018)
7. Huang, J., Chen, X., Li, Z.: Software-defined integrated electronic design and implementation of micro-nano satellites. *Mod. Electron. Technol.* **42**(02), 30–32 (2019)
8. Li, C.: Theory and Practice of Project Group Management. Publishing House of Electronics Industry, Beijing (2014)
9. Beyond GPS III, NTS-3: the next chapter, February 2019. [www.gpsworld.com](http://www.gpsworld.com)
10. Harris all-digital GPS III payload, March 2016. [www.gpsworld.com](http://www.gpsworld.com)