Research on Trends and Key Technologies of Small Satellites

Chuang Liu[1, a], Feng Wang[1, 2, b], Keke Shi[1, c] and Zongzeng Zhang[1, d]

[1]Research Center of Satellite Technology, Harbin Institute of Technology, Harbin 150001, China

[2]National&Local United Engineering Research Center of Small Satellite Technology, Changchun 130033, China

[a]liuchuangforever@msn.com, [b]wfhitsat@hit.edu.cn, [c]skkhit@qq.com, [d]zhangzongzeng2009@163.com

Abstract. Small satellites have attracted people's interest because of their unique fascination, the requirements concerning civil and military for the manifold application areas indicate the wide range of potential application for small satellites. This paper describes the applications and key technologies of small satellites according to their present research status and development trends.

Keywords: Small satellites, Development directions, Applications, Key technologies.

1. Introduction

With the development of micro mechanical system and integrated circuit technology, structural technology in small satellites has also made a breakthrough which provides lots of advantages such as light weight, small volume, low cost, short development cycle, low orbit, easy to launch, good survival ability and small risk. Last but not least, they will have high technical content because they have high spatial resolution. Because of these characters, they have absorbed more and more interest recently. The Earth observations group made plans for its Global Earth Observation System in 2008. Meanwhile, the Space Council of European Union continued to reaffirm the need for rapid implementation of the Global Monitoring. From the viewpoint of space-borne remote sensing, the only way to meet the requirements is to take steps to launch and operate low-cost small satellites [1].

Furthermore, the implementation of satellite constellations and formation to increase the spatial and time resolution is a unique feature of small, low-cost satellites. Several varieties of distributed satellites such as COSMIC[2,3,4] constellation, RapidEye[5,6,7] and SAR-Lupe[8,9] have been launched which show the potential of small satellites and how small satellites or constellations can be used to improve spatial and time resolution as well as to solve mission which a single satellite can't accomplish.

2. Development Directions and Applications

Small satellite missions can be accomplished by using different approaches and methods. With the development of modern technologies, small satellites have also offered an opportunity for countries without sufficient capital or experience in space technology to enter the field of space exploration.

Currently small satellites have two main directions of development. One is the single lightweight satellites which have been used to perform tasks on Earth Observations and provide high-resolution graphics of practical military value. Meanwhile, a variety of new technologies can be tested on small satellites. Some of the new technologies can be used to make smaller and more powerful satellites. The other direction is formation flying of small satellites working together. This constellation performance is not worse than single large satellite and new applications can be implemented, including advanced space-based radar systems, long baseline signals intelligence system and communication system which can work together with the ground terminal.

However, how to make small satellite much smaller? The way to make it smaller usually decides the development directions of small satellites. It is very significant to make each part of the small satellite a lightweight. Statistics show that the percentage of each part to the total weight can be seen in Table 1.

Table 1 Percentage of each part

Part	Attitude	Power	Thermal	Structure	Communication	Thrust	Data
Percentage	9%~14%	38%~42%	3%~4%	22%~29%	10%	10%	4%~5%

The attitude control part, power part and structure part account for the highest quality ratio, so we should take the lightweight of them into consideration to improve the performance-to-mass of small satellites to make them smaller and smaller.

Some steps should be taken as follows:

- Lightweight of the power.
  Satellite power system is composed of solar cells and batteries, and solar cell is the main part. In this part, two things should be done. One is to improve the conversion efficiency of solar energy and increase the efficiency of the energy storage battery. The other is that lightweight new materials should be adopted to make them.
- Lightweight of the structure.
  To make the structure of small satellites much lighter, integration of structural design should be considered. Once overall design of each unit is premeditated, the satellite can achieve common use of parts and control systems to reduce the weight of this part. Furthermore, multi-function structure should be applied. With the development of microelectronics technology, many components have been integrated to achieve good performance. Multi-function structure is developed to integrate some units on the satellite. Finally, new materials can also be applied into the structure to improve the performance of temperature resistance or other harsh environments.
- Lightweight of the attitude control system.
  Many sensors, attitude control devices and unloading equipment exist in this part. With the development of microelectronics technology, sensors have been becoming smaller and smaller, so microelectronics technology decides the weight and volume of sensors. With the lightweight of other equipment on the satellite, the control and unloading torques will become smaller, so it is inevitable for the corresponding equipment to become smaller. What's more, the new maglev flywheel can also be used to reduce the number of use because of its non-wear parts. Besides, fuel optimal control method can be employed to reduce the carrying fuels on in-orbit servicing satellite [10]. Robust control method based on LMI (Linear Matrix Inequality) can be used to make small satellites a fast response performance [11]. Other methods such as improving specific impulse of fuels, using riblet drag reduction technology can also be used to reduce the weight of this part.

The applications of small satellites are:

- Space countermeasure[12].
  Kinetic impactor, space mines[13], space-based microwave jammers, space-based chemical sprayers, space-based lasers, orbital position pushing device, defense and security, space observation and monitor, parasitic satellites, space flight test of stealth technology and so on.
- Global non real-time and real-time communications.
  One LEO small satellite can provide global non real-time communications(shown in Fig.1) such as email, letter, fax, telex, data, graphics, voice mail services and so on. Multi-satellite constellation can achieve real-time communications(shown in Fig.2) such as border posts communications, exploration, rural communication telecommunications, emergency, coastal fishing communications and so on.
- Remote sensing.
  Ground optical imaging, environment, resources, hydrological and disaster monitoring, meteorological observations and geography surveying.
- Scientific experiments.
  Conducting electromagnetic transmission and interference test.

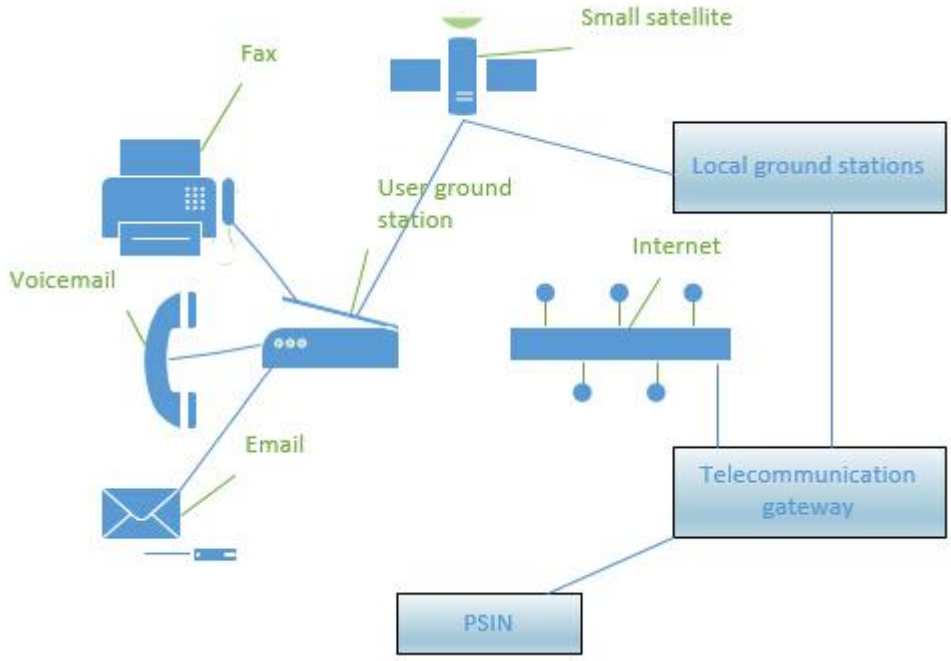

Fig.1 Non real-time communication

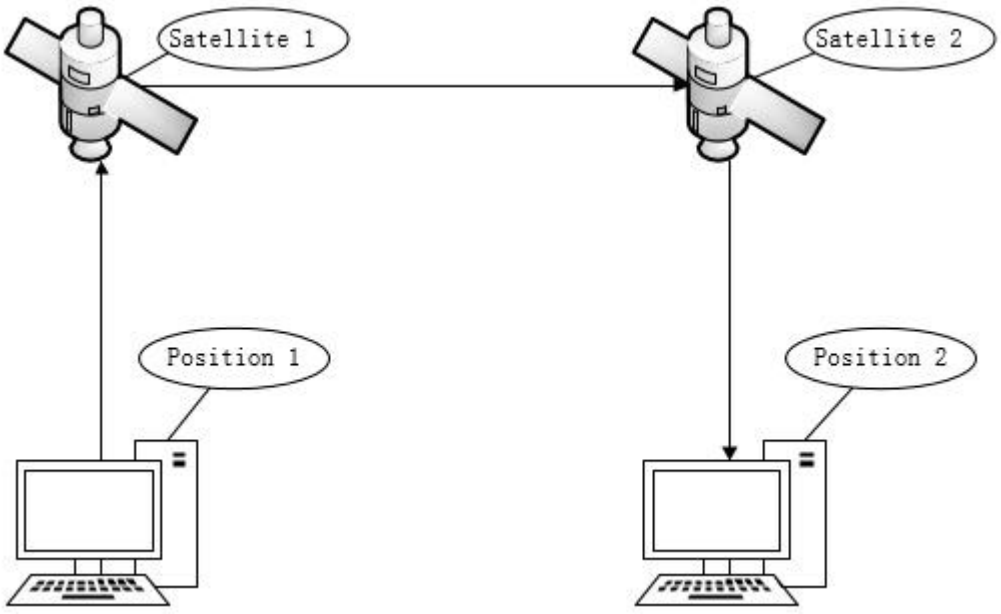

Fig.2 Real-time communication

- Small satellite system applications.
  Distributed satellites can be used for communication, navigation, distributed radar and optical interferometry in formation flying. Space-based sensing systems can perform visual and infrared Earth imaging, multi-spectral imaging and maps imaging, target detection and tracking tasks. Warning small satellites can be used to track the flight of intercontinental ballistic missiles and submarine-launched strategic missiles and warheads to guide interceptor missile to intercept the goal. Virtual aperture small satellite system can be used to improve awareness in military operations. Logistics satellite can be used to supply fuel when performing in-orbit maintenance.

3. Key Technologies

The key technologies of small satellite are as follows:

- Integrated design of small satellite.
  Traditionally, each development step of the satellite design is based on serial to develop and design individually. After the completion of the various subsystems, comprehensive integration tests have to be performed. Once one subsystem is found not meet the required performance, they have to repeat rework which is a waste of time and money [14]. If the idea of parallel development is based, perform development and test together and it will shorten the development cycle, reduce development costs and improve reliability.
- Intelligent satellite platform.
  Use lightweight composite material as structural framework, standard bus interface, software upload and radio technology to achieve a variety of payload integration.
- Small satellite constellation technology and networking group technology.
  Constellation dynamics, formation flying position maintenance and control technology, inter-satellite communications.
- Digital image processing.
  Digital image signal compressing, processing, fault tolerance resistance and recovery techniques.
- Light high-precision attitude control technology and micro-propulsion system technology.
  High directivity and high stability attitude control system and small quality, small size, high performance and propulsion system suitable for small satellites.
- Lightweight high resolution, wide coverage CCD visible light sensing technology.

4. Conclusion

With the development of satellite science and technology, the satellite family will become more and more enormous. What's more, with the development of micro-electro-mechanical system and emergence of new materials, small satellites will certainly achieve unprecedented development. This paper describes the development directions, applications and key technologies of small satellites. Small satellites have lots of advantages such as light weight, small volume, low cost, short development cycle, low orbit, easy to launch, good survival ability and small risk. It can be predicted that small satellites will play a more and more significant role in the future applications of civil and military.

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