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沈荣骏 董光亮 主编

第28届中国飞行器测控学术会议论文集

开放，融合，智联

Proceedings of the 28th Conference of Spacecraft TT&C Technology in China

Openness, Integration and Intelligent Interconnection

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内 容 简 介

本书精选并收录了第28届中国飞行器测控学术会议的优秀论文共47篇，分为飞行器测量科学与技术、空间目标探测与识别、通信与信息系统3个部分。本书反映了我国航天测控领域的最新科研进展，可供相关领域的科研人员以及工程技术人员阅读参考。

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Preface

China's aerospace cause will embrace a new round of dynamic development driven by the military-civil integration strategy of the government. In this backdrop, spacecraft TT&C will face both opportunities and challenges. Development and construction of spacecraft TT&C systems must follow an open philosophy and thinking and absorb state-of-the-art ideas and technologies in order to produce an iteratively creative momentum. Based on national demand, integration of the field with other specialties should be improved to seek innovative breakthroughs in a timely manner. At the same time, efforts should be made to extend fields of TT&C services home and abroad by leveraging intelligent linking, intelligent interfacing and intelligent service.

Taking "Openness, Integration and Intelligent Interconnection" as its theme, the 28th China Spacecraft TT&C Conference highlights better activation of the dynamic sources of development of the discipline of spacecraft TT&C and further promotion of creative development of TT&C operation and management integration. The conference will showcase the latest achievements of the country in the field of spacecraft TT&C and explore the future of China's spacecraft TT&C systems.

For the academic conference, totally 310 papers are received from specialists in different fields, and from them 47 papers are selected for publication in the proceedings. With rich contents, clear focus and high academic level, the proceedings has excellent practical and promotional values and we hope it will provide reference and help to officials and scientific and technical personnel at different levels in the field of spacecraft TT&C.

Beijing, China
November 2016

Rongjun Shen

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Part I
Spacecraft Instrumentation Science and Technology

Chapter 1
Discussion on Networked and Integrated Space-Ground Information System

Jianping Hu, Huizhong Xu, Ting Li, Tian Liu and Hongjun Yang

1.1 Introduction

The space electronic information system includes space-based and ground infrastructure for acquiring, processing, and transmitting information via space platform which is only used as information carrier in order to acquire and apply information.

Our current space information system including spacecraft TT&C and payload control systems is stove-piped, which are developed and deployed independently by various military and civil departments, and using various information acquiring, time reference and information transmission system without uniform technical specifications. There is little effective connection between military and civil resources leading to difficult data sharing and information fusion between them. No integrated space-based information system is formed.

The goal of the proposed space information system is to construct an integrated, open, expandable, interconnected, cross-support, safety, robust, flexible, and reconfigurable space-ground information application system supporting united planning and management. Considering the increasing military and civil application demands and manifold and sophisticated application modes, the system shall be implemented by means of network and integration technologies based on software defined everything (SDX), such as node-and- application-oriented software defined platform (SDP), software defined function (SDF) and so on.

The key to establish a networking and integrated space-ground information system is reconfigurable network topology architecture, definable protocol, and online processing and multifunction adaptability of network nodes, which can provide basis for future resilient construction, function expansion, capability improvement, tailoring by demands, and intelligent situation sensing.

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1.2 Space Information System Development Trends

Space system has developed from single satellite to constellation, and to space network, finally, it will become a networking and integrated space-ground architecture and application [1].

In the early phase of space system development, information acquiring and transmission depended only on a single satellite, whose orbit feature determined that it can only provide unsatisfied coverage, and limited information acquiring and transmission capability. Constellation mode can overcome shortcomings of single satellite mode on coverage area and time. However, in some space information applications, a user may require several kinds of information, such as on navigation and early warning, at the same time, which cannot be met using constellation mode. Space information network may implement connection among various satellites and constellations to provide 24/7 and globe coverage, and integrate resources on space, air, sea, and land to provide full-time and seamless access services. With introduction of integration technologies, space system had developed from a system consisting of single function spacecraft and ground system to a system with multifunction nodes and the SDN architecture. Acting as information carrier, spacecraft and ground infrastructure can join in, maintain, manage, and apply network as server, terminal, node, or transmission line.

Satellite system has developed from single satellite application mode to constellation application mode, with trends to networking mode. Typical constellation system includes GPS navigation satellite system, Iridium satellite system, Space-based Infrared Satellite (SBIRS) system, and so on. GPS system consists of 24 satellites constellation to provide global coverage and real-time location, velocity and timing information. Iridium satellite system consists of 66 satellites constellation in LEO. It is unsuccessful in commercial operation, but it is a technological leap for resolving problem of global mobile satellite communication [2]. SBIRS design utilized a composited constellation combing GEO, HEO, and LEO orbits in order to improve missile finding capability, expand flight midcourse tracking, and implement missile full-range tracking [3].

Onboard processing and crosslink are necessary components of constellation. Although US military TSAT program was cancelled, but its onboard processing and crosslink technologies can used to other applications [4, 5]. Milstar and AEHF communication satellite constellations incorporated crosslink to fast information transmission speed and improve satellite anti-jamming capability. Iridium satellite system had complex and advanced onboard processing capability, and can delivery and exchange information via crosslink without ground station to provide global coverage. GPS constellation began to provide UHF crosslink from Block-IIR satellite to perform inter-satellite radio pseudo range measurement. The ephemeris update information can be acquired frequently to perform onboard real-time obit estimation, keep autonomous navigation for long time, and improve location accuracy and availability in war conditions.

On January 2013, DARPA provided low rate crosslink radio communication platform for F6 satellite project, whose K-band radio allowing any spacecraft joining into F6 swarms. The platform used unique core architecture to provide sustained data links between satellites of swarms and support simultaneous the third part's point-to-point links. Its communication protocol incorporated a data link layer which can integrate the network protocols in higher layer and enable maximum bandwidth assignment via distributed calculation in unique architecture. Although the F6 project was cancelled, this technology can be used to other space networking applications in other smallest project [10].

Constellation system expands the former single satellite application mode and increases the application efficiency. However, the current satellite systems are still stove-piped, which fail to form a uniform and directly interconnected network, leading to little effective interconnection among systems. As a result, application efficiency of information resources in limited space is not fully utilized for data of each system could not be shared and utilized in time.

For the ground section of the space system, U.S. military is prepared to change the state quo where multiple independent ground systems are operated for the on-orbit satellite, and support establishment of a common system. For this purpose, the MOD launched an "Enterprise Ground System (EGS)" program to update the ground section for the military user via a more efficient and more cost effective system and meet challenges confronted with integration and expandability.

In 2015, Lt. Gen. David J. Buck, Commander of 14th Air Force and Joint Functional Component Command for Space have suggested that architecture of the ground section of the U.S. military space system must be safe, flexible and cost effective in an activity held at the Mitchell Institute. Operating multiple separated ground systems will cause stove-piped problem impairing safety, flexibility and economical efficiency. Currently, ground systems of various satellites which are divided by different scope of tasks use special software supplied by contractors, leading to insufficient management from the MOD. In addition, updated and new versions also require data and expertise from the original contractors. It is worth stressing that the government must possess technical baseline and must control interface and standards so as to avoid management ability being limited by those special software. For station network of the space system, the network requires open architecture as well as interface and standards that could be controlled by the user.

U.S. military is developing a common ground operation and control system for satellites. John Hyten, Commander of the Air Force Space Command, suggested that all new satellites for U.S. Air Force must be compatible with the "Multi-Mission Satellite Operation Center (MMSOC)". MMSOC initially established in 2006 is a trial ground system mainly used for demonstration of "Rapid Operationally Responsive Space" program. Characterized by plug and play, MMSOC is easy to modify and update, especially for safety. Leaders of the Air Force deem it as a potential prototype of the common ground architecture for EGS which will operate a number of constellations in the future.

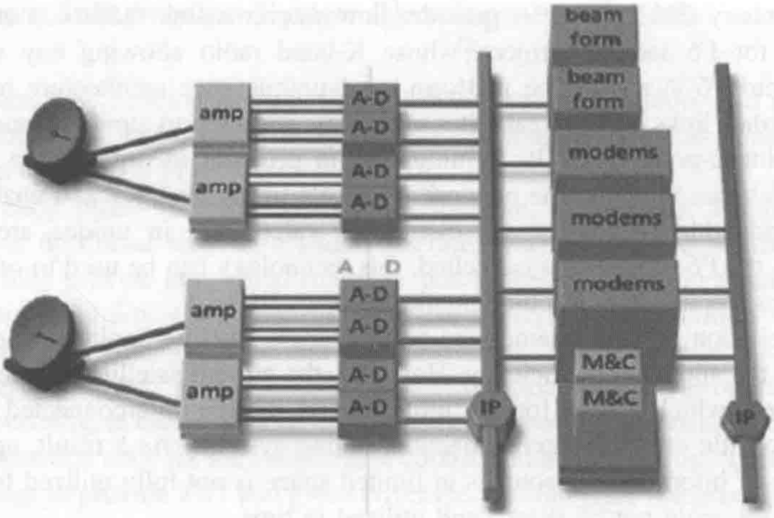

Fig. 1.1 Schematic diagram for SGSS resources pool

U.S. spares no effort to eliminate stove-piped nodes of the ground section. A typical example is the Space Network Ground Section Sustainment (SGSS) for tracking and data relay satellite (TDRS). Having been implementing from 2014 to the end of 2016, main objective of SGSS is to replace all hardwares and software of the space network for constructing a flexible, expandable, upgradable and supportable ground system. SGSS is of "pool" structure as shown in Fig. 1.1. A "resource pool" is formed by standardized and common system equipment. Although there is little special equipment for each TERS, equipment used to perform missions could be selected from the free resources in the pool and after mission, they will be returned to the pool for future use. With all ground terminals sharing the same resources in the pool, this "pool" structure not only decreases demand for equipment but also increases structure flexibility and utilization efficiency of hardwares.

In 1998, JPL initiated the Interplanetary Internet (IPN) [1] program which mainly focused on studying the scheme for end-to-end communication using network outside the Earth and a relevant draft for Internet Engineering Task Force (IETF) protocol was developed.

In 2001, U.S. Goddard Space Flight Center launched Operating Missions Nodes on the Internet (OMNI) which mainly developed the space communication scheme by using ground commercial IP protocol. OMNI took advantage of IP network, data rely satellites (TDRSS) to perform ground tests and airborne flight tests on shuttles, verifying feasibility of using ground IP protocol in space.

NASA plans to build an integrated network architecture as shown in Fig. 1.2 via Space Communications and Navigation (SCaN) program which will integrate existing Near Earth Network (NEN), Space Network (NE) and Deep Space Network(DSN) into one system around 2018. This integrated system will enable integrated management, control, strategy, telemetry, remote control and data

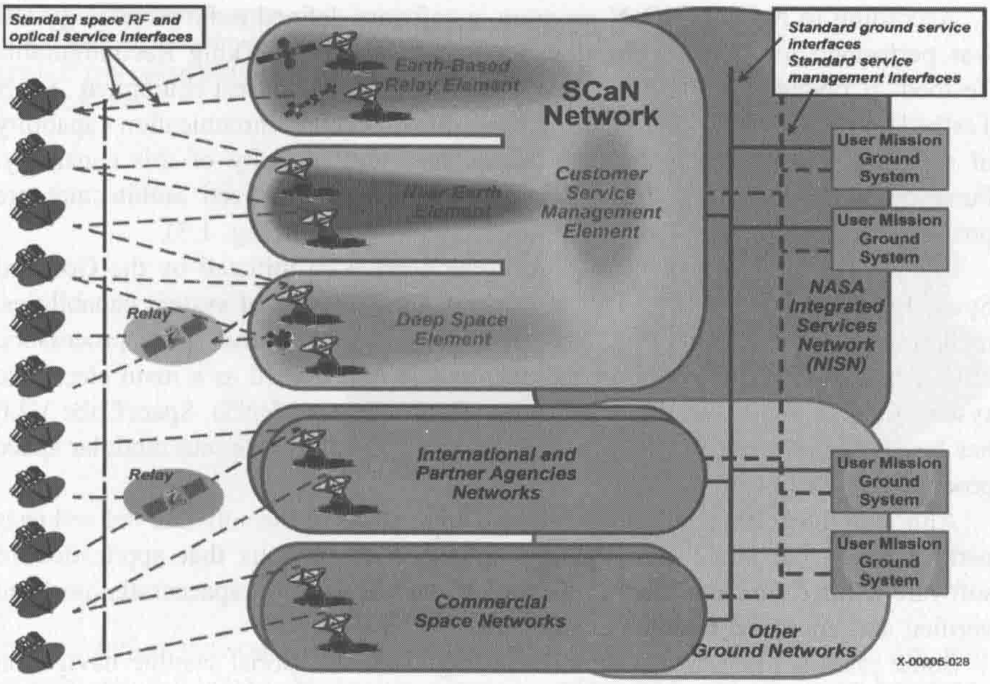

Fig. 1.2 Conceptual schematic for NASA integrated network system architecture around 2018

transmission for various spacecrafts via space/ground/sea-based TT&C navigation and communication resources, so as to gradually achieve the space-ground networking application of space-based information.

This shows that the development trend of the future space information system is to construct a networked, common and flexible space-ground information system, which will not only form ground and space networking, but also enable overall management and integrated application of space-ground resources, route and information, improvement of application efficiency of space-based information as well as more efficient control and management of space-based resources.

However, information application will be limited by the physical border of different platforms within various nodes or a single node caused by networked interconnection only limited among different nodes in the integrated space-ground network. If the satellite payload of space-based nodes still applies the traditional concept, i.e. special hardware/software combinations tailored by function needs leading to a one-to-one correspondence between the "carrier" (hosting hardwares for relevant functions) and the "payload" (functions need to be realized), which means one payload only for one function, information exchange between different functions, or nodes even within a single node will require more space links to meet the demands for information interaction and networking, consequently increasing the network load and requirements for resources processing.

To address this problem, the space-based information system specifically requires payload capacity which may load functions.

According to NASA's SCaN program, a software defined radio technology test was performed for "Communication, navigation and Networking Reconfigurable Testbed" (CoNNeCT) mission at the ISS in 2013. The major test equipment "ScaN Testbed" used software radio platform to enable on-orbit communication capability of software loading and verified the feasibility and maturity of this capability. Function-platform split mutual independence and standardized architecture are prerequisite for integrated application of software loading (Fig. 1.3).

The SpaceCube processing system research program initiated by the Goddard Space Flight Center (GSFC) in 2006 demonstrated a series of system capabilities, including computing capability and reconfigurability of typical space processors. NASA has approved potential of this technology and it used as a main electronic system for test payload of the Relative Navigation Sensor (RNS). SpaceCube V2.0 has basically met the requirements for a mixed, reconfigurable and modular space processing system (Fig. 1.4).

Although integration and multi-function application of the software defined tests performed on the space platform are limited, it is obvious that application of software defined function loading technology on the on-orbit spacecrafts has been verified and approved to some degree.

Some satellite systems of China (including "Beidou" global satellite navigation system [11], etc.) that gradually start to apply onboard processing, crosslink technology and space networking application mode could be independent from the

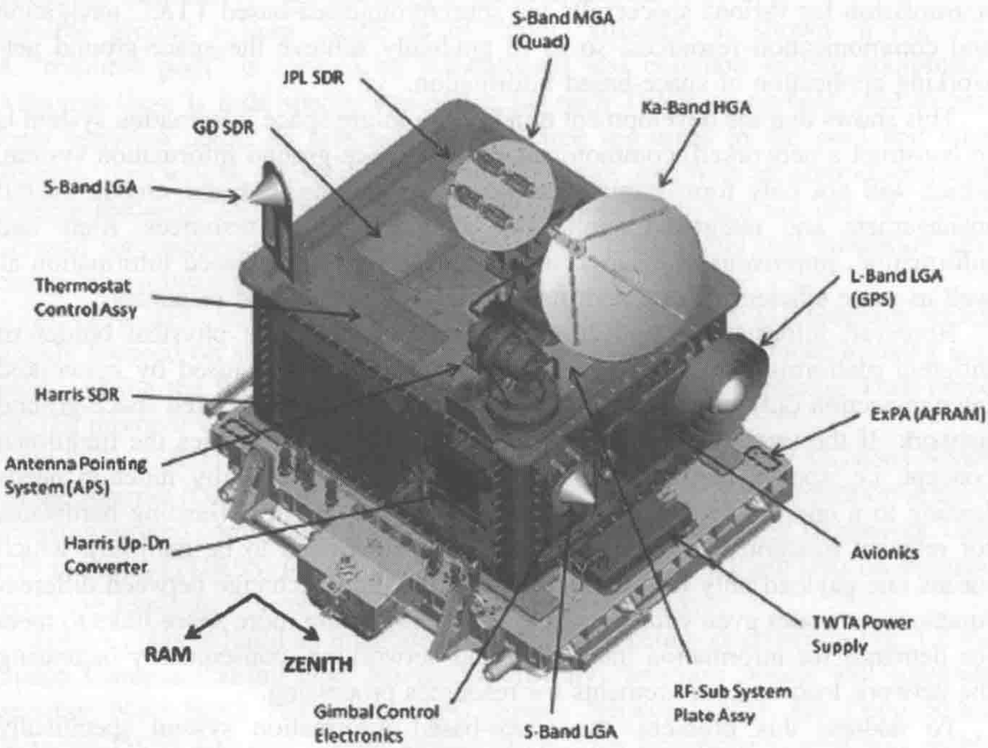

Fig. 1.3 SCaN testbed