Research on the Concept and Connotation of Space Proving Grounds (SPG)

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Abstract. In view of the limited overall planning of experiments in various fields of space technology/Science/application, the unclear mechanism faced by some core space technologies and the insufficient driving force of space as a strategic commanding point for the national economy and the people's livelihood, academician Luan Enjie put forward the concept of Space Proving Grounds (SPG) for the first time, hoping to systematically plan and lead the follow-up space test tasks by building a series of space facilities. SPG focus on three aspects: S science, E (exploration) and T (Technology). Through extensive investigation of the status quo of space tests at home and abroad, this paper puts forward the development trend of space experiments, studies the concept of space proving grounds, studies the composition of SPG from the three aspects of space segment, ground segment and soft environment. It also puts forward the phased objectives and system service framework in the future, so as to provide suggestions for China's "systematic and phased" construction of space test infrastructure, and provide decision-making reference for China's space test management to achieve "demand and high efficiency".

Keywords: Space Proving Grounds · Space technical tests · Space science

1 Introduction

Spacecraft is a type of equipment with the most complex system and the most advanced technology. It has high cost and needs to face the extreme and complex environment of space. For developing aerospace technology and equipment, it is necessary to go through the ground test stage, the space test stage and the application stage, of which the space test stage is the most indispensable and important one, which can accumulate flight experience for the development of spacecraft systems, reduce Satellite cost and reduce operational risk [1]. It is usually the first step to carry out space experiments and launching technology test satellites, for a country to enter the aerospace field.

With the advancement of technology and the further deepening of space cognition, the existing technical test system has been unable to satisfy the development demands of China's space technology, thus the construction of a basic space test platform serving China's space activities has become very urgent [2].

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At present, the United States, Russia, Germany and other major space countries have coordinated space tests to some extent [3–6], and carried out some space programs to coordinate space tests locally, including the "Space Test Program" (STP) carried out by the U.S. Department of Defense. The program of "On-Orbit Verification" (OOV) has been carried out by the German Space Agency and the plan of "Space Environment Reliability Verification Integrated System" (SERVIS) has been carried out by the Japanese Ministry of Economy, etc. These plans achieve the purpose of reducing duplication and reducing costs by establishing a platform for overall management of space experiments, setting up projects for space experiments or providing flight opportunities.

The space technology of China has developed to a critical stage of becoming a aerospace power. The construction of a space power requires a comprehensive understanding of the elements of space, and must strengthen the construction of space proving grounds to promote space science, space exploration, space applications and other fields. The overall and orderly development and technological progress of space resources will improve the efficiency of space resource application. The construction of the space proving ground is a comprehensive planning and top-level design for space experiments in various fields. It is necessary to clarify the concept and connotation of the space proving ground, study the framework and composition of the space proving ground, and provide support for China's comprehensive utilization of space resources.

2 Related Works

2.1 Development Status Abroad

Space is a testing ground for technological transformation and scientific progress. The purpose of the "Space Proving Ground" is to coordinate test projects and flight opportunities, avoid duplication of construction, and speed up technological upgrading. The core lies in sharing and coordination. Developed countries such as the United States consider the space as a test base, test a variety of advanced technologies, and promote them into applications [6–8], such as the International and Day Coexistence Program, the James Webb Space Telescope Program, and the Mars Exploration Mission Program [8–10]. NASA has substantially increased success rates and benefits by establishing a series of specifications and guidelines for the test site. The core is to use resources rationally, invest in more economical projects, and provide guidelines to ensure the effectiveness of NASA's investment. In particular, space technology experimentation is a technical area of particular concern to countries, but the way of development differs.

The United States has formed a relatively complete satellite technology test system, mainly based on a series of dedicated technology test satellites, including manned spacecraft platform loading and technical test parts of various application satellite series. In recent decades, a number of technical test satellite development plans have been formulated successively [1–3], among which the more famous ones are Lincoln Test Satellite Program (LES), Applied Technology Test Satellite Program (ATS), Space Test Program (STP) and New Prosperity Project (NMP) [4], etc.

"On-Orbit Verification" (OOV) is a national space program in Germany, which aims to provide test opportunities for applying new technology solutions to space projects, especially high-tech on-orbit verification. The key element of the plan is the demonstration flight of regarding the microsatellite "Technology Experiment Carrier" (TET) as a platform [5].

Russia has comprehensively developed a series of spacecraft such as communication and broadcasting, navigation and positioning, civil remote sensing, military reconnaissance, data relay, missile early warning, manned spaceflight, and space exploration. The early development scale was large, and the technical level in some fields was in a leading position. In the 21st century, since the total number of satellites launched by Russia has dropped sharply to less than 20, the number of satellites launched by its technology test satellites is very few.

Japan has formed a special and stable series of technical test satellites, and mainly relies on the series of technical test satellites to carry out engineering technology tests of various application satellites including communication and remote sensing.

Japan has vigorously carried out technology development in the fields of microsatellite technology, space optical communication technology, large-scale communication platform, mobile communication and broadcasting technology, broadband multimedia technology, commercial off-the-shelf (COTS) products and other fields. Many aerospace countries have formed two series of comprehensive space technology test satellites—Engineering Test Satellites (ETS) and space planes, including Communication and Broadcasting Engineering Test Satellites (COMETS), Optical Inter-orbit Communication Technology Test Satellites (OICETS) and a series of communication test satellites, etc.

2.2 General Situation of China's Space Experiments

According to the support channels, space technology test satellites of China have categories such as military, civilian, and enterprise-independent. As shown in Fig. 1, Space technology test channels also include manned serial loading, application satellite loading and other forms [11]. Figure 1 shows current technology test system framework in the field of satellite development. Among them, the enterprise independent technology test satellite series and the national civil technology test satellite series have just begun. For the civil technology test satellite series, which aims at verifying the development achievements of each "five-year" plan of national aerospace, improving satellite system capabilities, and solving satellite common problems, long-term planning at the national level is also required. Strict test project selection criteria, sufficient ground and on-orbit verification and rational use of limited funds are also necessary to enhance aerospace technology capabilities.

In general, the development of international space experiments shows the following trends:

- The space test verification system has been continuously developed and improved
- The test satellites move towards the special application test and the synchronous development of common basic support
- Participation in the test becomes more extensive, and the opportunity to enter orbit becomes more convenient

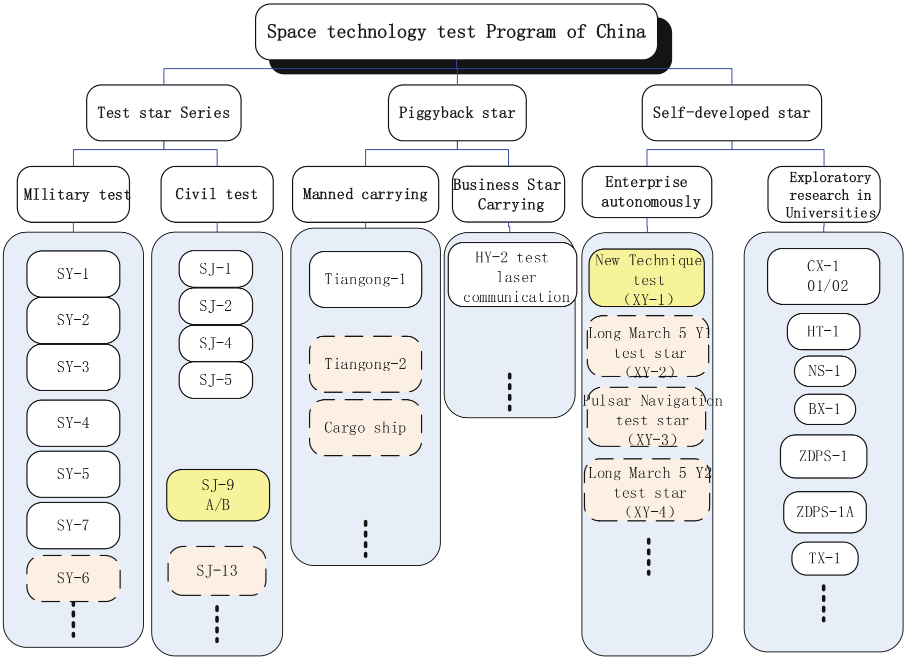

Fig. 1. Space technology test channel of China

3 The Concept and Connotation of Space Proving Grounds (SPG)

As an independent field of aerospace technology, space technology experiments of China focus on three aspects: S (science), E (exploration), and T (technology). Considering national conditions of China, relevant test tasks should include space science experiments tasks, technical verification test tasks, and application test tasks related to the national economy and people's livelihood.

The overall goal of the SPG is to build a basic space test facility for China, to implement space science, technological innovation, and application development "according to demand, into a system, and with high efficiency". Advanced layout to break through the international leading technologies such as near-earth space, in-situ arrival in the solar system, and extra-system remote sensing; build and improve the experimental engineering system for systematic access, cognition and control of space commanding heights and new frontiers; exploring major scientific discoveries and innovations, verifying key core technology products, smoothing the transformation mechanism of scientific and technological applications, and supporting the construction of major national projects related to the national economy and people's livelihood.

The SPG is: to "promote the comprehensive development of space science, space technology, and space applications", guide the strategic direction of space power, and implement a set of system coordination, standardized operation, and autonomous and controllable national space test infrastructure, including: 1) Sound soft environment. Establish a space experiment information system, to strengthen basic and normative research on space engineering and mechanism, innovation and application, military-civilian business sharing, etc., and form a national space experiment information database and management standard system; 2) Build an operation system. Demonstrate the spatial location of the proving ground and the layout of satellites, develop and deploy spacecraft in the space segment, and an operation center in the ground segment to form an integrated test operation system for space and earth; 3) Coordinate service demonstrations. Coordinate resources and needs, implement services through space experiments, and integrate verification, expansion, and demonstration of space engineering technology baselines, space application calibration benchmarks, and space science space-time benchmarks.

The service scope of the space proving grounds specifically covers four key tasks in space science, space exploration, space technology, and space applications, and finally can be used for China's existing high-resolution Earth observation major projects, space infrastructure, deep space exploration, manned, moon landing and other projects. It can provide calibration benchmarks and technical baselines, and supply experimental verification guarantees for detection and exploration. The details are shown in Fig. 2 below.

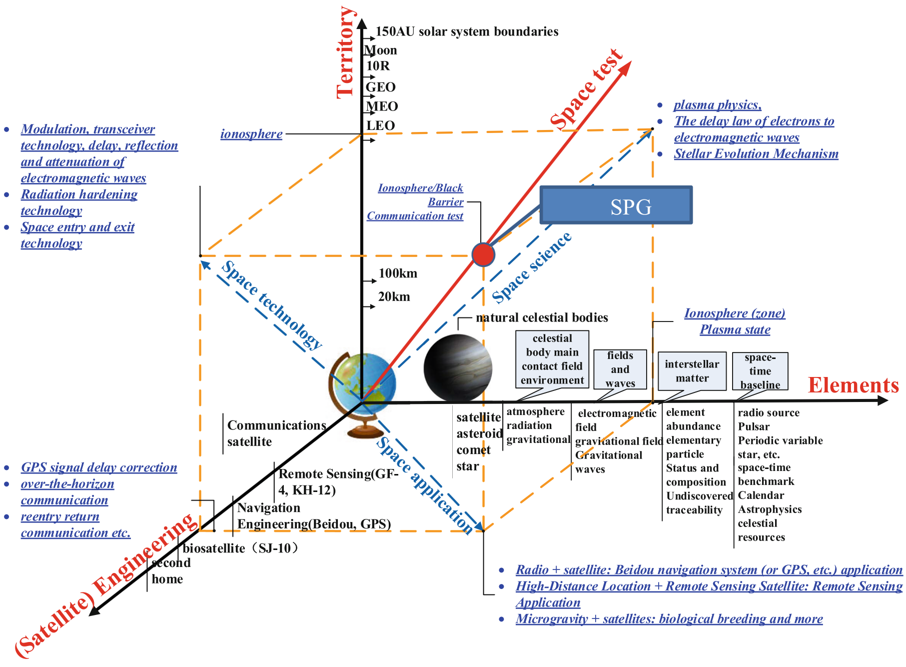

Fig. 2. Schematic diagram of the connotation of SPG

4 The Composition of the SPG

The SPG consists of three parts: the soft environment, the space segment, and the ground segment, which are shown in Fig. 3.

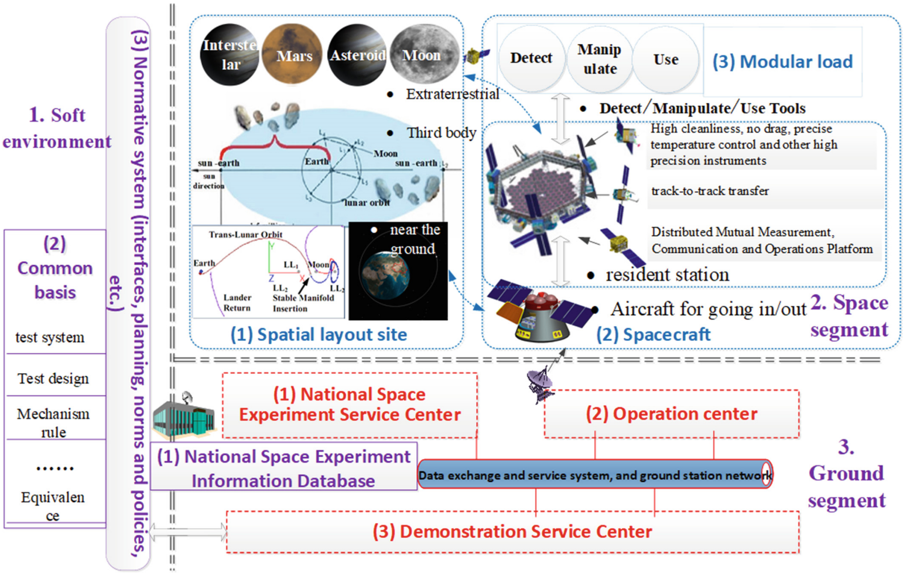

Fig. 3. Schematic diagram of the composition of SPG

4.1 Space Segment Design

The space proving grounds aims to be a national space test infrastructure that conforms to national conditions, develops in an orderly manner, and has a complete system. It coordinates the common needs of space science, technology, and engineering through tests, to form a functions-oriented space science platform architecture, which covers the six major capabilities of "entry, station, exit, exploration, control, and use".

The SPG is a materialized concept. It is based on the systematic perspective of space as a unified overall research. Oriented by application development, the SPG system will consist of a series of various technical test platforms and loads with multi-type orbital layouts. The orbits should be distributed, including large elliptical orbits and other tracks with special significance, etc.

Considering the space orbit design and the space physical characteristics, three categories of traditional low, medium and high orbits, space dynamic balance points and extraterrestrial objects are selected to design the space proving grounds structure. The space segment test platform is divided into types of locations, including low orbit test platform, medium orbital general test and transfer platform, high-orbit test platform, space dynamic balance point test platform, lunar test base and deep space exploration test base. Different users can choose different test platforms according to their needs.

4.2 Test Platform Design

For the LEO space experiments, the SPG continues to learn from the existing management plan, which adopts the space station as the long-term resident test platform, and uses various technology test satellites as the dynamic test platform to build the LEO space proving grounds. The low-orbit test mission can be launched into orbit by normal carrying or carrying into orbit, and can carry out technical tests related to active removal of space debris in LEO orbit, material space exposure flight test, application of new technology verification of satellite platform, new load technology test, sky Base comprehensive calibration and space benchmark technology test.

The SPG will set up a general test and transfer platform with a relatively fixed height in a suitable environment in the middle orbit. On the one hand, the platform is used to solve the common needs of the medium-orbit space test, and can also be used as a springboard for transferring to different orbit heights to solve the test needs at special orbit heights. On the other hand, as a transfer platform, it is necessary for the platform to have on-orbit refilling, charging or assembly capabilities. The medium-orbit test platform can be utilized to carry out space environment detection tests, on-orbit flight tests of new microelectronic devices and commercial devices, flight tests of new high-voltage solar cell arrays, on-orbit refueling tests, orbital transfer station related technology tests, and medium-orbit application satellite technology Tests and other related technical tests.

The cost of high-orbit satellites is high, and the available orbital resources are very limited. It is necessary to configure a general test site platform to stay in orbit for a long time to meet the needs of long-term and multi-type high-orbit test tasks. The high-orbit test platform can be used to carry out continuous real-time monitoring of the space environment detection such as the evolution process of active regions, the process of solar eruption, orbital radiation environment and radiation effects. It can also explored for flight tests such as new microelectronic devices and commercial devices, new high-voltage solar cell arrays, and spacecraft charge and discharge effects.

The dynamic balance point in space attracts many researchers. Various types of space exploration and technology application experiments can be carried out, and orbital position resources are extremely important. A general-purpose special test field is configured at the L1 point of the earth and the moon. This point can not only carry out test missions such as interstellar highways, but also serve as a transit platform for space exploration, providing for subsequent moon, Mars and interstellar exploration. It can support the development of deep space probe fueling, energy relay, communication relay, earth or orbiting satellite weapon delivery, communication navigation and earth observation (including electromagnetic spectrum).

The use of lunar test bases can realize the development and utilization of lunar resources, and carry out in-depth research and exploration of space science. It can also verify key lunar test base construction technologies such as lunar engineering construction, energy, lunar movement, thermal control, data communication, base structure configuration, life support and space protection.

4.3 Ground Segment Design

A dedicated data receiving and processing system for space experiments will be built on the ground, and a network of space experiment data receiving stations will be formed by establishing multiple data receiving stations to uniformly receive and manage the data of various space experiment platforms in the space segment. The SPG will develop a comprehensive information system platform for the reception and processing of space test data, and form a comprehensive database of space technology test projects, resources, on-orbit test databases, ground test databases, parallel management information systems, and assessment and evaluation result databases. The ground part of SPG will have the capabilities of data processing and distribution.

4.4 Soft Environment Design

First, the SPG makes it easy for users to design relevant application interfaces by clarifying the specifications of different sequence platforms, operation services and carrier interface services. At the same time, according to the national space test and evaluation standards, SPG will evaluate the feasibility of different test requirements, and reasonably select test projects.

Secondly, the on-orbit test operation management system, as a guarantee system for the test and verification of new space technologies, supports the unified planning of multiple space test platforms and tasks in the space segment, and completes the overall planning of various space technology test work. Effective operational management of life processes.

Finally, by improving the ground evaluation mechanism and facilities for space technology experiments, the informatization management and service capabilities of space technology experiments will be realized. An experiment mission planning and assessment evaluation platform will be built to support multi-satellite and multi-mission planning. The SPG also can effectively store and manage on-orbit test data information, and promote the rapid popularization and application of the results of major test projects.

5 Conclusion

This paper discusses the concept, connotation and development route of the space proving grounds. The SPG of China will build an engineering technology system for systematic entry and exit, cognition and control of space, avoid duplication of space resources construction, realize high-efficiency space experiments, and can be used as the next-generation space test infrastructure. The service platform system of the SPG has a variety of platform types, covering the six major capabilities of "entry, station, exit, exploration, control, and use", which will provide platform means for space science; will formulate national space test and evaluation standards and specifications, space technology capability baselines, and provide exploration for space technology.

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