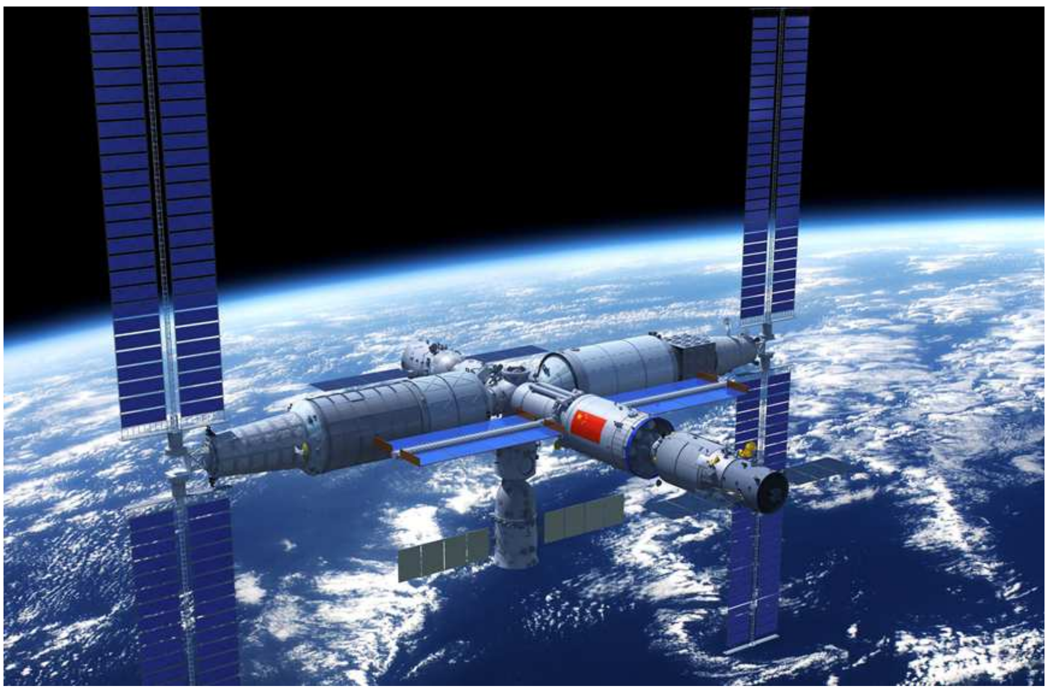
UNITED NATIONS
Office for Outer Space Affairs

CMS

Handbook

China Space Station and its Resources for International Cooperation

(Ver 1.0)



UN Office for Outer Space Affairs **China Manned Space Agency**

28 May 2018

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1. Overview of China Manned Space Program

1.1 Program Outline

On 21 September 1992, the China Manned Space Program (CMSP) was officially approved by the Government of China, a three-step program designed to build a permanently-manned Earth-orbiting Space Station.

The first step of this program was to launch a manned spaceship with the aim of building up the fundamental capability in human space exploration and space experiments.

The second step was to launch a space laboratory tasked with making technological breakthroughs for extravehicular activities, space rendezvous and spacecraft docking procedures, as well as providing a solution for man-tended space utilization on a certain scale and short-term basis.

The third step was to establish a Space Station with the aim providing a solution for man-tended -space utilization on a larger scale and longer-term basis.

At present, the first and second steps have been achieved while the third of setting up a manned Space Station is well underway.

SZ-1 SZ-2 SZ-3

SZ-4 SZ-5 SZ-6

Figure 1.1 First Step Missions

SZ-7 TG-1 SZ-8 SZ-9

SZ-10 TG-2 SZ-11 TZ-1

Figure 1.2 Second Step Missions

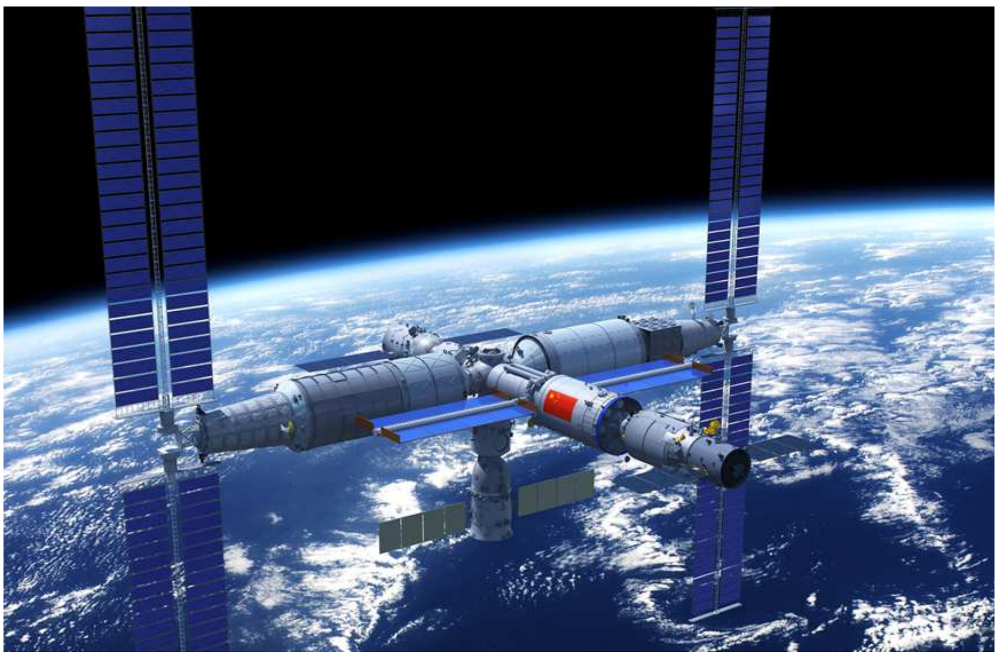


Figure 1.3 Third Step: Depiction of the manned China Space Station

Between 1999 and 2017, China has carried out 15 successful flight missions, from the Shenzhou I to Shenzhou XI as well as Tiangong I, Tiangong II, CZ-7 Debut and Tianzhou I. These missions made technological breakthroughs for manned space transportation, extravehicular activities, space rendezvous and spacecraft docking, mid-term accommodation for on-orbit astronauts, cargo transportation and on-orbit refueling, and were instrumental in helping establish a complete manned space engineering system.

In addition, the resources provided by the Shenzhou, Tiangong I, Tiangong II and Tianzhou I missions allowed for the execution of more than 100 space research experiments in various fields, such as earth observation, astronomy, life science, aerospace medicine, materials science, microgravity fluid physics, earth weather monitoring, space environment monitoring and forecasting, etc. The results of these experiments led to the harvesting of significant results and more than 500 payloads, showcasing the benefits behind the development of China's manned space program.

CMSP is run following a specialized management system. As a specialized agency and organizational command department, the China Manned Space Agency (CMSA) was set up to be responsible for the overall management of the CMSP. Its duties include organizing, guiding and coordinating the program's various departments and units to complete research, construction and experiment missions, and oversee and manage every dimension of the process and life-cycle of its technical programs, scientific research plans, infrastructure maintenance, quality control, operational management, etc. The CMSA is also responsible for international cooperation and exchanges with space agencies and organizations from other countries and regions for its manned Space Station on behalf of the Government of China.

1.2 Profile of the China Space Station

The China Space Station (CSS) will become the main scientific and technological laboratory in low-Earth orbit to contribute to the peaceful use of outer space technology and knowledge and the progress of humankind. The mission of the CSS Project is as follows:

1) To develop technology for long-term manned space flight and study related medical issues to find long-term solutions for the healthy living and efficient work of astronauts and lay the foundations for future exploration in long-term manned space flight;

2) To build a national space laboratory of an internationally advanced level for large-scale science and technology experiments, educative purposes and promote international/regional cooperation to study and uncover significant scientific results and benefits;

3) To establish a complete manned spacecraft operation and its corresponding operation and management systems, and to train a high-quality engineering and management team to lay the foundations for the future development of manned space exploration.

The CSS Project consists of both space and terrestrial elements (See Figure 1.4). The space element is composed of the "Tiangong" Space Station, "Shenzhou" manned spaceship, "Tianzhou" cargo vehicle and "Tianlian" data relay satellites. The terrestrial part is composed of the Beijing Aerospace Control Center (BACC), Payload Operation and Application Center (POAC), Space Science and Application Research Center, monitoring stations/ships, Jiuquan Satellite Launch Center, Wenchang Space Launch Site, Jiuquan Landing Site, etc.

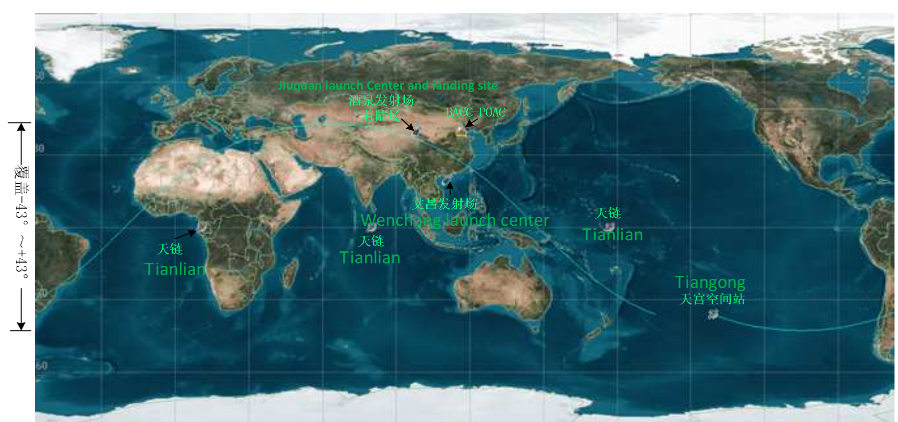


Figure 1.4 The Space/Terrestrial System of China's Space Station Project

The CSS is designed to operate in low-Earth orbit about 400km above the Earth's surface, with an inclination of approx. 41°~43°. The station's three main module components are horizontally symmetrical and T-shaped. The total mass is approx. 66 tons, and may reach approx. 100 tons when docked with several manned spaceships and cargo vehicles.

The three modules are launched separately into orbit atop the Long March CZ-5B rockets from the Wenchang Space Launch Site and then assembled into a T-shaped configuration. Manned spaceships are launched atop the Long March CZ-2F carrier rockets at the Jiuquan Satellite Launch Center to send crew and supplies to the station and return them and few supplies back to Earth. Cargo vehicles are launched atop the Long March CZ-7 carrier rockets at the Wenchang Space Launch Site to bring food supplies, experiment facilities and other supplies to the Space Station, and remove and destroy waste in the atmosphere.

The data relay satellites in geostationary orbits provide up- and down-link capabilities to transmit voice, image and data to and from the Space Station.

As the mission control center of the CSS Project, the Beijing Aerospace Control Center (BACC) is responsible for the CSS's command and dispatch procedures, flight control, data processing and data exchange.

The POAC is the Earth-based operational management center for the CSS's science and application research, including status monitoring and payload control, health management, data processing and distribution, etc. Other science and application centers around China control the CSS's payloads through the POAC and carry out space science experiments and research based on data obtained from the CSS payloads.

1.3 System Composition

The CMSP consists of the Astronaut System, Space Utilization System, Spacecraft System, Carrier Rocket System, Launch Site System, TT&C and Communications System, Landing Site System, etc.

1) Astronaut System

The Astronaut System is responsible for ensuring the long-term health and efficiency of astronauts onboard the spacecraft. Its main tasks are building a qualified astronaut team for Space Station operations, selecting flight crews, establishing living protocols onboard the Space Station, establishing health protection systems to ensure safe and habitable conditions on the spacecraft, and studying and developing advanced medical and human support systems and technologies to ensure the efficient work of astronauts in space.

Figure 1.5 Astronauts Under Water Training

2) Space Utilization System

The Space Utilization System is responsible for science research. Its primary mission includes planning, organizing and managing science research projects, developing and using space science and operational payloads of manned spacecrafts and the CSS, building space and terrestrial support facilities, organizing and implementing scientific experiments and research on manned space flights and achieving significant scientific results.

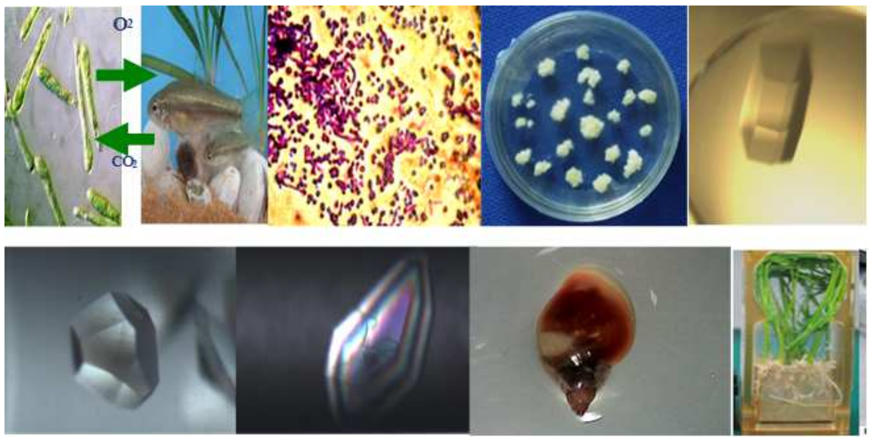


Figure 1.6 Space Utilization System

3) Spacecraft System

There are five spacecraft systems: Manned Spaceship System, Cargo Vehicle System, Space Laboratory System, Manned Space Station System and Optical Module System.

The primary mission of the Manned Spaceship System, comprised of the Shenzhou manned spaceships, is crew rotation and station resupply.

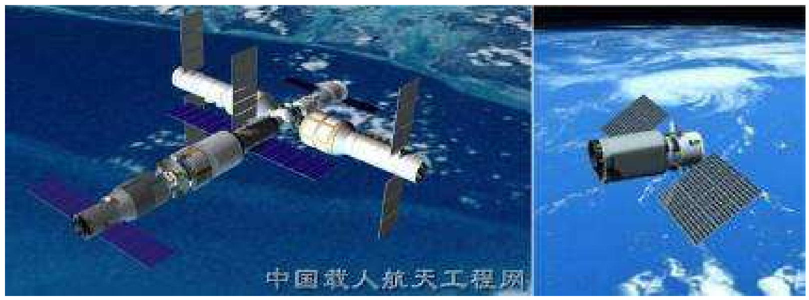
The Cargo Vehicle System is comprised of the Tianzhou cargo vehicles which are used for delivering supplies and payloads, refueling, on-orbit storage and disposal. It will reenter Earth's atmosphere in a controlled manner following a preset path after mission completion.

The Space Laboratory System consists of the Tiangong 1 and Tiangong 2 Space Labs, which are the foundation for the development of the Manned Space Station System.

The Manned Space Station System consists of the China Space Station (CSS) named "Tiangong" and the Earth-based monitoring, control, operation and research application centers. The CSS serves as a large scale and long-term manned space laboratory in which crew members live and conduct experiments. Three modules are equipped with various onboard scientific experiment racks and outboard exposed platforms and hanging points to support various science and research projects. During on-orbit operations, the Shenzhou and Tianzhou will rendez-vous and dock with the Tiangong. The Shenzhou will then complete a crew rotation while the Tianzhou will deliver supplies and return any waste.

The optical module, the main section of the Optical Module System, is launched into orbit separately and flies along the same orbit as the CSS. It can support multi-color photometry, seamless spectrum survey and Earth observation with multi-function optical capabilities. If necessary, it can dock with the CSS for refueling, equipment maintenance, payload equipment upgrade and other maintenance activities.

The Manned Spaceship The Space Lab The Cargo Vehicle



The Space Station The Optical Module

Figure 1.7 Spacecraft System

4) Carrier Rocket System

The CMSP involves three carrier Long March rocket systems: the Long March CZ-2F Carrier Rocket System, the Long March CZ-7 Carrier Rocket System and the Long March CZ-5B Carrier Rocket System.

The Long March CZ-2F Carrier Rocket uses conventional propellant. With a carrying load of 8 tons on low-earth orbit, it is mainly used for launching the Shenzhou spaceship.

The Long March CZ-7 Carrier Rocket is a medium-sized rocket using a liquid oxygen/kerosene engine. With a carrying load of 13.5 tons on low-earth orbit, it is mainly used for launching cargo spaceships.

With a carrying load of 23 tons in low-earth orbit, the Long March CZ-5B Carrier Rocket is used to launch the modules of the CSS. This carrier rocket is so far the launch vehicle with the largest carrying capacity in China.

CZ-2F Carrier Rocket CZ-7 Carrier Rocket CZ-5B Carrier Rocket

Figure 1.8 Carrier Rocket System

5) Launch Site System

The Jiuquan Satellite Launch Center (JSLC) and Wenchang Space Launch Site (WSLS) are used to launch spacecrafts. The JSLC is used to launch manned spaceships and space laboratories while the WSLS is used to launch the Space Station's modules and cargo vehicles.

Jiuquan Satellite Launch Center Wenchang Space Launch Site

Figure 1.9 Launch Site System

6) TT&C and Communications System

The Telemetry, Tracking and Control (TT&C) and Communications System is mainly responsible for measuring, monitoring and controlling the flight path, altitude and operating status of the rockets and spacecrafts, providing channels for video and voice communications with the astronauts and sending scientific data back to Earth. It consists of a number of command and control centers, fixed domestic tracking stations, foreign tracking stations, mobile tracking stations, oceangoing surveying vessels, and Tianlian data relay satellites. With a downlink data transmission ability of 1.3Gbps, China's new generation of data relay satellites cover the entire world.

Figure 1.10 TT&C and Communications System

7) Landing Site System

Located in Jiuquan, Gansu Province, the landing sites are used for the return of the astronauts to Earth in the re-entry capsules. Its main task is to track, search and locate the landed re-entry capsules, rescue the astronauts and refurbish and recycle the re-entry capsules and payloads.

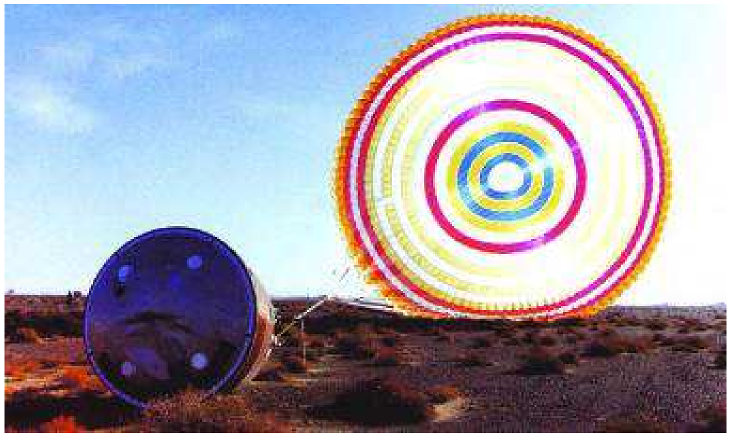


Figure 1.11 Landing Site System

1.4 Future Plan

China will complete the construction of the CSS around 2022, and build onboard facilities used in a wide variety of research fields including space medicine, astronomy, life science, microgravity science, Earth science and space technology. The Shenzhou and Tianzhou will be regularly launched to ensure the stable operation of the Space Station and its long-term manned space flight. The Space Station will be utilized to its maximum capacity to carry out long-term manned scientific space and technology experiments. These results will be shared and transferred to promote industrial progress, providing new momentum for the sustained and healthy development of China's national economy.

2. Basic Structure and Technical Conditions of the China Space Station

2.1 Basic Structure

The main structure of the Space Station includes the Core Module (CM), Experiment Module I (EM I) and Experiment Module II (EM II), forming a horizontally symmetrical T-shaped structure. With the front end of the CM pointing in the flight direction (see Figure 2.1), the CM is used to control and manage the Space Station's assembly and to provide living quarters and work areas for the astronauts. The two EMs are mainly used to support space science research.

The CM is the Space Station's management and control center, supporting the rendezvous, docking and berthing of the Shenzhou and Tianzhou spaceships, long-term visits of astronauts and supply of materials. Facilitated by robotic arms, the CM can support astronauts' extravehicular activities.

The EM I has the ability to manage and control the Space Station and act as a back up for some of the key platform functions of the CM. It is the astronauts' main living quarters and emergency shelter and can support onboard and outboard space experiments. A special airlock module and small robotic arms are provided to support astronauts' extravehicular activities and the outboard experiment payloads with the help of the robotic arms of the CM.

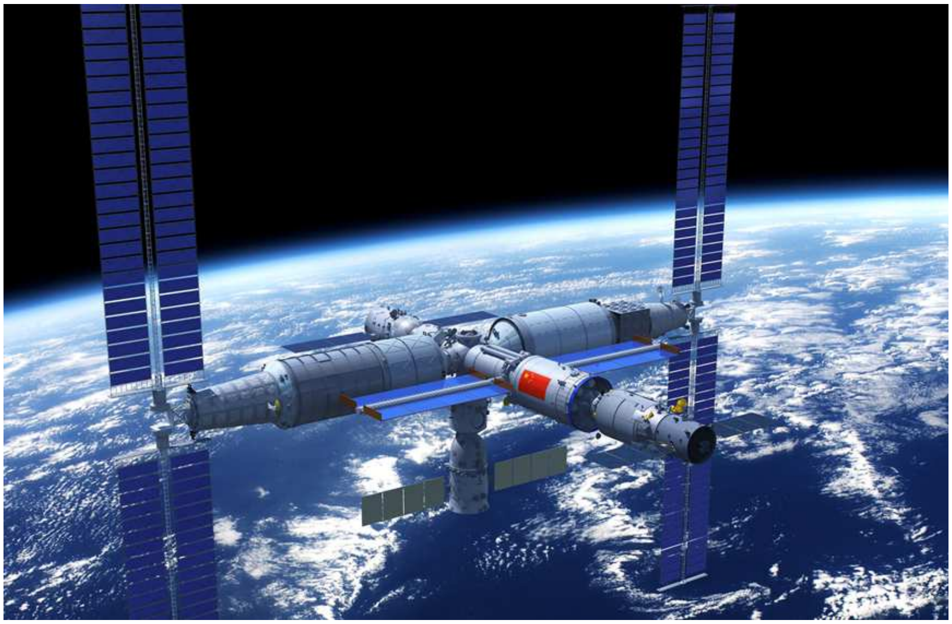


Figure 2.1 Configuration of the China Space Station

The EM II is used to carry out the onboard and outboard space experiments. It consists of the resource module, the payload module and the working module. Inside the payload module is equipped with a cargo airlock module to support the loading and unloading of payloads and equipment by the astronauts assisted by the robotic arms.

The pressurized modules of the CM, EM I and EM II are equipped with scientific experiment racks to support space and technology experiments in areas such as life science and biotechnology, aerospace medicine, microgravity fluid physics and combustion science, materials science, and multi-purpose science.

Multiple standard payload interfaces and large payload hanging points are provided on the exterior of the CM, EM I and EM II to support astronomical and Earth observation, space material experiments, biological experiments and other outboard experiments.

2.2 Technical Characteristics

The main technical characteristics of the China Space Station are listed in Table 2.1.

Table 2.1 Main Technical Characteristics of China Space Station

No.	Item		Technical Characteristics
1	In-orbit life span (after the assembly of the three modules)		≥10 years
2	Total mass		≥66T
3	Power supply capacity		Power supply capacity ≥ 27kw; Payload power consumption capacity≥12kw
4	Manned capacity	Number of crew members	3 (rated) or 6 astronauts (at most)
		Stay period of a crew	≥180 days
5	Support for astronaut extravehicular activities	Airlock module	2 modules, located in CM and EM I.
		Number of extravehicular astronauts	2 astronauts
		Allowed time for a	≥8 hours

No.	Item		Technical Characteristics
		extravehicular activity	
6	Operating orbit	Orbital altitude	340km～450km
		Orbital inclination	41°～43°

2.3 In-orbit Operation of the Robotic Arms

The CM and EM I are equipped with a set of robotic arms. The CM's robotic arms are mainly used to support the extravehicular activities of astronauts, outboard cargo handling, outboard status examination, outboard equipment maintenance and replacement, hovering and docking activities. With the ability to transport large modules, they can support the in-orbit assembly of modules. The robotic arms of the EM I are primarily used to support outboard payload operations, astronauts' extravehicular activities, outboard status examination and outboard cargo handling.

Standard outboard payloads can be deployed by the EM's robotic arms using preset plans and the engineering tolerance of payload adapters. Large outboard payloads can be installed using a cascaded combination of both sets of robotic arms.

2.4 Upward and Downward Transportation Support

1) Spaceships' Transportation Capacity

The Shenzhou manned spaceships can deliver astronauts and supplies to the Space Station and return back to Earth the astronauts, experiment samples, equipment and other materials as well as dispose of waste elements.

The Tianzhou cargo spaceships can deliver goods and supplies to the Space Station and dispose of waste. There are fully pressurized, semi-pressurized and unpressurized cargo spacecrafts which can support the pressurized transport of supplies, outboard facilities and experiment platforms, etc.

2) Payload Transport Support

The Shenzhou and Tianzhou can provide power supply, data and thermal support for the payloads during their transportation.

3) Spacecraft Docking Support

The Space Station provides rendezvous and docking, grid connection, personnel and material transport, and thermal support for each spacecraft. It can also control pressure, humidity and atmospheric conditions in the pressurized module.

4) Payload Transport between Modules

Pressurized transport channels are formed by rigid connections between pressurized modules to support the passage of astronauts and materials.

2.5 Flight Crew Support

1) On-orbit Experiment Support Capability

All astronauts have the capability to perform space experiments and other tasks, including on-orbit operations, status monitoring, sample replacement, recovery and disposal as well as on-orbit construction and the expansion of payload projects as required.

2) On-orbit Payload Maintenance and Replacement

Onboard astronauts have the capability to repair and replace intravehicular and extravehicular payloads.

3. Space Utilization Fields and Orientation

Research and experiments in thirteen (13) fields and directions have already been made possible under the framework of China manned space programme, by taking advantage of the support capability of the CSS, its microgravity and radiation environment, long-term human habitation, upward and downward transportation service, crew rotation and re-supply of living goods. The science research fields include space medicine, life science, biotechnology, microgravity fluid physics, microgravity combustion science, materials science, basic microgravity physics, astronomy, astrophysics, physics, space environment and geosciences.

Space medicine research and experiments will focus on the relevant key scientific issues and innovative protective technology to counter the "human risk/factor" restricting long-term manned space flight. It is aimed at establishing a complete assessment of the "human risk/factor", provide theoretical and technical reserves for long-term space flights, explore possible solutions for major human medical and health problems, and improve the ability of astronauts to live in-orbit.

Research and experiments in space life science and biotechnology will focus on the reactions of the living body to gravity variations and radiation damage. They will also look at the origins of life, evolution, development and fecundity, taking advantage of the Space Station's regular long-term microgravity, magnetic field, rapid changes in day and night, special radiation and other environmental conditions. The objectives of this research are to promote the understanding and cognition of the fundamentals of life and the uncovering of the laws of science. Technology and applications in this field can also fall into the development and use of biological technologies in order to promote the development of modern life sciences and biotechnology, improve human health and help advance social progress.

Relevant experiments in microgravity fluid physics and combustion science aim to reveal the workings of fluid mechanics and the combustion process of flowing materials under microgravity. The research could improve the use of technologies, advance long-term human space exploration activities and the development of life on Earth as well as new ground- and space-based materials and technologies, thus contributing to the resolution of the Earth’s resources and environmental issues and the sustainable development of society.

Research and experiments in space materials science focus on improving and developing material science theories, guiding and promoting ground material processing technologies, studying and producing high performance materials of important scientific significance, and testing the performance of space materials. The results of this research could reveal the laws of the physical and chemical processes of materials in a microgravity environment and contribute to the development of new materials science.

Research, experiments and technology applications in basic microgravity physics focus on material structure and laws of motion in a microgravity environment, the physical properties and laws of the four fundamental interaction forces (gravity, electromagnetic force, weak force and strong force). The research will strive for breakthroughs in relevant fields and test existing physical theories (such as the theory of relativity, electrodynamics, and particle standard model as well as nuclear theory) and discover new physical phenomena and physical laws such as the gauge theory of gravitation, supergravity and the large unified theory.

Research and experiments in space astronomy and astrophysics focus on studying black holes, dark matter, dark energy, the origin and evolution of the universe and of celestial bodies, the search for extraterrestrial life and other cutting-edge scientific issues by conducting high-precision photometry and spectrum surveys on the largest scale in the world. Major scientific and technological achievements and revolutionary discoveries are expected from this research.

Research and experiments in space physics and space environment focus on studying and forecasting solar proton events, studying relations between the sun, magnetosphere and ionosphere at mid and low latitudes with the aim of ensuring the long-term habitation and extravehicular activities of astronauts in space.

Research and experiments in the application of space geoscience could focus on the mesosphere interaction of earth science, the influence of human activities on the global environment and ecology, and geoscience related issues such as natural disasters. Taking into consideration the characteristics of a non-polar orbit and the long-term monitoring of the Space Station, research will also focus on developing a new generation of high-precision, quantitative space remote-sensing technologies, obtaining multi-dimensional information about land, sea, atmosphere and earth systems, and conducting research on natural disasters and environmental pollution monitoring, marine monitoring, resource exploration, food security, etc.

4. On-orbit Facilities for Space Experiments and Applications on board the Space Station

4.1 Inboard General Science Experiment Racks

A certain number of general science experiment racks in the pressurized modules of the Space Station will have been provided with free space for international partners to develop and equip their own payloads and experiment facilities. The payloads and experiment facilities will be installed inside payload units to be developed by international partners. Each general experiment rack provides different kinds of interfaces for accommodating multiple payload units. Onboard astronauts could install payload units and replace them with new ones, allowing space experiments to be conducted in a rolling fashion.

The interfaces include mechanical interfaces, power supply interfaces, data interfaces and thermal interfaces, as well as nitrogen, vacuum and venting interfaces. There are three types of specifications for payload units namely the Standard Payload Unit (SPU), Standard Drawer Unit (SDU) and Standard Payload Locker (SPL). The internal thermal control units can provide liquid cooling for multiple payload units through cooling pipes connected in parallel or in a series. The nitrogen, vacuum and venting interfaces are available to some payload units in the general science experiment racks.

4.2 Inboard Domain Research Experiment Racks

A number of scientific experiment racks in the pressurized modules of the Space Station will have been equipped with experiment facilities for scientific and technological research in different fields. Each experiment rack functions as a small space lab that supports research on space science in one or more research domains. International partners can take advantage of these facilities to conduct their experiments by developing experiment units or providing samples or designs independently or jointly with the China Manned Space Agency.

The overview, main functions and research topics of these research experiment racks are illustrated each below:

Table 4.1 Human System Research Rack

<table>
<tr><td>Overview</td><td>The human system research rack supports the research of the physiological effects, psychological characteristics, and changes of human capacity under long-term space travel, as well as human experiments aiming at developing new protective technologies. Important research and/or application value are expected from these innovative experiments.</td><td>
Schematic Diagram
Subject to change</td></tr>
<tr><td>Main Functions</td><td colspan="2">1) Physiological function experiments on the human body's cardiovascular, muscles, bones, nervous systems, etc., as well as experimental data synchronization and acquisition.
2) Measurement of the human body's basic ability, biological rhythm, operating status and performance, and study of confrontation and intervention methods.
3) Cultivation facility suitable for a microgravity space environment to provide stable nutritional conditions for the cultivation and reproduction of medical cells, tissues and organs. The temperature, liquid displacement and gas components of the cultivation environment can be controlled, supporting the normal growth, proliferation and differentiation of biological samples.
4) On-orbit nutritional metabolomics study based on Raman spectroscopy;
5) Monitoring, precise observation and on-orbit analysis and detection are supported during the experiments.
6) The replacement of on-orbit test samples and modules is supported.</td></tr>
<tr><td>Research Topics</td><td colspan="2">1) Effects of long-term weightlessness on astronauts' health and on protective technology.
2) Effects of space radiation on astronauts' health and on protective technology.
3) Behaviors and abilities of astronauts.
4) Advanced on-orbit monitoring and medical treatment.
5) Application of Chinese traditional medicine to aerospace medicine.</td></tr>
</table>

Table 4.2 Medical Sample Analysis Rack

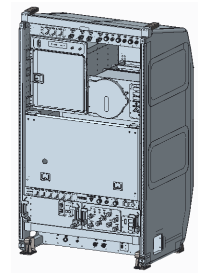
Overview	The medical sample analysis rack is designed to support real-time on-orbit detection and biochemical index analysis of the body fluids of astronauts, reflect the health status of the organism, and support the testing of medical biology samples and the study of astronaut metabolomics.  Schematic Diagram Subject to change
Main Functions	1) Centrifugal separation of samples; 2) Refrigeration of agents and samples at 4℃; 3) Multi-index on-orbit detection analysis including human body fluid sample and cell biological sample based on chip lab technology.
Research Topics	1) Effects of long-term weightlessness on astronauts' health and protective technology. 2) Effects of space radiation on astronauts' health and protective technology. 3) Behaviors and abilities of astronauts. 4) Advanced on-orbit monitoring and medical treatment. 5) Application of Chinese Traditional Medicine to aerospace medicine.

Table 4.3 Ecological life Experiment Rack

Overview	The ecological life experiment rack is used for studying the effect of microgravity on biological life, including plants, small mammals, insects, aquatic organisms, microbes, etc., tissues at the microscopic cellular level and the macroscopic holistic level, as well as basic research on ecological life support systems in space.  Schematic Diagram Subject to change
Main Functions	1) Environmental control and life support for multiple types of biological samples like biochemical molecules, tissues, microbes and plants. Featuring good biocompatibility. 2) Cultivation methods suitable for a microgravity space environment to achieve dynamic control of temperature, liquid displacement and gas components of the cultivation environment to provide stable nutritional supply conditions for the growth of biological samples, and to support the normal growth, proliferation and differentiation of biological samples.

	3) Monitoring of space experiment processes and the precise observation of biological samples. 4) Component testing for gas in an experimental cultivation environment. 5) Microbiological testing of the entrance and exit area of experimental cultivation. 6) Real-time measurement of particle type and energy spectrum of the space radiation field in the experimental module. 7) Capability to replace and extend experiment samples and modules.
Research Topics	1) Gravity biology. 2) Space radiation biology. 3) Space biotechnology and its applications. 4) Fundamental research on ecological life support systems in space.

Table 4.4 Biotechnology Experiment Rack

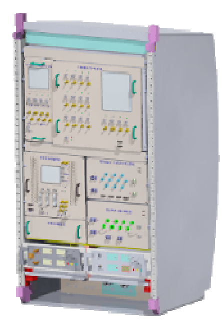
Overview	The biotechnology experiment rack is set up for space biotechnology research on biological cells and tissues, microbes, animals, etc., as well as basic biology research on cell and tissue samples.  Schematic Diagram Subject to change
Main Functions	1) Suitable life support and environmental conditions for various categories of biological samples, such as molecules, cells, tissues, small animals and small mammals; Featuring good biocompatibility. 2) Cultivation methods suitable for a microgravity space environment to achieve the control of temperature, liquid displacement, gas components and other elements of the cultivation environment, to provide stable nutritional supply conditions for the growth of biological samples, and to support the normal growth, proliferation and differentiation of biological samples. 3) Dynamic monitoring of space experiment processes, observation of biological samples, in-situ detection of biological samples, monitoring of animal physiological parameters, and dynamic analysis of metabolites. 4) Accurately measurable microgravity levels in the experimental area. 5) Capability to replace and extend experiment samples and modules.
Research Topics	1) Space biotechnology and its applications. 2) Space radiation biology. 3) Forefront and cross study of space life science. 4) Space-based biology.

Table 4.5 Fluid Physics Experiment Rack

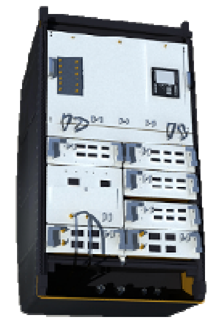
Overview	The fluid physics experiment rack carries out research on basic laws of the macroscopic and microscopic movement of fluids , diffusion process, heat and mass transfer in a space environment as well as complex fluid research and experimental research for transparent space materials, space life sciences and biotechnology.  Schematic Diagram Subject to change
Main Functions	1) Real-time diagnostic methods for static and dynamic light scattering, spectroscopy, turbidity and other rheology parameters in the course of complex fluid experiments; Preprocessing of image data. 2) Accurately measurable microgravity levels in the experimental area. 3) Ability to replace and extend experiment modules.
Research Topics	1) Microgravity hydrodynamics and its applications. 2) Complex fluid. 3) Mechanisms for material preparation processes in a microgravity environment. 4) Crystal growth kinetics and protein crystallization. 5) Process of space biotechnology-related fluid transportation.

Table 4.6 Two-Phase System Experiment Rack

Overview	The two-phase system experiment rack is implemented for research on key scientific issues and technical applications, such as space evaporation and condensation transformation, boiling heat transfer, two-phase flow and loop systems, and space fluid control.  Schematic Diagram Subject to change
Main Functions	1) Observation methods for the morphology of gas-liquid interface (bubble and droplet) and phase transition of liquid layer and liquid film, two-phase fluid flow or spray atomization. The surface temperature field is measured. 2) Gas and liquid fluid required by the experiment in which the temperature, flow and pressure can be adjusted and controlled. The gas environment required by the experiment is effectively controlled. 3) Capability to replace and extend experiment samples and modules.
Research Topics	Two-phase flow, phase transition, heat transfer and their applications.

Table 4.7 High Temperature Materials Science Experiment Rack

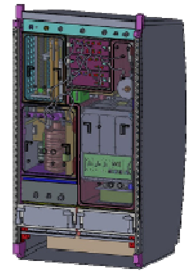
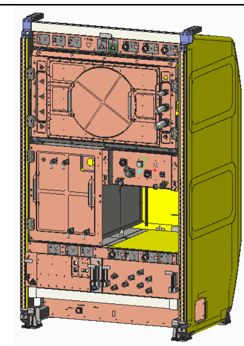
Overview	The high temperature materials science experiment rack is implemented for scientific experiments for melt growth and the solidification of multiple types of materials, such as metal alloys, semiconductor optoelectronic materials, nano and mesoporous materials, and functional inorganic materials.	 Schematic Diagram Subject to change
Main Functions	1) High-temperature heating of materials, sample movement and rapid cooling to find the solution for material thermal environment management such as heating temperature curve and temperature gradient control. 2) Rotating magnetic field to achieve active control of the melt flow during the preparation of space materials. 3) Real-time on-line detection of resistance, conductance, diffusion coefficient, Seebeck coefficient and other parameters of material samples. 4) X-ray fluoroscopy and real-time optical observations to obtain visual information and data on solid/liquid interface morphology and the effects of interface transport in the sample preparation process. 5) Accurately measurable microgravity levels in the experimental area. 6) Capability to replace and extend experiment samples and modules.	
Research Topics	1) Mechanisms for the materials preparation process in a microgravity environment. 2) Preparation and research on materials with an important application background.	

Table 4.8 Combustion Science Experiment Rack

Overview	The combustion science experiment rack supports combustion research in a microgravity space environment, including fundamental combustion questions and techniques, rocket propulsion, and applications in manned space flight.	 Schematic Diagram subject to change
Main Functions	1) Providing an environment for combustion experiments under microgravity conditions and meeting combustion requirements for various solid, gas and liquids;	

	2) Having sufficient means of measurement and diagnosis. Measurable experimental parameters include the flame structure, temperature, pressure, velocity, product component concentration and spectral characteristics. 3) Capability to purify and dispose of exhaust gas.
Research Topics	Fundamental combustion science and its applications in a microgravity environment.

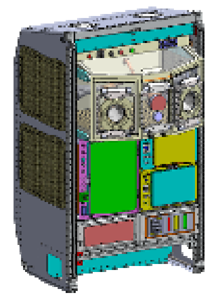
Table 4.9 Container-Free Materials Science Experiment Rack

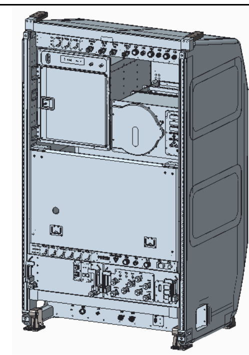
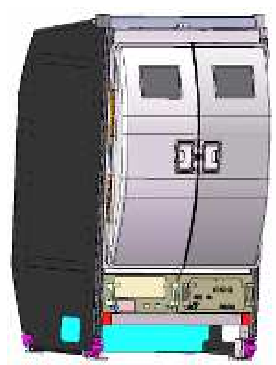
Overview	The container-free materials science experiment rack allows for container-free processing through electrostatic levitation technology and is used to carry out research on metal, non-metallic and other container-free processing as well as the deep supercooling of materials.  Schematic Diagram, subject to change
Main Functions	1) Container-free processing environment to avoid container wall effects on materials' properties and achieve a deep supercooling capacity of the material. 2) Capability of direct in-orbit measurement to allow for accurate measurement of the starting point of material solidification and determine the relationship between supercooling characteristics and supercooling solidification of the material. 3) Ability to obtain accurate data on melting, start of solidification, completion of solidification, cooling, and the completion of processing of materials during the container-free processing of materials. 4) Accurately measure the thermophysical properties of high temperature materials such as density, surface tension, viscosity coefficient, specific heat, solidification latent heat and conductivity, providing basic data for material research. 5) Capability of nucleation trigger of the material in microgravity. 6) Capability to replace and expand experiment samples and modules.
Research Topics	1) Mechanisms of material preparation processes in a microgravity environment. 2) Preparation and research on materials with important applications background.

4.3 Inboard General Supporting Racks and Facilities

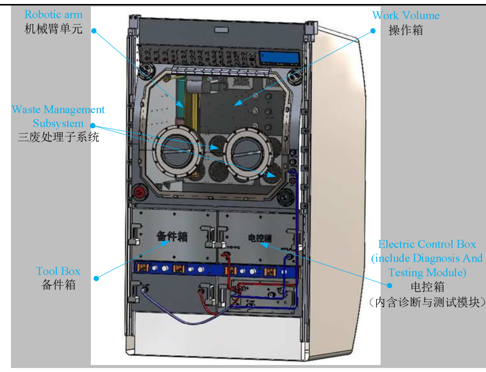
To satisfy the common demands of space experiments utilizing domain experiment racks, general support racks and facilities are developed and deployed onboard the China Space Station. They include a scientific glovebox, freezers, a high microgravity rack, a variable gravity rack, an online maintenance and adjustment operation facility, and an independent payload support facility. Their functions are illustrated described below:

Table 4.10 General Supporting Racks and Facilities

Rack/ Facility	Description of Main Functions
Scientific Glovebox & Freezer Facility	The scientific glovebox is mainly employed for the isolation, airtight and specific operation of various scientific experimental samples. Research on space medicine, space life science and biotechnology, space materials science, microgravity fluid physics, basic physics and other directions are supported. The freezer facility is equipped to store samples at low temperatures.  Schematic Diagram Subject to change
	Main functions of the scientific glovebox: 1) Astronauts could transfer or replace experiment facilities, samples, diagnostic instruments and other items through the door of the glovebox; 2) Astronauts could install and debug experimental facilities and directly or remotely operate scientific experiments through the wrist (entrance) of the glovebox; 3) Astronauts could observe the items in the glovebox and the operation process directly through the internal instrument or by connecting to a laptop; 4) Astronauts could check the experimental results and screen the result by operating instruments equipped with the glovebox; 5) The environment (light, humidity, temperature, gas, etc.) within the glovebox is controllable and adjustable and can be disinfected; 6) Supporting precise or micro operations such as injection, extraction and separation; 7) Providing power, communication and installation conditions for the experimental facilities or scientific instruments inside the glovebox; 8) Providing interface capabilities for the laptop to inspect and manage the experiment facilities; 9) Supporting tele-science operations.
	Main functions of the Freezer Facility: 1) Three typical low temperatures are provided to meet the storage requirements of samples; 2) The samples in the three low temperature storage zones may be accessed independently; 3) Each low temperature storage zone features temperature detection, display and high temperature alarm; 4) Each low temperature storage zone is frost-free; 5) Liquid water generated in the process of refrigeration and operation may be collected; 6) When each low temperature storage zone is opened, auxiliary lighting comes on automatically;

	7) Each low temperature storage zone is designed to prevent condensation; 8) The low temperature storage device may be tested and managed by the controller of the experiment racks.
High Microgravity Science Experiment Rack	By using levitation technology, the rack could effectively provide microgravity experimental conditions at the microgram level for experimental payloads, thus supporting research on microgravity hydrodynamics and its applications, mechanisms for material preparation processes and relativistic and gravitational physics.  Schematic Diagram Subject to change
	1) Providing mechanical, power, measurement and control data and thermal control interfaces; 2) Different experiments may be performed through the replacement of experiment payloads; 3) Interface is provided for laptops to examine, test and manage the rack; 4) Astronauts may participate in experiment management and sample recovery; 5) Supporting tele-science operation.
Variable Gravity Experiment Support Facility	It achieves the separation of microgravity from other space environmental effects by establishing a simulated experimental gravity environment through centrifugal technology and comparison with the experimental results in the microgravity environment. The rack is suitable for multidisciplinary research such as basic space biology, forefront and cross study of space life science, space ecological life support system and fluid science, two-phase flow, phase transition heat transfer and applications.  Schematic Diagram Subject to change
	1) Supporting various standard experiment modules which may be combined for use; 2) Providing experiment modules with mechanical, power supply, command, data and thermal control interfaces. The experiment modules may be replaced conveniently in orbit; 3) Dynamically adjusting balance to adapt to the change in status due to the replacement of experiment modules;

<table>
<tr><td></td><td>4) Measuring acceleration of the variable gravity area to determine its gravity level;
5) Providing interface capabilities for a laptop to detect and manage the support facility;
6) Astronauts may participate in managing experiments and replacing and retrieving samples;
7) Supporting tele-science operation.</td></tr>
<tr><td rowspan="2">In-orbit Maintenance/Installation/Commissioning Support Platform</td><td>It supports specific mechanical operations of scientific and technical experiments, structural and electronic assembly, and other operations and testing validation, as well as research on space robotics and remote science technology.



Schematic Diagram
Subject to change</td></tr>
<tr><td>1) Providing online diagnosis and test function;
2) Supporting structural lubrication, structural assembly, electronic assembly, and other specific maintenance operations;
3) Supporting in-orbit precise operation, and capability to clean and sterilize internal payload modules;
4) Providing independent experimental modules and scientific instruments with mechanical, power and thermal interfaces;
5) Providing space welding mechanisms and processes for homogeneous / heterogeneous materials, the experimental study of the use of functional space-oriented materials, and experiments on new equipment components and parts;
6) Capability to replace and extend experiment modules;
7) Dealing with exhausts, effluents and waste residues;
8) Astronauts may participate in experiment management and sample recovery;
9) Providing interface capabilities for a laptop to detect and manage the support platform.</td></tr>
<tr><td>Independent Payload Support</td><td>Independent payload support facilities are equipped to provide interfaces of heat, power and data for independent payloads inside the Space Station. It provides:
1) Interfaces for installation of standard payloads in different specifications. Support for installation of non-standard payloads by a combination of multiple standard interfaces;
2) Integrated payload management equipment to provide power supply, monitoring and data interfaces for independent payloads;
3) Payload thermal control unit to provide interface for independent payload;
4) Interfaces for high purity nitrogen, vacuum or exhaust gas.</td></tr>
</table>

4.4 Exposed Experiment Support Facility

4.4.1 Standard Experiment Support

Exposed platforms are deployed on the exterior of the EM I and EM II of the Space Station on which standard interface support equipment, called payload adapters, are installed to provide standard mechanical, electrical, thermal and data interfaces for exposed payloads to support exposed experiments. International partners can use payload adapters to carry out exposed scientific experiments by developing exposed payloads.

A standard exposed payload is installed on a payload adapter. A large exposed payload could be installed through the combination of multiple payload adapters. A payload adapter includes an active end and a passive end. The passive end is set up on the exposed platform while the active end is attached to the exposed payload.

The cargo airlock module of the EM II provides access for payloads to Station modules. Astronauts inside the module operate the robotic arm for on-orbit mounting and replacement of exposed payloads. In order to achieve in-orbit mounting of standard exposed payloads, the robotic arm target adapters are required to be attached to exposed payloads.

When mounting exposed payloads on orbit, astronauts will attach them to the egress mechanism of the cargo airlock module of the EM II, then operate the robotic arm to grab the target adapter. After taking it off the egress mechanism and moving it to the desired position at the passive end of the exposed platform payload adapter, they will perform the docking, locking and electrical connection between the active and passive ends of the payload adapter. The strategy applies to dismounting exposed payloads from exposed platforms.

4.4.2 Non-standard Experimental Support

In order to support specific exposed payload experiments that require a long testing period and hold significant scientific and application value, mounting points for large payloads and an expanded experimental platform are also deployed on the exterior of the CM and EM I.

Large payloads will be delivered to the Space Station by cargo spaceship and will be mounted onto the payload mounting points by on-orbit astronauts using the robotic arm.

5. On-orbit and Ground Support Conditions for Space Experiments

5.1 On-orbit Support Conditions

On-orbit support conditions include the information utilization system, payload power distribution management equipment, fluid circuit, and nitrogen supply system and space environment element monitoring payload.

1) The information utilization system is used to implement classification and hierarchical management of payloads, and enable data access at high, medium and low data rates. The system features high-performance data processing, data transmission, mass storage, shared information broadcasting, uplink data transmission and forwarding, payload monitoring and control support, etc. It is used to meet the needs of control, management, data processing and transmission of payloads on the Space Station.
2) The payload power distribution management equipment is used for managing the power

supply and distribution as well as energy management. Integrated with the information utilization system, it makes for the efficient, optimized use and reliable control of energy.

3) The fluid circuit is used to support and manage the cooling of the intravehicular scientific experimental platforms and independent payloads mounted in vacant payload spots.
4) The nitrogen supply system is used to support and manage the intravehicular scientific experimental platforms and independent payloads mounted in vacant payload spots where nitrogen is needed.
5) The space environment monitoring payload is equipped on the exterior of the CM and EMs, providing space environment security for the long-term operation of the Space Station, providing support for the space environment measurement of extravehicular scientific experiments, and providing information for basic research on the space environment.

5.2 The Ground Support Conditions

The ground support system for space experiments onboard the China Space Station consists of the Payload Operation and Application Center (POAC), Center for Space Environment Research and Prediction, Space Science and Application Center, as shown in Figure 5.1.

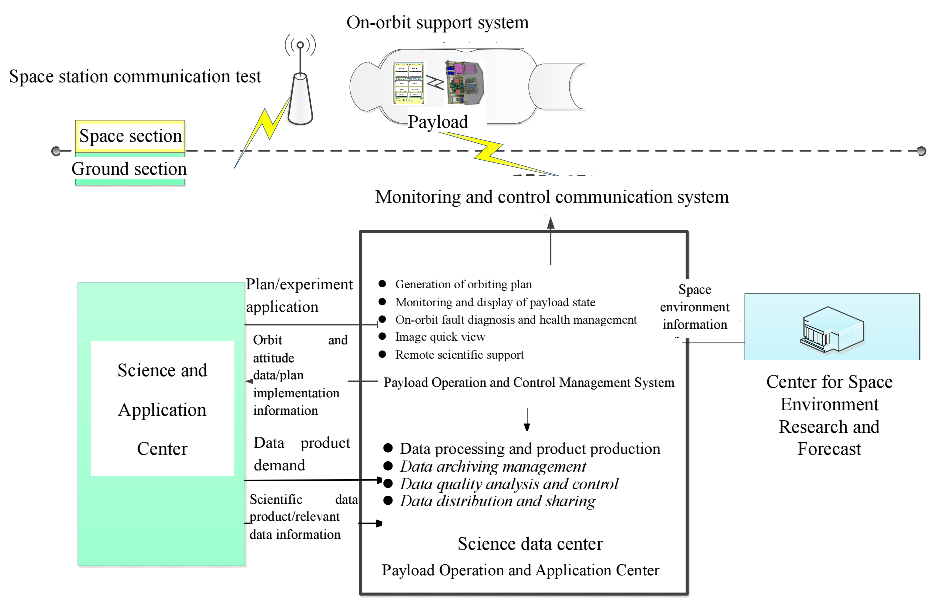


Figure 5.1 Ground Support Conditions for Space Experiment

The Payload Operation and Application Center is a science operation control center for China's manned space flight control, supporting space science experiments and research. It is composed of the Payload Operation and Control Center and the Data Application Center. It provides operational support for payload and scientific experiment facilities onboard the Space Station, provides monitoring and management support for the long-term steady in-orbit operation of payloads onboard the Space Station and provides comprehensive data support and guarantee for scientific research.

The Science and Application Center serves scientists in various fields based on missions and objectives of all the science and research fields of the Space Station. Through experimental verification, experimental sample preparation, scientific data processing and analysis and technical ground support it carries out large-scale astronomical observation research, earth science research and application, as well as research on materials and life sciences and so on, to promote the output and use of major scientific results.

The Center for Space Environment Research and Forecast is responsible for forecasting the space environment and provides support for the entire Space Station project on this theme.

Each science and application center needs to submit an experiment application to the POAC which will generate a specific command that will be uploaded to the Space Station through the monitoring and communication control system. It will then be transmitted to the payload for execution after being processed by the application system. The POAC is responsible for the in-orbit management of the condition and troubleshooting of the payloads. After being processed by the application information system, the experiment data of the payloads will be downloaded to the POAC for pre-processing and then transmitted to each science and application center for research.

6. Development and Operation Support System

6.1 Development Phases

The execution of a space project follows the development process of China's Manned Space Program, which includes four phases: Design Phase, Engineering Development Phase, Production and Deployment Phase, Launch and Performance Phase.

6.1.1 Design

It includes the following tasks:

1) Coordinate the available platform and overall technical resources;
2) Design payloads, scientific experiment schemes and system interfaces in a layered manner;
3) Tackle any problems in key technologies and interfaces with other systems;
4) Conduct a simulation of the system, plan and conduct prototype developments and tests as necessary.

6.1.2 Engineering Development

It includes the following tasks:

1) Develop the engineering model of the payloads;
2) Conduct comprehensive ground tests such as flight calibration and experiments to verify functions, performance and technical specifications;
3) Conduct quality testing such as quality assurance, safety and reliability control, and performance verification;
4) Conduct systematic and comprehensive environment simulation tests at approved levels;
5) Conduct ground-based research on space experiments.

6.1.3 Production and Deployment

It includes the following tasks:

1) Develop flight products;
2) Conduct routine environment tests at acceptable levels;

3) Assess functions, performance and technical specifications of the flight models;
4) Conduct reliability tests;
5) Conduct system verifications by testing the products in a systematic and comprehensive integration system;
6) Conduct every verification test in spacecraft flight platforms;
7) Make on-the-ground preparations for space experiment research.

6.1.4 Launch and Performance

It includes the following tasks:

1) Establish operational procedures for the experiment;
2) Launch the experiment-related payloads;
3) Conduct on-orbit tests for the payloads;
4) Conduct experiments following the established procedure;
5) Monitor the experiment;
6) Conduct ground-based comparative experiments in parallel;
7) Perform post-flight analyses on scientific experiment data and samples;
8) Evaluate overall mission efficiency and promote experiment achievements.

6.2 Development Support System

The development support system under the framework of the China Manned Space Program includes parallel design, simulation and verification systems and the flexible integration test system.

6.2.1 Parallel Design, Simulation and Verification system

The parallel design and simulation verification system is designed to complete mission planning, parallel design, comprehensive simulation and verification, and offer mirror support for science experiments. This system may facilitate the parallel design of payloads, optimization of related astronaut operational plans, uplink/downlink planning, control and maintenance plans and verification and simulated drills of each plan, all through interface with the simulation and verification systems. Each part has the following main functions:

1) The mission planning and parallel design provide technical support and comprehensive information management for payload design and optimization, product development and test and verification.
2) The comprehensive simulation and verification systems provide a solution for mission planning to verify its effectiveness and enforceability; provide verification and corrections for mission models and payloads and system models in each phase to optimize the development process; provide model simulations for other ground systems such as flexible integration test systems and software evaluation and verification systems.
3) The mirror support platform may provide technical support and good environmental conditions for space experiment planning, the preparation of experimental units and samples, experiment design and verification, simulated drills, ground control experiments, sample and data processing and the analysis and management of experiment results.

6.2.2 Flexible Integration Test System

This system provides tests on different levels, scales and/or statuses, including the integrated test of interfaces, the function and work modes of payloads, interface matches tests, integration tests and system tests at spacecraft module levels for a single device or platform, facility and individual payload system.

6.3 Operation Support System

The operation support system includes the payload operation and control management system, science data center, space environment research and forecast center, and the science and application center.

1) The payload operation and control management system is designed to monitor and display the on-orbit operation status of payloads. It could receive medium and long-term operation, control and maintenance plans from the mission planning system and convert it into a payload operation plan, which will uniformly manage the on-orbit operation of payloads, guide astronauts to participate in the construction, maintenance, replacement, operation and control of payloads and provide support for executing in-orbit tasks.
2) The science data center is designed to store downward data. It could receive and process downstream data, analyze and control data quality, archive all science data and data production, distribute and share with users the data for scientific research and application, conduct data exchange services for international cooperation and support outreach activities.
3) The space environment research and forecast center is designed to release long-term, medium-term and short-term space environment forecasts and warnings of disastrous accidents in a space environment, prepare preventive and mitigation measures against the accidents to ensure successful launches and the safe long-term, in-orbit functioning of the Space Station. The center also makes assessments on the space environment effect and offers suggestions on preventive and migration measures against accidents in a space environment.
4) Relying on domestic strengths, the science and application center is to conduct in-depth scientific and application research, increase the capacity in space science research and application and achieve significant results. The center mainly consists of the center for astronomical science studies, the center for earth science studies and application, and the disciplinary research laboratory.

7. General Requirements for Payload Development

1) Payloads should be designed, developed and tested in accordance with the China manned space engineering standards, the norms of the Space Station and space system operations, and should be able to withstand all environment conditions during the whole flight mission;
2) Maintainability design should be applied to the payloads. Maintenance strategies should be prepared scientifically, and maintenance and repair will be carried out by astronauts or the robotic arm to ensure a safe and reliable payload. The maintainability design should meet the ergonomic requirements and pass ergonomic evaluation;
3) The engineering design of the payloads should meet the medical requirements of the Space Station and pass the independent evaluation;
4) The items to be sent to space on a cargo spaceship and to/from space through a manned spaceship should meet the related requirements of the spaceships;
5) During normal operation or in malfunction mode, the normal running of other systems should not be affected, and particularly, the health and safety of astronauts should not be endangered;
6) The electromagnetic compatibility design and test of the payloads should be carried out

according to the manned space engineering standards, the norms of the Space Station and the norms of the space system utilization;

7) The software of the payloads should be developed in accordance with the manned space engineering standards and the norms of the space system utilization;
8) The design, development and test of the payloads should also consider and meet the requirements in terms of mechanical, thermal, electrical and data design, data communication design, safety, reliability and maintainability design, environment adaptability, ergonomic design, medical requirements, microorganism control, electromagnetic compatibility and grounding design requirements, as well as waste disposal.

8. Operation and Development Planning of the Space Station

The in-orbit assembly of the basic configuration of the three modules of the China Space Station is planned to be completed around 2022 when the station is operational and able to carry out large-scale space science research. Astronauts will be living on the Space Station for long term, crew rotations guaranteeing an uninterrupted orbit presence. The Space Station supports the long-term stay of astronauts without interruption or unmanned short-term flights.

The life span of the Station can be further extended by maintenance, replacement, upgrading and expansion to enable longer term space science research. Primarily, extensible interfaces are reserved on the Space Station. After completion of the basic configuration of the three modules, the inboard and outboard utilization support capabilities can be enhanced further by adding extra modules. Secondly, outside the modules of the Space Station, many large-scale payload mounting points and extensible experiment platform interfaces are reserved, through which more payload support capability can be provided. In addition, based on the need of space science research and international cooperation, the Space Station can meet the needs of evolving space science research through the maintenance, replacement and extension of payloads.

9. Principle and Mechanism of Cooperation on Utilizing the Space Station

9.1 Cooperation Principle

The principle of Peaceful Use, Equality and Mutual Benefit, and Common Development should always be pursued in order to ensure a cooperative environment and activity within the scope of China's manned space program. Following these principles, China is willing to cooperate with any other countries in different areas including space science research, astronaut selection, training and flight, and manned space technology and its applications.

9.2 Cooperation Mechanism

1) International Partners to Develop Experiment Facilities or Exposed Payloads

International partners can develop experimental facilities or exposed payloads independently or jointly with the China Manned Space Agency. The experiment facilities will be installed in the reserved racks dedicated to international cooperation, or deployed onto the exposed platforms outside the CSS. The intravehicular support equipment needed for extravehicular payloads for international cooperation are arranged in the reserved racks in the EM I and II. The developed facilities and payloads will be uploaded to the CSS for on-orbit assembly during the operation period of the CSS.

2) International Partners to Provide Experiment Schemes

International Partners can only propose experiment schemes such as experimental samples, experimental units or experimental designs independently or in cooperation with the China Manned Space Agency and conduct experiments by using the experimental facilities or exposed payloads already developed by China or by adding extra relevant facilities. The experimental unit and samples can be delivered to the Space Station together with the EM or by cargo transportation during the construction of the CSS.