* 1. **Main specifications of the spacecraft. General requirements for spacecraft design**

The main specification of the spacecraft include Payload Weight，Payload Size and shape，Payload Power，spacecraft weight，spacecraft power，solar array area，booster diameter，pointing requirement。

设计的总体要求：Functional performance design requirements, manufacturing process requirements, testability, testability, maintainability requirements, economic cost requirements, development cycle requirements, development risk requirements, and development connection requirements.

**1-2 Propulsion systems in the spacecraft structure**

推进系统承担着卫星轨道与姿态控制、轨道与姿态机动及位置保持等各种功能。

推进系统的要求分两部分：飞行功能要求和系统设计要求。

推进系统包含冷气推进系统、固体推进系统、单组元推进系统、双组元推进系统、双模式推进系统、电推进系统。

The propulsion system is responsible for various functions such as satellite orbit and attitude control, orbit and attitude maneuvering, and position retention.

Propulsion system requirements are divided into two parts: flight function requirements and system design requirements.

The propulsion system includes a cold air propulsion system, a solid propulsion system, a single-element propulsion system, a dual-element propulsion system, a dual-mode propulsion system, and an electric propulsion system.

**2-1 Classification of spacecraft. Main technical characteristics of spacecraft**

航天器按是否载人可分为无人航天器和载人航天器两大类。无人航天器按是否环绕地球运行又分为人造地球卫星和空间探测器两大类。载人航天器可分为载人飞船、空间站和航天飞机。人造地球卫星分为科学卫星、技术试验卫星和应用卫星；空间探测器分为月球探测器和行星探测器；载人飞船分为卫星式载人飞船和登月载人飞船。

航天技术已成为一门具有完整体系的综合性工程技术，它主要包括：喷气推进、火箭制导和控制、航天器轨道控制、航天器姿态控制、航天器热控制、航天器电源、航天遥测、火箭设计与制造、航天器设计与制造、火箭与航天器实验、航天器返回、航天生命保障、航天系统工程等技术。

Spacecraft can be divided into unmanned spacecraft and manned spacecraft according to whether they are manned. Unmanned spacecraft are divided into two categories: man-made earth satellites and space probes according to whether or not they orbit the earth. Manned spacecraft can be divided into manned spacecraft, space stations and space shuttles. Artificial earth satellites are divided into scientific satellites, technology test satellites and application satellites; space probes are divided into lunar probes and planetary probes; manned spacecraft are divided into satellite-type manned spacecraft and moon-landing manned spacecraft.

Aerospace technology has become a comprehensive engineering technology with a complete system, which mainly includes: jet propulsion, rocket guidance and control, spacecraft orbit control, spacecraft attitude control, spacecraft thermal control, spacecraft power supply, spacecraft telemetry, rockets Design and manufacturing, spacecraft design and manufacturing, rocket and spacecraft experiment, spacecraft return, aerospace life support, aerospace system engineering and other technologies.

**2-2 Evaluation of the energy cost of the orbital transfer maneuvers**

The #V budget is traditionally used to account for this energy. It is the sum of the velocity changes required throughout the space mission life. In a broad sense the #V budget represents the cost for each mission orbit scenario

**3-1 Main stages of spacecraft development. Criteria for evaluating the results of the development**

航天器的发展历程：航天器的发展大致可以分为三个历程，这三个阶段可以分为 探索实验阶段，完善实用性系统阶段，战术应用为主的新阶段。

The development process of spacecraft: The development of spacecraft can be roughly divided into three phases. These three phases can be divided into the phase of exploration and experiment, the phase of perfecting the practical system, and the new phase of tactical application.

These three stages fully reflect the spacecraft from simple to complex, functional diversification of the direction of development, but its most fundamental purpose is still exploration and discovery, only continuous exploration and discovery can obtain innovation.

**3-2 Spacecraft crew life support systems. Radiation hazards in space.**

载人航天器生命保障系统是在飞机环境控制系统和生物卫星生命保障系统的基础上发展起来的。它除包括压力、温度、湿度、供气和空气分配等环境控制系统外，还设有航天员系统，即航天员的饮食、休息、睡眠、排泄等日常生活保障系统。

The life support system for manned spacecraft is developed on the basis of the aircraft environmental control system and the biological satellite life support system. In addition to environmental control systems such as pressure, temperature, humidity, air supply, and air distribution, it also has an astronaut system, that is, the astronaut’s daily life support system such as diet, rest, sleep, and excretion.

空间辐射对人体和设备都会造成危害。辐射对人体的影响主要表现在两个方面：严重的短期影响；有延迟的长期影响。其中长期影响是空间辐射的主要危害，典型的有癌症、遗传性疾病等。电离辐射环境同样也会对设备与表面材料产生影响，对设备造成短时间或永久性的损坏。

Space radiation can cause harm to the human body and equipment. The effects of radiation on the human body are mainly manifested in two aspects: serious short-term effects; delayed long-term effects. Among them, long-term effects are the main hazards of space radiation, typically cancers, genetic diseases, etc. The ionizing radiation environment will also affect the equipment and surface materials, causing short-term or permanent damage to the equipment.

**4-1 Features of interplanetary spacecraft**

星际航天器是对太阳系内各行星进行探测的无人航天器。特点是：在空间进行长期飞行，地面不能进行实时遥控，所以必须具备自主导航能力；向太阳系外行星飞行，远离太阳，不能采用太阳能电池阵，而必须采用核能源系统；承受十分严酷的空间环境条件采用特殊防护结构；在月球或行星表面着陆或行走，需要一些特殊形式的结构。

The interstellar spacecraft is an unmanned spacecraft that probes the planets in the solar system. Its characteristics are: long-term flight in space, real-time remote control on the ground cannot be carried out, so it must have autonomous navigation capabilities; flying to outer planets in the solar system, far away from the sun, can not use solar arrays, but must use nuclear energy systems; withstand very harsh Special protective structures are adopted for space environmental conditions; landing or walking on the surface of the moon or planets requires some special forms of structures.

**4-2 Materials used for spacecraft structure**

针对不同的使用环境载荷和不同的结构形式，航天器结构用材料可以分为两大类：结构材料和功能材料。结构材料主要指用于提供刚度、强度、安装边界、结构外形的材料，大量使用的是复合材料和金属材料。功能材料主要指用来提供各种特定功能（如防热、密封、胶接、润滑等）的材料，使用量比较多的是防热材料。

In view of different environmental loads and different structural forms, the materials used in spacecraft structures can be divided into two categories: structural materials and functional materials. Structural materials mainly refer to materials used to provide rigidity, strength, installation boundaries, and structural appearance. A large number of composite materials and metal materials are used. Functional materials mainly refer to materials used to provide various specific functions (such as heat protection, sealing, bonding, lubrication, etc.), and heat protection materials are used more frequently.

**5-1 The main trends in the development of spacecraft. Composition of the** **space complex. Features of manned space stations.**

the development of spacecraft is mainly focused on the following three aspects: to further improve the ability to obtain information from space and transmit information, expand the scope of application; Accelerating experiments in the production of new materials and products under space environment conditions: exploring space using solar radiation energy to provide new energy. Getting information, materials and energy from space will be a long-term problem in space development. But with advances in technology, these ideas could become reality in the near future.

space complex consists of space labs and spacecrafts.

The space station is characterized by relatively large size, complex structure, long flight time, many functions, and many space scientific research projects. But it needs to be economical and can be operated by no one.

**5-2 Technological requirements for spacecraft design**

航天器设计是在火箭和导弹技术的基础上，为实现太空飞行，综合利用现代先进的科学技术成果而发展起来的，是航天工程的重要组成部分。航天器设计通常分为可行性论证、方案设计、初样设计和正样设计4个阶段。

航天器技术亦称空间飞行器技术，是对航天器进行设计、制造、发射、跟踪、返回和控制的技术。包括温度控制技术、姿态控制技术、轨道控制技术、无线电控制技术、生命保障技术等，是一种技术和知识密集型的高技术群。

Spacecraft design is developed on the basis of rocket and missile technology to realize space flight and comprehensively utilize modern advanced scientific and technological achievements. It is an important part of aerospace engineering. Spacecraft design is usually divided into four stages: feasibility demonstration, schematic design, initial sample design and actual sample design.

Spacecraft technology, also known as space vehicle technology, is the technology for designing, manufacturing, launching, tracking, returning, and controlling spacecraft. Including temperature control technology, attitude control technology, orbit control technology, radio control technology, life support technology, etc., it is a technology and knowledge-intensive high-tech group.

**6-1 Technological requirements for spacecraft design. Ground tests of the spacecraft**

设计的总体要求：Functional performance design requirements, manufacturing process requirements, testability, testability, maintainability requirements, economic cost requirements, development cycle requirements, development risk requirements, and development connection requirements.

为了保证在轨航天器能够满足合同规定的性能和寿命要求，在航天器地面研制过程中需进行全面严格的试验，以再现并摸拟航天器发射和在空间轨道运行的各类环境。这些环境包括发射时的超重、振动、噪声、热、电磁相容和轨道运行中的高、低温和带电粒子辐射等。

In order to ensure that the orbiting spacecraft can meet the performance and life requirements specified in the contract, comprehensive and rigorous tests must be carried out during the spacecraft ground development process to reproduce and simulate the various environments in which the spacecraft launches and orbits in space. These environments include overweight, vibration, noise, heat, electromagnetic compatibility, high and low temperature and charged particle radiation during orbiting during launch.

**6-2 Features of the thermal regime of spacecraft. External and internal heat fluxes affecting the spacecraft**

外部热流主要来自太阳直接热辐射、地球对太阳辐射的反射和地球热辐射三部分。地球对太阳辐射的反射是地球大气层对太阳辐射的反射(大气向上光)和大气向下光通过地球反射穿过大气层到航天器。地球热辐射是由于地球本身的温度为300K而产生的热流。当航天器进人地球阴影时，航天器只接收地球热辐射的热量。航天器在空间热环境及内外热交换示意图如图3-10所示。内部热流来自航天器各个分系统的仪器设备的耗电或机械摩擦等而产生的热量。同时，航天器的热量通过其专门设计的外表散热面向4K深冷空间辐射出去。

一般,对航天器的热设计来说，热环境主要考虑外部热流、内部热耗和空间热沉(即4K深冷空间)。而对于高轨道来说，如地球静止轨道(轨道高度为35786km),外部热流主要就考虑太阳辐射，即忽略地球热辐射和反射。

The external heat flow mainly comes from three parts: the direct thermal radiation of the sun, the reflection of the earth's solar radiation and the earth's thermal radiation. The earth's reflection of solar radiation is the reflection of the earth's atmosphere to the solar radiation (atmospheric upward light) and atmospheric downward light through the earth's reflection through the atmosphere to the spacecraft. The earth's thermal radiation is the heat flow generated by the earth's own temperature of 300K. When a spacecraft enters the shadow of the earth, the spacecraft only receives heat from the earth's thermal radiation. A schematic diagram of the spacecraft's thermal environment and internal and external heat exchange is shown in Figure 3-10. The internal heat flow comes from the heat generated by the power consumption or mechanical friction of the instruments and equipment of each sub-system of the spacecraft. At the same time, the heat of the spacecraft is radiated to the 4K deep cold space through its specially designed exterior heat dissipation.

Generally, for the thermal design of spacecraft, the thermal environment mainly considers external heat flow, internal heat loss and space heat sink (ie 4K deep cold space). For high orbits, such as the geostationary orbit (orbital height of 35786km), the external heat flow mainly considers solar radiation, that is, ignoring the earth's thermal radiation and reflection.

**7-1 Physical conditions in space. The effect of weightlessness. The concept of spacecraft reliability. Key reliability indicators.**

太空的物理条件：Since the Big Bang, with the expansion of the universe, the temperature has continued to drop. At present, space has become an alpine environment with an average temperature of minus 270.3°C. In space, various celestial bodies also radiate electromagnetic waves, and many celestial bodies also radiate high-energy particles to form cosmic rays. For example, the sun has solar electromagnetic radiation, solar cosmic ray radiation and solar wind. Solar cosmic ray radiation is high-energy particles emitted by the sun when a flare erupts, while solar wind is a high-energy plasma stream blown out from the corona. Many celestial bodies have magnetic fields, and the magnetic fields capture the above-mentioned high-energy charged particles to form a radiation belt with strong radiation. For example, in the sky above the earth, there are two radiation belts inside and outside. This shows that space is still a strong radiation environment. Space is still a high vacuum, microgravity environment. Gravity is only one-hundredth to one-hundredthousandths of a g (g-gravitational acceleration), and the gravity that people feel on the ground is 1g.

失重的影响：(1) Weightlessness causes the load of bones and muscles to be reduced, leading to increased excretion of calcium, phosphorus, potassium, etc., resulting in loose and weak bones, which makes the body's load-bearing capacity and anti-overweight ability when returning to the earth (the person will be overweight when returning to the earth) Impact) decline. This effect can be greatly reduced by proper physical exercise: and supplementation of calcium and other minerals. (2) Weightlessness will cause blood redistribution, blood transfer to the upper part of the body and the head, reduction of aldosterone and antidiuretic hormone in the blood, causing polyuria, loss of body water, reduction of plasma volume, and long-term weightlessness. The compensatory function can restore plasma volume to near normal levels. (3) Weightlessness causes the cardiovascular system to adapt, manifested as hypotension in the upright position after returning to the earth, which reduces the body's load capacity. (4) Weightlessness will change the stimulation of the vestibular organs, which can cause some people's vestibular dysfunction and cause motion sickness and disorientation, but these vestibular symptoms can be relieved or disappeared after treatment and adaptation. The current aerospace practice shows that humans have a relatively rapid ability to adapt to the environment of weightlessness, and humans need to re-adapt to the environment of normal gravity when returning to the earth.

可靠性:The possibility of a spacecraft completing a scheduled mission under specified conditions and within a specified time is usually expressed in terms of probability (percentage less than 1). It is an important indicator of the quality of a spacecraft and one of the design indicators of the spacecraft. The reliability of a spacecraft is determined by the reliability of its components (units). For a series system (where the failure of one unit will cause the failure of the entire system), the reliability of the entire system is equal to the product of the reliability of each unit. The more components of a spacecraft, the harsher the environmental conditions, and the longer the storage time, the lower the reliability.7-2 Design features of small and ultra-small spacecraft

可靠性指标：Launch preparation reliability, flight reliability, maintainability, storage integrity rate, technical readiness rate, standby readiness rate, launchability rate

**7-2 Design features of small and ultra-small spacecraft**

The role of ultra-small spacecraft (weighing up to 10 kg) in the study, development, and use of near earth space is constantly increasing. The advantage of ultra-small spacecraft (USSC) is their speed and low cost of development due to the possibility of using commercial components, fewer ground tests, ease of execution and the low cost of the ground control and communication segment (most often one ground receiving and control station), as well as the ability to create groups of such satellites for solving commercial and scientific problems.

**8-1 Spacecraft electrical system**

电力系统：The electrical system of the spacecraft consists of a power supply system and electrical equipment. Among them, the power supply system needs to provide electrical energy to the electrical equipment, and the electrical equipment consumes the electrical energy provided by the power supply system to complete specific functions. The power supply system must have the functions of electric energy generation and transformation, and electric energy transmission and distribution in order to provide electric energy to electrical equipment. The links and facilities that realize the functions of power generation and transformation are called power systems; the links and facilities that realize the functions of power transmission and distribution are called power transmission and distribution systems. The power supply system in a spacecraft has a short path for electric energy transmission, and its power transmission and distribution system is generally referred to as the power distribution system for short. The power supply system of the spacecraft consists of a power supply system and a power distribution system, which includes all links from the power supply to the input end of the electrical equipment. Among them, the part between the power supply and the power bus is the power supply system, and the equipment between the power bus and the input end of the electrical equipment is the power distribution system. The electrical equipment of a spacecraft refers to all equipment, devices and systems on the spacecraft that use electrical energy.

**8-2 The main stages of the design of a spacecraft**

1) Engineering demonstration stage: Carry out task analysis and program feasibility demonstration. 2) Engineering development stage: including schematic design stage, preliminary sample design and development stage, positive sample design and development stage. 3) Launch stage: launch site test and launch. 4) On-orbit testing and application stage: on-orbit testing stage, on-orbit application stage

**9-1 Life support system for the crew of the spacecraft.**

The life support system of a manned spacecraft is a comprehensive equipment that maintains the atmospheric environment in the airtight compartment of the manned spacecraft and guarantees the safety, life and work of the astronauts.It consists of an environmental control system, an atmosphere regeneration system, a water supply and treatment system, a waste treatment system, a thermal control system, a living system, and an extra-vehicle activity system.It can meet the physiological and metabolic needs of people, the supply of air, the supply of water, the supply of food, and the detection and control of microorganisms.

**9-2 Features of spacecraft for remote sensing of the Earth and meteorological observations**

地球遥感是指是从人造卫星、飞机或其他飞行器上收集地物目标的电磁辐射信息，判认地球环境和资源。可获取大范围数据资料。获取信息的速度快、周期短。获取信息受条件限制少。获取信息的手段多，信息量大。

卫星气象观测（satellite meteorological observation）是通过人造地球卫星上的遥感器探测地球大气的气象要素和天气现象的技术。卫星气象观测具有观测范围广，观测次数多，实效快，不受自然和国界条件的限制的特点。

Earth remote sensing refers to the collection of electromagnetic radiation information of ground objects from artificial satellites, airplanes or other aircraft to identify the earth's environment and resources. A wide range of data can be obtained. The speed of obtaining information is fast and the cycle is short. There are few restrictions on access to information. There are many ways to obtain information, and the amount of information is large.

Satellite meteorological observation is a technology for detecting meteorological elements and weather phenomena in the earth's atmosphere through remote sensors on artificial earth satellites. Satellite meteorological observations are characterized by a wide range of observations, a large number of observations, quick results, and are not restricted by natural and national boundary conditions.