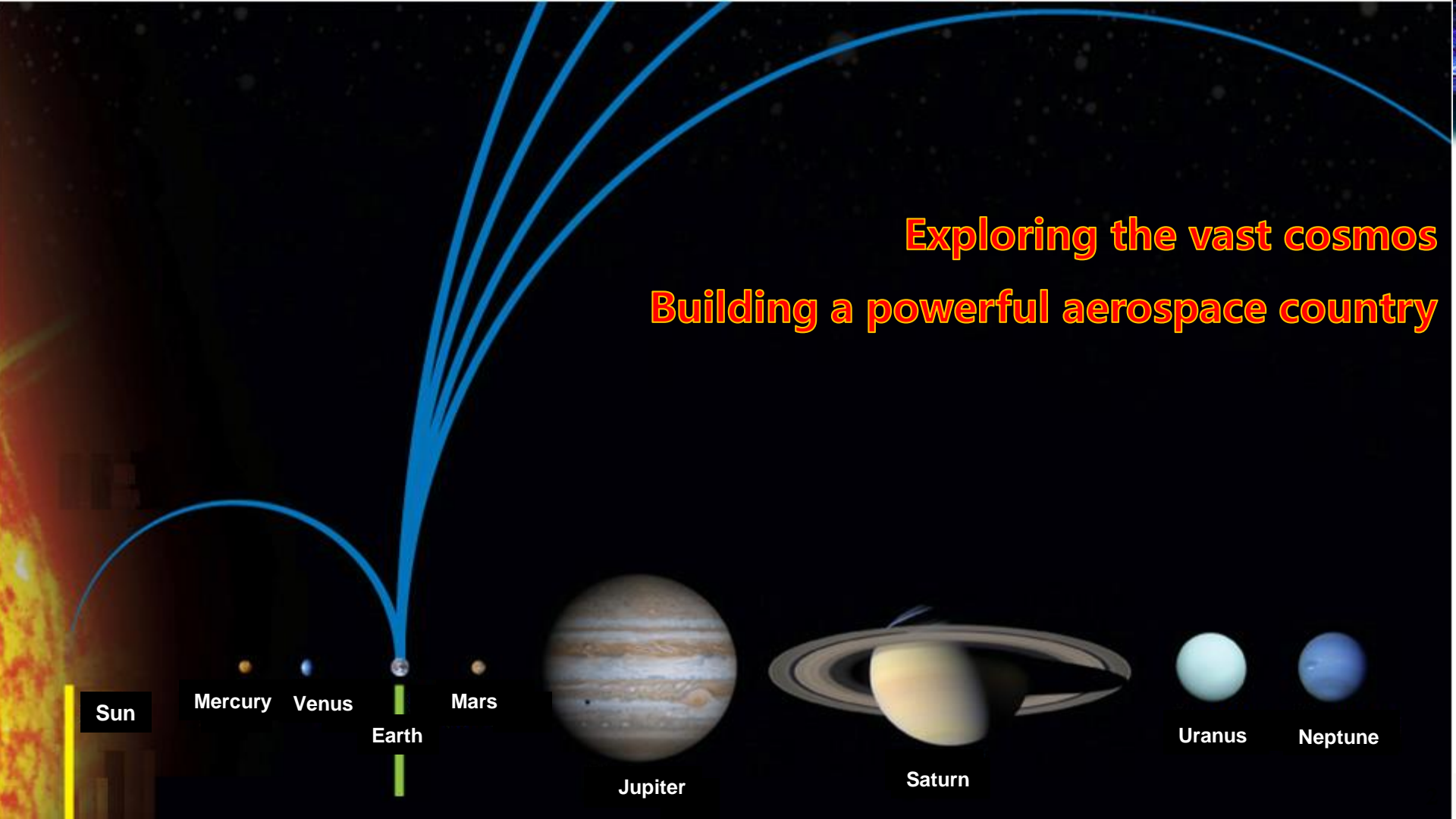


The background is a deep blue space scene with a nebula. On the left, a large portion of Jupiter is visible, showing its characteristic brown and white swirling bands. In the upper right, a satellite with a grey body, a large white parabolic dish, and a long boom with a conical antenna is shown. On the far right, a pale, featureless planet is partially visible. The main title is centered in large, bold red letters with a green outline.

Assumption of Ice Giant Exploration Mission

Presented by: Zhu Xin Bo

**Shanghai Academy of Spaceflight Technology (SAST)
November 2022, Haikou, China**



Exploring the vast cosmos
Building a powerful aerospace country

Sun

Mercury

Venus

Earth

Mars

Jupiter

Saturn

Uranus

Neptune

We have left the Chinese mark on Mars!
We have to go further!





Part 1

**Development of Planetary
Exploration of China**

Part 2

**Ice Giant Exploration
Mission**

Part 3

Summary and Prospect



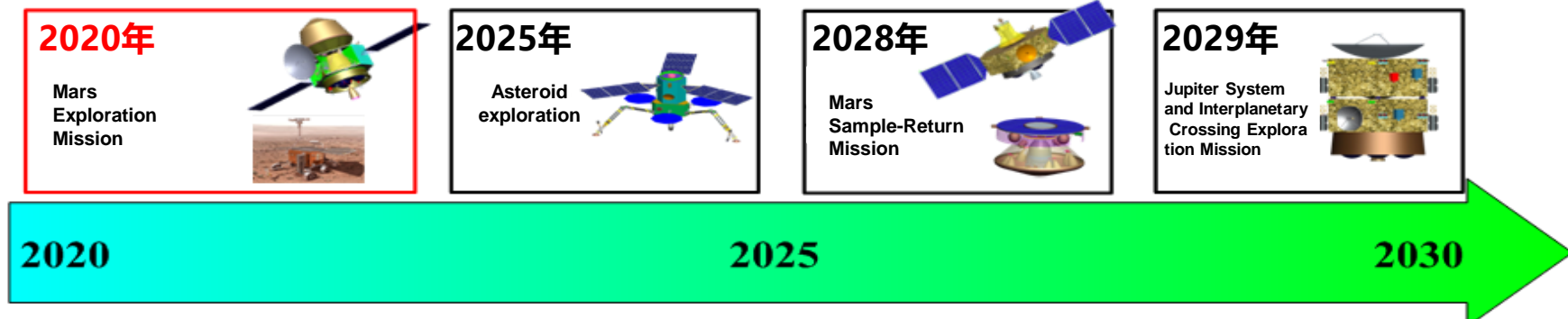
PART 1

Development of Planetary Exploration of China

Part 1: Development of Planetary Exploration of China

Planetary Exploration Roadmap

According to the national deep space exploration development plan, we are implementing the **Planetary Exploration of China(PEC)**, designing deep space exploration innovation tasks, and building our deep space exploration capability system in stages.

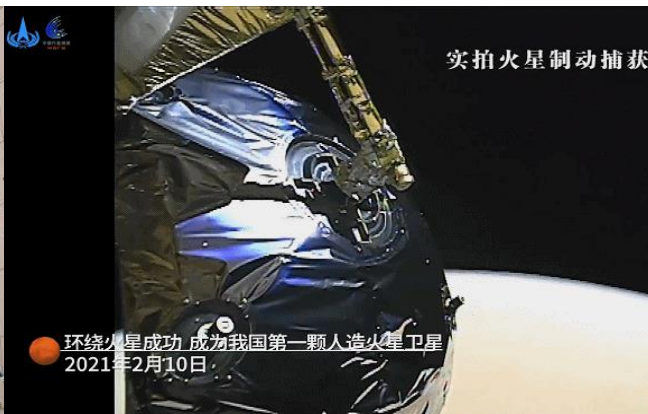


Next target, Ice Giant

Part 1: Development of Planetary Exploration of China

Implementation of Tianwen 1

China's first Mars exploration mission was approved in **January 2016**, successfully launched into orbit on **July 23, 2020**, orbited Mars on **February 10, 2021**, and landed on Mars **on May 15, 2021!**

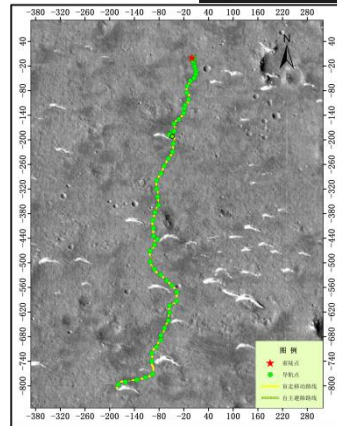


Part 1: Development of Planetary Exploration of China

Implementation of Tianwen 1

Tianwen 1 achieved the first **interplanetary transfer**, **Mars orbit**, **Mars landing** and **inspection** in China, and successfully completed the project mission objectives.

- **By May 2022**, the rover went into hibernation and traveled nearly 2km.
- **By August 2022**, the orbiter completed the global imaging coverage of Mars.
- 1480GB of scientific data has been returned.
- Relevant expansion tasks will continue to be carried out in the future.



Phobos

travel path Mars image

Part 1: Development of Planetary Exploration of China

Development of Tianwen 2

Around **2025**, the Tianwen 2 mission will be implemented to detect the **NEA 2016HO3**, sample and return, and fly to the main belt **comet 311P**.

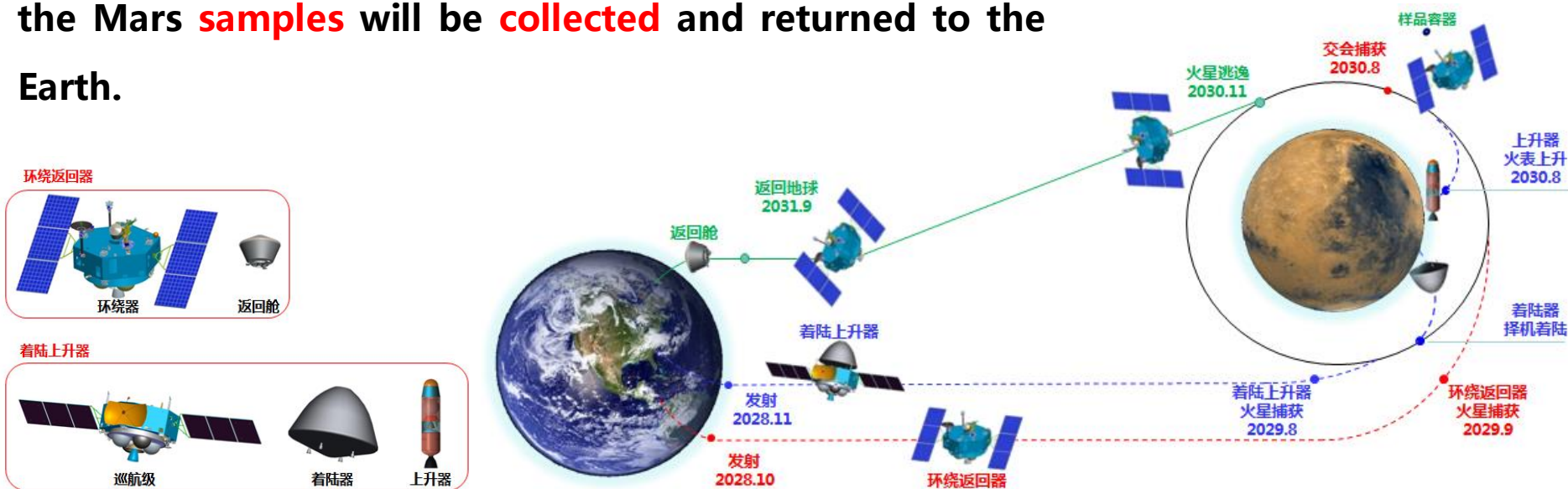
At present, the prototype of the detector is being developed.



Part 1: Development of Planetary Exploration of China

Follow up mission of PEC——Tianwen 3

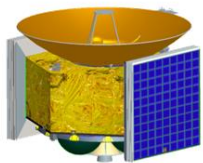
Around **2028**, Tianwen 3 will be implemented, and the Mars **samples** will be **collected** and returned to the Earth.



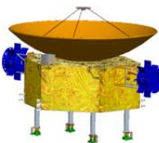
Part 1: Development of Planetary Exploration of China

Follow up mission of PEC——Tianwen 4

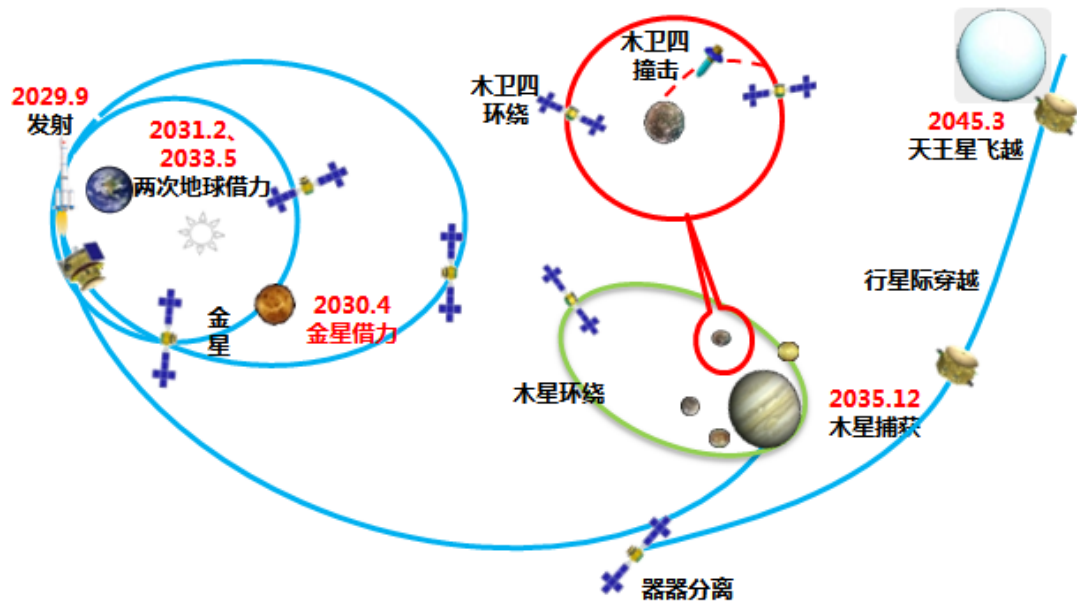
Around **2029**, the Tianwen 4 mission will be implemented, and the **Jupiter system orbit** and **Uranus flyover** exploration will be realized.



木星系环绕器



行星际穿越器

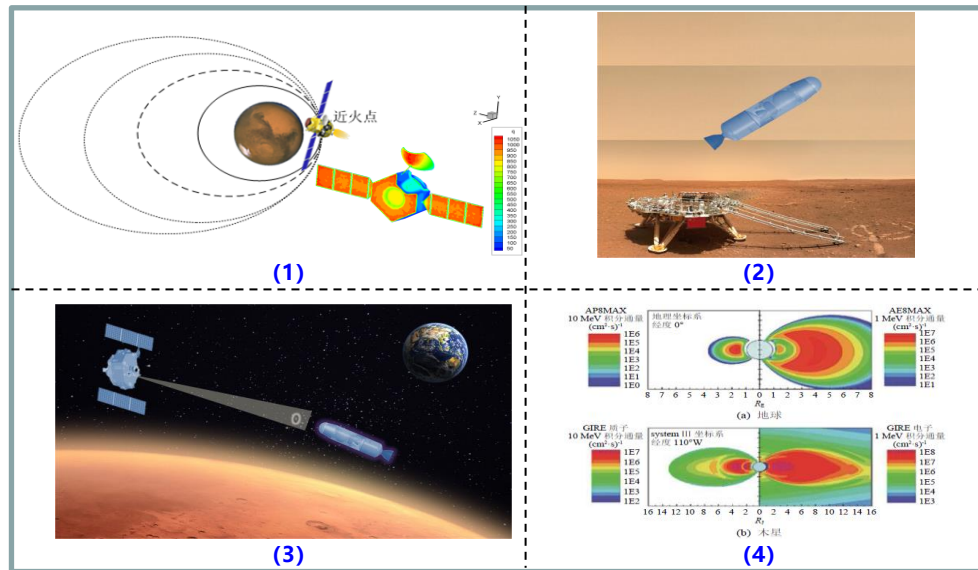


Part 1: Development of Planetary Exploration of China

Follow up mission of PEC

The scheme **design** and **key technology** tackling work of Tianwen 3 and Tianwen 4 are being actively carried out.

1. Planetary atmosphere assisted orbit transfer technology
2. Mars surface rising technology
3. Autonomous rendezvous technology in mars orbit
4. Jupiter's Strong Magnetic Field and Radiation Environment and Protection Technology
5. ...





PART 2

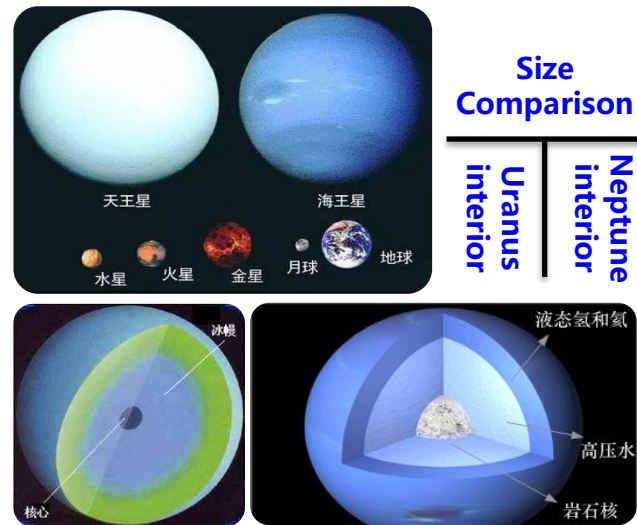
Ice Giant Exploration Mission

Part 2: Ice Giant Exploration Mission

Ice Giants

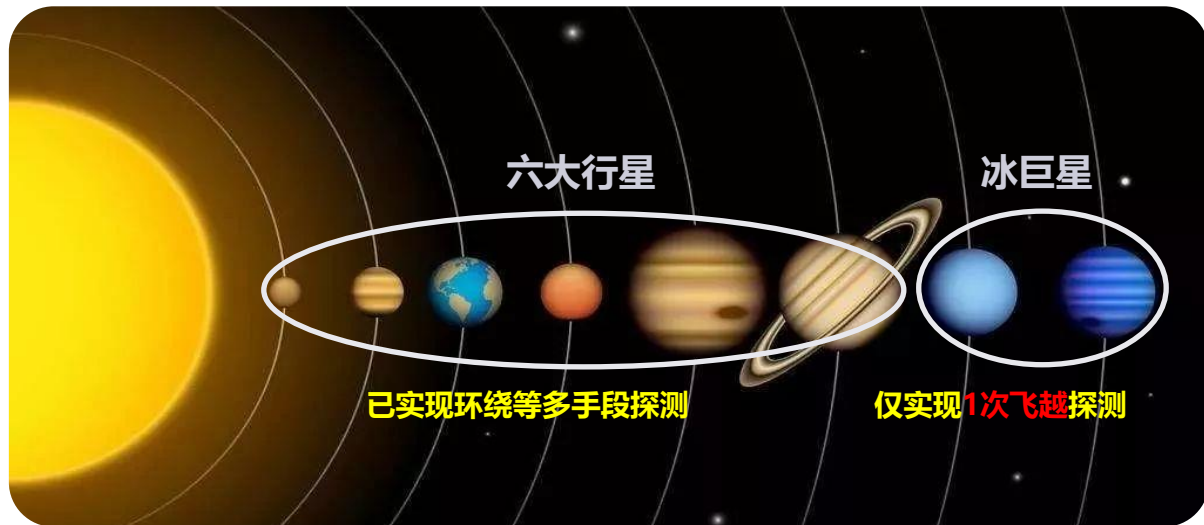
The eight planets of the solar system are divided into two categories: terrestrial planets and gas giants. Ice giants are different than gas giants, namely Jupiter and Saturn, which are primarily made up of gases, especially hydrogen and helium, and contain very small amounts of heavier elements.

Parameters	Uranus	Neptune
Equatorial radius(AU)	19.22	30.4
Ellipticity	0.0044	0.0112
Orbit period (years)	84.32	165.17
Gravity (eq.,1 bar)(m/s ²)	8.69	11.15
Volume ($\times 10^{13}\text{km}^3$) Ratio(Plant/Earth)	6.833 (63.08)	6.254 (57.74)
Mass ($\times 10^{25}\text{kg}$) Ratio(Plant/Earth)	8.68 (14.53)	10.243 (17.14)
Satellite	27	14



Part 2: Ice Giant Exploration Mission

Ice Giants Exploration Review



So far, human beings have carried out more than 140 deep space missions (excluding the moon), realized the exploration of **six planets** by multiple means such as circling, and only carried out **one flyby exploration of ice giants** obtaining limited scientific data.

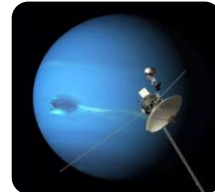
Part 2: Ice Giant Exploration Mission

Ice Giants Exploration Review

Voyager-2

Voyager 2 (NASA) taking advantage of the geometric formation of planets once in 176 years, carried out overflight exploration of Jupiter, Saturn, Uranus and Neptune.

- ❑ Launch: 8/25/1995
- ❑ Arrive: 2/1986 ,& 10 new satellites found.



Parameters

- ❑ 825 kg
- ❑ RTG 39kg, 470We
- ❑ antenna 3.7m, S/X
- ❑ 11 INSTRUMENTS

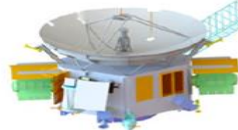
Part 2: Ice Giant Exploration Mission

Ice Giants Exploration review

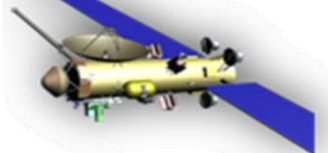
NASA has designed several ice giant exploration mission plans in the form of overflight and orbit, and has carried out continuous research on scientific problems and key technologies.



Triton-flyby: Trident Mission



Neptune Probe



1977年

.....

2018年

2025年

2030年



Voyager-2



Uranus Probe

Part 2: Ice Giant Exploration Mission

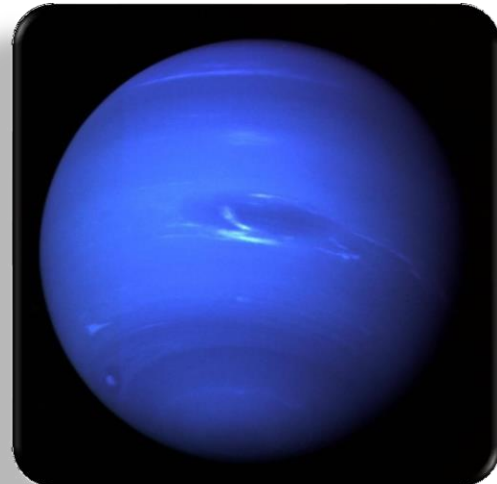
Fill in the blank of ice giant in place detection



Solar System



Uranus



Neptune

For the first time, ice giant star detection is carried out by means of orbit, atmospheric entry/impact penetration, etc., which will fill the gaps in ice giant star positioning detection and science, and further expand human understanding of the solar system.

Part 2: Ice Giant Exploration Mission

Obtain original scientific data

Hot topics

- ◆ The big Question
- ◆ searching for extra-terrestrial life
- ◆ Human habitable place



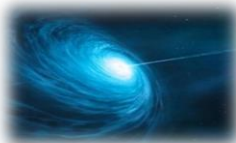
Important scientific problems

- ◆ Formation and evolution
- ◆ Exoplanet system
- ◆ The mystery of the early solar system



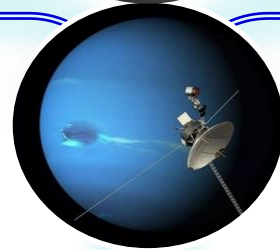
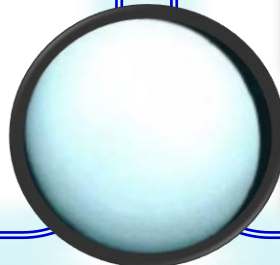
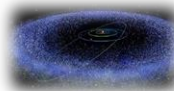
science of Ice Giants

- ◆ formed
- ◆ Looking for water
- ◆ 2400km/h Causes of storm formation



Satellite science of Ice Giants

- ◆ Whether there is underground ocean
- ◆ Whether there is life



Part 2: Ice Giant Exploration Mission

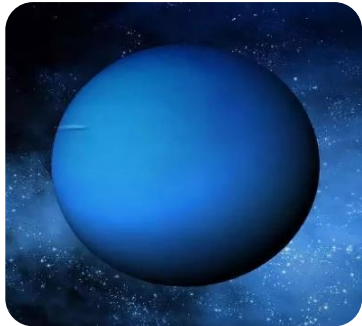
Mission Objectives

- ◆ **Science:** Study the atmosphere, magnetosphere, moons and planetary rings of ice giants, and Try to solve scientific problems such as the origin and evolution of the solar system, the origin of life.
- ◆ **Project :** Orbiting ice giants ice giants, and release aerostats and impactors for spot detection.



Part 2: Ice Giant Exploration Mission

Ice Giant Exploration Mission: Objectives of the mission



Neptune



Uranus



Triton



Amaymede

By means of surround, entry and impact, three aspects of exploration will be carried out

1. Atmospheric structure and composition

The initial state of the protostellar cloud, the origin and evolution of the solar system

2. Magnetosphere and ionosphere

Layer conductivity, material properties, and motion mechanism in the planetary fluid mantle and crust

3. Moons and planetary rings

Build a complete list of planetary rings and their Collie moons

Part 2: Ice Giant Exploration Mission

Ice Giant Exploration Mission : Task analysis

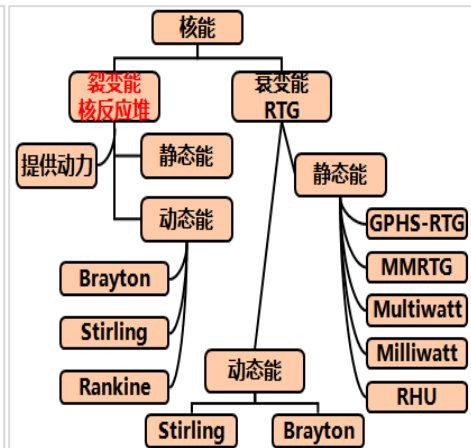
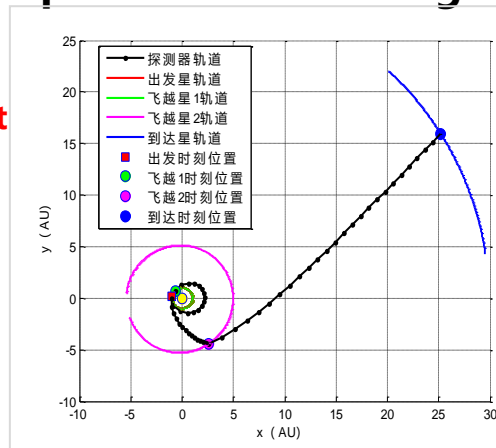
- ❑ The speed increment around the ice giant is required to be large, but the launch capability of the rocket is limited;
- ❑ The distance from the sun is far, and the power demand of the probe is large;
- ❑ High data transmission capacity is required for ultra long distance.

◆ **Orbit:** Planetary capture by force+small thrust transfer ;

◆ **Power:** Fission reactor ;

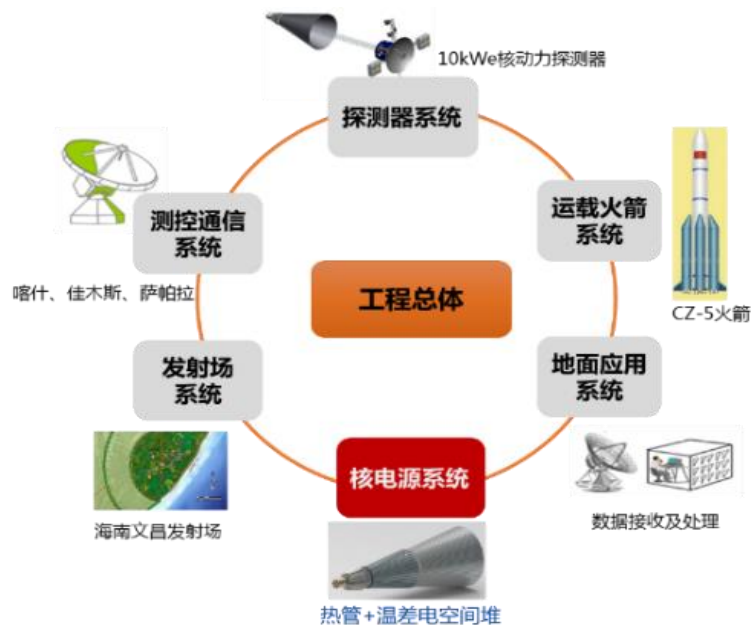
◆ **Communication :** Large aperture antenna.

Tianwen series tasks lay the technical foundation

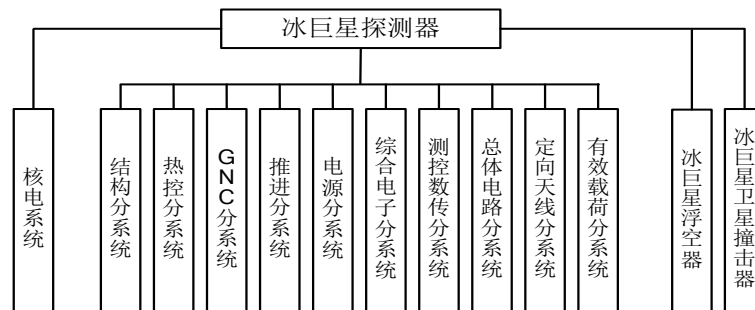
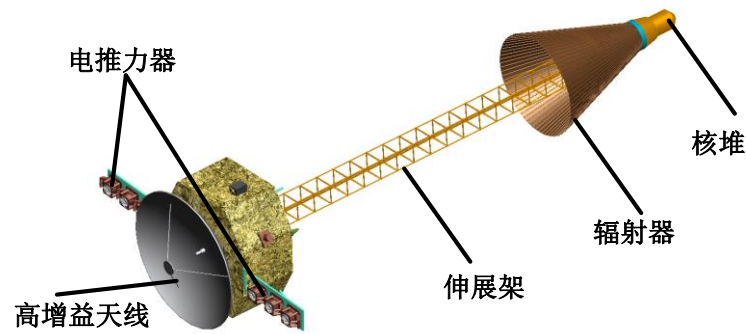


Part 2: Ice Giant Exploration Mission

Ice Giant Exploration Mission : System composition



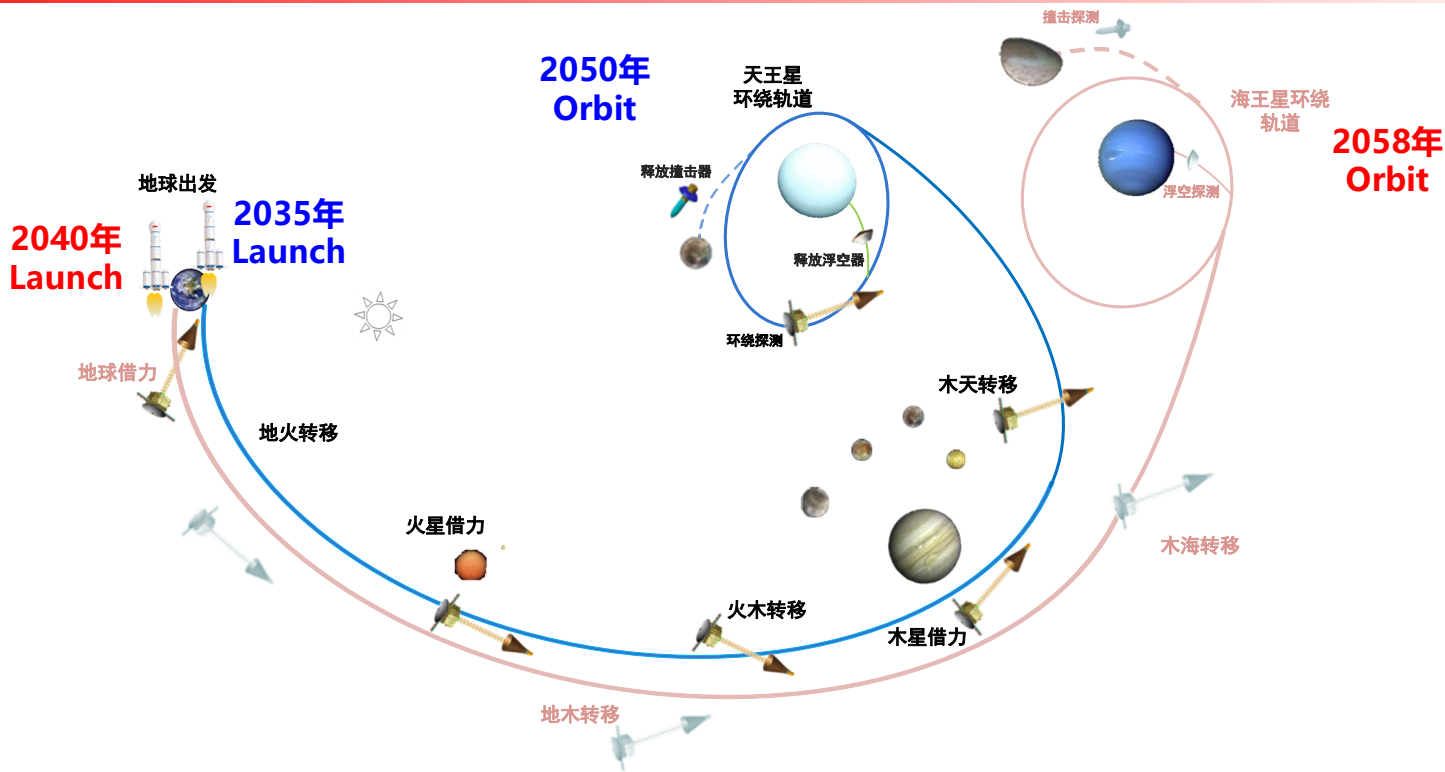
project system



Probe

Part 2: Ice Giant Exploration Mission

Ice Giant Exploration Mission



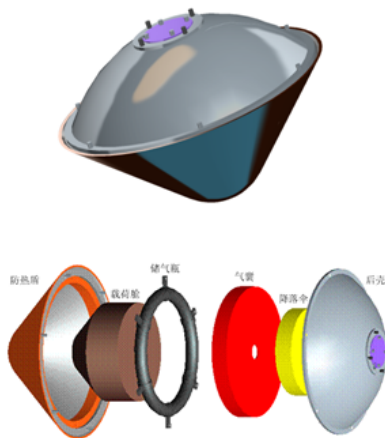
Part 2: Ice Giant Exploration Mission

Ice Giant Exploration Mission

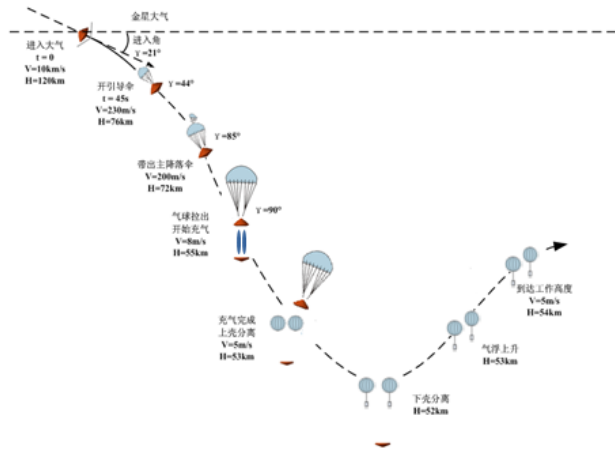
- Atmospheric entry/floating exploration**

Entering Ice Giant atmosphere, obtaining fine information of atmospheric structure, composition, and internal activities, and carrying out scientific research on the internal structure, atmospheric composition, atmospheric dynamics, and magnetosphere of Ice Giant.

Design of aerostat



Process of entry and floating



Ice Giant Exploration Mission

Ice Giant impact/penetration was carried out to obtain the temperature, humidity, and conductivity data of the shallow and sub-surface layers, and to carry out scientific research on the shallow structure, surface composition, and internal dynamics.

Design of impactor

The diagram illustrates the design of an impactor, showing its main components and their arrangement. The impactor is depicted as a central blue cylindrical body (结构) with a conical nose cone. It is flanked by two smaller cylindrical modules: a yellow one on the left (控制模块) and a blue one on the right (贮箱). Below the main body, a grey rectangular module (管理模块) is shown, which is connected to a yellow cylindrical module (飞行控制器) and a blue cylindrical module (推力器). The yellow module also contains a battery (电池) and a navigation sensor (导航敏感器). A small antenna (天线) is located at the bottom of the yellow module.

Diagram illustrating the components of an impactor:

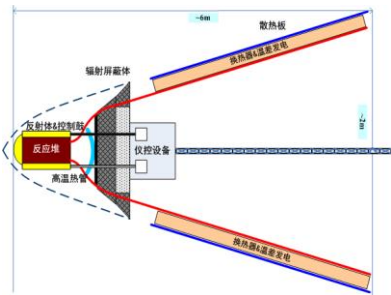
- 控制模块 (Control Module)
- 结构 (Structure)
- 贮箱 (Tank)
- 导航敏感器 (Navigation Sensor)
- 管理模块 (Management Module)
- 飞行控制器 (Flight Controller)
- 天线 (Antenna)
- 推力器 (Thruster)
- 电池 (Battery)

Process of impact

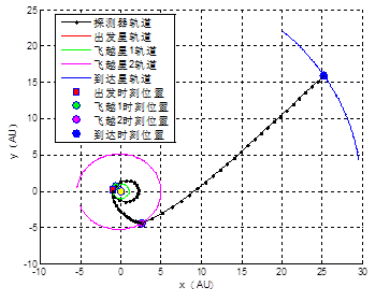
Diagram illustrating the process of impact on a flexible battery. The diagram shows a satellite in orbit (环绕器) emitting a laser beam (辐射) that hits a flexible battery (柔性电池片) on the ground. The battery is shown with a crack (断裂界面) and is connected to a flexible cable (柔性电缆). The battery is also shown with a temperature sensor (温度) and a conductive segment (侵入段). The diagram indicates a depth of 1m-3m and a conductive rate (电导率).

Part 2: Ice Giant Exploration Mission

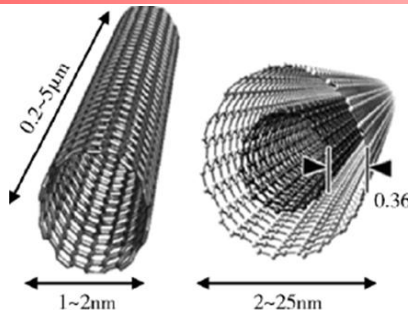
Core technology in Ice Giant exploration



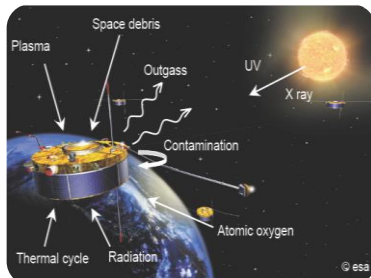
1. Integration and operation control of space heat pipe stack



4. Borrowing force and small thrust capture



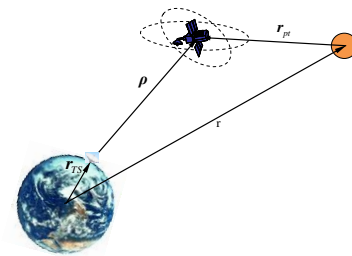
2. High efficient thermoelectric conversion materials



5. High reliability and long service life platform



3. Very long distance high-speed data transmission



6. Long term autonomous management



Part 2: Ice Giant Exploration Mission

■1. Integration and operation control technology of high temperature space heat pipe reactor

➤ Mission requirement

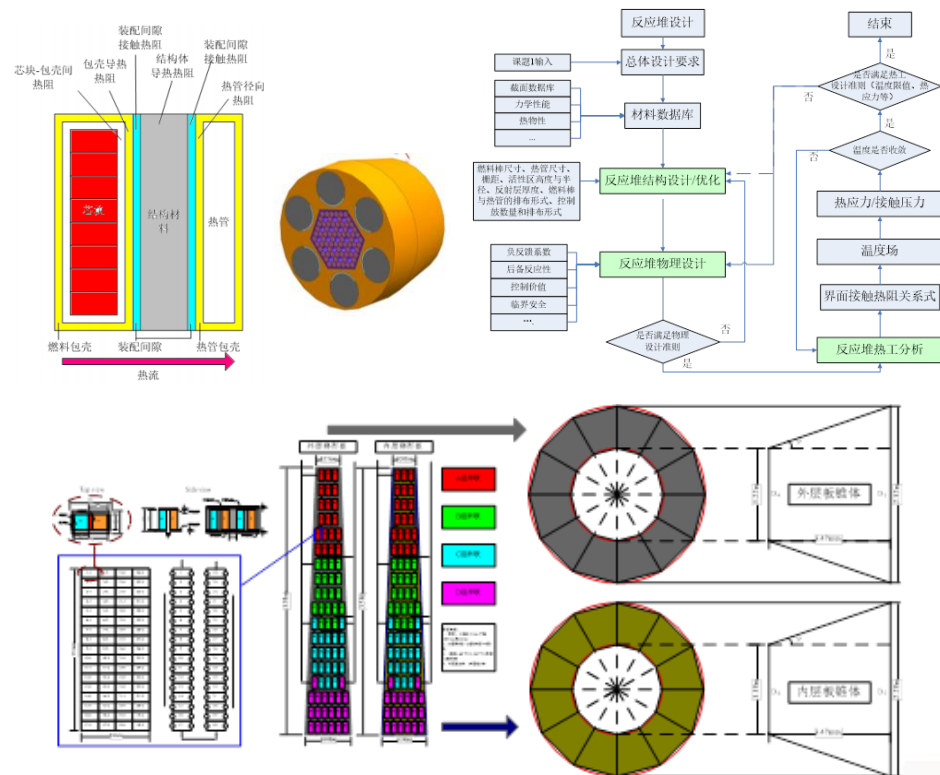
- The requirement of output power is 10kW
- The design service life is no less than 15 years

➤ Technical status

- **Tianwen-4 : studies on RTG technology**
- **Civil space flight: research on nuclear reactor and temperature difference power generation**

➤ Technical approach

- **Combined with the requirements of Ice Giant Exploration missions, further research on long-life and lightweight will be carried out.**



Part 2: Ice Giant Exploration Mission

■2. High efficiency and low degradation rate thermoelectric conversion material

➤Mission requirement

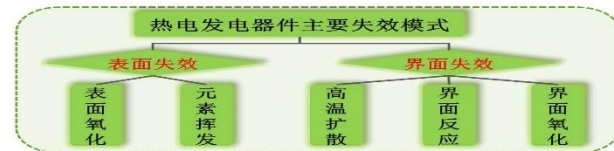
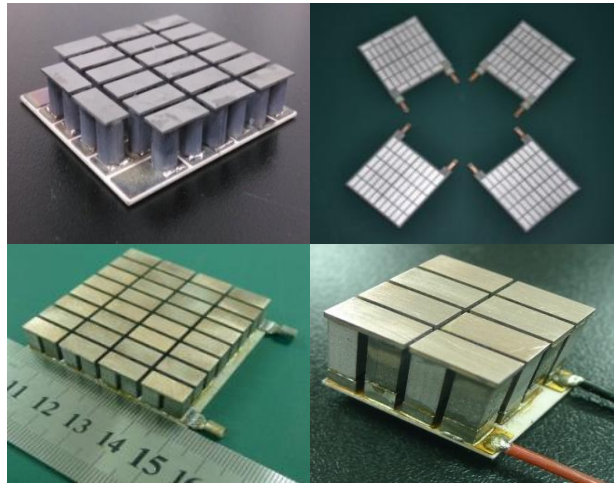
- The thermoelectric conversion efficiency needs to be more than 7%
- The mission period is 15 years with an annual decay rate of no more than 3%

➤Technical status

- Tianwen-4 : The RTG-oriented conversion material has an efficiency of 8% and an annual decay rate of 2%

➤Technical approach

- Further improve the thermoelectric conversion efficiency and reduce the material attenuation rate



Part 2: Ice Giant Exploration Mission

■3. Extremely long distance high-speed data transmission technique

➤ Mission requirement

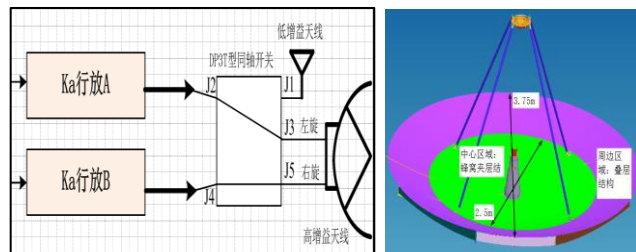
- Data transmission code rate needs to be more than **64Kbps** in **30AU** long communication distance
- Ground pointing accuracy requirement of **0.01°**

➤ Technical status

Spacecraft	Distance	Accuracy	Rate of code	Equivalent code rate of 30AU
Tianwen-1	2.67AU	0.1°	1Mbps	~2Kbps
Tianwen-4	20AU	0.05°	256Kbps	~8Kbps

➤ Technical approach

- Ka or above frequency band communication
- High precision thermal deformation and pointing control of 4.2m large diameter antenna
- 30AU high speed data transmission



Part 2: Ice Giant Exploration Mission

■4.Low thrust force and planet capture technique

➤Mission requirement

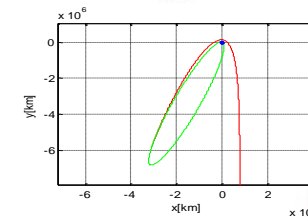
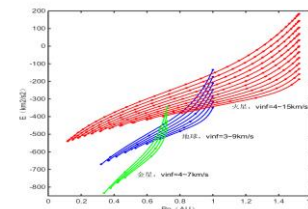
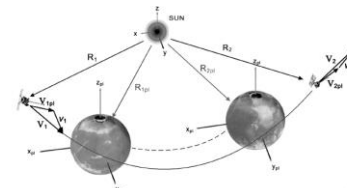
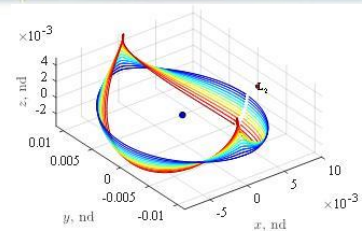
- The total mission period of interplanetary flight is **15 years**
- Fast transfer flight at nearly **30AU distance**
- Capturing the ice giant after continuous electric propulsion for nearly **40,000 hours**

➤Technical status

- Tianwen-2 : Gravity-Assist technique and 40,000 hours of low thrust propulsion
- Tianwen-4 : Venus and Jupiter Gravity-Assist technique

➤Technical approach

- Optimization of Gravity-Assist and low thrust transfer and planetary capture trajectory design
- Increase electric propulsion thrust
- Carry out research on astronomical autonomous navigation at ultra-long distances



Part 2: Ice Giant Exploration Mission

■5. High reliability and long-life platform technique

➤ Mission requirement

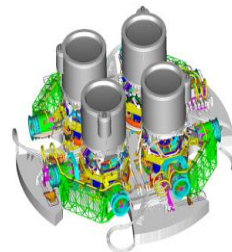
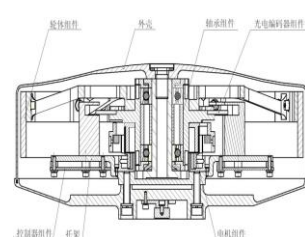
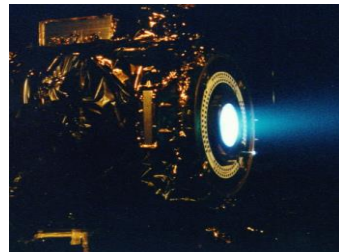
- The electric propulsion needs to be fired for more than **40,000 hours**
- Withstand Jupiter's strong irradiation environment and long-term radiation from nuclear reactors
- Service life of mechanism and moving parts is **15 years**

➤ Technical status

- Tianwen-2 : The electric propulsion will be fired for **40,000 hours**
- Tianwen-4 : Withstand Jupiter's strong irradiation environment
- Near Earth satellite: Long service life of mechanism

➤ Technical approach

- Inherit the ion electric propulsion of Tianwen-2
- Utilize new shielding material from Tianwen-4 and carry out long-term radiation tolerance study
- Carry out research on the long life technology of scientific probe payloads



Part 2: Ice Giant Exploration Mission

■6. Long period autonomic management technique

➤ Mission requirement

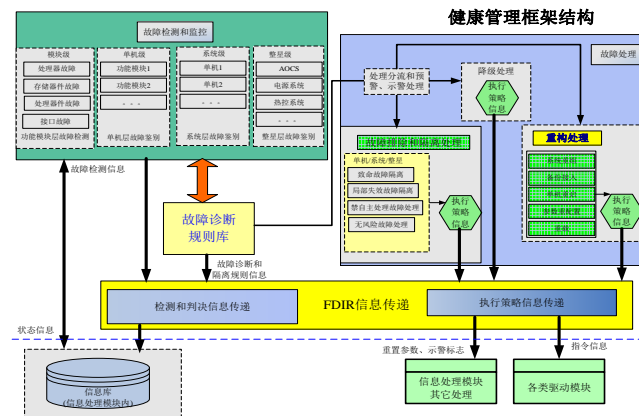
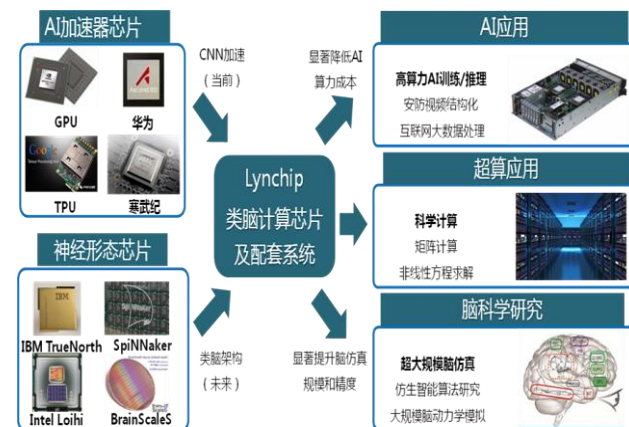
- About **13 years** of Planetary cruise flight
- The time delay of the spacecraft is greater than **250min**

➤ Technical status

- Tianwen-1 has overcome the communication time delay of **22min**, and has realized self-management during the sun transit outage for **35 days**
- Tianwen-4 will overcome the communication time delay of 175min, and realizes self-management for **120 days** at most

➤ Technical approach

- Based on the long period and time delay management techniques, the research on the intelligent cruise flight and autonomous will be further carried out





PART 3

Summary and Prospect



Part3 : Summary and Prospect

Through the development of **Planetary Exploration of China** —— "**Tianwen**", a solid technical foundation has been laid for the **Ice Giant Exploration Missions**. Through **the first Ice Giant Orbital Exploration**, it is expected to make **major scientific original discoveries** such as the origin and evolution of the solar system and the origin of life. At the same time, it will further improve the engineering technology level of China' s Deep Space Exploration.

How Big is the Universe?

THE STARS

If you attempted to count all the stars in a galaxy at a rate of one every million seconds, it would take around 3,000 years to count them all.

There are about 100 stars visible to the naked eye in a clear, dark sky. There are 68 constellations altogether.

The smallest star measures about 900 miles across, which is a white dwarf called LP 207-16. That's roughly the length of Alaska's coastline completely stretched out.

Although Earth is the homeland of mankind,

human being can not live forever in the cradle.

93 million miles away

SUN

The light from the Sun takes about 8 minutes to reach Earth. Only 8 of those 19.2 billion minutes are spent travelling through space from the Sun to the Earth.

JUPITER

THE MOON
644,646 miles from the Earth to the Moon.
Same as 3.16 Trillion \$1 dollar bills stacked on top of each other.

Circumference of the Earth
24,900 miles

We are moving through space at the rate of 300 miles a second. That means that in one minute you are about 11,000 miles away from where you were.

Any space vehicle must move at a rate of 7 miles per second in order to escape the earth's gravitational pull. As the Earth travels through space at 660,000 miles per hour.

Next Step, Ice Giant!

SPACE DISTANCES

For distances within our solar system, or other solar systems, the common unit is the "Astronomical Unit" (A.U.)



1 A.U. = the average distance between the Earth and the Sun (93 Million Miles)

1 light year = approximately 6 trillion miles
The distance light travels in one year.

For measuring the distance to the stars and galaxies - a parsec (pc) is used
1 parsec = 3.26 light years

ESTIMATED SIZE OF THE UNIVERSE - 93,000,000,000 light years

OBSERVABLE UNIVERSE - Universe is only about this old - everything past this would take more than 14,000,000,000 light years to reach us, which is more time than the universe has existed.

M81 CLUSTER

OUR SOLAR SYSTEM - About 100,000,000,000 the size of this 1 pixel dot

2,000
megaparsecs away
(10,000,000 light years)

Our galaxy is thought to have formed from a cloud of gas and dust. It is thought to be a spiral galaxy and is one of the most common types of galaxy in the universe.

3.37
megaparsecs away
(10,991,714.2 light years)

One of the most striking examples of a grand design spiral galaxy, with more perfect arms spiraling into the very center. Its active galactic nucleus matches a 10 million solar mass supermassive black hole.

1 megaparsec = 1,000,000 parsecs

3,848.94
megaparsecs away
(12,882,500,000 light years)

The most distant known galaxy today. It lies at a redshift of 6.94 which puts it at about 12.88 billion light years away from Earth.

How Big is the Universe?

THE STARS

If you attempted to count all the stars in a galaxy at a rate of one every million seconds, it would take around 3,000 years to count them all.

There are about 100 stars per cubic light year in a clear, dark sky. There are 68 constellations altogether.

The smallest star measures about 932 miles across, which is a white dwarf called LP 327-16. That's roughly the length of Alaska's coastline completely stretched out.

93 million miles away

SUN MERCURY VENUS EARTH MARS

The light hitting the Earth is about 26,000 years old. Only 8 of those 12.5 billion minutes are spent travelling through space from the Sun to the Earth.

JUPITER

SATURN

URANUS

NEPTUNE

THE MOON

248,149 miles from the Earth to the Moon (Same as 3.18 Trillion \$1 dollar bills stacked on top of each other)

Circumference of the Earth 24,900 miles

We are moving through space at the rate of 330 miles a second. That means that in one minute you are about 19,800 miles away from where you were.

Any space vehicle must move at a rate of 7 miles per second in order to escape the earth's gravitational pull. As the Earth travels through space at 660,000 miles per hour.

SPACE DISTANCES

For distances within our solar system, or other solar systems, the common unit is the "Astronomical Unit" (A.U.)



1 light year = approximately 6 trillion miles
The distance light travels in one year.

For measuring the distance to the stars and galaxies - a parsec (pc) is used
1 parsec = 3.26 light years

ESTIMATED SIZE OF THE UNIVERSE - 93,000,000,000 light years

OBSERVABLE UNIVERSE - Universe is only about this old - anything past this would take more than 14,000,000,000 light years to reach us, which is more time than the universe has existed.

M81 CLUSTER

OUR SOLAR SYSTEM - About 100,000,000,000 the size of this 1 pixel dot

If you were travelling at speed of light, would still take 4 years to reach Alpha Centauri. If you, travelling in a car at 100mph it would take 29,000,000 years.

100,000 light years

100,000 light years

100,000 light years

1 megaparsec 300,000 parsecs

3,848.94 megaparsecs away (12,892,600,000 light years)

PROXIMA CENTAURI
A red dwarf star in the constellation of Centaurus.

CANIS MAJOR DWARF
A galaxy that contains a relatively high percentage of red giant stars, and is thought to contain an estimated one billion stars in all. Classified as an irregular galaxy and is now thought to be the closest neighbouring galaxy to our location in the Milky Way.

M31 (Andromeda)
A spiral galaxy in the constellation Ursa M. One of the most striking examples of a grand design spiral galaxy, with near perfect arms spiraling into the very center. Its active galactic nucleus harbors a 10 million solar mass supermassive black hole.

IKR-1
The most distant known galaxy cluster. It has a redshift of 6.94 which puts it at about 12.89 billion light years away from Earth.