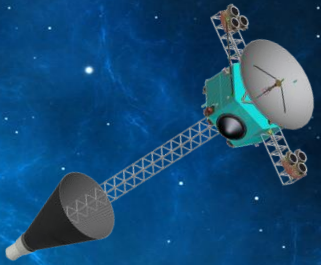
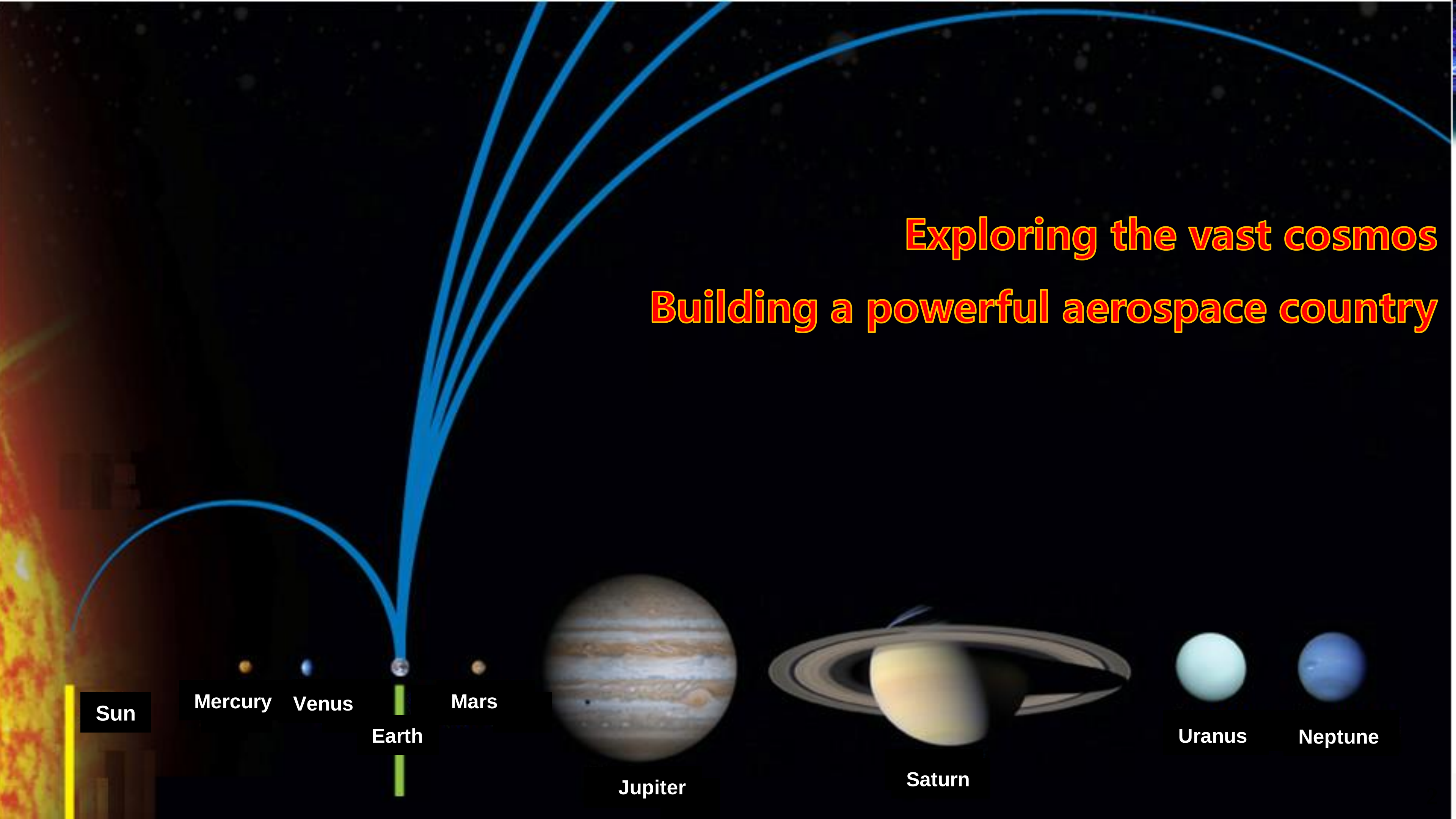
Assumption of Ice Giant Exploration Mission



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!

Contents

PART 1

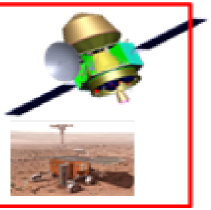
Development of Planetary Exploration of China

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.

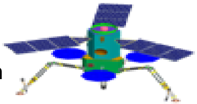
2020年

Mars Exploration Mission



2025年

Asteroid exploration

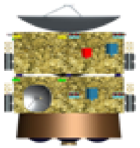


2028年

Mars Sample-Return Mission

2029年

Jupiter System and Interplanetary Crossing Explora tion Mission

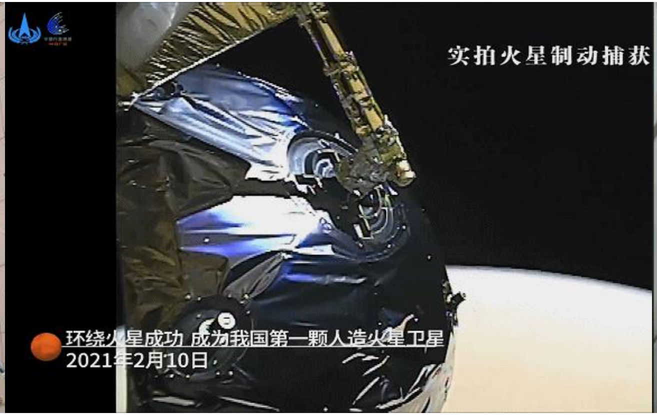


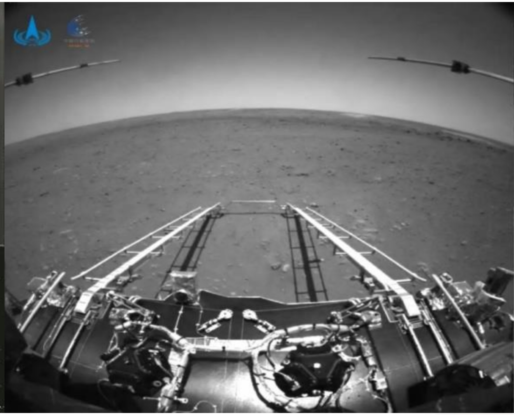
2020 **2025** **2030**

Next target, Ice Giant

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!

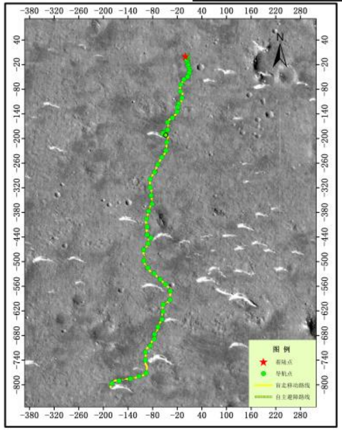




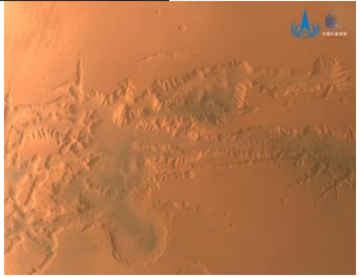
Implementation of Tianwen 1

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.



制图：北京航天飞行控制中心



Phobos

travel path | Mars image

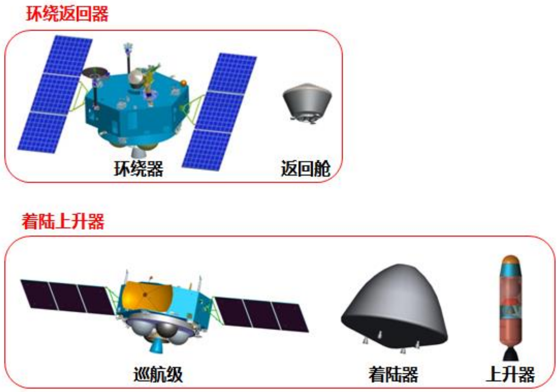
Development of Tianwen 2

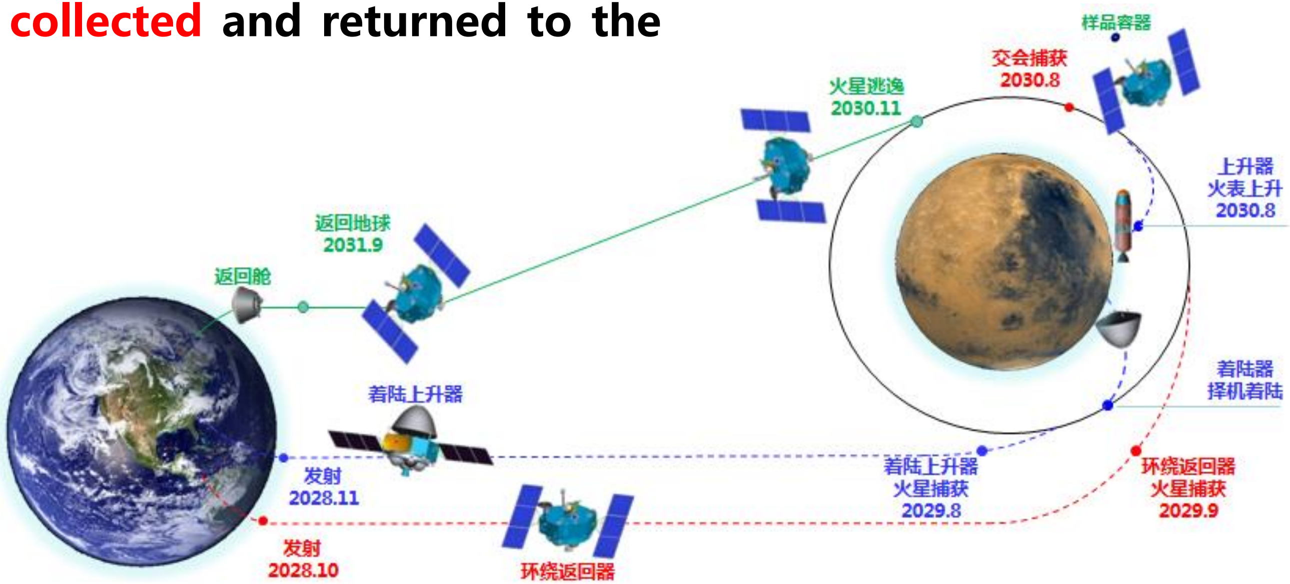
Around 2025, the Tianwen 2 mission will be implemented to detect the NEA 2016HO3, sample and return, and fly to the main belt comet 311P.

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

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.

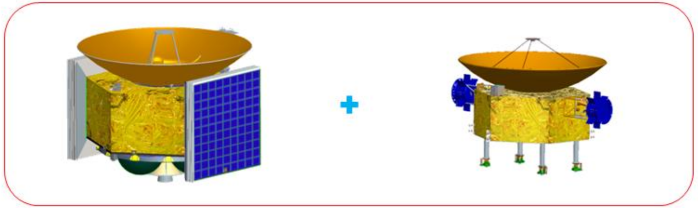




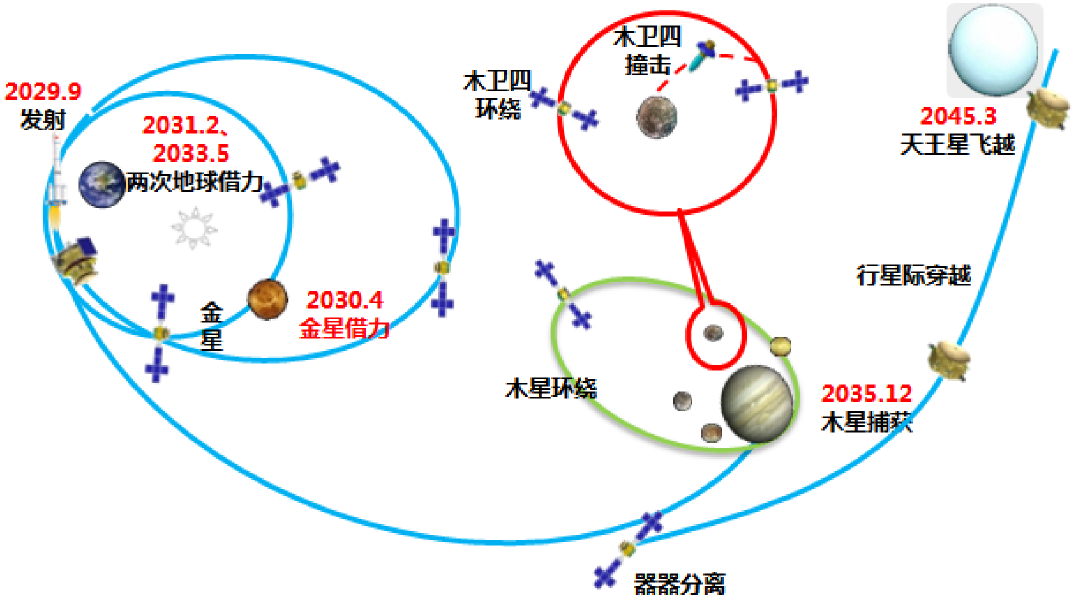
Part 1: Development of Planetary Exploration of China

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.



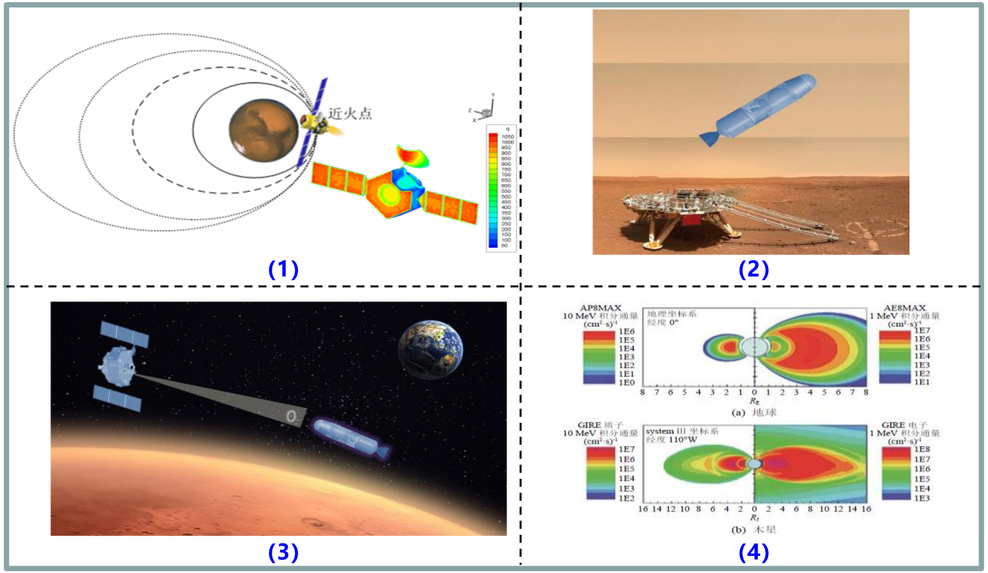
木星系环绕器　　行星际穿越器



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. …



(1) (2) (3) (4)

PART 2

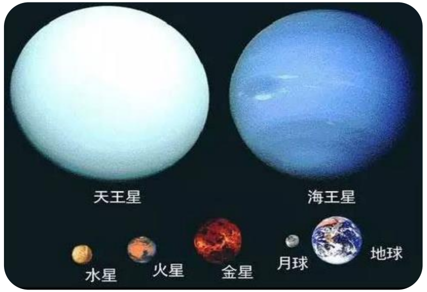
Ice Giant Exploration Mission

Part 2: Ice Giant Exploration Mission

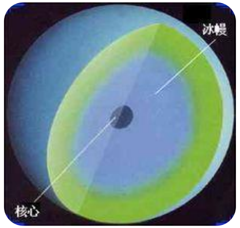
Ice Giants

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.

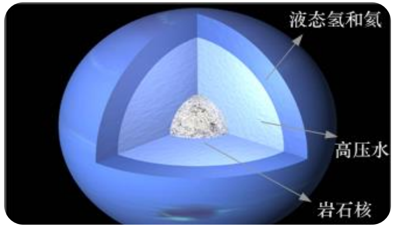
Parameters	Uranus	Neptune
Equatorial radius(AU)	19.22	30.4
Ellipticity	0.0044	0.0112
Orbit period (years)	84.32	165.17
Gravity (eq.,1 bar)(m/s^2)	8.69	11.15
Volume (×10^{13}km^3) Ratio(Plant/Earth)	6.833 (63.08)	6.254 (57.74)
Mass (×10^{25}kg) Ratio(Plant/Earth)	8.68 (14.53)	10.243 (17.14)
Satellite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



Size Comparison



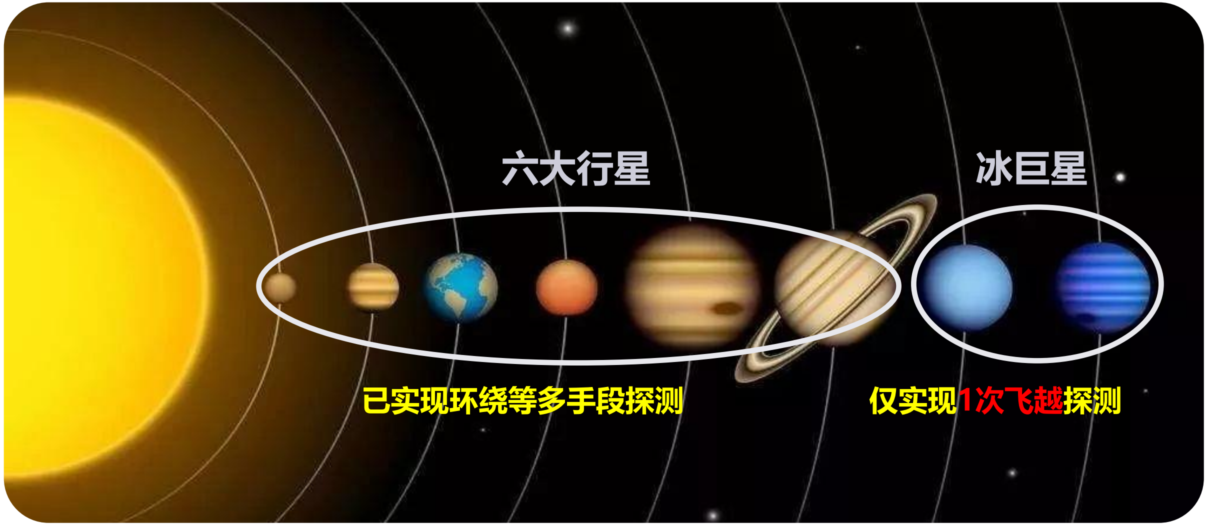
Uranus interior



Neptune interior

Part 2: Ice Giant Exploration Mission

Ice Giants Exploration Review



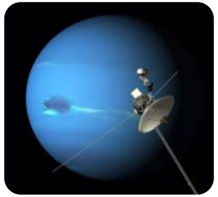
So far, human beings have carried out more than 140 deep space missions (excluding the moon), realized the exploration of six planets by multiple means such as circling, and only carried out one flyby exploration of ice giants obtaining limited scientific data.

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

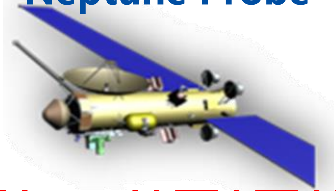
Part 2: Ice Giant Exploration Mission

Ice Giants Exploration review

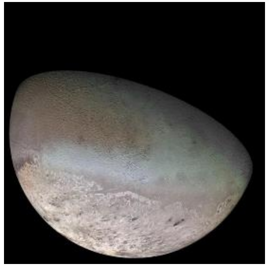
NASA has designed several ice giant exploration mission plans in the form of overflight and orbit, and has carried out continuous research on scientific problems and key technologies.

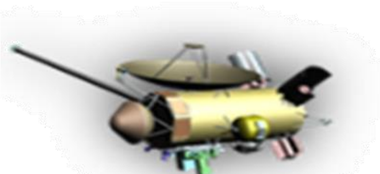
Triton-flyby：Trident Mission

Neptune Probe



1977年 …… 2018年 2025年 2030年





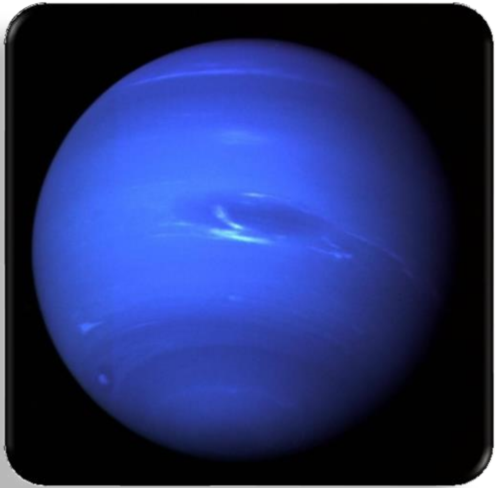
Uranus Probe

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

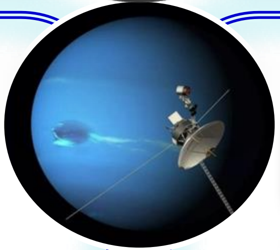
◆The mystery of the early solar system

science of Ice Giants

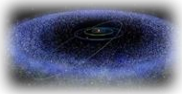
◆formed

◆Looking for water

◆ 2400km/h Causes of storm formation



Satellite science of Ice Giants



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

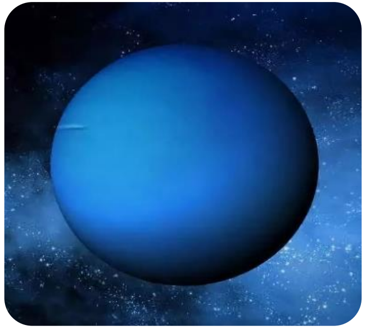
Part 2: Ice Giant Exploration Mission

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


Amanymede

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

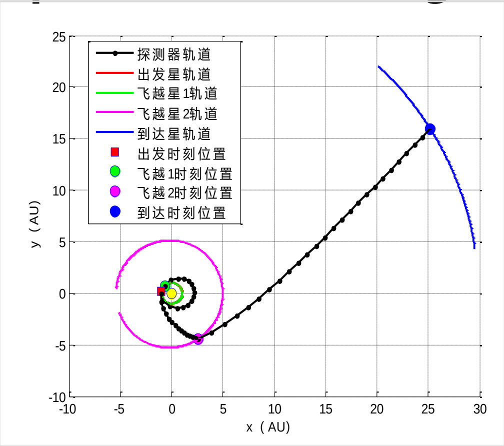
- ☐ The speed increment around the ice giant is required to be large, but the launch capability of the rocket is limited;
- ☐ The distance from the sun is far, and the power demand of the probe is large;
- ☐ High data transmission capacity is required for ultra long distance.

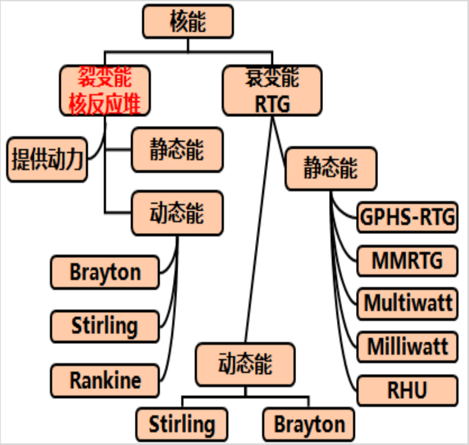
◆ **Orbit**： Planetary capture by force+small thrust transfer；

◆ **Power:** Fission reactor；

◆ **Communication**： Large aperture antenna。

Tianwen series tasks lay the technical foundation

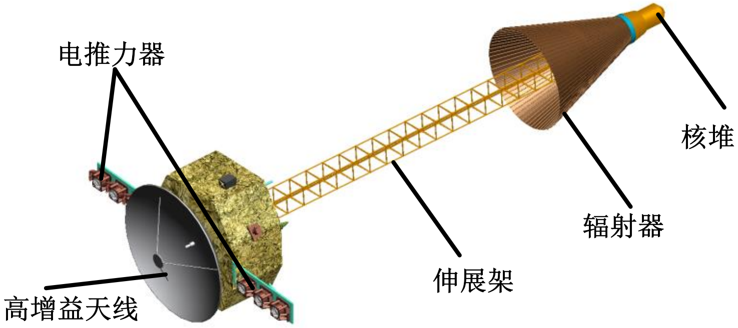


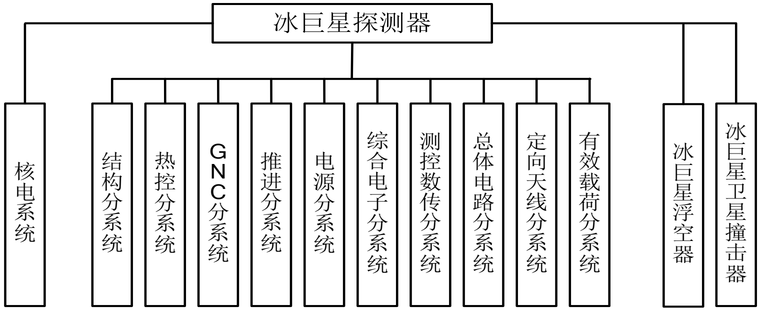


Part 2: Ice Giant Exploration Mission

Ice Giant Exploration Mission： System composition

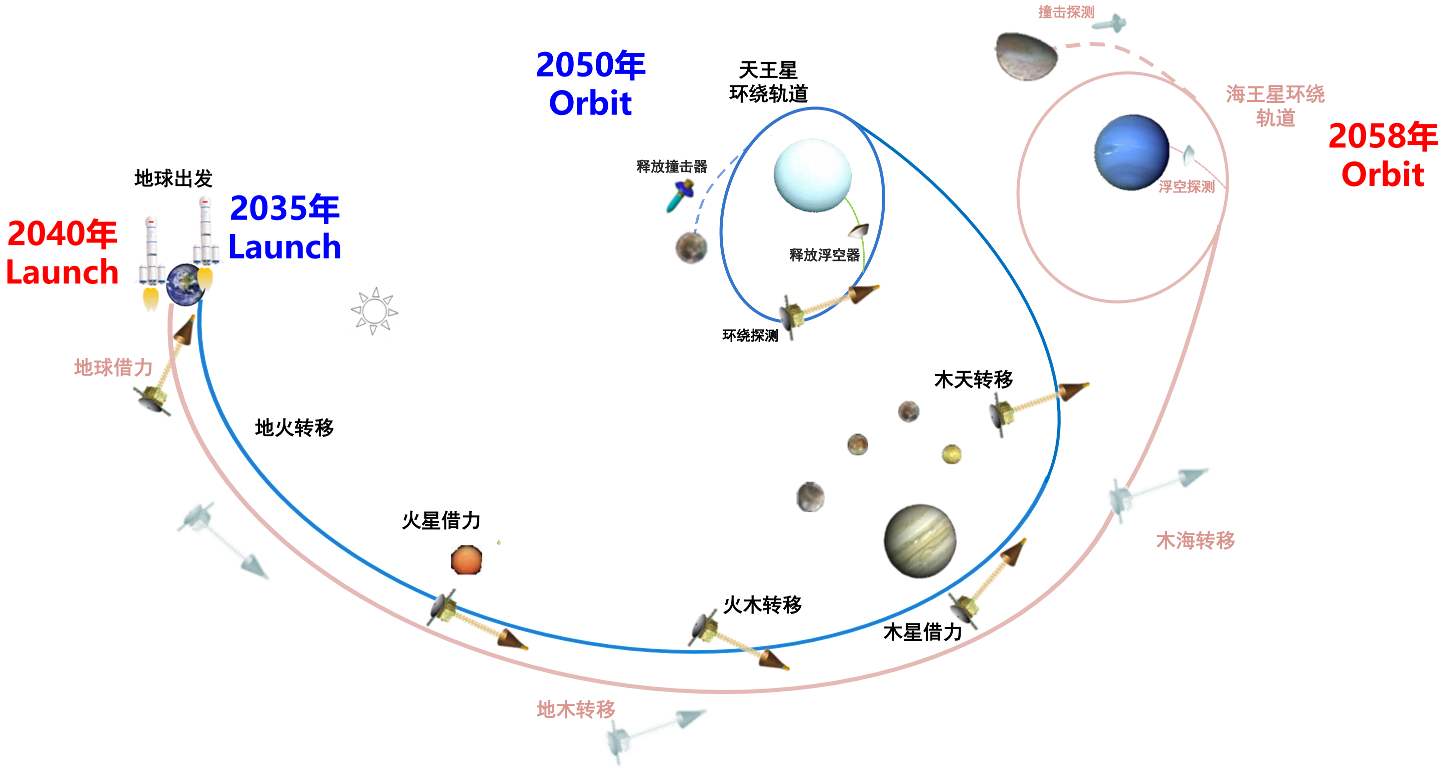
project system





Probe

Ice Giant Exploration Mission

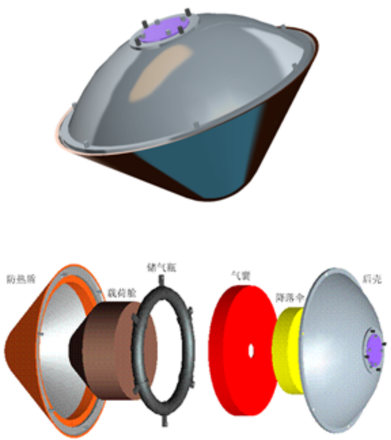


Ice Giant Exploration Mission

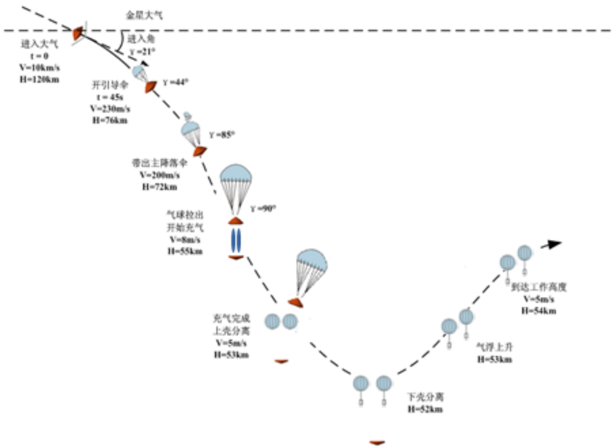
- **Atmospheric entry/floating exploration**

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

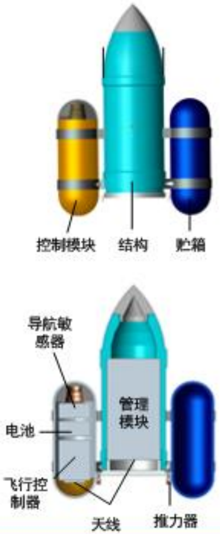


Ice Giant Exploration Mission

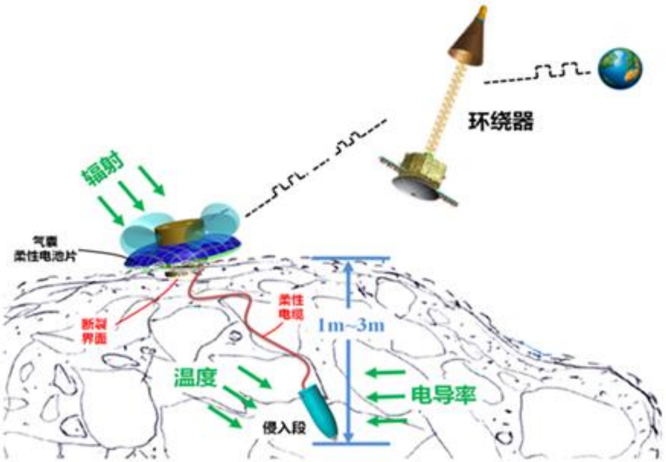
- **Impact/penetration exploration**

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

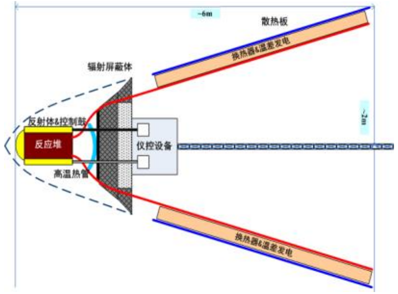


Process of impact

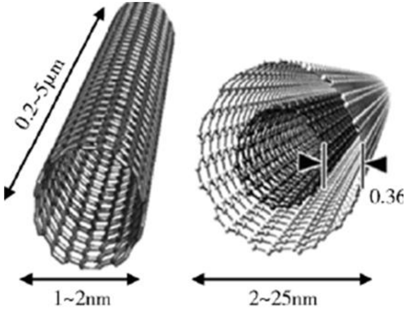


Part 2: Ice Giant Exploration Mission

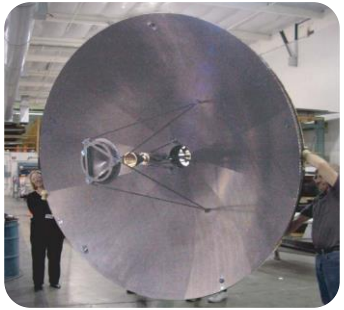
Core technology in Ice Giant exploration



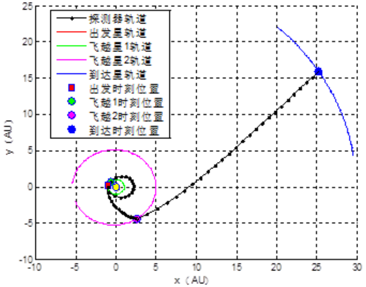
1. Integration and operation control of space heat pipe stack



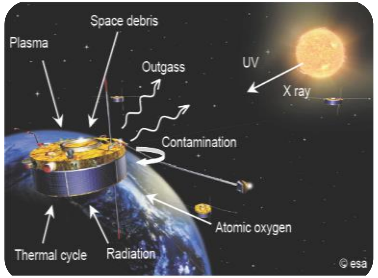
2. High efficient thermoelectric conversion materials



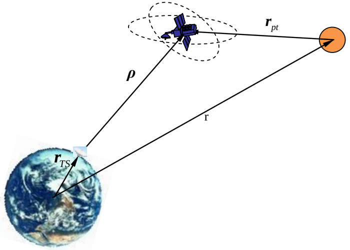
3. Very long distance high-speed data transmission



4. Borrowing force and small thrust capture



5. High reliability and long service life platform



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

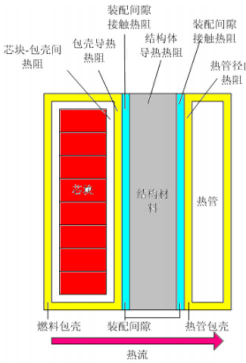
- The requirement of output power is 10kW
- The design service life is no less than 15 years

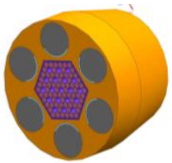
➢Technical status

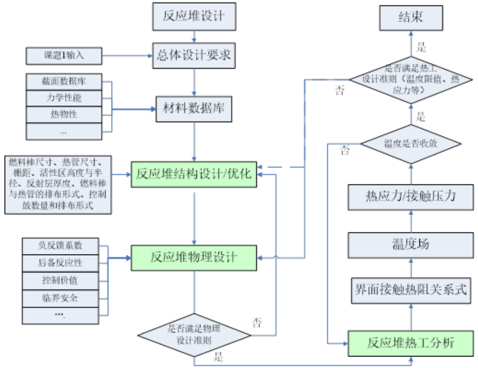
- Tianwen-4： studies on RTG technology
- Civil space flight： research on nuclear reactor and temperature difference power generation

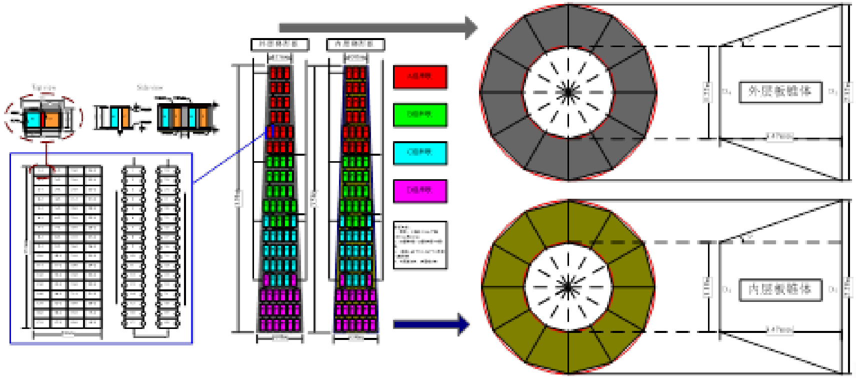
➢Technical approach

- 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

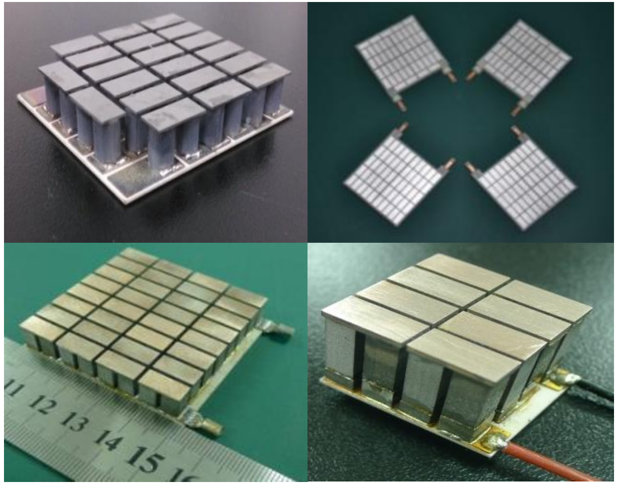
- The thermoelectric conversion efficiency needs to be more than 7%
- The mission period is 15 years with an annual decay rate of no more than 3%

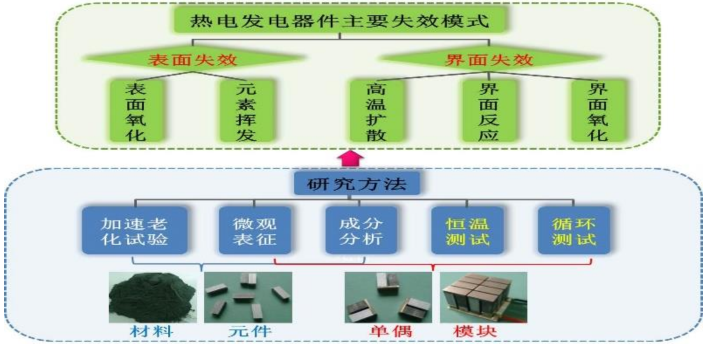
➢Technical status

- 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

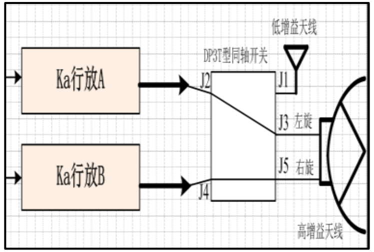
- Data transmission code rate needs to be more than **64Kbps** in **30AU** long communication distance
- Ground pointing accuracy requirement of **0.01°**

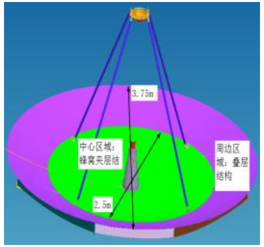
➢ Technical status

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

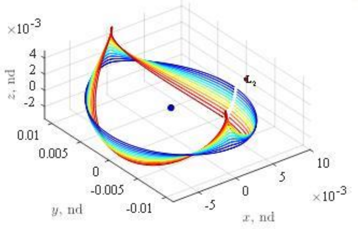
- The total mission period of interplanetary flight is **15 years**
- Fast transfer flight at nearly **30AU distance**
- Capturing the ice giant after continuous electric propulsion for nearly **40,000 hours**

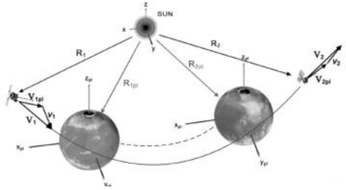
➢Technical status

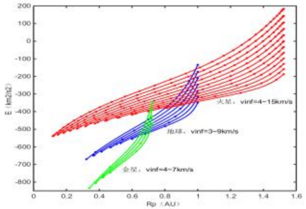
- Tianwen-2： Gravity-Assist technique and 40,000 hours of low thrust propulsion
- Tianwen-4： Venus and Jupiter Gravity-Assist technique

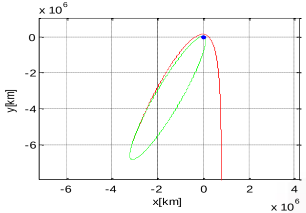
➢Technical approach

- 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

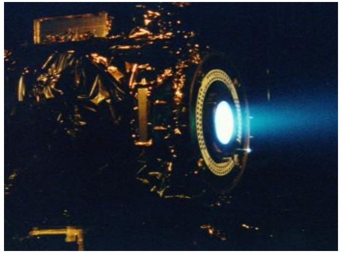
- The electric propulsion needs to be fired for more than 40,000 hours
- Withstand Jupiter's strong irradiation environment and long-term radiation from nuclear reactors
- Service life of mechanism and moving parts is 15 years

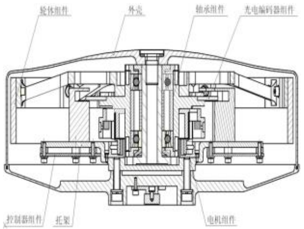
➢Technical status

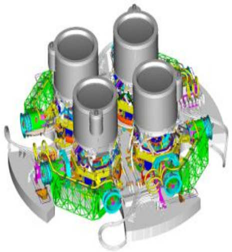
- Tianwen-2： The electric propulsion will be fired for 40,000 hours
- Tianwen-4： Withstand Jupiter's strong irradiation environment
- Near Earth satellite：Long service life of mechanism

➢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

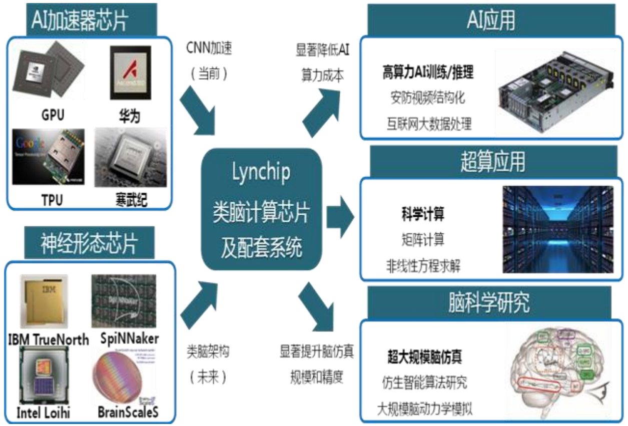
- About 13 years of Planetary cruise flight
- The time delay of the spacecraft is greater than 250min

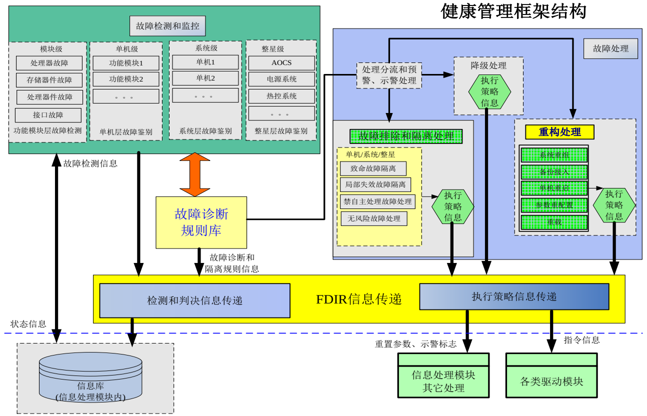
➢Technical status

- 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.

Although Earth is the homeland of mankind, human being can not live forever in the cradle.

Next Step, Ice Giant!

Thank you for listening！