绚丽天宫
九霄上的实验室

杨　扬　陈梦云　曹　骞◎编著

GORGEOUS SKY PALACE
LABORATORY ABOVE THE SKY

科学出版社

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Luna

序

中国载人航天工程于 1992 年开始实施，是继“两弹一星”后，实现中华民族伟大复兴的重大工程，承载着中国梦、航天梦。

我国载人航天工程按照“三步走”的发展战略，已发射载人飞船，突破航天员出舱活动技术、空间飞行器的交会对接技术，并已发射空间实验室，解决了有一定规模的、短期有人照料的空间应用问题。天宫二号空间实验室将是中国载人航天工程第二步的完美收官，具有里程碑意义。

天宫二号是继天宫一号之后，以实施空间科学和应用实验、空间技术试验为主要目标的空间实验室，学科领域涵盖微重力基础物理、空间天文观测、空间生命科学、空间材料科学等，航天员也将直接参与到科学实验中。它继往开来，为未来我国在载人空间站上开展较大规模、长期有人照料的空间应用积累技术和经验。

天宫二号搭载五十余部科学应用载荷，将在轨开展十余项科学和应用实验，探索国际科技前沿。全球第一台空间冷原子钟，能将航天器自主守时精度提高两个数量级；与欧洲空间局合作的伽玛暴偏振探测实验，可在空间中观测伽玛暴爆发及瞬变现象，在伽玛暴本质、宇宙结构、起源和演化等天体物理研究领域取得突破；空间生命科学研究，探究空间环境下高等植物的生长发育规律，获得微重力条件下植物的光周期诱导开花规律、调控机理等科学成果；量子密钥分配实验，保持我国在先进量子调控科学领域的领先地位。除此之外，天宫二号上还将开展多角度宽波段成像、多波段紫外临边成像、三维微波成像高度测量、综合精密定轨、液桥热毛细对流、综合材料实验、空间环境探测、伴随卫星等多项科学和应用实验。

《绚丽天宫：九霄上的实验室》采用彩色插图、实物照片，配以精炼的中英文介绍，以生动简明的形式将我国天宫二号空间实验室的科学应用任务展现给读者。本书主要编写人员有着长期从事载人航天应用任务管理和实践的经验。在本书的制作过程中，得到了中国载人航天工程总设计师周建平院士，载人航天空间应用系统前总指挥、总设计师顾逸东院士的指导，并为本书提出了宝贵的意见，在此表示衷心的感谢。

高铭

中国科学院空间应用工程与技术中心主任
中国载人航天空间应用系统总指挥

Preface

China Manned Space Program was launched in 1992, and is one of the National Science and Technology Major Programs to realize the great rejuvenation of the Chinese nation, bearing the China Dream, the Space Dream.

Following the Three-step Strategy, China Manned Space Program has launched manned spaceships, mastered the technology of extravehicular activities as well as space rendezvous and docking, launched the space laboratory, settled space utilization of a certain scale with man-tending on short-term basis. Tiangong-II space laboratory marks the consummate completion of the second step.

Tiangong-II space laboratory has scientific research, utilization and technology testing as primary goals. Various disciplines are covered, such as fundamental physics, astronomy, life science, space material science, etc. The astronauts will take part in these experiments in-orbit. The experience and knowledge gained on Tiangong-II will be key guidance for the space utilization on the Chinese Space Station in the near future.

Tiangong-II accommodates more than fifty scientific instruments to conduct more than ten projects in-orbit, exploring the frontier of science and technology. The first space cold atomic clock in the world increases the autonomous punctual accuracy of spacecraft by two orders of magnitude. Gamma-ray burst polarimetry, in cooperation with the European Space Agency, will make breakthrough discoveries in revealing the nature of gamma-ray bursts, as well as the origin and evolution of the universe. Space life science experiments studies the laws of higher plants growth and development in space environment. The quantum key distribution experiment consolidates China's leading position in advanced quantum manipulation science. In addition, a number of scientific and utilization projects would be carried out, such as multi-angle polarization and wide band spectral imaging, multiband limb UV spectral imaging, interferometric imaging radar altimetry, precise orbit determination, thermocapillary convection, multiple materials experiment, space environment monitoring and concomitant satellite.

In *Gorgeous Sky Palace*, introductory texts in both Chinese and English languages supported by color illustrations and actual pictures are presented, introducing the readers to the utilization of Tiangong-II in a living and concise way. The authors are experienced in project management and engineering of the manned space utilization. During the composing of this book, the Chief Designer of China Manned Space Program, Academician Zhou Jianping, and the former Chief Commander and Chief Designer of the utilization system in China Manned Space Program, Academician Gu Yidong, put forward valuable advice and guidance. We extend our heartfelt appreciation to them.

Director General of the Technology and Engineering Center
for Space Utilization, Chinese Academy of Sciences
Chief Commander of Utilization System of China Manned
Space Program

星空调色盘
Starry Palette

天蝎座心宿二周围，黄色、蓝色反射恒星光芒的尘埃云和红色电离发光的发射星云，色彩丰富，遂以调色盘著称。

Around the Scorpio Antares, there is a colorful region with yellow, blue dust clouds reflecting stars' light, and red emission nebula formed by ionized hydrogen. Next to the galactic center and rich of color, this region is known as starry palette.

银心
Galactic Center

整个银河条带中最明亮、恒星最密集的一片区域，拥有非常丰富的星团、星云，以及弥漫的尘埃。

The brightest and densest region in the Milky Way, populated with star clusters, nebulae and dispersed with interstellar dust.

该图片由中国科学院国家天文台兴隆观测站特聘天文摄影师王卓骁提供
Image courtesy of astrophotographer Wang Zhuoxiao from Xinglong Observatory, National Astronomical Observatories, Chinese Academy of Sciences.

从直立行走到石器时代结束，人类用了将近 400 万年，而从建立最早文明到进入太空，只用了不到 6500 年。

It took almost 4 million years for human beings to evolve from walking to mastering the use of tools, while it took merely less than 6.5 thousand years to go from establishing original culture to space exploration.

2003 年 10 月 15 日，北京时间上午 9 时，航天员杨利伟乘坐神舟五号飞船从酒泉发射场进入太空，历时 21 小时，于 10 月 16 日 6 时 23 分安全返回，着陆在内蒙古阿木古郎草原，完成了中国首次载人空间飞行。这一壮举使得中国成为第三个自主掌握载人航天技术的国家。

On 15th October, 2003, Shenzhou-V with Chinese astronaut Yang Liwei aboard launched from Jiuquan satellite launch center at 9:00 (GMT+08:00). After 21 hours in space, he safely landed in Inner Mongolia at 6:23 on 16th October. With this feat, China became the third nation in the world to master the manned space flight technology, after Russia and the United States.

明朝万户陶成道设想利用火箭的推力加上风筝的力量起飞。他是世界上第一个利用火箭向太空搏击的英雄，但是他也为这一勇敢的尝试献出了生命。

Tao Chengdao, a Ming Dynasty official, tried to take off with rockets and kites. He is the first human who attempted to explore space by rockets, losing his life in this brave endeavor.

冯如决心靠中国人自己的力量制造飞机。他谢绝了国外多方的邀请，带着飞机和技术回到祖国。

Feng Ru built his first airplane and even manufactured his own engine. After refusing many offers from foreign countries, he came back to China with his airplane and technology.

东方红一号卫星是中国于1970年4月24日成功发射升空的第一颗人造卫星，树立了中国航天史上的里程碑，使中国成为继苏联、美国、法国、日本后第五个能制造和发射人造卫星的国家。

Launched successfully on 24th April, 1970, Dongfanghong-I was China's first space satellite. It set the first footprint of China's space exploration. With Dongfanghong-I, China became the fifth nation attaining independent space technology, after Russia, the United States, France and Japan.

2008年9月25日，三名中国航天员翟志刚、刘伯明、景海鹏乘坐神舟七号载人飞船从酒泉卫星发射基地升空。2008年9月27日，北京时间16时30分，翟志刚出舱作业。
翟志刚为时22分钟的太空漫步标志着中国成为第三个有能力实现航天员舱外活动的国家。

The Shenzhou-VII manned spaceship launched on 25th September, 2008 at 21:10 (GMT+08:00), carrying three crew members, astronauts Zhai Zhigang, Liu Boming and Jing Haipeng.
On 27th September, at 16:30, Zhai Zhigang stepped out of the Shenzhou-VII and performed a 22 minutes extravehicular activity (EVA) in outer space. This was the first EVA of China.

北京航天飞行控制中心测控大厅内，正在进行发射前的最后准备，我国航天人辛勤工作的成果即将得到检验。

In Beijing Aerospace Control Center, experts are preparing the final launch sequence.

长征二号F型火箭发射塔架高达百余米，供科研人员对飞行器、火箭进行发射前的最后测试、检查。

发射塔架的主要任务包括完成飞船火箭组合体功能检查、推进剂加注、航天员进舱、点火发射、航天员应急救生等工作。

The launch tower of the Longmarch-2F is about 100 meters high, and supports the testing of both the spacecraft and the rocket.

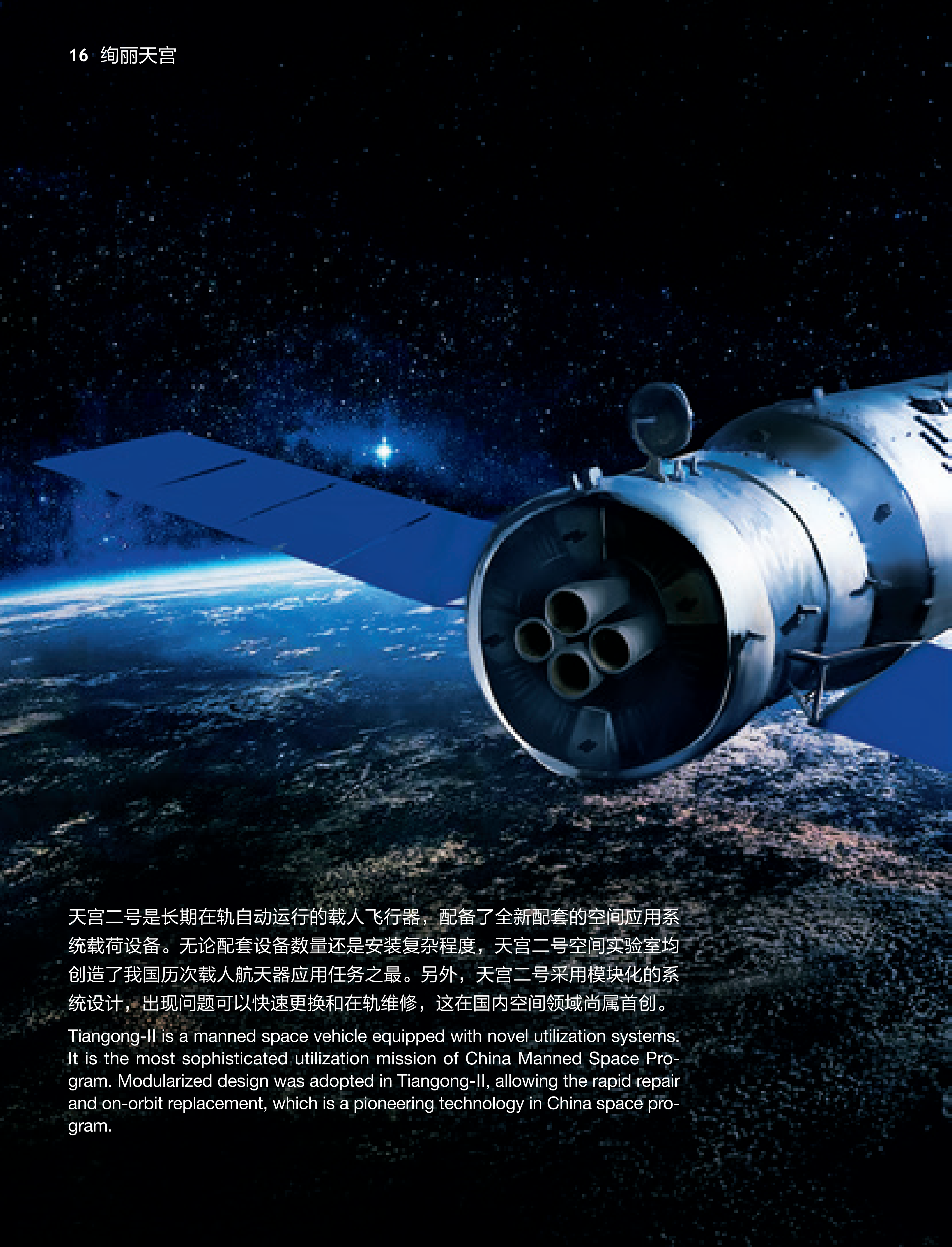
The launch tower allows testing the assembly of the spacecraft and the rocket, rocket fuelling, astronaut boarding, rocket igniting, astronaut rescuing in case of emergency and other functions.

酒泉发射场

Jiuquan Satellite Launch Center

天宫二号空间实验室将由长征二号 F 型运载火箭送入轨道。长征二号 F 型运载火箭是在长征二号捆绑运载火箭基础上，按照发射载人飞船的要求，进一步提高可靠性、确保安全性而设计的运载火箭。长征二号 F 型运载火箭曾是我国运载火箭中起飞质量最大、长度最长的火箭，多次成功发射神舟系列飞船等飞行器进入轨道。

The Longmarch-2F is the launch vehicle of Tiangong-II and it is designed to meet the demands of manned spacecraft. The Longmarch-2F was the most powerfull rocket of China, and has successfully launched many spacecraft into orbit, such as the Shenzhou spaceship series.



天宫二号是长期在轨自动运行的载人飞行器，配备了全新配套的空间应用系统载荷设备。无论配套设备数量还是安装复杂程度，天宫二号空间实验室均创造了我国历次载人航天器应用任务之最。另外，天宫二号采用模块化的系统设计，出现问题可以快速更换和在轨维修，这在国内空间领域尚属首创。

Tiangong-II is a manned space vehicle equipped with novel utilization systems. It is the most sophisticated utilization mission of China Manned Space Program. Modularized design was adopted in Tiangong-II, allowing the rapid repair and on-orbit replacement, which is a pioneering technology in China space program.

天宫二号空间实验室将在近地轨道工作两年以上，在此期间将开展一系列空间实验并进一步验证空间交会对接技术，实现有一定规模、短期有人照料的空间应用，是我国建造空间站之前进行技术验证的重要平台。

The Tiangong-II space laboratory will serve in low earth orbit for more than two years. Various space experiments will be conducted, and the rendezvous and docking technology will be further verified. It provides a solution for space utilization of a certain scale with man-tending on short-term basis, which is a key stage prior to the construction of the future Chinese Space Station.

神舟十一号飞船将载两名航天员与天宫二号进行交会对接，航天员将进入天宫二号空间实验室进行中期驻留试验。

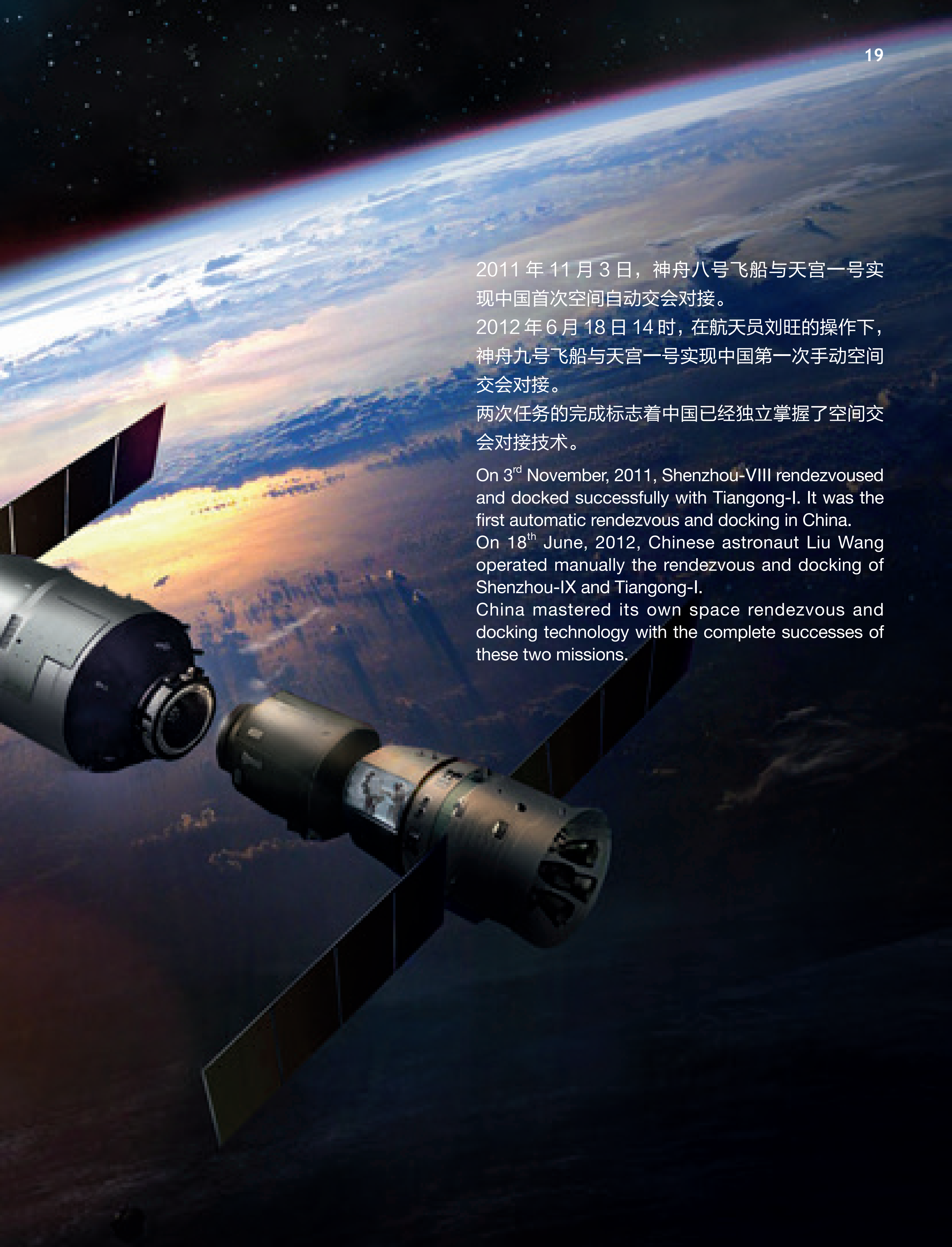
With two astronauts aboard, Shenzhou-XI launched and docked at Tiangong-II. Astronauts then entered the space laboratory to live and work onboard Tiangong-II for several weeks.

交会是指两个航天器在交会轨道上相互接近的过程；对接是指两个航天器完成相互耦合和刚性密封连接的过程。

空间交会对接技术是进行航天器的空间装配、补给、维修、航天员交换及营救等在轨服务的必要空间技术。

Rendezvous is the process of two spacecraft getting close to each other on the rendezvous orbit. Docking refers to the process of completing a mutual coupling and rigid sealing between two spacecraft.

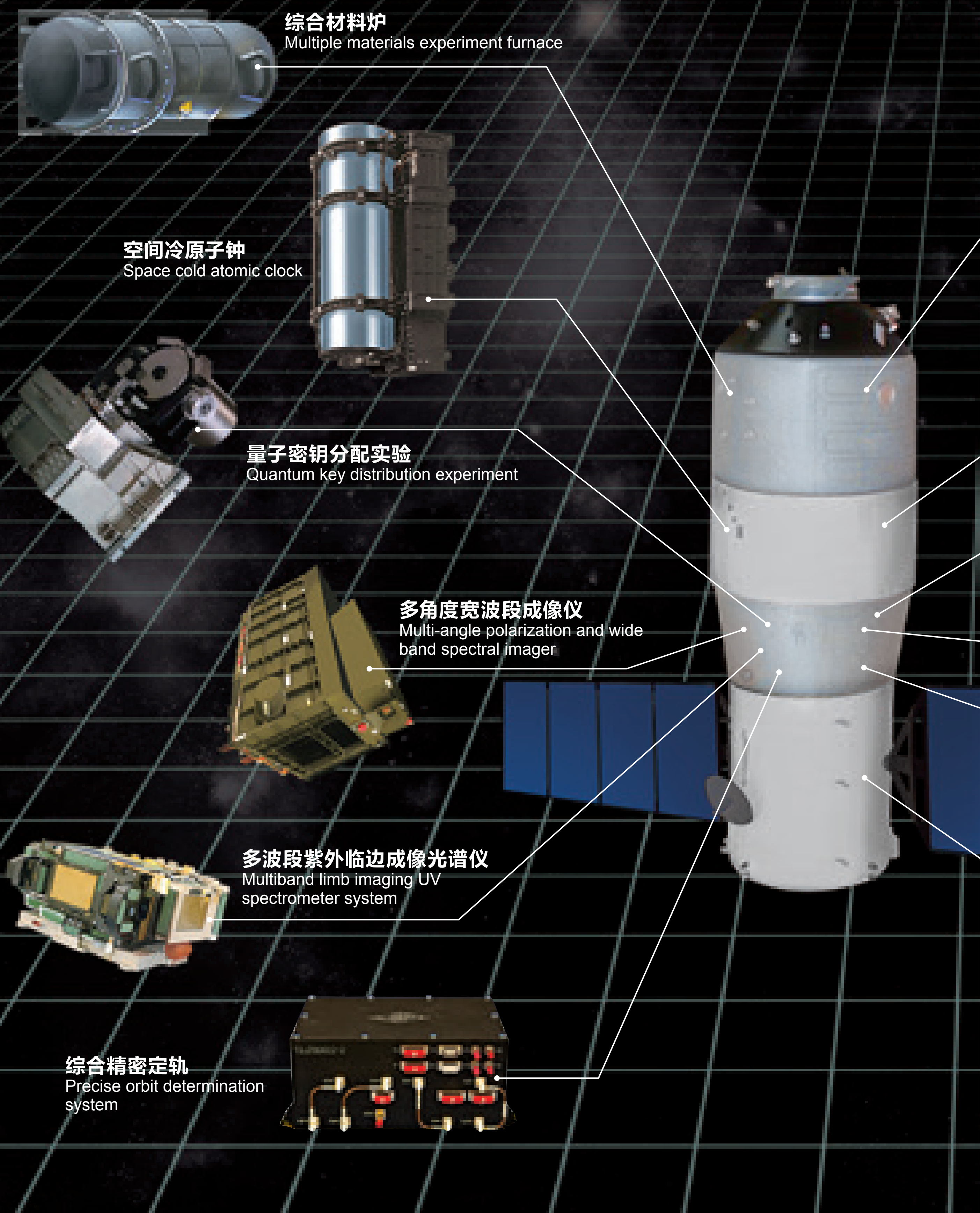
Rendezvous and docking are key space technologies necessary for spacecraft assembly, supply, maintenance, exchange of astronauts and other services in orbit.

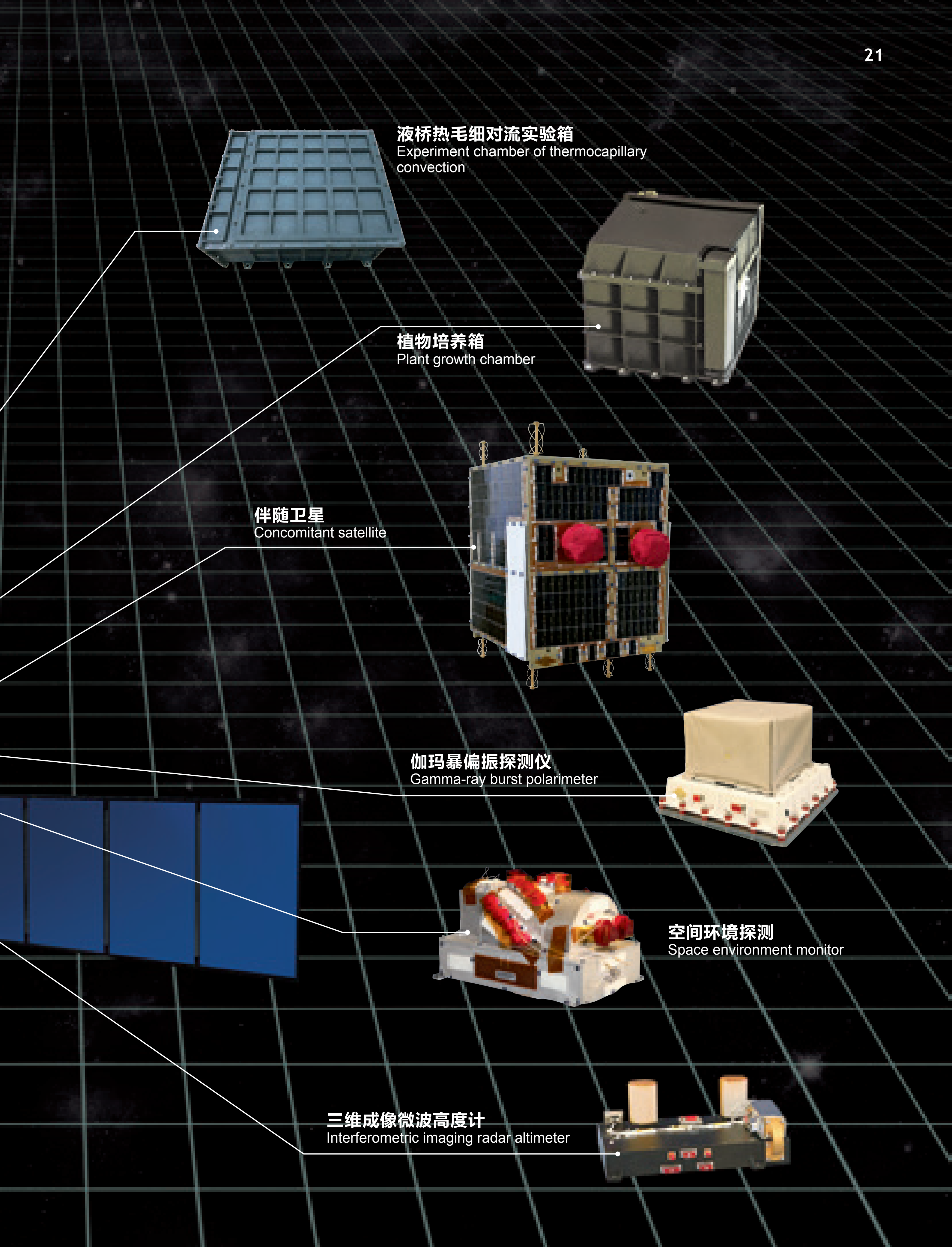


2011年11月3日，神舟八号飞船与天宫一号实现中国首次空间自动交会对接。
2012年6月18日14时，在航天员刘旺的操作下，神舟九号飞船与天宫一号实现中国第一次手动空间交会对接。
两次任务的完成标志着中国已经独立掌握了空间交会对接技术。

On 3rd November, 2011, Shenzhou-VIII rendezvoused and docked successfully with Tiangong-I. It was the first automatic rendezvous and docking in China.
On 18th June, 2012, Chinese astronaut Liu Wang operated manually the rendezvous and docking of Shenzhou-IX and Tiangong-I.
China mastered its own space rendezvous and docking technology with the complete successes of these two missions.

天宫二号空间实验室搭载若干科学实验设备
Tiangong-II with Scientific Experiment Devices




液桥热毛细对流实验箱
Experiment chamber of thermocapillary convection
植物培养箱
Plant growth chamber
伴随卫星
Concomitant satellite
伽玛暴偏振探测仪
Gamma-ray burst polarimeter
空间环境探测
Space environment monitor
三维成像微波高度计
Interferometric imaging radar altimeter

空间冷原子钟
Space Cold Atom Clock

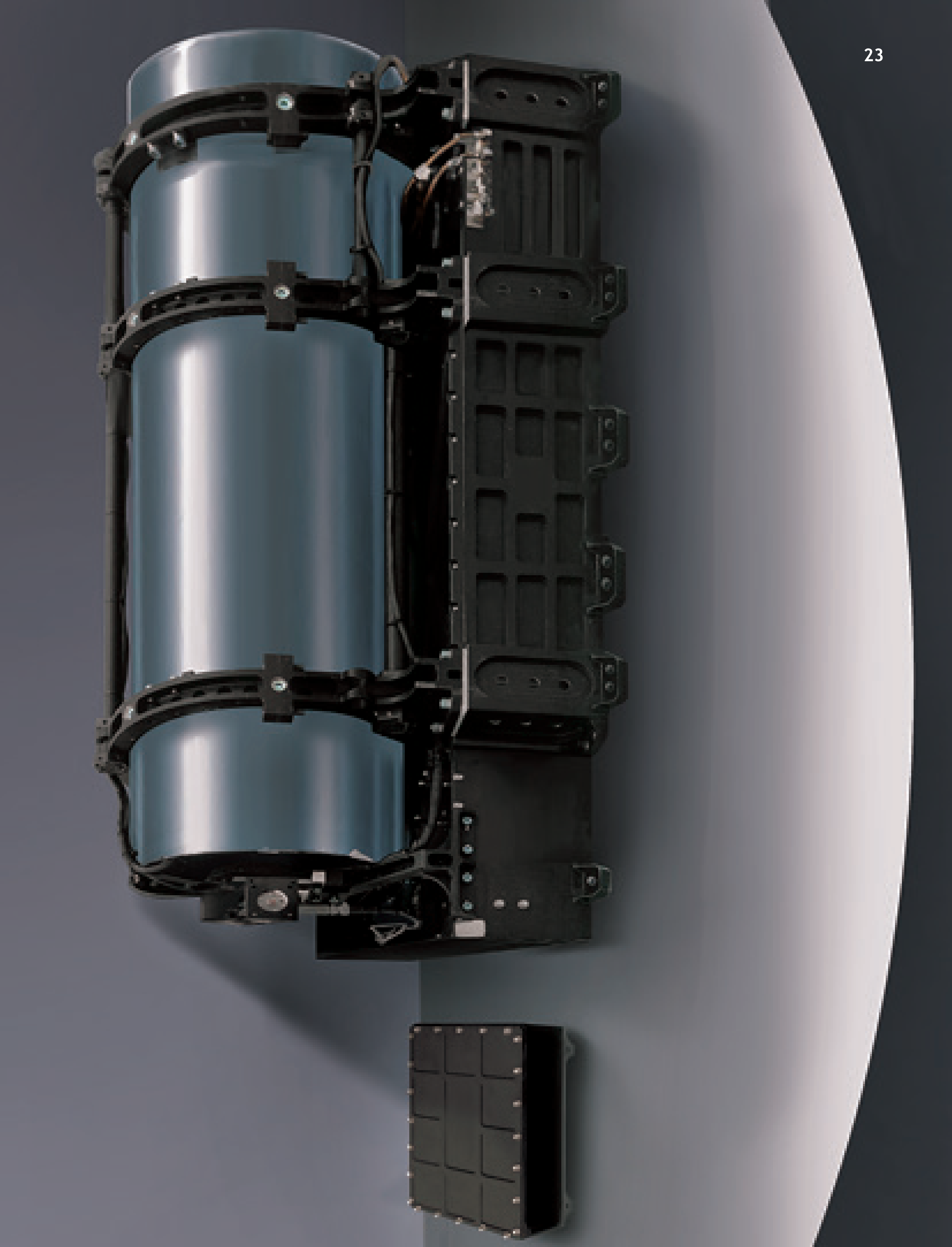
天宫二号上搭载了全球第一台空间冷原子钟，利用空间特殊环境，天宫二号上冷原子钟的频率稳定度将高达 10^{-16}，将航天器自主守时精度提高两个数量级，为空间科学和技术、深空探测、广义相对论验证、基本物理常数测量、导航系统等方面获得超高精度时频基准奠定基础。

The space cold atom clock in Tiangong-II will perform a pioneering timing experiment with cold atoms in space. The frequency stability will reach a 10^{-16} level in space, increasing the autonomous punctual accuracy of spacecraft by two orders of magnitude. This research lays a solid foundation to apply highly performing time-frequency bases in space sciences and technologies, deep space missions, verification of general relativity, navigation systems, and measurements of fundamental constants, etc.

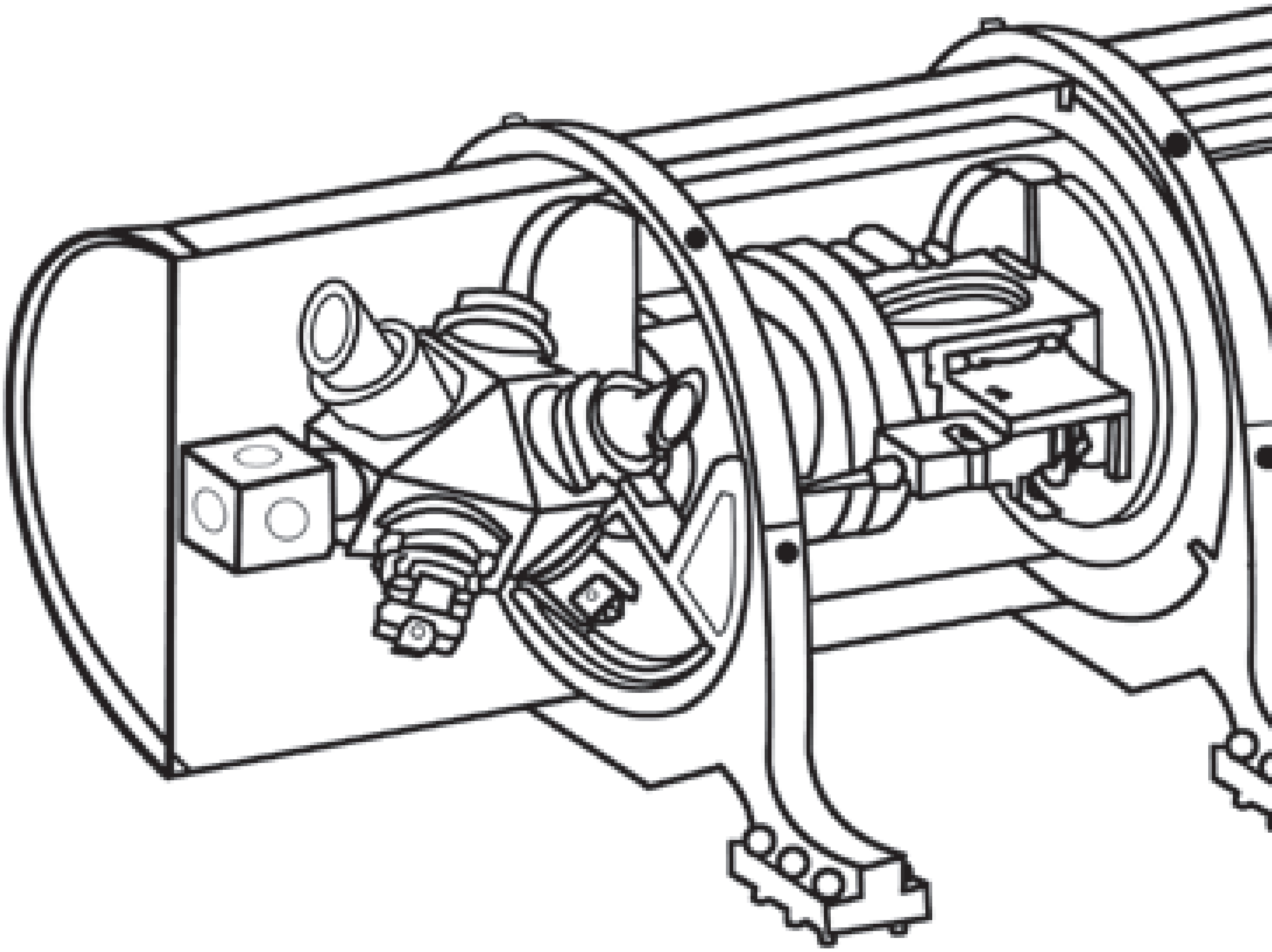
激光冷却原子技术，利用激光和原子的相互作用降低原子运动速度，可以获得超低温原子，把原子冷却到绝对零度附近。在空间环境下，这种冷却后的原子被抛射进微波场时，原子与微波的作用时间大大加长，使得原子钟的精度显著提高，从而实现高精度的“冷原子钟”。

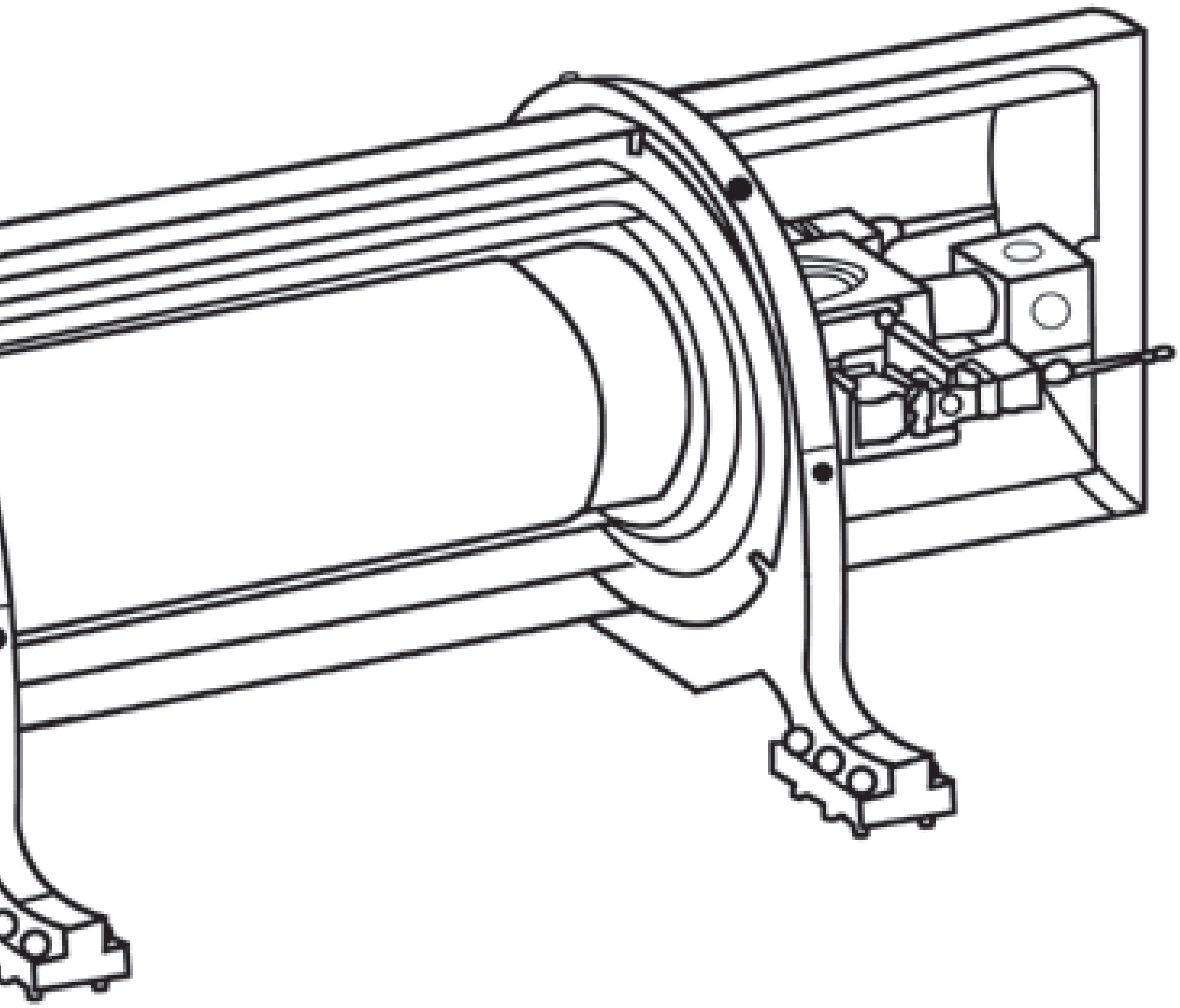
The atom laser cooling technology employs the interaction between laser and atom to lower down the atomic activity, obtaining a state close to the absolute zero degree. When the cooled atoms are injected into microwave field in space environment, the duration of the interaction between atoms and microwave becomes much longer. This phenomenon is used to improve the accuracy of atomic clocks, allowing their development and application.

空间冷原子钟主体
Main part of the space cold atom clock

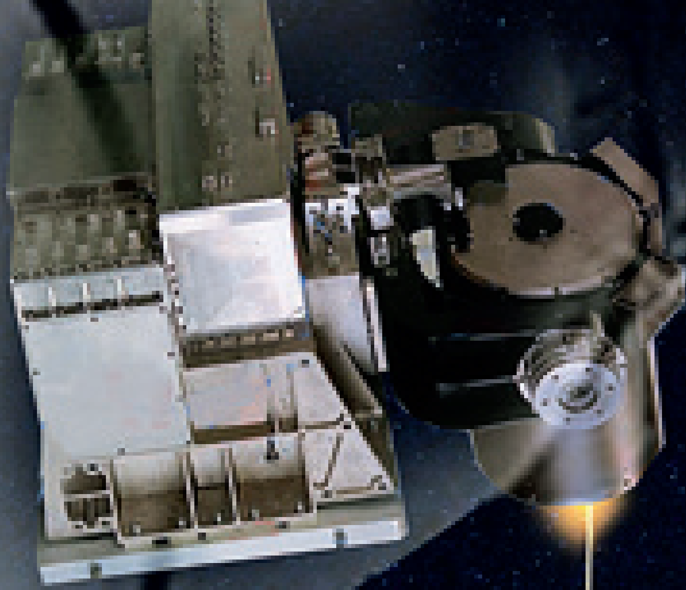


空间冷原子钟主体
Main Part of the Space Cold Atom Clock





研制团队：中国科学院上海光学精密机械研究所空间冷原子钟实验团队
Project team: Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences



量子密钥分配实验
Space-to-Earth Quantum Key Distribution

量子通信是指利用量子不可克隆定律进行信息传递的新型通信方式。使用量子通信方式，可以确保通信中密钥分发的无条件安全，从根本上解决信息安全问题。

Quantum communication is a new means of information transmission by utilizing Quantum No-Cloning Theorem. Quantum communication ensures unconditional security of the key distribution, which can solve the fundamental problem in information security.

量子密钥分配实验光机主体
Main part of the quantum key distribution experiment device

量子密钥分配是量子通信的核心环节。天宫二号上的量子密钥分配实验将诞生不会被窃听和破译的密信，验证量子密钥传输，并为实现广域保密通信网络奠定基础。

In this experiment, the space-to-earth quantum key distribution comes true, which would never be decoded nor intercepted. Meanwhile, it lays a solid foundation for wide-area security communication network.

动态跟瞄测试
Acquisition-Tracking-Pointing Test (ATP)

量子是微观物理世界里不可分割的基本个体。由于作为信息载体的单光子具有不可分割、量子状态不可克隆等特性，因而密钥分发可以抵御任何形式的窃听，进而保证用其加密的内容不可被破译。从原理上来说，这种通信方式就是无条件安全的。

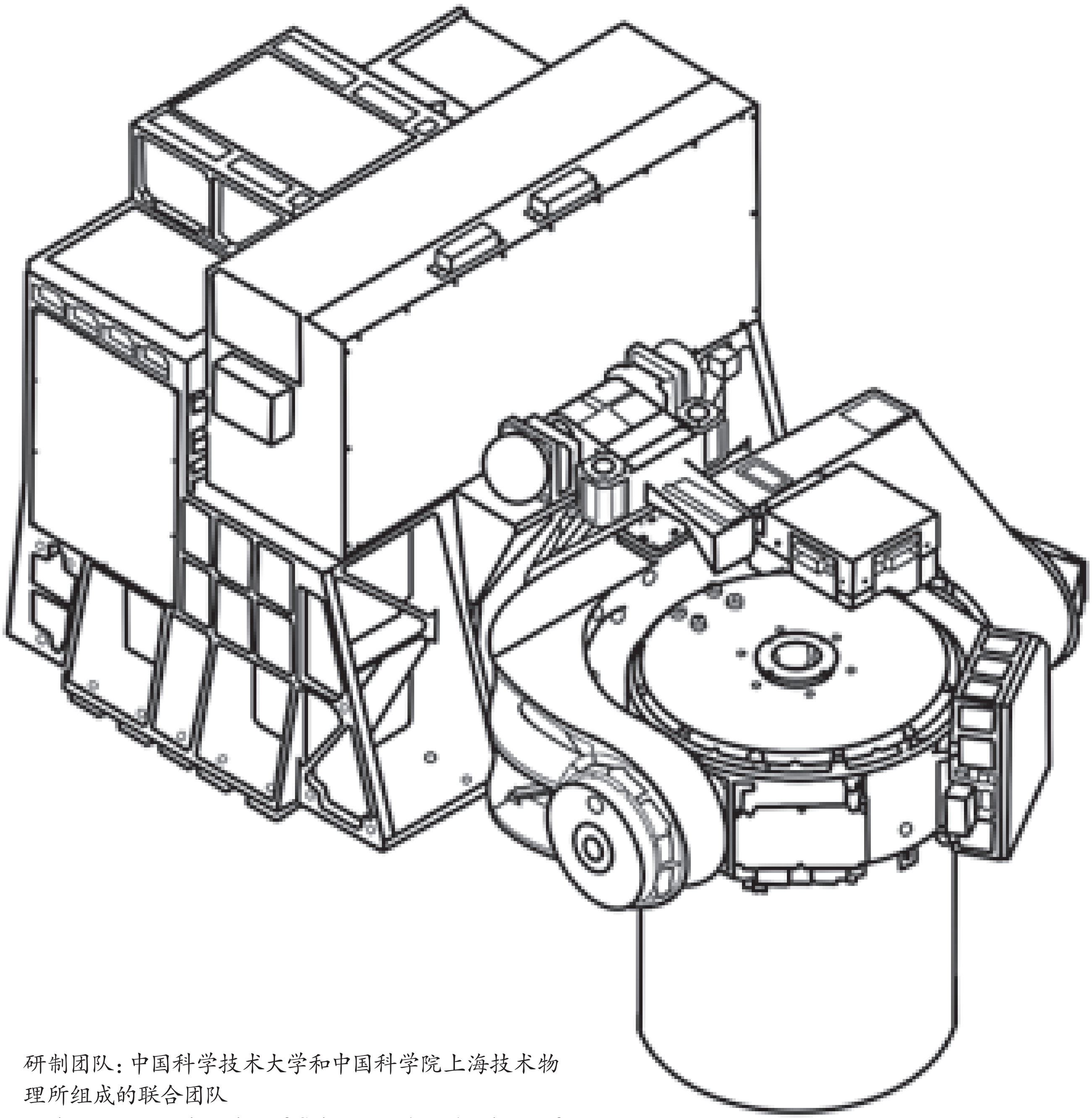
近年，我国还将建成世界第一条量子通信保密干线——“京沪干线”，建设连接北京、上海的广域光纤量子通信网络。

Quantum is indivisible in the microscopic world. As a medium of information, a single photon is indivisible and cannot be copied, reproduced or cloned. Key distribution can resist any form of interception, ensuring that encrypted data cannot be deciphered. This means that communication can be made unconditionally secure by nature.

The fiber quantum communication network, Beijing-Shanghai route, is under construction, which will be the world’s longest confidential communication system.

量子密钥分配实验空间载荷

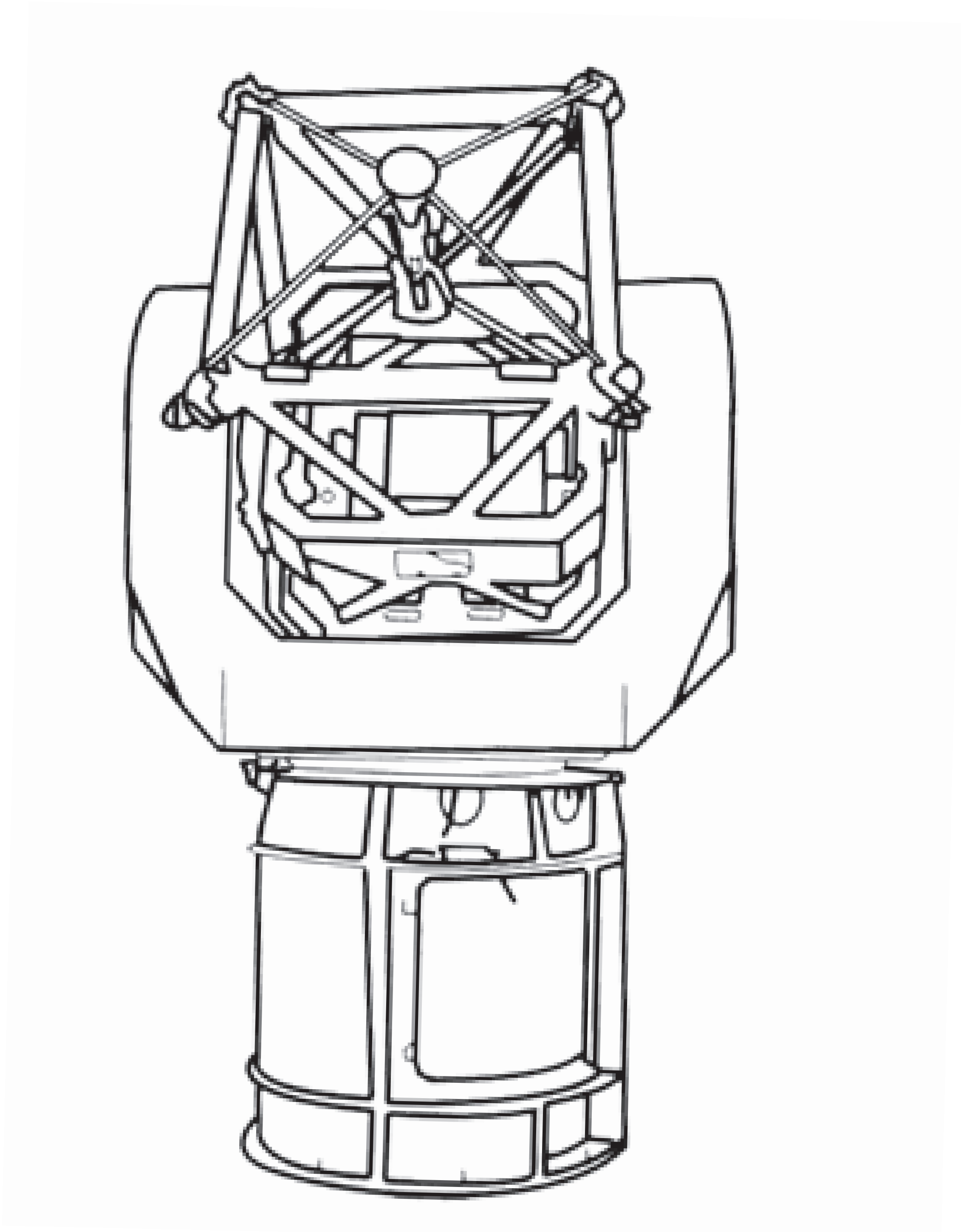
Space Payload of the Space-to-Earth Quantum Key Distribution Experiment

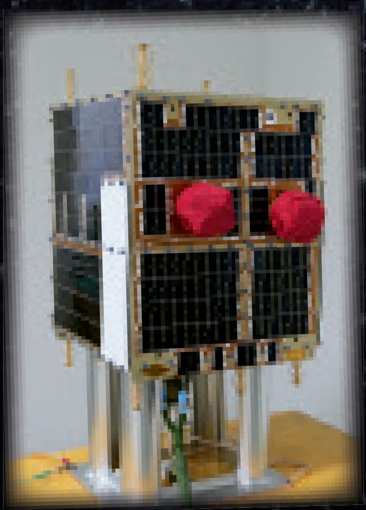


研制团队：中国科学技术大学和中国科学院上海技术物理所组成的联合团队

Project team: University of Science and Technology of China and Shanghai Institute of Technical Physics of the Chinese Academy of Sciences

量子密钥分配实验地面终端
Ground Segment of the Space-to-Earth Quantum Key Distribution Experiment





地面试验中的伴随卫星
Concomitant satellite in ground-based experiment

伴随卫星释放机构
Deploy device of concomitant satellite

伴随卫星
Concomitant Satellite

天宫二号携带小卫星，并将在空间中验证小卫星在轨释放、驻留伴随飞行等技术。

Tiangong-II carries and deploys a small satellite in orbit. Technologies such as small satellite in-orbit deployment and concomitant flying will be further verified.

伴随卫星拍摄到的天宫二号
Tiangong-II in the “Eye” of Concomitant Satellite

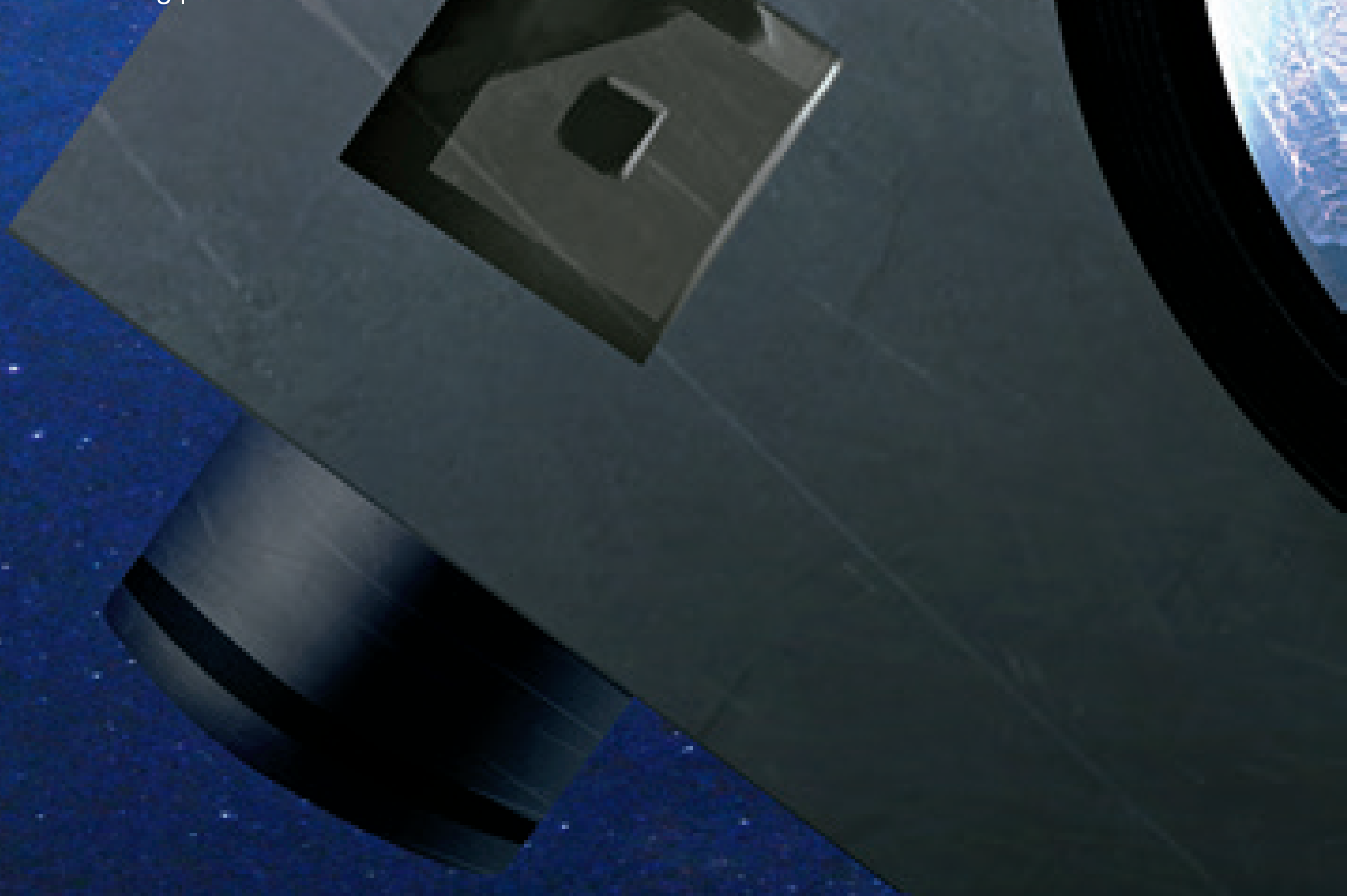
伴随卫星具有结构小、重量轻、任务灵活的特点，可以在主航天器上直接释放，节约发射成本。

天宫二号的伴随卫星作为空间实验室的一部分，释放后对天宫二号近距离实时跟随，并可对天宫二号进行近距离拍摄。伴随卫星利用其独特的位置优势，可以对主航天器进行实时监测，作为主航天器的安全辅助工具，还可对航天员的舱外活动和飞行器交会对接提供支持。

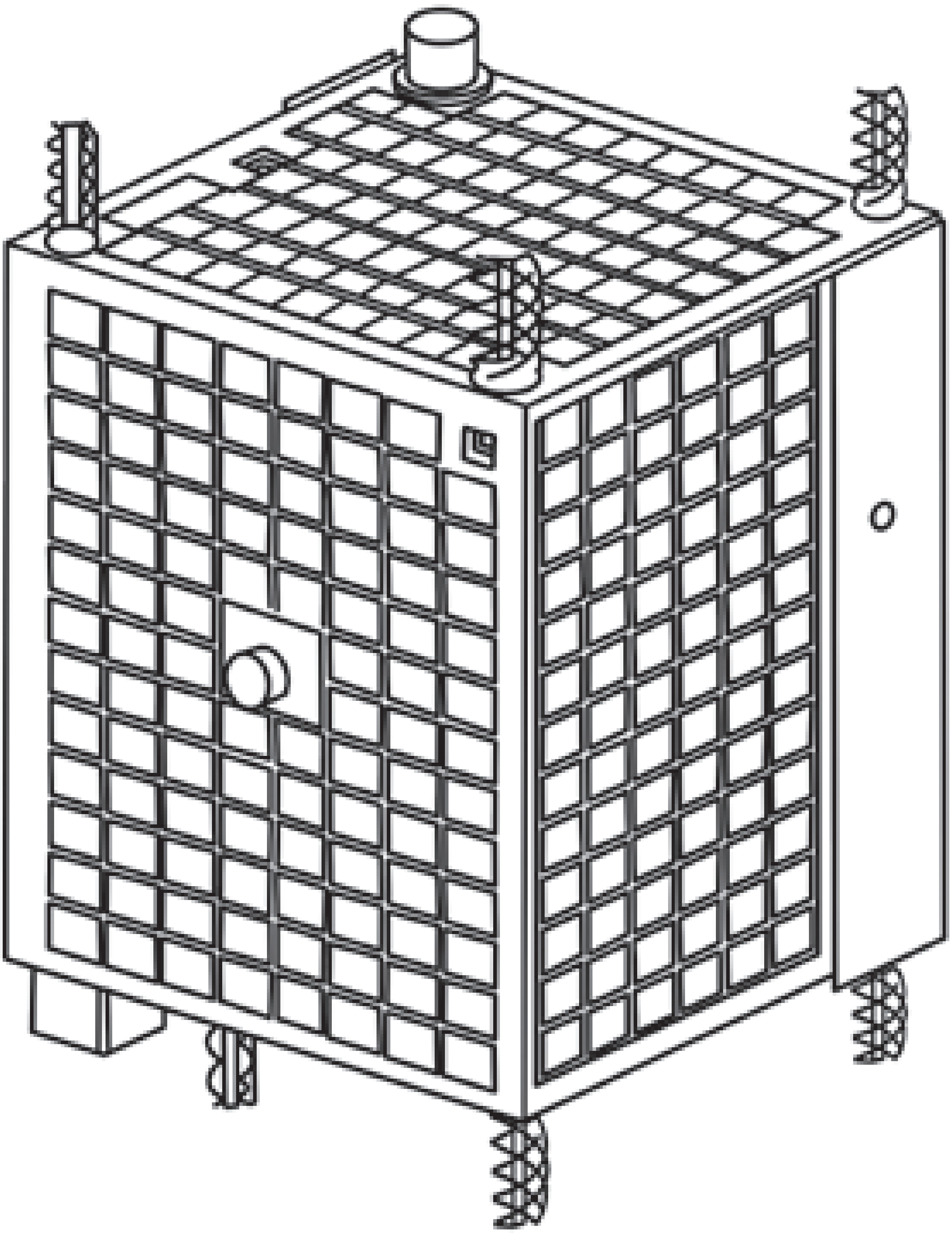
With features of small, lightweight and flexible, concomitant satellites can be directly deployed by the mother spacecraft to save launch costs.

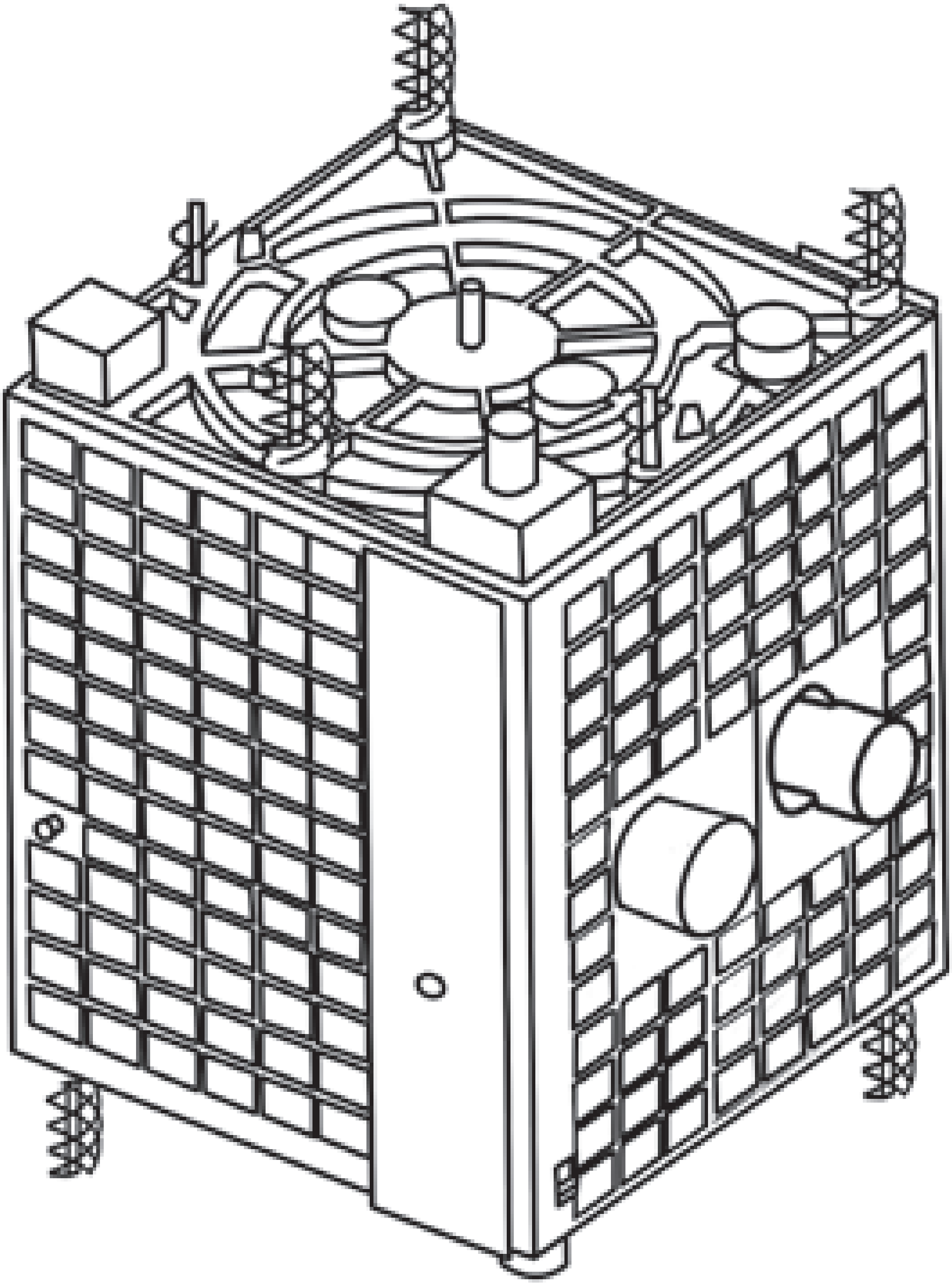
As part of the space laboratory, concomitant satellite flies with Tiangong-II closely in real-time after deployment, and takes close-up pictures of the spacelab.

Concomitant satellite can conduct real-time monitoring of Tiangong-II. Acting as an auxiliary of Tiangong-II, concomitant satellite can support astronauts’ extravehicular activity and spacecraft rendezvous and docking processes.



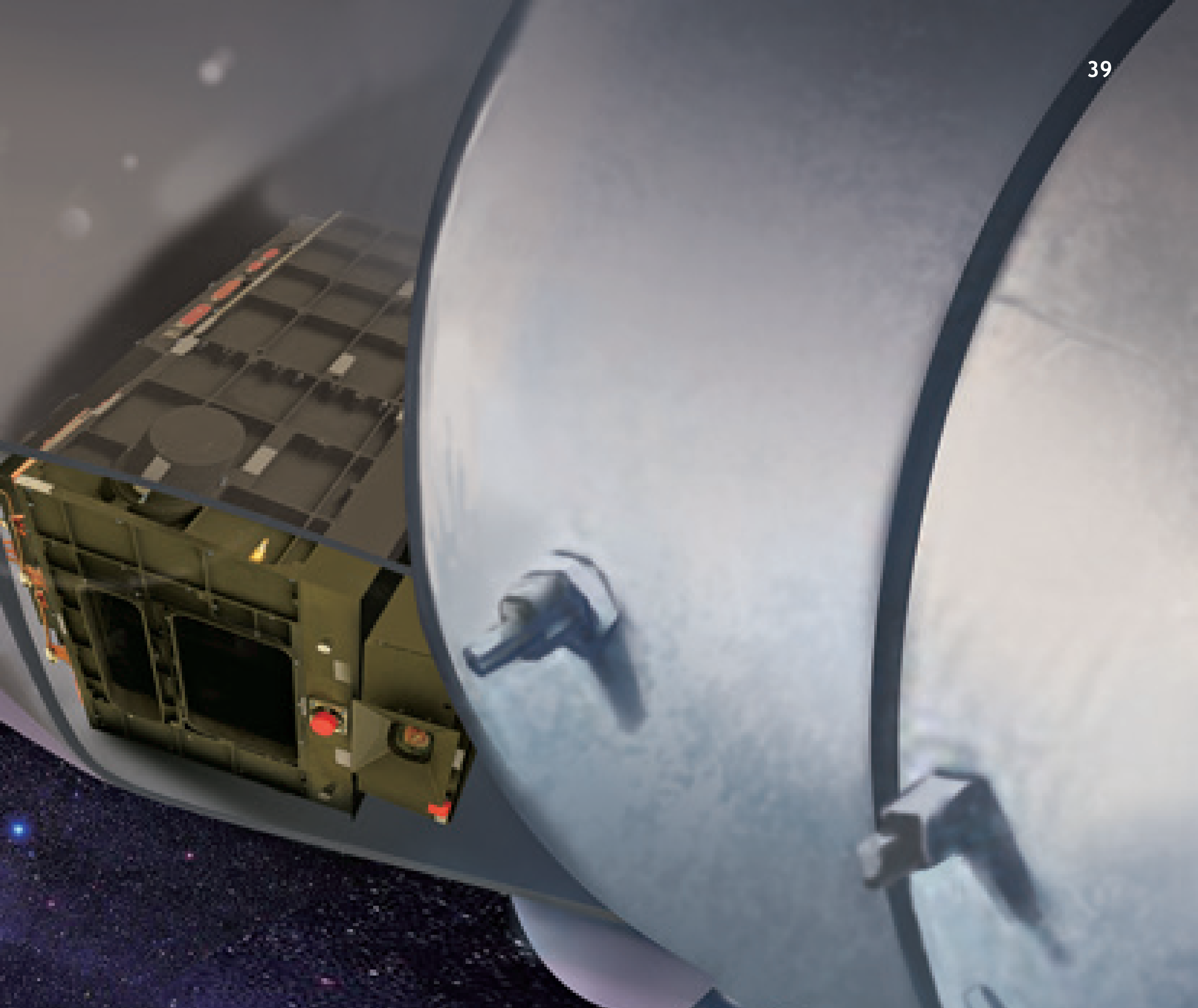
伴随卫星
Concomitant Satellite





研制团队：中国科学院微小卫星创新研究院微纳卫星研究所
Project team: Innovative Academy for Microsatellites of Chinese Academy of Sciences

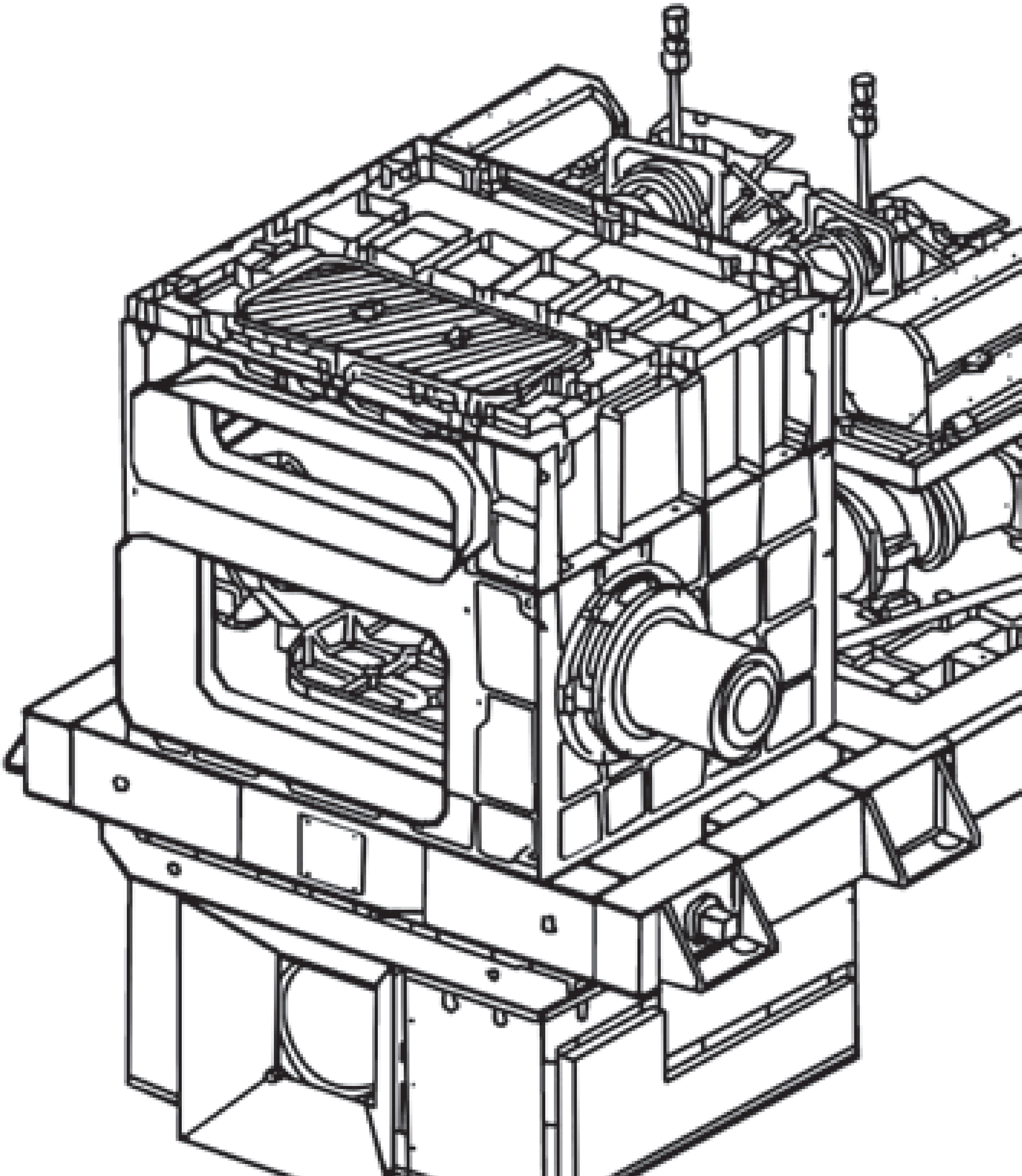
多角度宽波段成像仪主体
Main part of the multi-angle polarization and wide band spectral imager

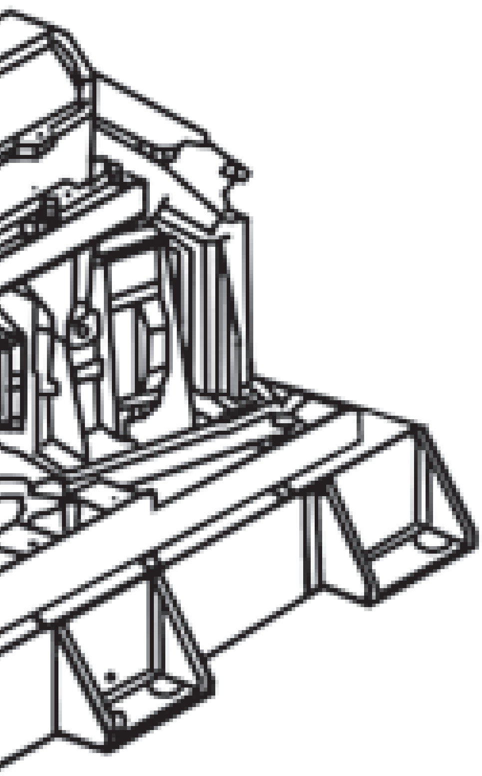


多角度宽波段成像仪
Multi-angle Polarization and Wide Band Spectral Imager

多角度宽波段成像仪可获取广域覆盖的海洋、大气、陆地等图谱合一宽光谱景象，探测卷云、气溶胶、云顶高度等环境因素，将服务于地球环境监测、农业、林业、地质、灾害等领域。

The multi-angle polarization and wide band spectral imager can get image of the oceans, the atmosphere and land in wide spectrum. It can be used to detect cirrus clouds, aerosols, cloud-tops and other environmental factors, and support environmental surveillance, agriculture, forestry, global climate change and so on.

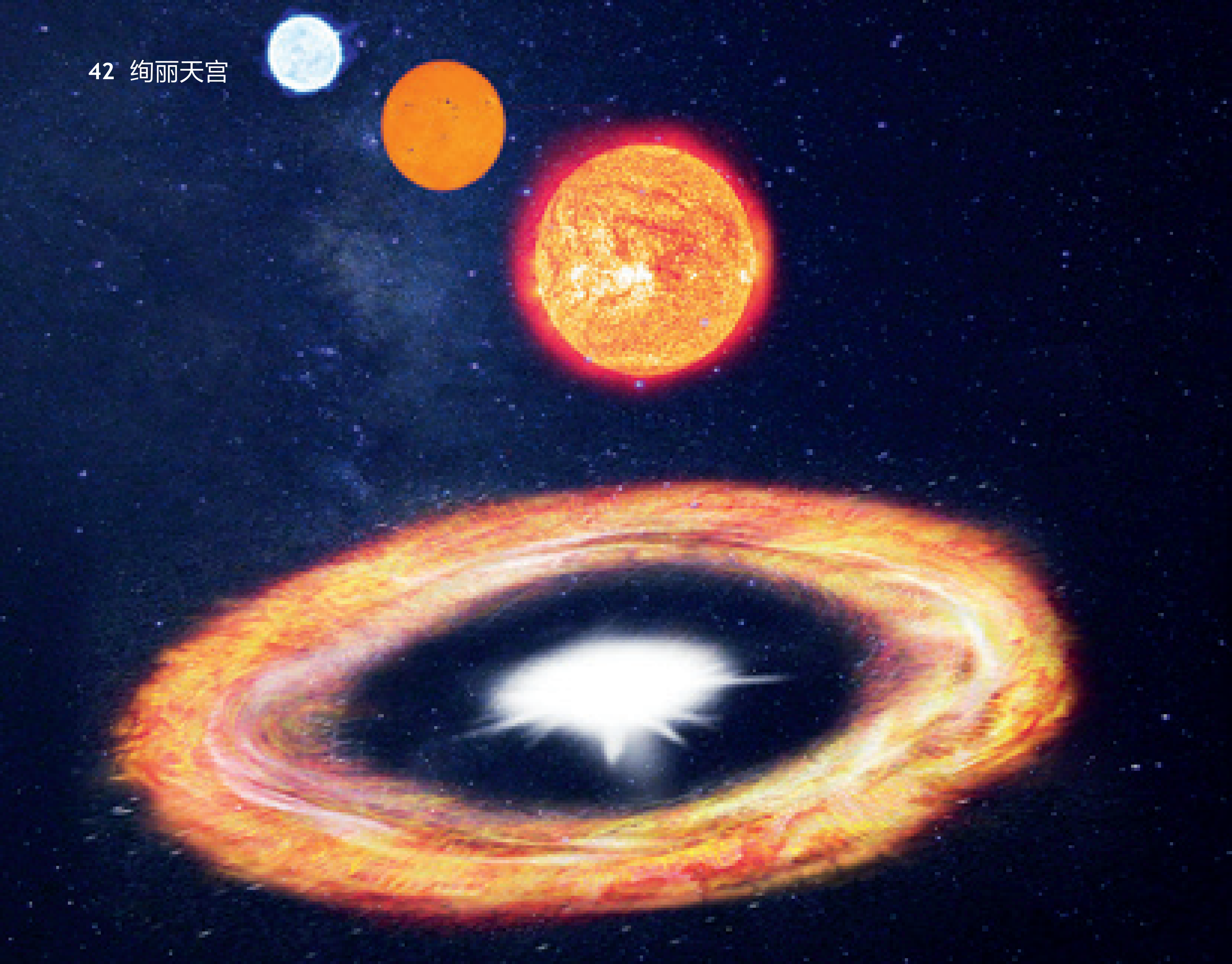




多角度宽波段成像仪
Multi-angle Polarization and Wide Band Spectral Imager

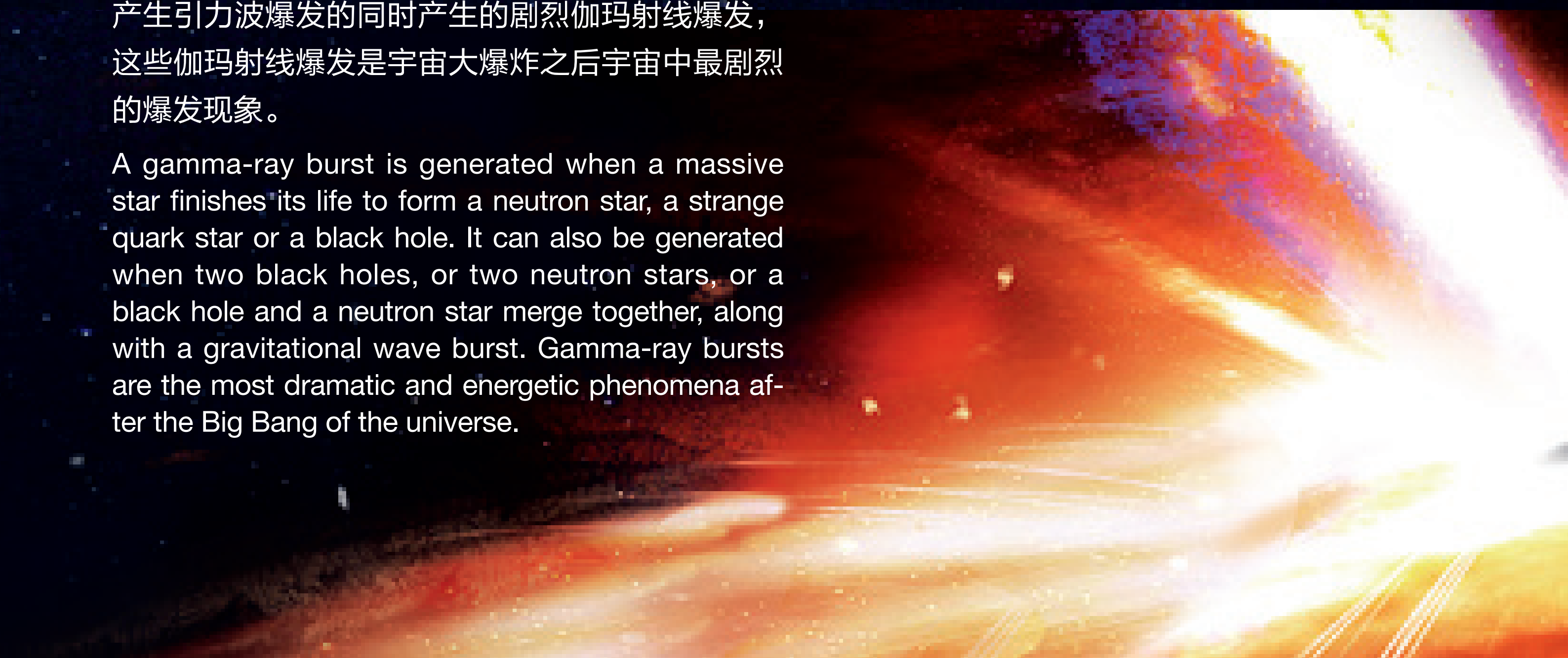
研制团队：中国科学院上海技术物理研究所多角度宽波段成像仪项目研制组

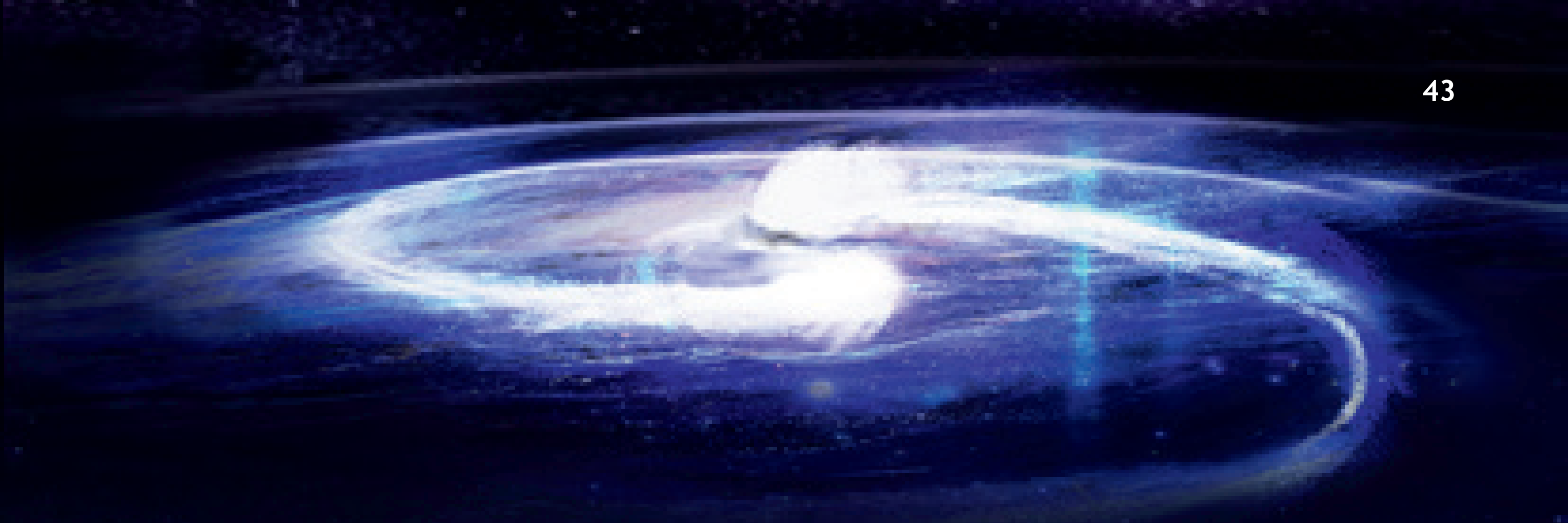
Project team: Team of Multi-angle Polarization and Wide Band Spectral Imager, Shanghai Institute of Technical Physics of the Chinese Academy of Sciences



伽玛暴是大质量恒星演化到最后形成中子星、奇异夸克星或黑洞过程中产生的剧烈伽玛射线爆发，也可能是由黑洞或者中子星组成的双星系统最后并合产生引力波爆发的同时产生的剧烈伽玛射线爆发，这些伽玛射线爆发是宇宙大爆炸之后宇宙中最剧烈的爆发现象。

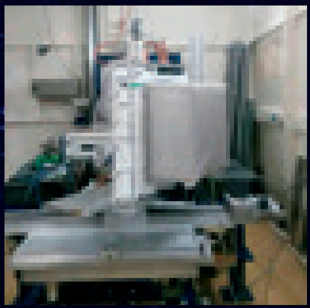
A gamma-ray burst is generated when a massive star finishes its life to form a neutron star, a strange quark star or a black hole. It can also be generated when two black holes, or two neutron stars, or a black hole and a neutron star merge together, along with a gravitational wave burst. Gamma-ray bursts are the most dramatic and energetic phenomena after the Big Bang of the universe.





伽玛暴偏振探测仪
Gamma-Ray Burst Polarimeter

伽玛暴偏振探测器
Gamma-ray burst polarization detector

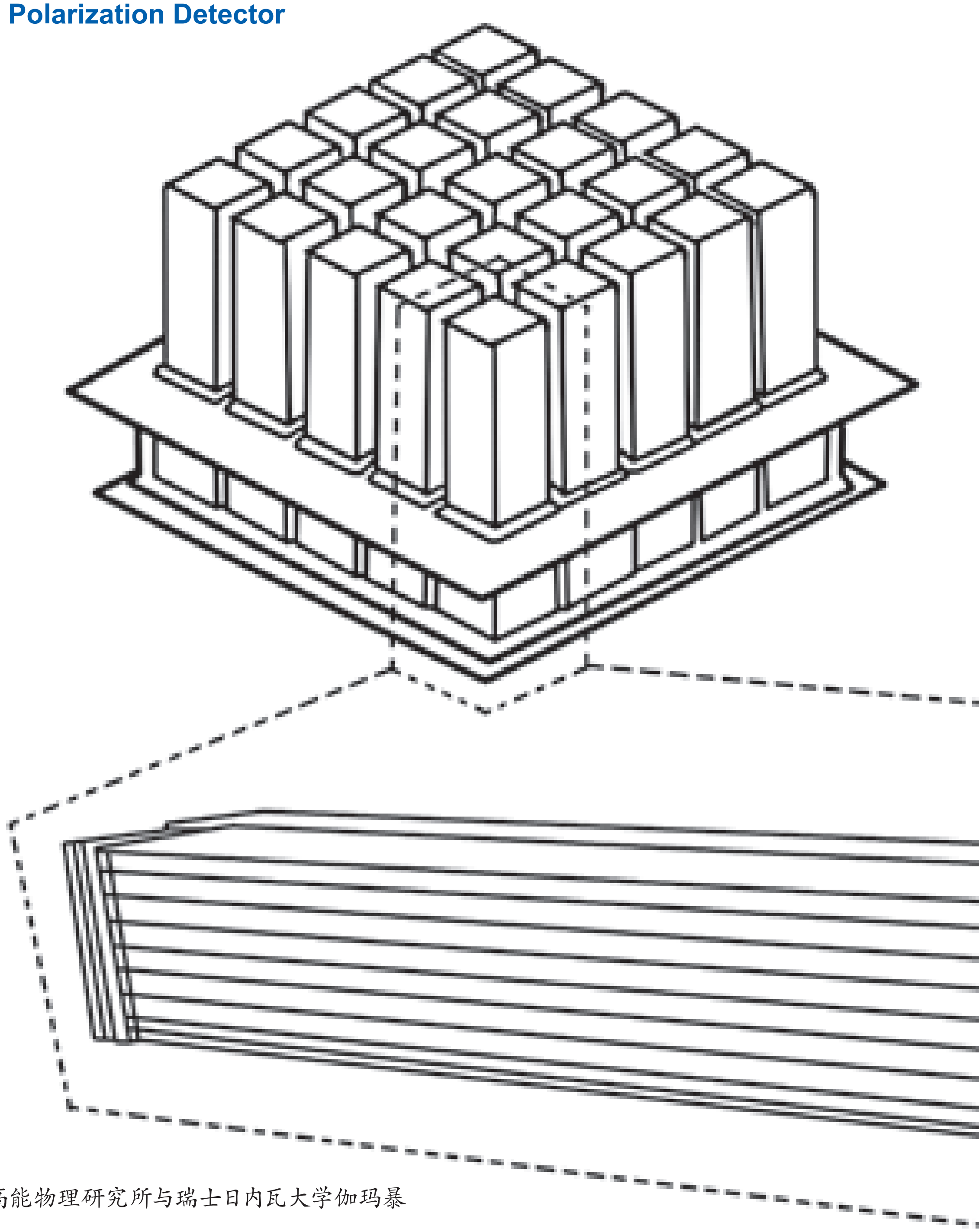


欧洲同步辐射定标试验
European Synchrotron Radiation Facility (ESRF) bracketing experiment

伽玛暴偏振探测仪由中欧合作联合研制，采用康普顿散射效应测量伽玛暴偏振度，探测效率比国际上同类仪器高几十倍。在天宫二号空间实验室中，开展在轨观测天体伽玛暴爆发、瞬变现象并进行偏振测量，将开辟伽玛射线偏振天文学的新窗口，并对伽玛暴爆发模型进行研究，在伽玛暴本质、宇宙结构、起源和演化等天体物理研究领域预期可获得具有重大科学影响的新发现。

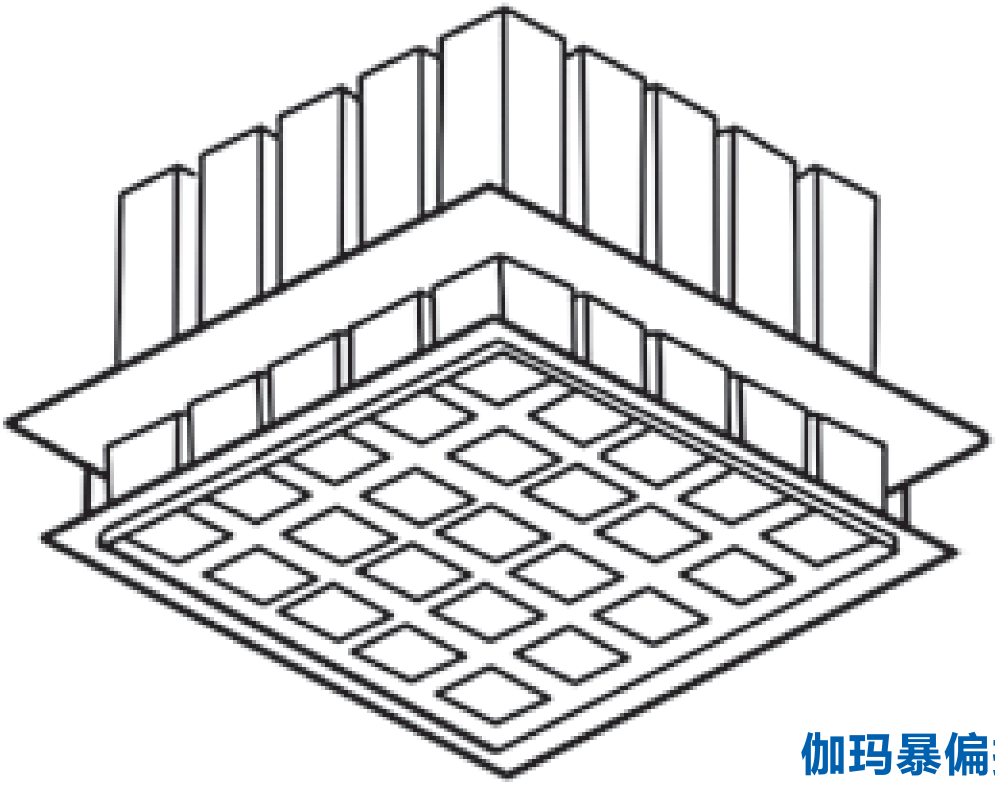
Jointly developed by scientists from China and Europe, the polarimeter applies Compton Scattering Effect to measure the degree of polarization of gamma-rays with the world's best sensitivity. In Tiangong-II, the in-orbit observations and polarimetry of the transients and outbursts of the gamma-ray bursts open a new window for polarized gamma-ray astronomy. The model of gamma-ray bursts will be studied in Tiangong-II space laboratory, which will make an important contribution in revealing the nature of gamma-ray bursts, the origin and evolution of the universe.

伽玛暴偏振探测器
Gamma-Ray Burst Polarization Detector

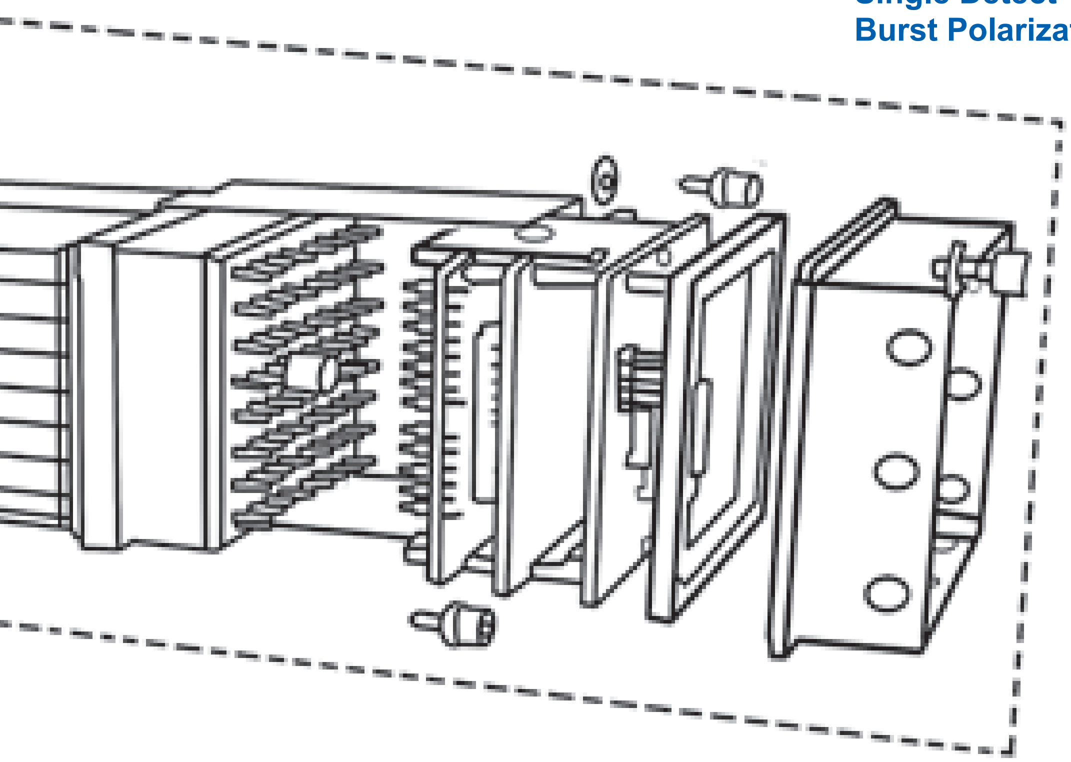


研制团队：中国科学院高能物理研究所与瑞士日内瓦大学伽玛暴偏振仪联合项目组

Project team: Joint Project Team of Gamma-ray Burst Polarimeter involving Institute of High Energy Physics, Chinese Academy of Sciences and University of Geneva, Switzerland

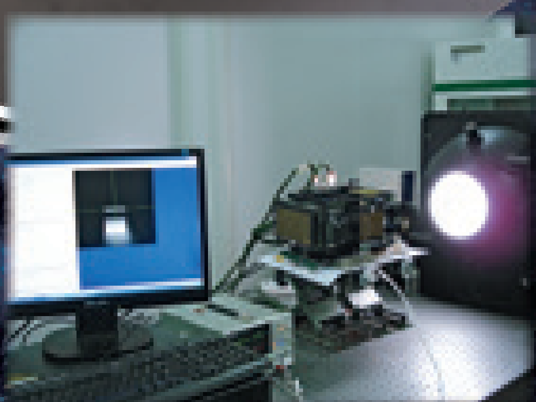


伽玛暴偏振探测器探测单体
Single Detect-Unit of the Gamma-Ray Burst Polarization Detector



多波段紫外临边成像光谱仪
Multiband Limb Imaging Ultra-Violet Spectrometer System

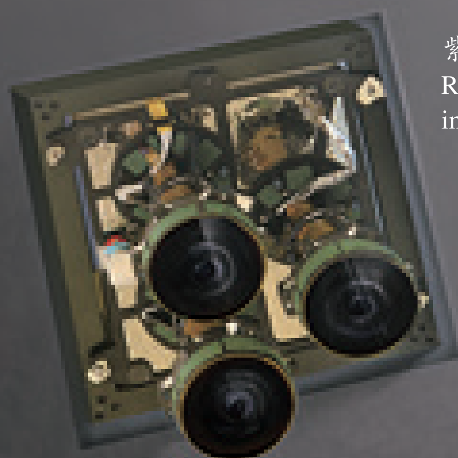
紫外前向光谱仪
Forward Ultra-Violet limb imaging spectrometer



紫外前向光谱仪地面定标
Ground-based calibration of forward Ultra-Violet limb imaging spectrometer

通过临边大气的紫外成像和光谱探测，获取全球整层大气密度、臭氧分布和气溶胶等微量成分的垂直结构及三维分布，观测数据将用于大气层相互作用、太阳活动与地球天气气候关系的研究，还将应用于大气臭氧、气溶胶等大气遥感。

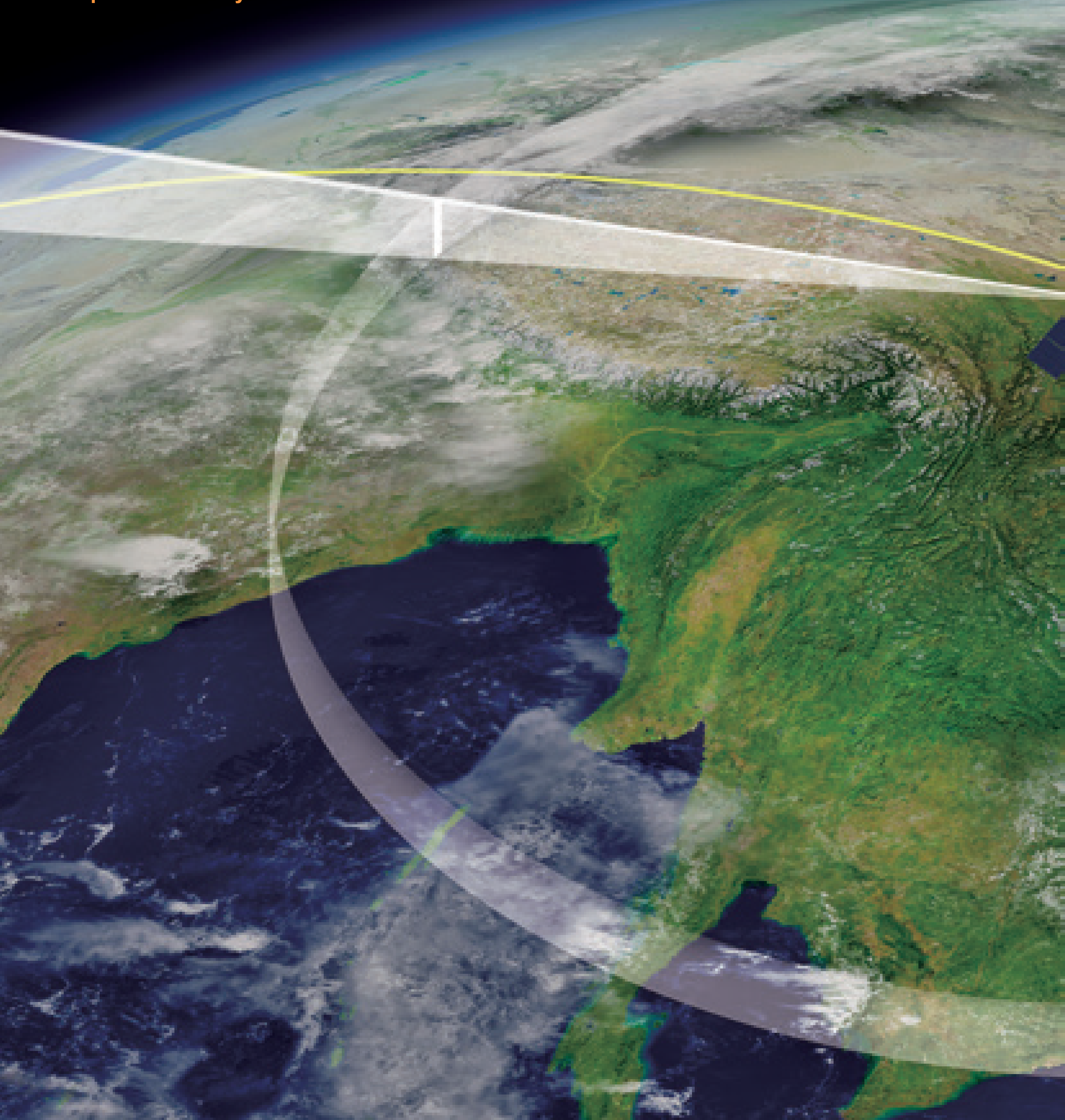
Using UV imaging and spectral detection of the limb atmosphere, the global data about the three dimension distribution of aerosols and other micro-constituents, atmosphere density and distribution can be acquired. The observational data can be used to study the interaction of atmosphere processes, the correlation between solar activities and earth climate, as well as the atmospheric remote sensing of ozone and aerosols.

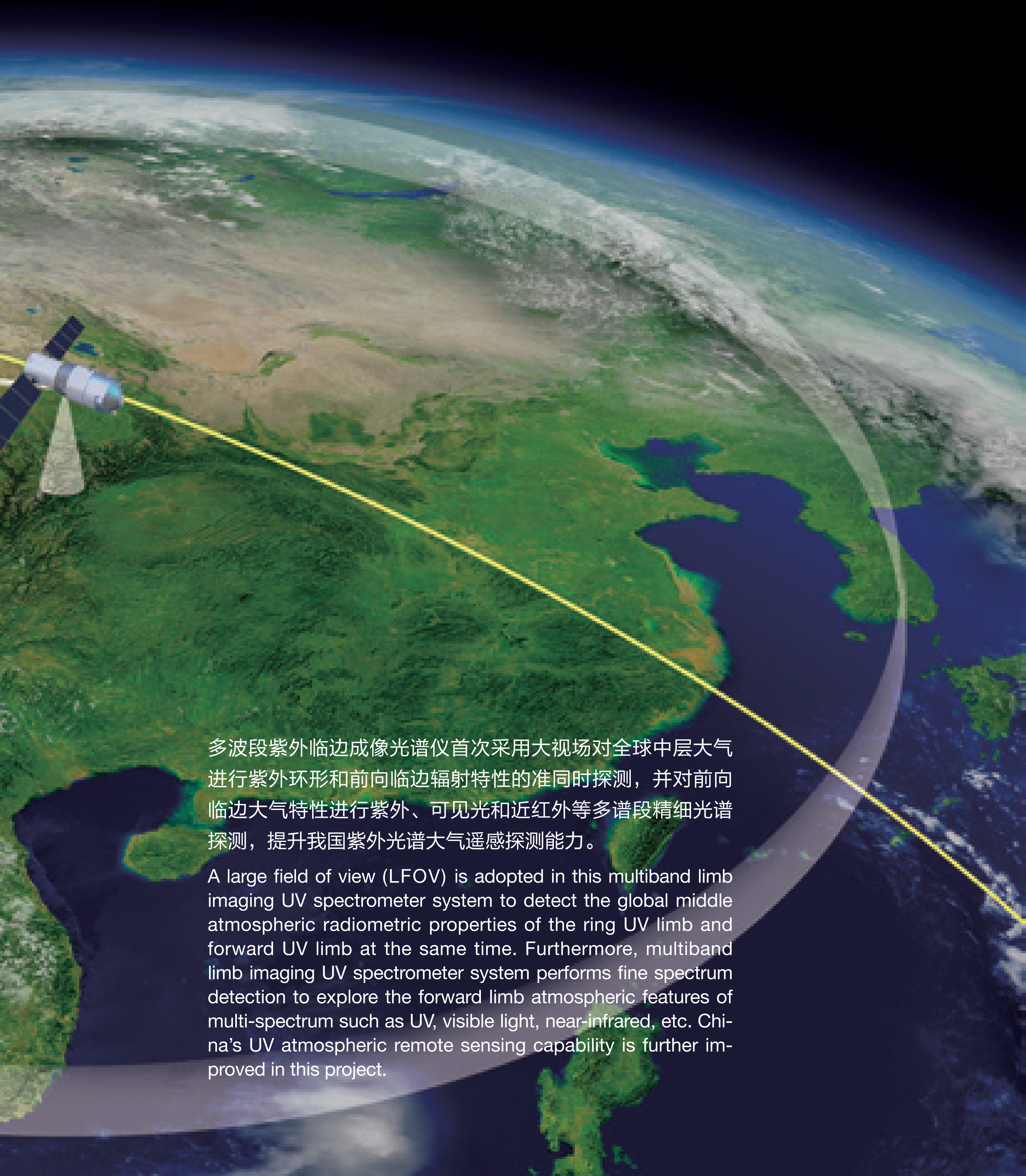


紫外环形成像仪
Ring Ultra-Violet limb imager system

紫外环形成像仪地面定标
Ground-based calibration of ring Ultra-Violet limb imager system

多波段紫外临边成像光谱仪成像视场
Imaging Field of the Multiband Limb Imaging Ultra-Violet Spectrometer System



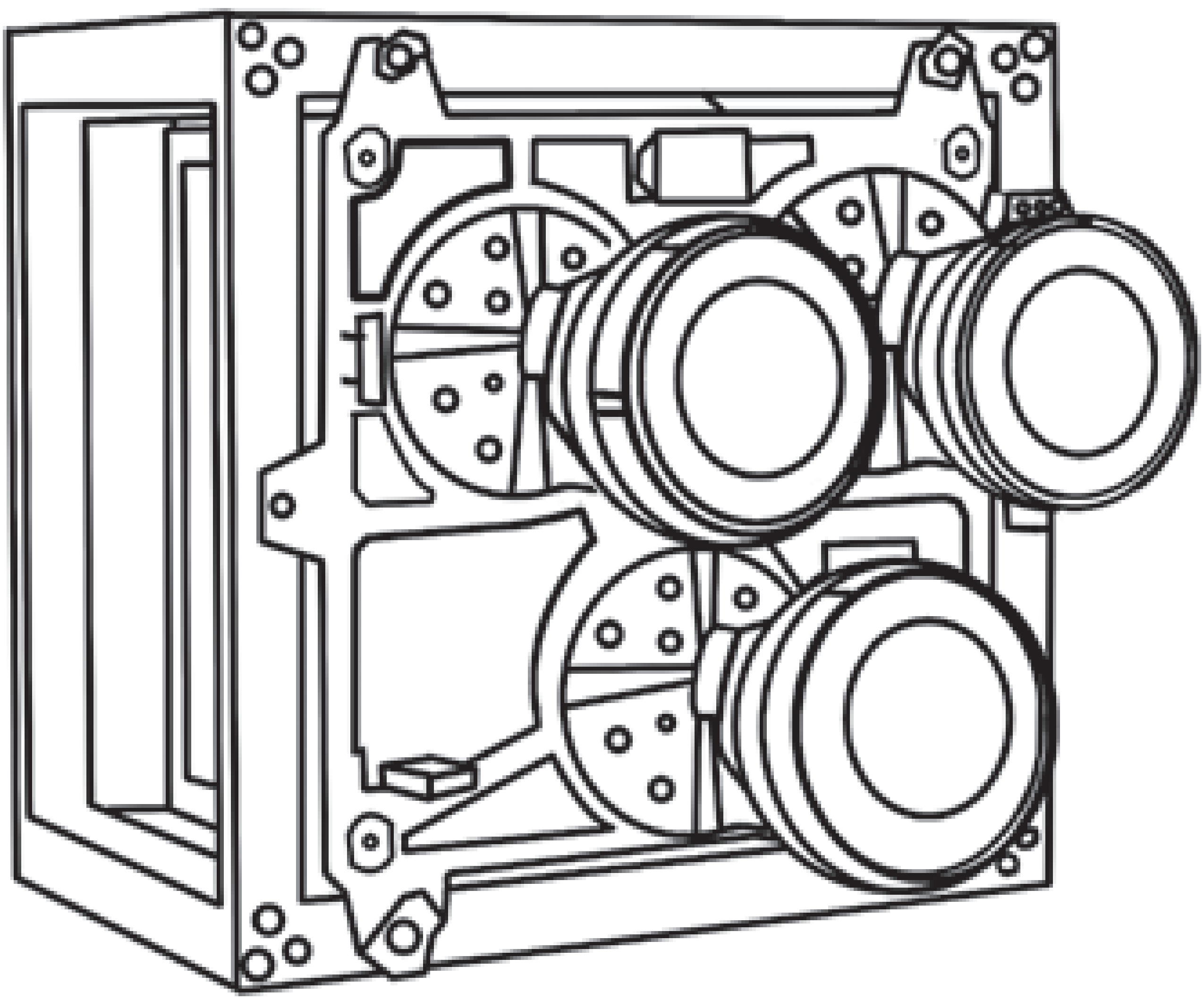


多波段紫外临边成像光谱仪首次采用大视场对全球中层大气进行紫外环形和前向临边辐射特性的准同时探测，并对前向临边大气特性进行紫外、可见光和近红外等多谱段精细光谱探测，提升我国紫外光谱大气遥感探测能力。

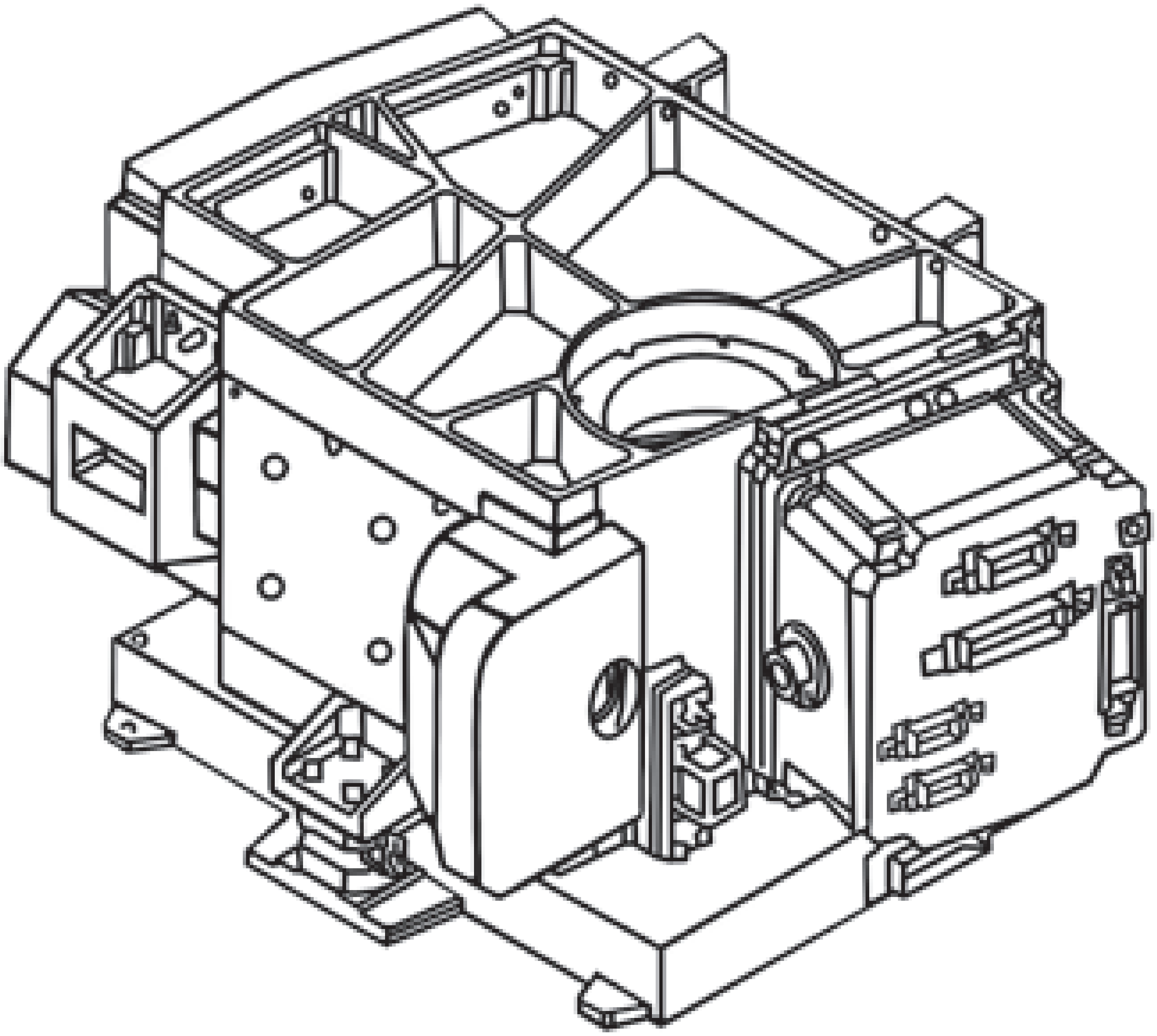
A large field of view (LFOV) is adopted in this multiband limb imaging UV spectrometer system to detect the global middle atmospheric radiometric properties of the ring UV limb and forward UV limb at the same time. Furthermore, multiband limb imaging UV spectrometer system performs fine spectrum detection to explore the forward limb atmospheric features of multi-spectrum such as UV, visible light, near-infrared, etc. China's UV atmospheric remote sensing capability is further improved in this project.

紫外环形成像仪

Ring Ultra-Violet Limb Imager System



紫外前向光谱仪
Forward Ultra-Violet Limb Imaging Spectrometer

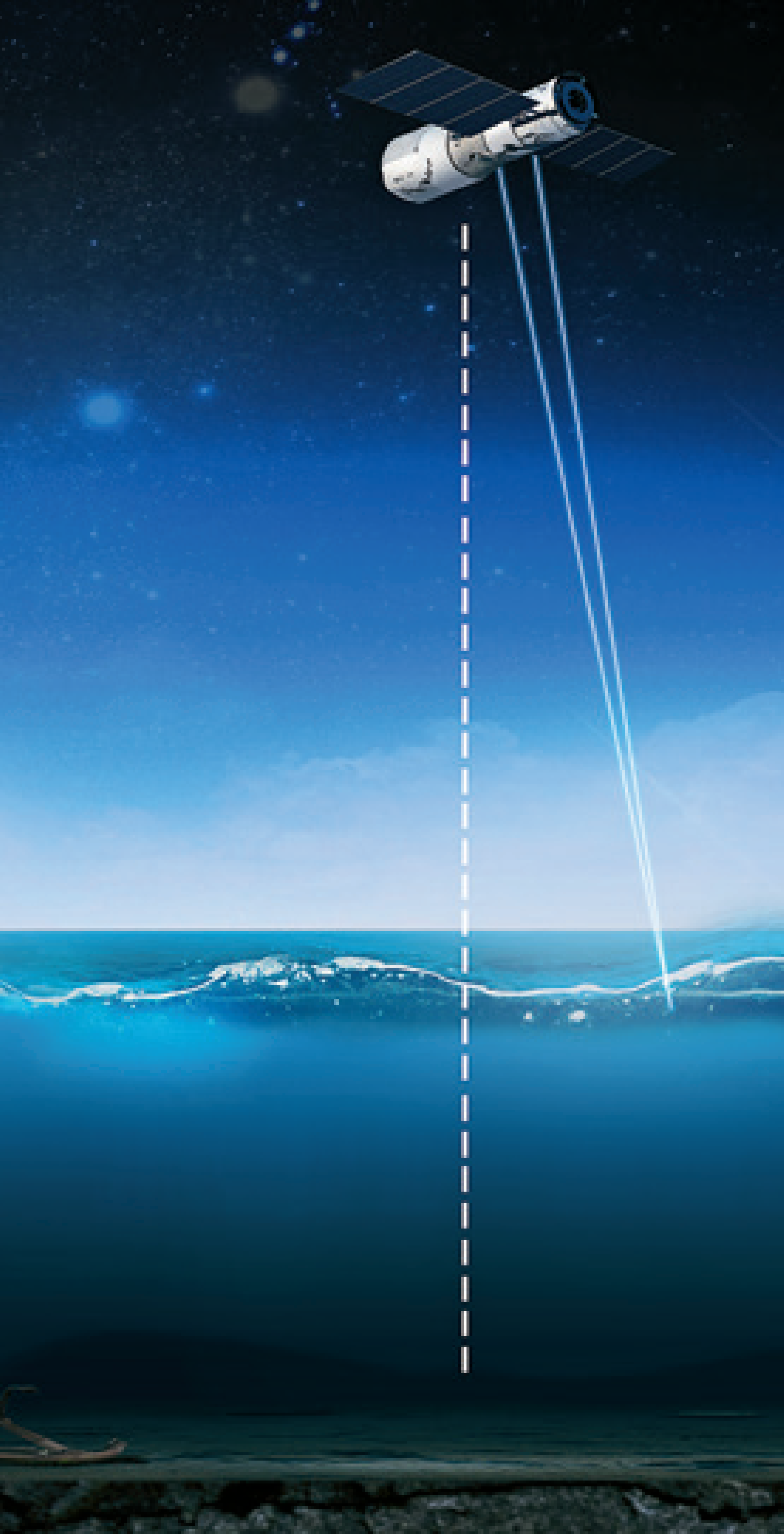


研制团队：中国科学院长春光学精密机械与物理研究所紫外光谱及成像技术研究室
Project team: Division of Ultra-Violet Spectrum and Imaging Technology, Changchun Institute of Optics, Fine Mechanics and Physics, Chinese Academy of Sciences

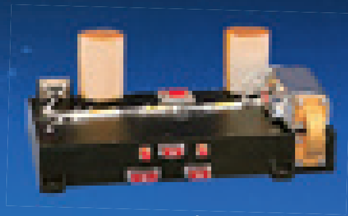
三维成像微波高度计
Interferometric Imaging Radar Altimeter

国际首台三维宽刈幅成像高度计。全天候全天时对宽刈幅范围内的三维海面进行拓扑测量和高精度海面高度测量，获取广域范围内的海浪、潮汐潮流等海洋动力环境参数、二维海 / 陆图像和三维海 / 陆地形数据，应用于全球气候与环境变化监测、海洋动力学环境研究、热点海域环境信息获取以及海洋环境预报等。

The interferometric imaging radar altimeter is the world's first three dimension wide-swath imaging radar altimeter. Working day and night, in all weather conditions, and with a wide swath, it measures the height of the sea surface and the significant wave, the speed of the sea surface wind, the topography of the ocean surface, as well as the direction of ocean wave spectrum, etc. At the same time, it can also acquire the land topography. The observational data is crucial for the studies of the global climate and environmental changes.

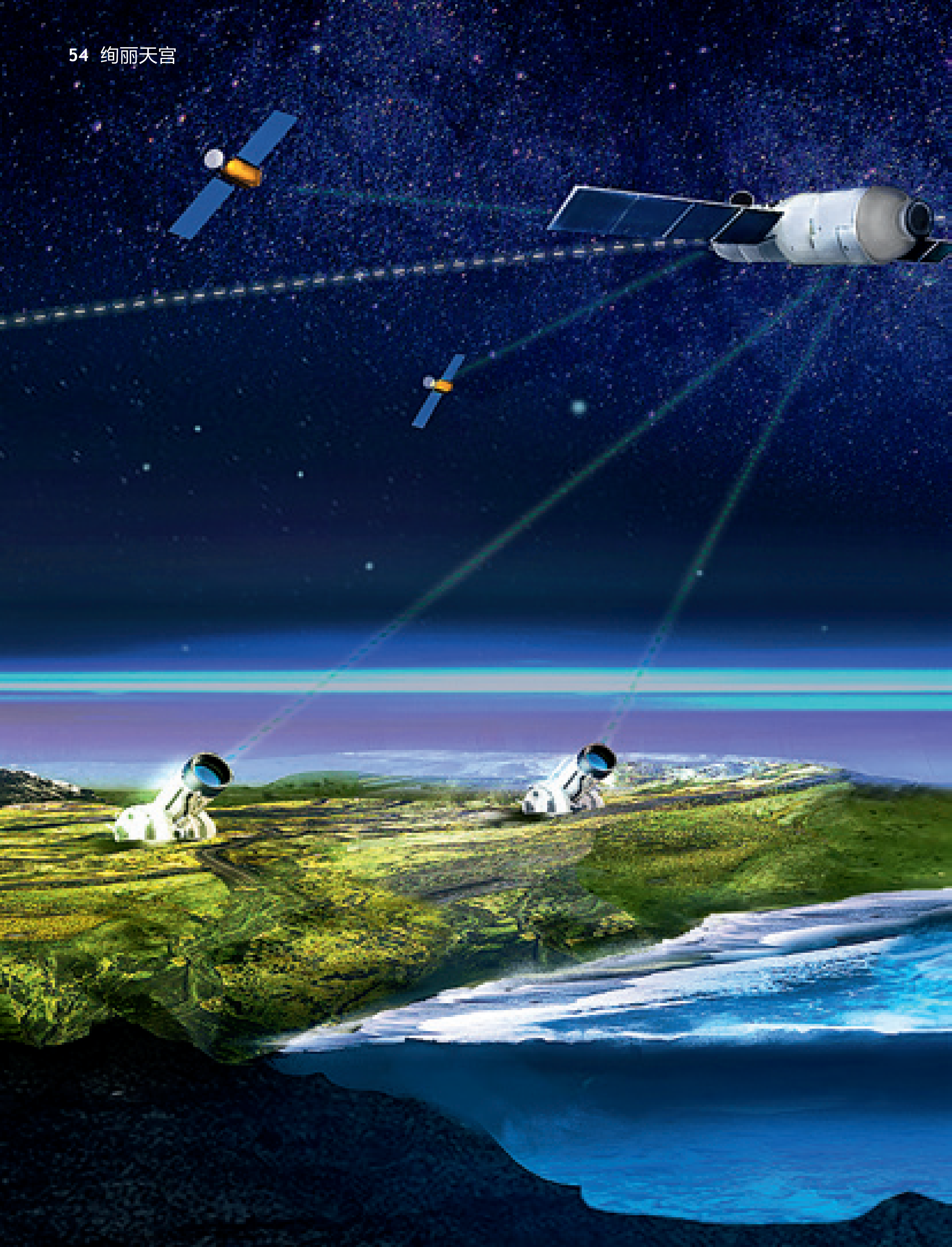


三维成像微波高度计天线
Antenna of interferometric imaging radar altimeter



三维成像微波高度计前端
Front end of interferometric imaging radar altimeter

研制团队：中国科学院微波遥感技术重点实验室雷达团队
Project team: Radar Team of the Key Laboratory of Microwave Remote Sensing, Chinese Academy of Sciences



综合精密定轨
Precise Orbit Determination

综合精密定轨系统将提供高精度的航天器轨道状态与时间信息，定轨精度有望达到厘米级。这些信息可服务于天宫二号上多项空间科学与技术实验，特别是三维成像微波高度计。

综合精密定轨系统是低轨道大型航天器精密定轨的一次重要实践，将进一步推动空间科学的交叉研究。

The precise orbit determination system provides precise orbit characteristics and timing information with high accuracy. The orbit precision is in the order of centimeters and the information is used by several experiments onboard Tiangong-II, particular by the interferometric imaging radar altimeter.
The multidisciplinary use of this system is to determine orbits of large-scale spacecraft in low Earth orbits precisely, which is an important milestone in space research.

研制团队：中国科学院空间应用工程与技术中心、北京遥测技术研究所、中国科学院上海天文台、中国科学院紫金山天文台、中国西安卫星测控中心

Project team: Technology and Engineering Center for Space Utilization, Chinese Academy of Sciences; Beijing Research Institute of Telemetry; Shanghai Astronomical Observatory, Chinese Academy of Sciences; Purple Mountain Observatory, Chinese Academy of Sciences; China Xi'an Satellite Control Center

综合材料实验
Multiple Materials Experiment

空间微重力条件下，与重力相关的对流、沉降等效应明显减弱，适合研究与此相关的材料形成和加工过程。

In space microgravity environment, convection, sedimentation and other effects associated with gravity decrease significantly, which provide unique conditions for related material formation and processing studies.

综合材料实验炉
Multiple materials experiment furnace

综合材料实验样品
Multiple materials experiment samples

天宫二号上将研究半导体光电子和功能晶体、金属合金及亚稳材料、纳米及复合材料的形成机理，在空间和地面改进材料质量，获得高性能材料的加工和合成技术。航天员将在轨更换实验样品，并携带实验样品返回地面。

The multiple materials experiments conducted in Tiangong-II studies the formation mechanism of semiconductors and optoelectronics materials, metal alloys and metastable materials, nano-materials and composite materials. These experiments will improve the quality of materials, and the process and synthesis technologies for materials with excellent properties both in space and on ground. Astronauts will replace the experiment samples for several times and take these samples back to the earth by Shenzhou-XI.

研制团队：中国科学院物理研究所、中国科学院上海硅酸盐研究所、中国科学院金属研究所等组成的联合团队

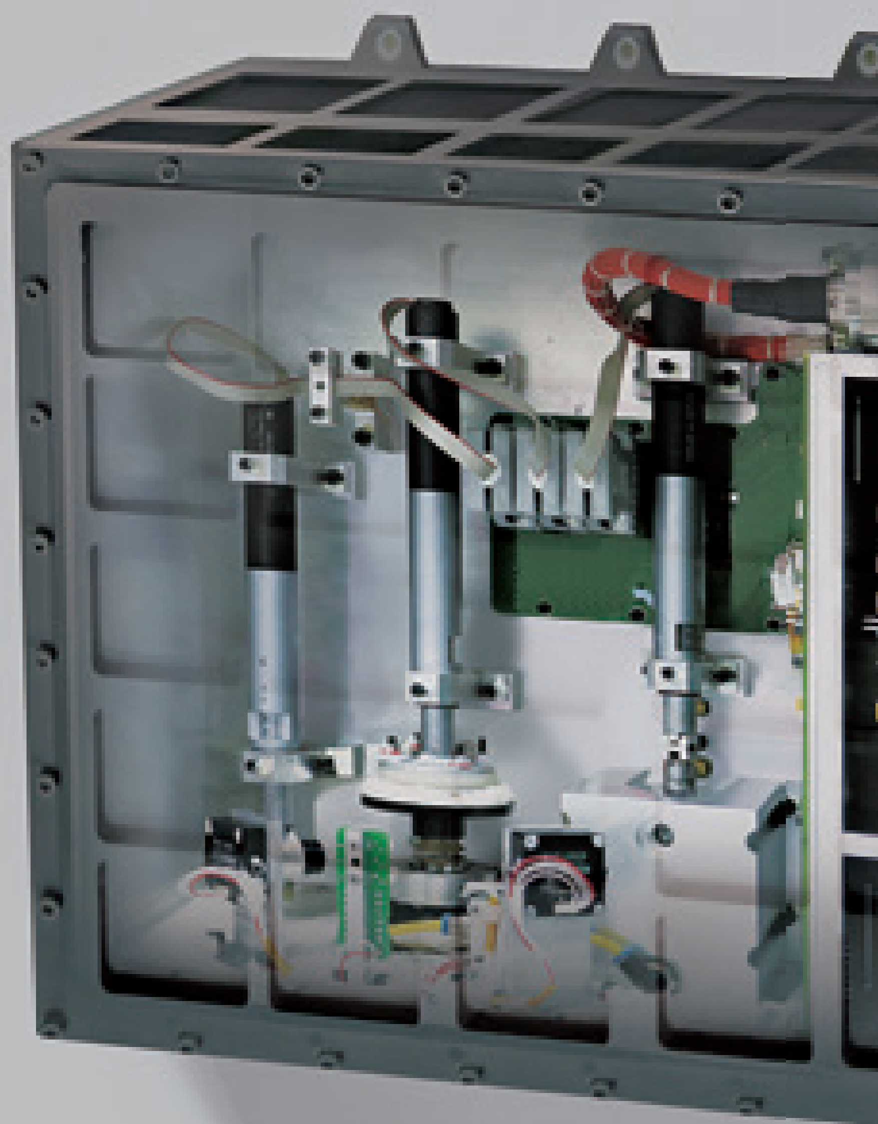
Project team: Joint Project Team of Institute of Physics, Chinese Academy of Sciences; Shanghai Institute of Ceramics, Chinese Academy of Sciences and Institute of Metal Research, Chinese Academy of Sciences

液桥热毛细对流实验

Experiment of Thermocapillary Convection in Large Scale Liquid Bridge with Large Prandtl Number

微重力流体物理研究流动物质在微重力下的流体力学特殊规律，对验证相关理论和物理模型具有不可替代的作用，为揭示许多被重力掩盖的现象和规律开辟了一条真正有效的途径，其机理和应用与多种重要生产加工过程和空间基础技术密切相关。

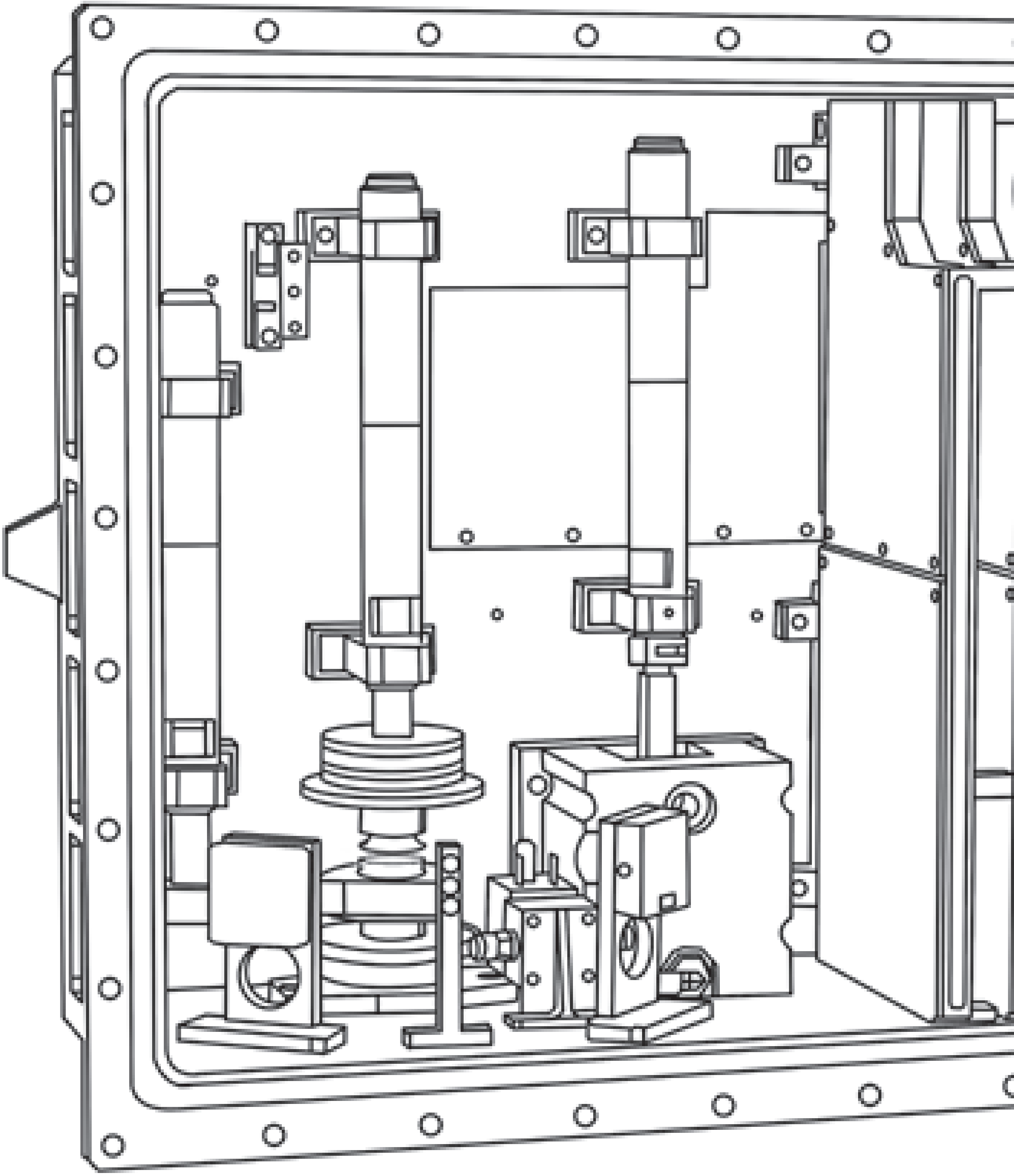
Microgravity fluid physics studies the special laws of hydrodynamics in a microgravity environment, which plays an irreplaceable role in verifying the related theory and physical models. Besides, it opened up an effective way for revealing phenomena and laws which have been masked by gravity on ground. The mechanism and applications of microgravity fluid physics are closely related to a variety of important production processes and fundamental space technologies.

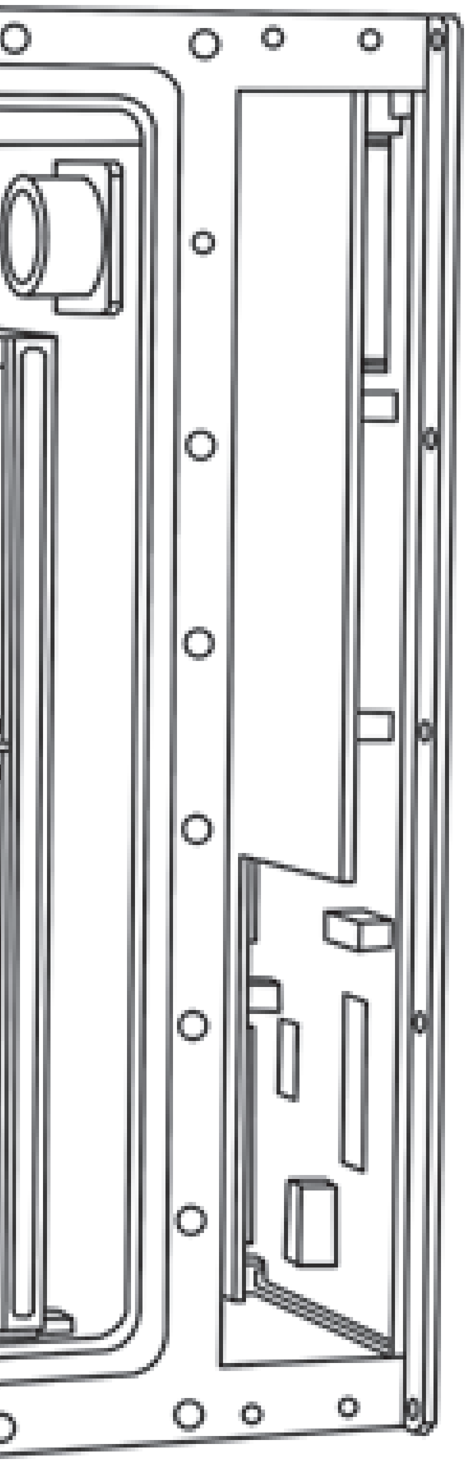


液桥热毛细对流实验箱
Experiment chamber of thermocapillary convection

天宫二号上将开展大普朗特数液桥热毛细对流稳定性相关问题的研究，发现和认识在空间微重力环境下热毛细对流的失稳机理问题，拓展流体力学的应用领域。

The aim of the thermocapillary convection experiment is to conduct stability research on thermocapillary convection of large scale liquid bridge with large Prandtl number, and study the instability mechanism of thermocapillary convection in space microgravity environment. This research will broaden the application of fluid mechanics.





液桥热毛细对流实验箱
Experiment Chamber of Thermocapillary Convection

研制团队：中国科学院力学研究所国家微重力实验室
Project team: National Microgravity Laboratory of Institute of Mechanics, Chinese Academy of Sciences

高等植物培养实验

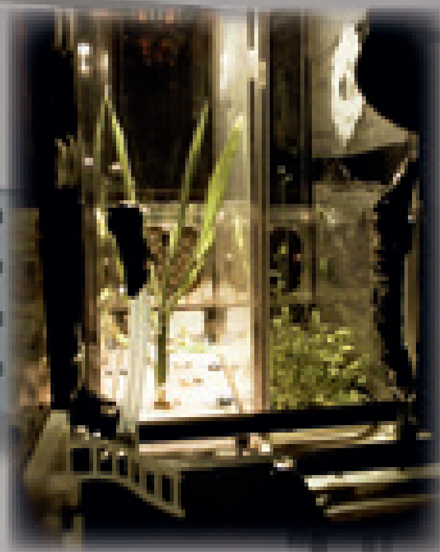
Higher Plant Flowering and Seed-setting in the Space

天宫二号上的高等植物培养实验将研究空间环境下高等植物从种子到种子的生长发育规律，探究微重力条件下植物的光周期诱导开花规律和调控机理。

Higher plant flowering and seed-setting experiment in Tiangong-II is to explore the whole life cycle laws of higher plants, and the regulation mechanisms of photoperiod induced flowering in space environment.

生命是最复杂的物质存在形式。生物体和人类的存在和演化一直是在地球上实现的，在空间条件下研究生命的存在和响应，是深刻认识生命现象本质的重大科学需求，其他途径无法替代。

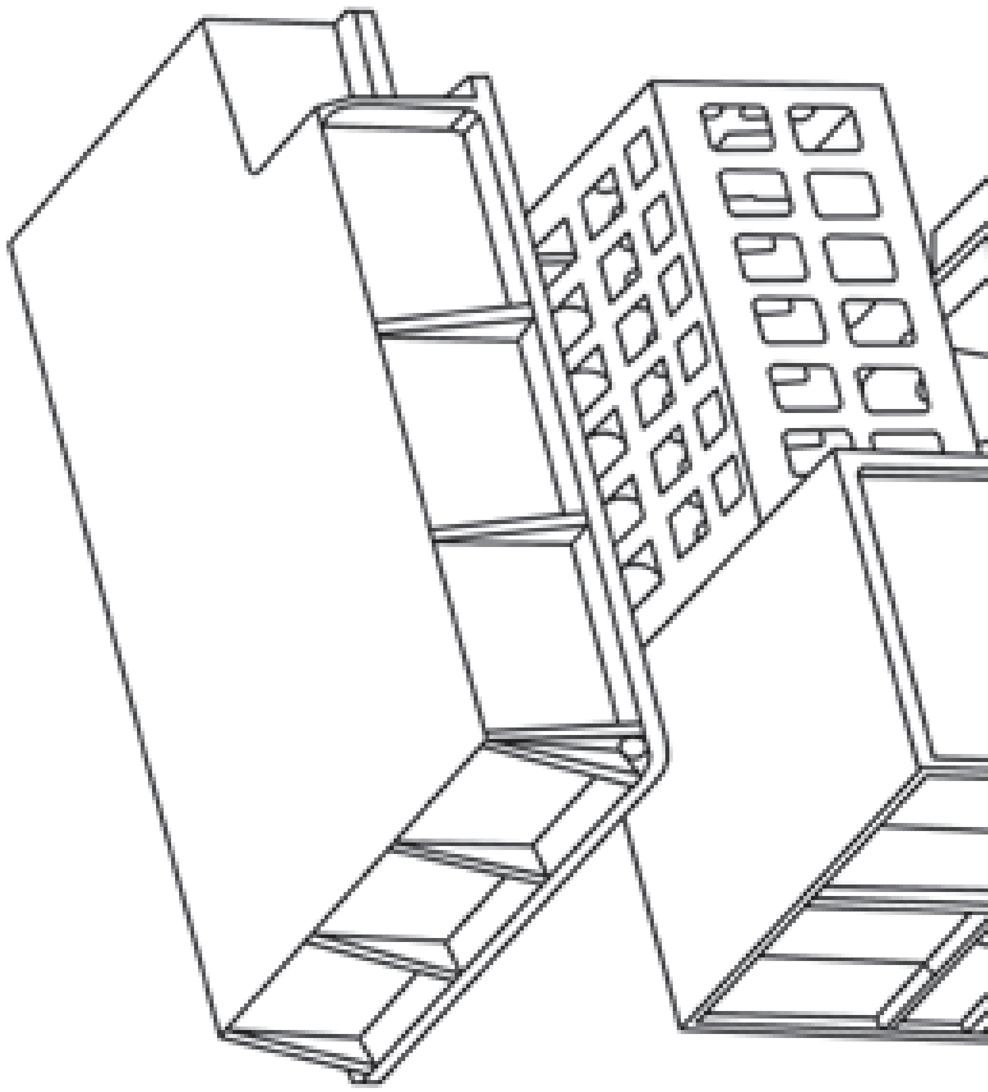
Life is the most complex form of material existence. The existence and evolution of living organisms always take place on Earth. The studies of the presence and response of life in space will lead to a profound and better understanding of the nature of life that cannot be obtained otherwise.



地面匹配试验
Ground-based matching experiment

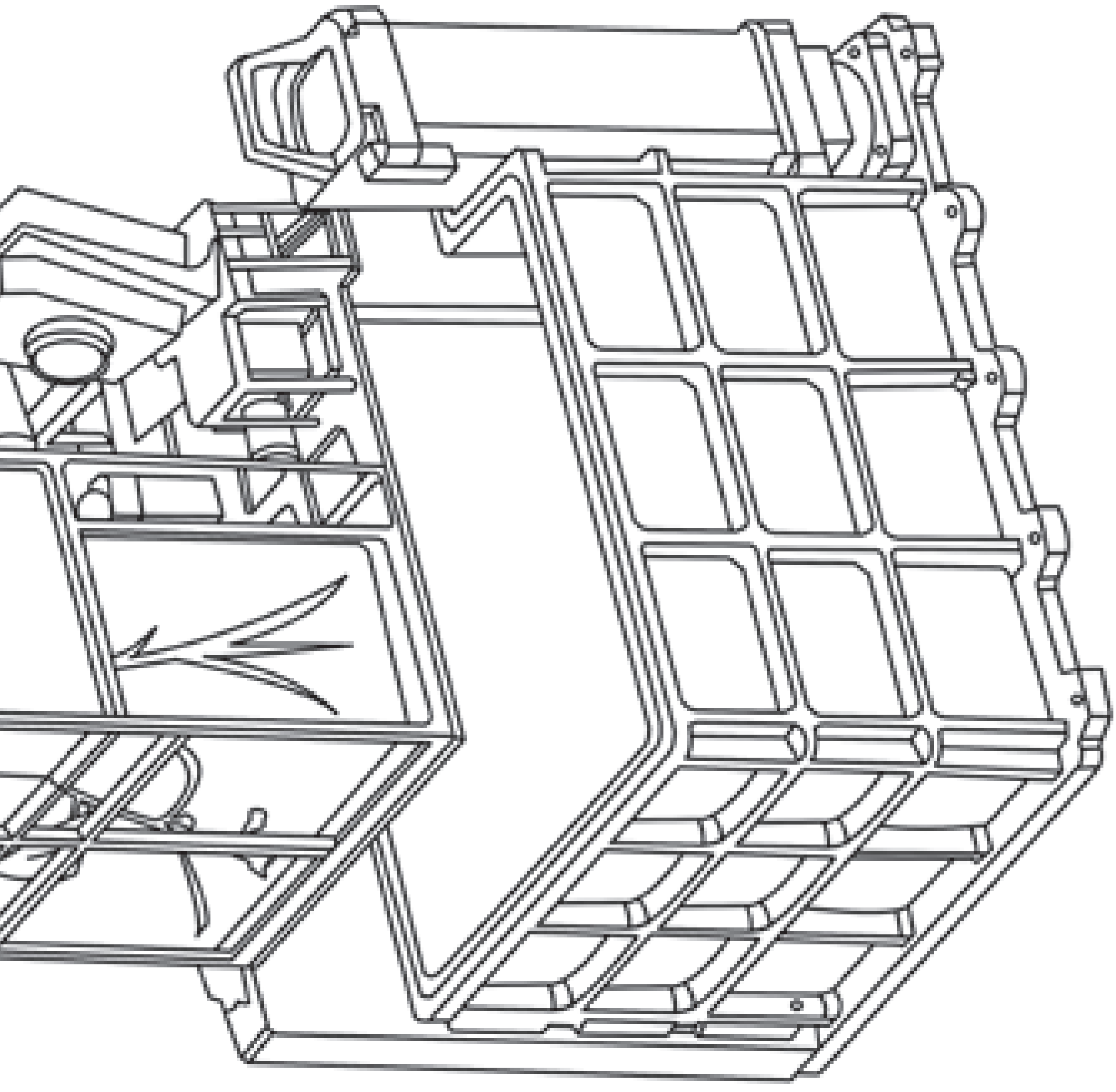
植物培养箱
Plant growth chamber

植物培养箱
Plant Growth Chamber



研制团队：中国科学院上海生命科学研究院植物生理生态研究所、中国科学院上海技术物理研究所

Project team: Institute of Plant Physiology and Ecology, Shanghai Institutes for Biological Sciences, Chinese Academy of Sciences and Shanghai Institute of Technical Physics, Chinese Academy of Sciences



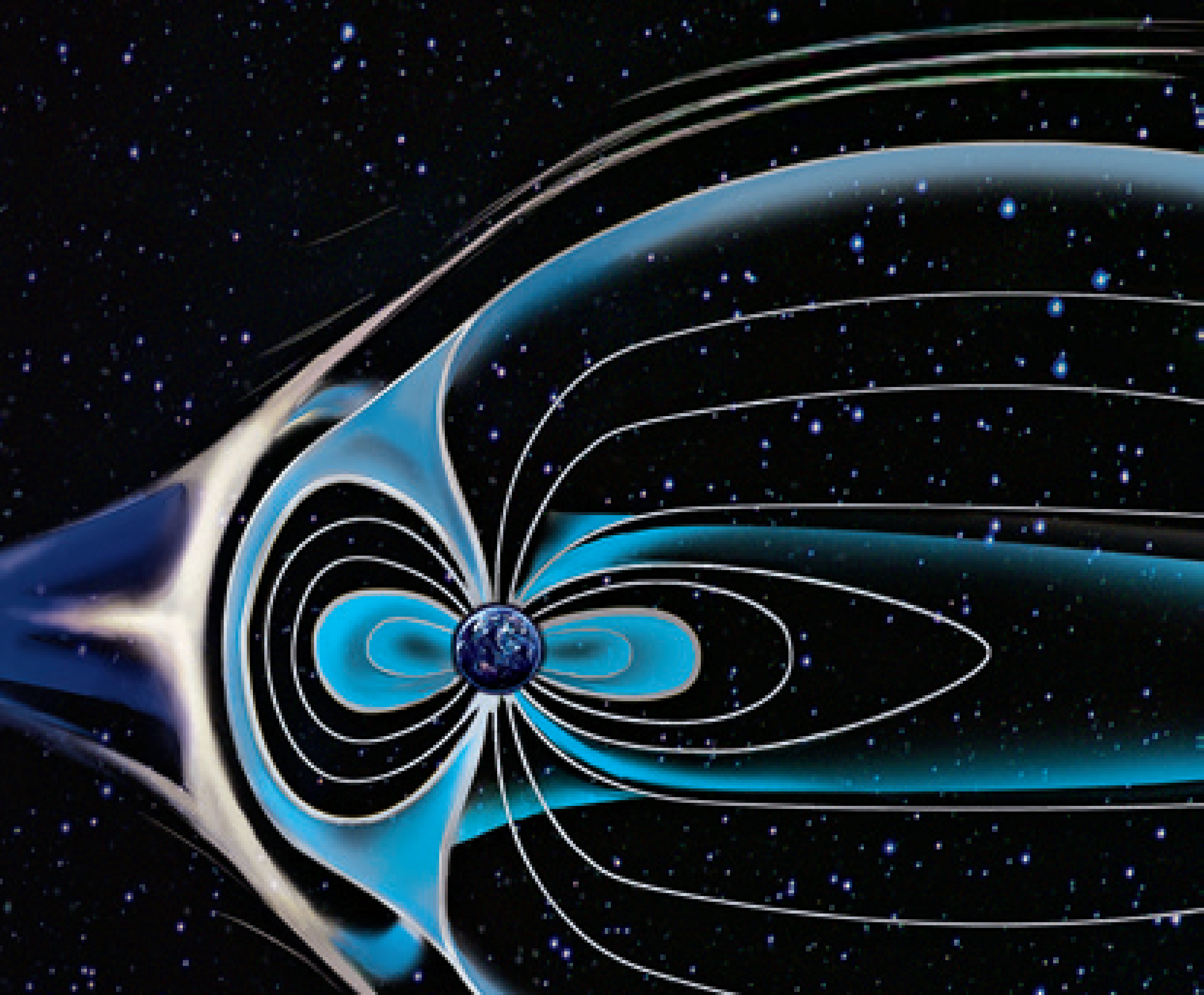
空间环境探测
Space Environment Monitor

空间环境探测系统综合监测高能带电粒子辐射和轨道大气环境及其效应，为空间环境预报、航天器和航天员的安全保障提供准实时监测数据。

The space environment monitor system aims to measure the high energy particle radiation environment, the orbit atmosphere environment and their effects. The system can provide quasi real-time monitoring data to forecast the space environment and to ensure the safety of the spacecraft and its astronauts.

轨道大气环境探测器
Orbit atmosphere detector

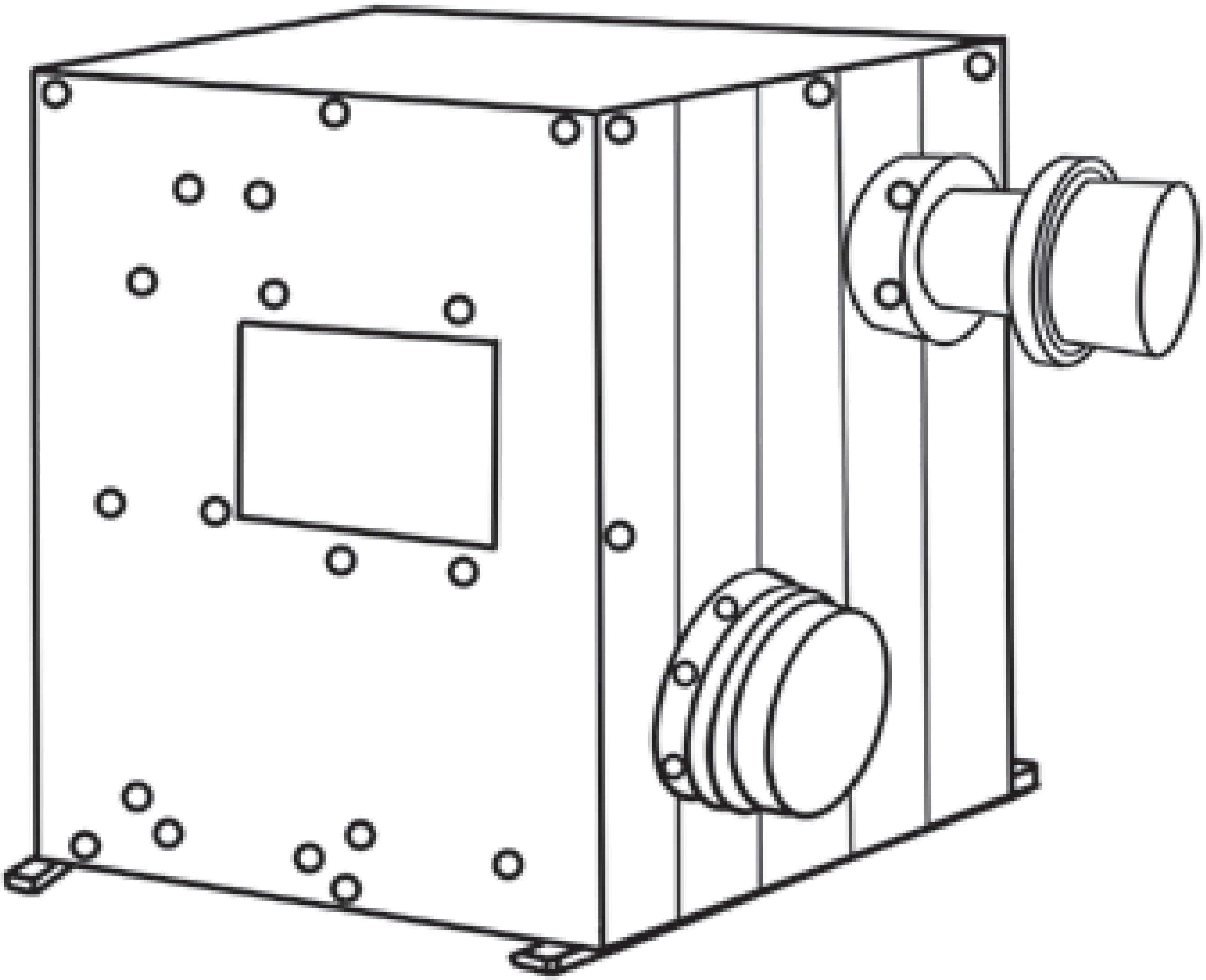
带电粒子辐射探测器
Charged particle radiation detector



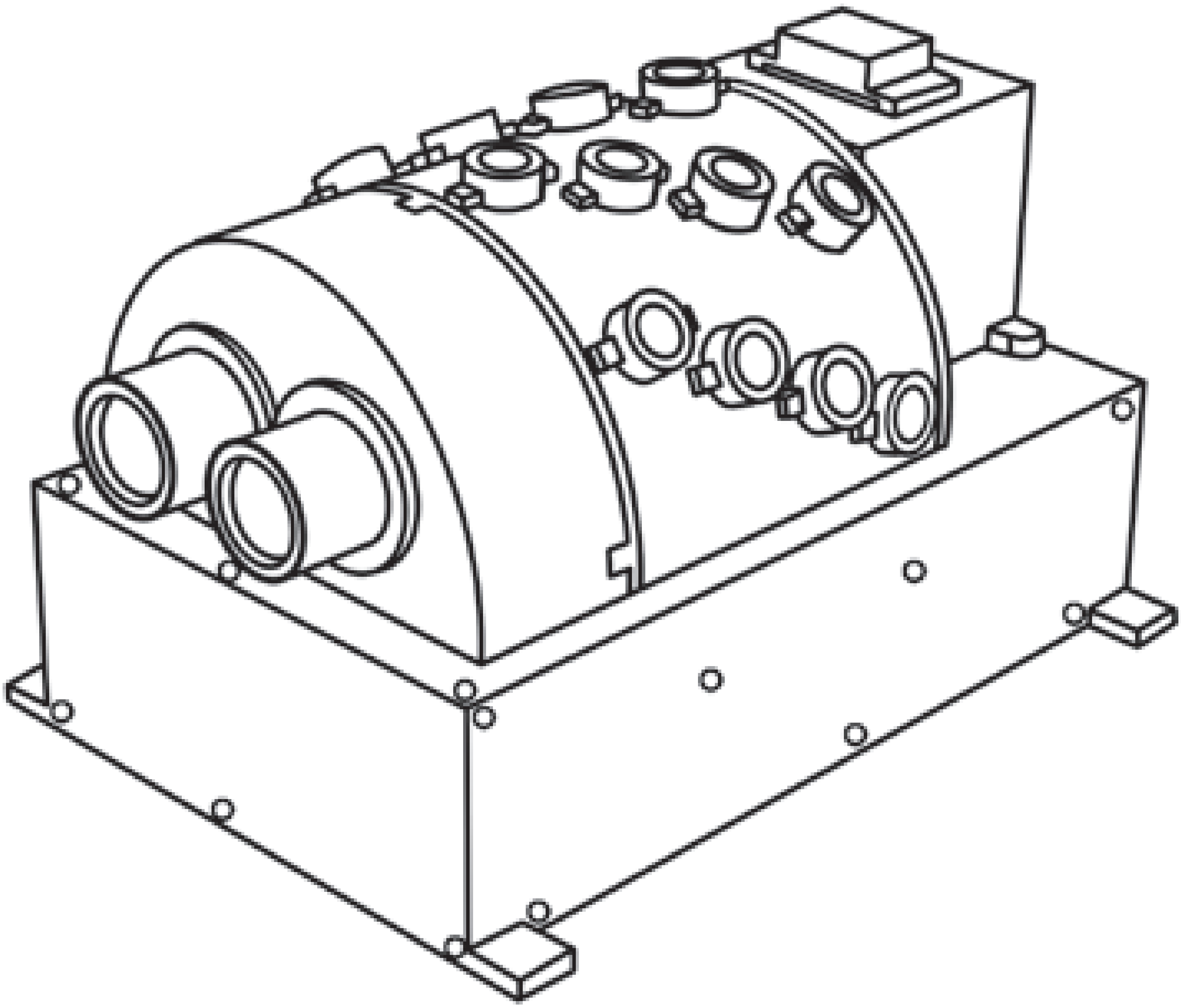
天宫二号上搭载的带电粒子辐射探测器和轨道大气环境探测器可获取舱外各个方向粒子的强度和能谱，监测轨道大气密度、成分及其时空分布变化，并具备监测原子氧和其他空间环境污染效应的多项功能。

The two detectors of the space environment monitor system, the charged particle radiation detector and the orbit atmosphere detector, onboard Tiangong-II are designed to measure the directional differential particle intensity and energy spectrum distribution with a panoramic field of view, as well as the variation of the spatial and temporal distributions of the atmosphere density and composition. The pollution effects caused by atomic oxygen and other factors of the space environment can also be measured by the space environment monitor system.

轨道大气环境探测器
Orbit Atmosphere Detector



带电粒子辐射探测器
Charged Particle Radiation Detector



研制团队：中国科学院国家空间科学中心
Project team: National Space Science Center, Chinese Academy of Sciences

两名航天员在天宫二号上生活工作约一个月后，携带实验样品搭乘神舟十一号飞船返回地面。

After working and living in Tiangong-II for about one month, the two astronauts bring experiment samples back to ground by Shenzhou-XI.

神舟十一号分为轨道舱、返回舱和推进舱。推进舱呈圆柱形，内部装载有发动机和推进剂，为飞船提供调整姿态和制动减速所需要的动力。

Shenzhou-XI is composed of an orbital module, a returning capsule and a propulsion module. The propulsion module is of cylindrical shape with the engine and propellant, providing power for attitude adjustment and braking deceleration.

返回舱为密闭结构，位于飞船中部，上部有舱门与轨道舱相通，供航天员进出轨道舱使用。

Located in the middle of the spaceship, the returning capsule has a door in the upper part connected to the orbital module, which is the access for astronauts to the orbital module.

轨道舱位于返回舱前部，前端装有舱门和对接装置，对接时可作为缓冲段。轨道舱在飞船返回后继续在轨道运行一段时间，最终再入大气层烧毁。

The orbital module locates in front of the return capsule with a cylindrical shape. The front end is equipped with doors and docking devices which can act as a buffer segment for docking. After the return of the returning capsule, the orbital module will stay in space for some time followed by a destructive reentry into the atmosphere.

2020 年前后，我国将建成和运营载人空间站，解决较大规模、长期有人照料的空间应用问题。

中国载人航天将不断迈向更高、更远的目标。

Chinese Space Station will be built around 2020, and will support larger scale space utilization with man-tending on a long-term basis.

China Manned Space Program will keep flying towards higher and further goals.

北京门头沟沿河城向西有十七座明代敌楼，此为第十三座。敌楼之上是北半球冬季夜空明亮的猎户座天区，除了七颗耀眼的恒星外，还有猎户座大星云、巴纳德环、玫瑰星云等著名的电离氢区域。

One of the seventeen watchtowers built in Ming Dynasty is at the west of Yanhecheng Mentougou, Beijing. The bright Constellation Orion of the Northern hemisphere in winter can be watched here. Except seven bright starts, Nebula, Barnard’s Loop, Rosette Nebula and some well-known ionized hydrogen regions could also be watched clearly in this area.

该图片由中国科学院国家天文台兴隆观测站特聘天文摄影师王卓骁提供
Image courtesy of astrophotographer Wang Zhuoxiao from Xinglong Observatory, National Astronomical Observatories, Chinese Academy of Sciences.

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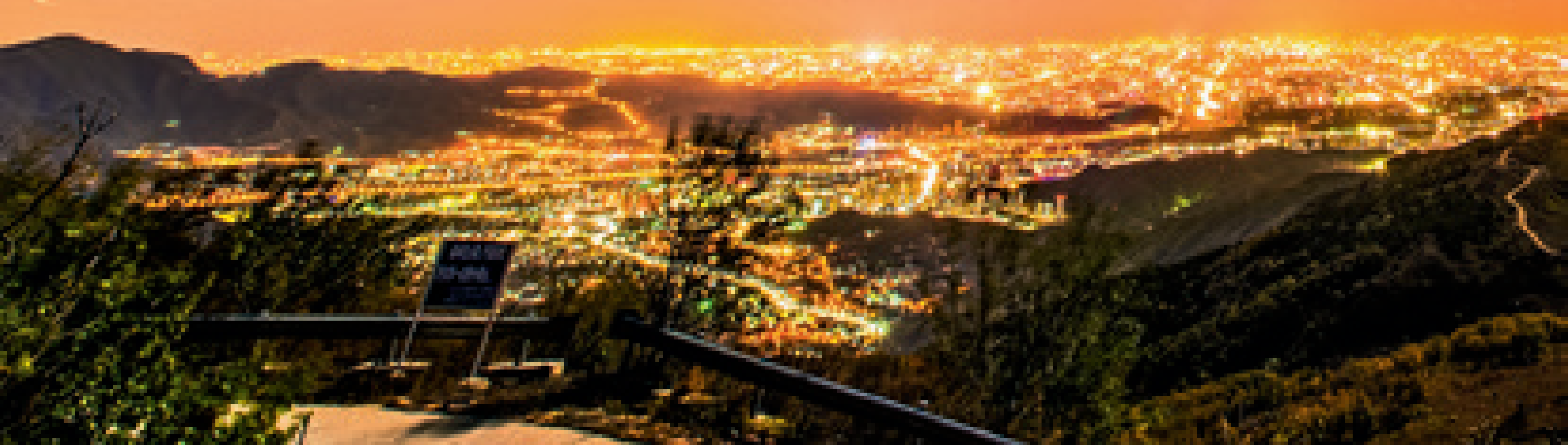

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