

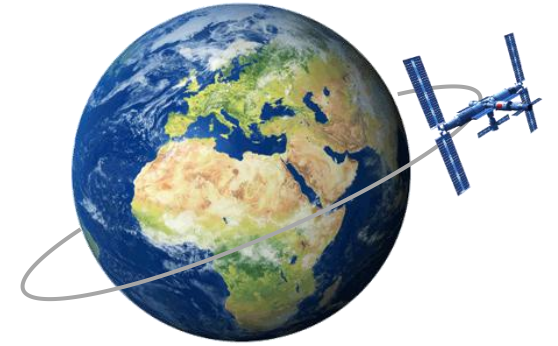


中国科学院空间应用工程与技术中心
Technology and Engineering Center for Space Utilization, CAS

Experiment Interface of Space life science and Material science

Zhao Liping

February 2025
Islamabad, Pakistan

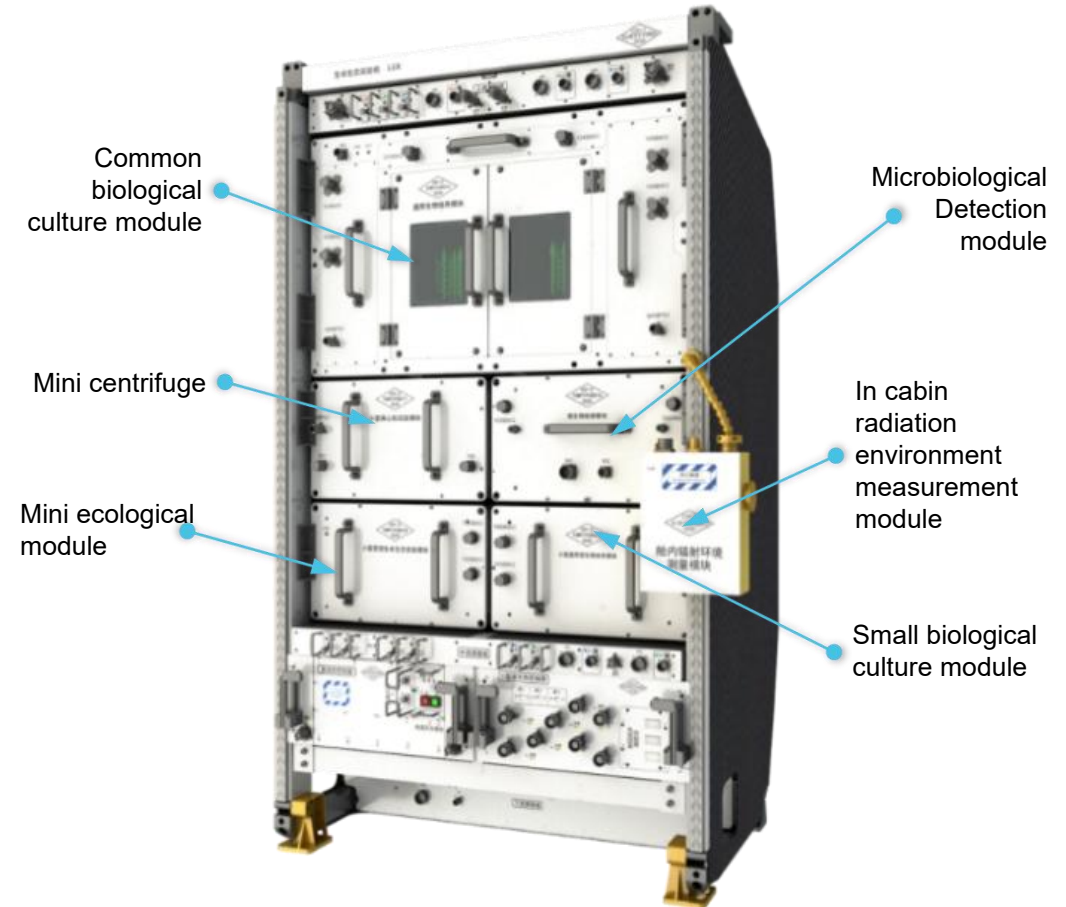


1 Experiment Interface-Space life science and biotechnology

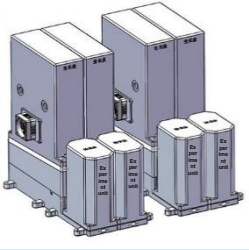
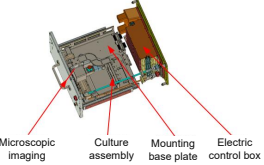
1 Ecology Science Experiment Rack (ESER)

Ecology Science Experiment Rack (ESER)

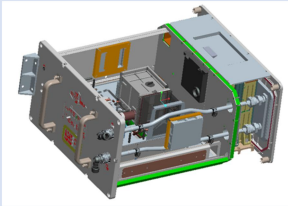
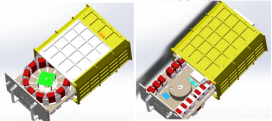
- Long period culture of plant, animal and other biological samples
- 1g ~ 2g simulated gravity + microgravity experimental conditions
- In-situ measurement of radiation particles and energy spectra
- 5 experiment modules +2 support modules



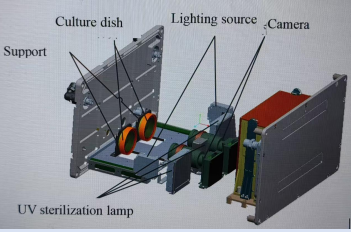
1 Ecology Science Experiment Rack (ESER)

Module	Experiment interface	User requirements
<p>Common biological culture module</p> 	<ul style="list-style-type: none"> ● Experimental support ✓ Illumination: light source (0-200 $\mu\text{mol}/\text{m}^2/\text{s}$), intensity reaching the sample surface 131.6 $\mu\text{mol}/\text{m}^2/\text{s}$, spectral range 400~700 nm ✓ Bright-field observation+ fluorescence observation: transmission wavelength of excitation filter 442 498 nm, central wavelength 472 nm; transmission wavelength of emission filter 500 568 nm, central wavelength 540 nm. ✓ Temperature control: full temperature zone: 17~30°C, double temperature zone: 17~25°C, 25~30°C ✓ Gas adjustment: CO₂ concentration adjustment ● Standard experiment unit(4 units) ✓ Composition: electric control box and sample units (including solution storage chamber, soil chamber, seed mounting plate, growth chamber, etc.) ✓ Envelope size: 302 mm (growth direction) × 308 mm × 86.5 mm ● Non-standard experiment unit ✓ Available space (double temperature zone): 400 mm (growth direction) × 225 mm × 425 mm 	<ul style="list-style-type: none"> ● Recommendation:use the standard experiment unit ● Support: Improvement based on standard experiment unit. ● Feasibility: new experiment unit be developed.
<p>Small biological culture module</p> 	<ul style="list-style-type: none"> ✓ Microscopic observation: visible light/fluorescence (excitation/emission wavelength 488/507 nm) ✓ Temperature: intravehicular temperature 19°C~26°C in the module, which can be controlled automatically ✓ Humidity: intravehicular humidity 30%~70%, which can be controlled automatically ✓ Available space: 460 mm×273 mm×545 mm 	<ul style="list-style-type: none"> ● Recommendation:Use the present experiment module ● Support: Improvement based on present experiment module ● Feasibility: new experiment module be developed.

1 Ecology Science Experiment Rack (ESER)

Module	Experiment interface	User requirements
<p>Mini ecological module</p> 	<ul style="list-style-type: none"> ✓ Temperature: 0~35°C, adjustable ✓ Observation: CCD, resolution of 0.2 cm~5 cm, pixel \leq 1,024×1,024 ✓ Illumination: LED array illumination intensity 0~200μmol·m⁻²·s⁻¹, adjustable ✓ Humidity: intravehicular humidity (30%~70%), which can be controlled automatically ✓ Available space: 460 mm×545 mm×273 mm, sample unit is about 216 mm×133 mm×124 mm, culture room Volume: 1150ml 	<ul style="list-style-type: none"> ● Recommendation: Use the present experiment module ● Support: Improvement based on present experiment module ● Feasibility: new experiment module be developed.
<p>Mini centrifuge</p> 	<ul style="list-style-type: none"> ✓ Total number of experiment unit: 12 1g units, 12 microgravity units ✓ Temperature: 17-28°C, adjustable, precision: \pm2°C@21~28°C ✓ Gravity level: 1~2 g, adjustable, control precision is \pm2% of current centrifugal acceleration ✓ Humidity: intravehicular humidity (30%~70%), which can be controlled automatically ✓ Air pressure: module pressure (0.8~1 atm), which can be controlled automatically 	<ul style="list-style-type: none"> ● Recommendation: Use the present experiment module ● Support: Improvement based on present experiment module ● Feasibility: new experiment module be developed.

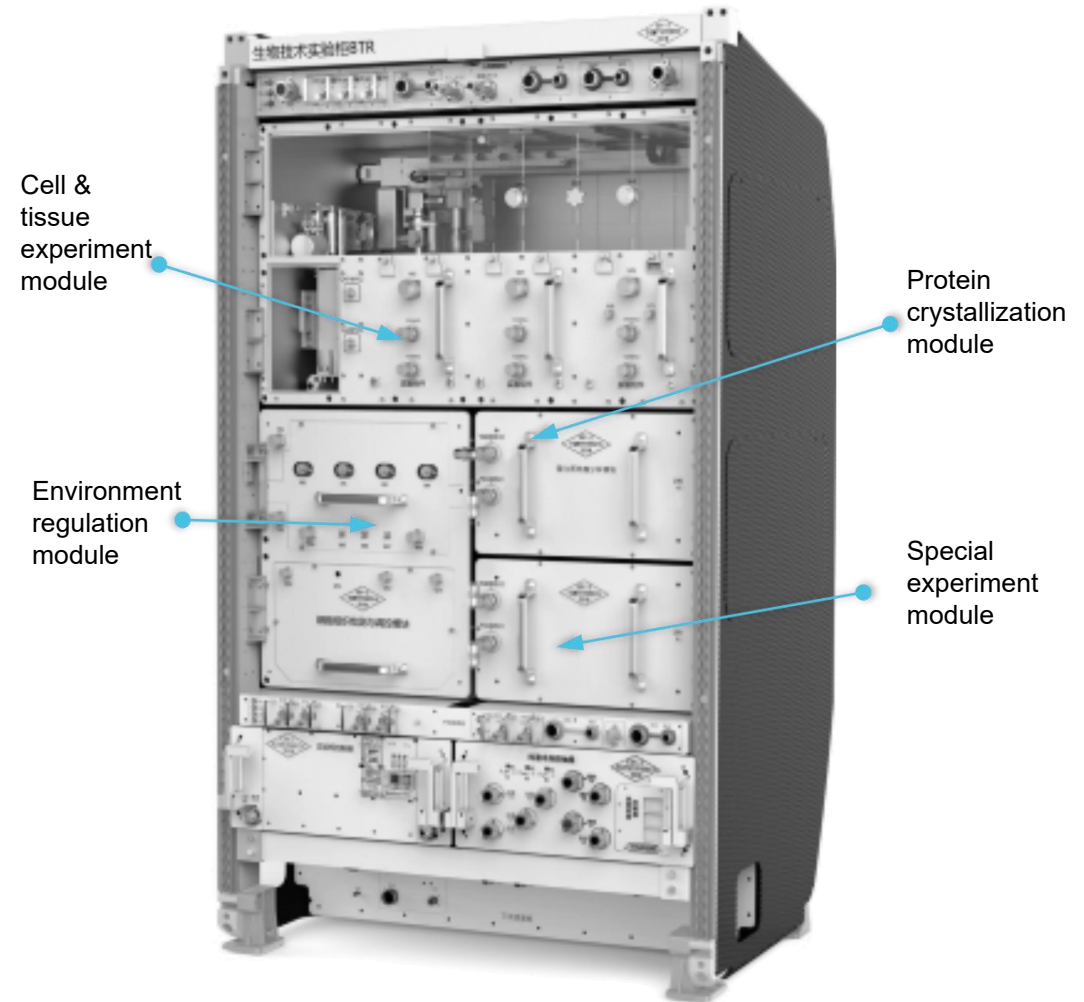
1 Ecology Science Experiment Rack (ESER)

Module	Experiment interface	User requirements
<p>Microbiological Detection Module</p> 	<ul style="list-style-type: none"> ✓ detection method: culture observation ,polymerase chain reaction (PCR) nucleic acid amplification ✓ PCR method temperature: 45°C--95°C ✓ Isothermal amplification method temperature: 55°C--65°C ✓ 2 culture dishes ✓ Size of the dish: $\phi 58\text{mm}$ (diameter) $\times 27\text{mm}$ (height) ✓ two lighting LED components ✓ three ultraviolet LED sterilization components ✓ two Cameras ✓ Module temperature: $(26^{\circ}\text{C}\sim 40^{\circ}\text{C}) \pm 1^{\circ}\text{C}$ ✓ Available space: 460 mm\times545 mm\times273 mm 	<ul style="list-style-type: none"> ● Recommendation: Use the present experiment module ● Support: Improvement based on present experiment module ● Feasibility: new experiment module be developed

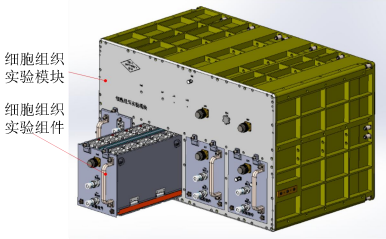

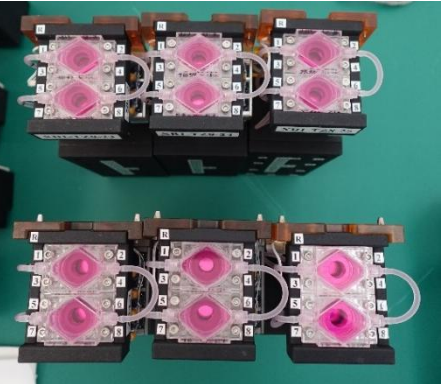
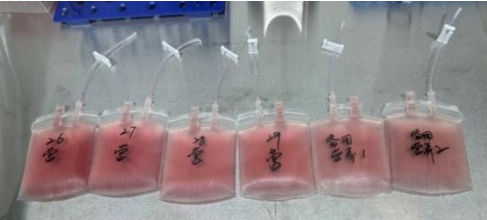
2 Biotechnology Experiment Rack (BER)

Biotechnology Experiment Rack (BER)

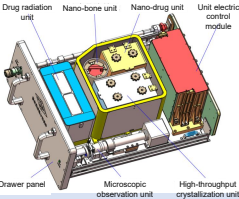
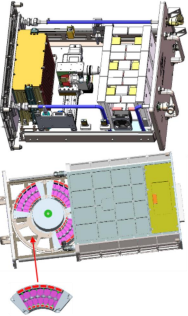
- Cell, tissue, biochemical molecules and other samples culture
- Brigh field, fluorescence and laser confocal microscopy
- Multi-sample automatic imaging, spatial resolution of 1 μ m
- 4 experiment modules +2 support modules



2 Biotechnology Experiment Rack (BER)

Module	Experiment interface	User requirements
<p>Cell&tissue experiment module</p> 	<ul style="list-style-type: none"> ✓ Type of standard Cell&tissue experiment unit :TypeI,TypeII&TypeIII , customizable ✓ Total:36 TypeI, 2 Culture Chambers(3ml/CC) + liquid bags ✓ Culture temperature: 37°C± 0.5°C ✓ liquid bags storage temperature: 0°C~10°C ✓ Nutrient supply: intermittent solution replacement, with solution replacement cycle adjustable ✓ Gas supply and regulation : O₂ concentration 20%~22%, CO₂ concentration 4.5%~5.5% ✓ Microscopic observation, Fluorescence microscopic observation and Laser confocal microscopic observation are available ✓ Microscopic observation: ✕ 1,024×1,024 pixels, objective lens magnification 1-40 times/grade, adjustable ✓ Fluorescence microscopic imaging: ✕ 1,024×1,024 pixels, imaging bands 405 nm, 488 nm, 515 nm, 589 nm   	<ul style="list-style-type: none"> ● Recommendation:use the standard experiment unit ● Support: Improvement based on standard experiment unit ● Feasibility: new experiment unit be developed

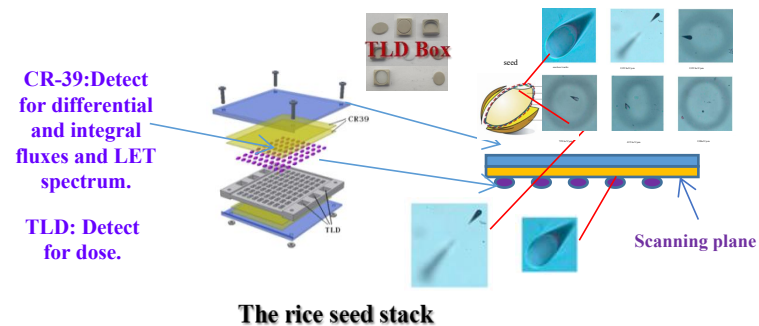
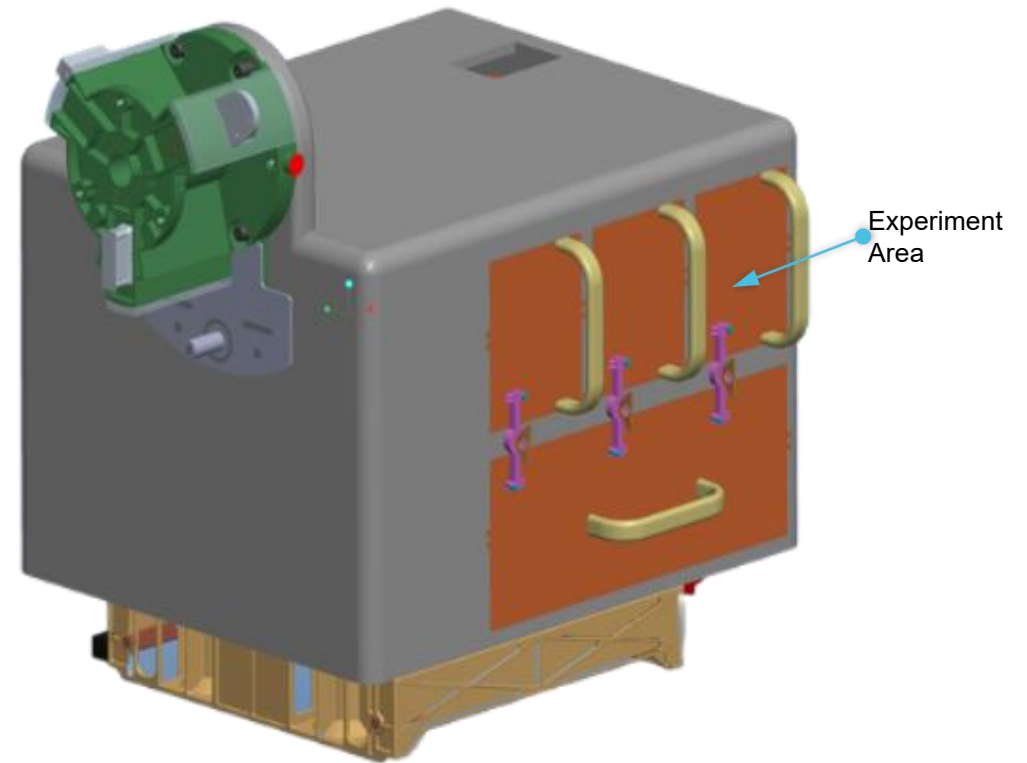
2 Biotechnology Experiment Rack (BER)

Module	Experiment interface	User requirements
<p>Protein crystallization module</p> 	<ul style="list-style-type: none"> ✓ Available space: $\leq 460\text{mm} \times 545\text{mm} \times 273\text{mm}$, temperature zone I ($25^{\circ}\text{C}$) $\leq 202\text{ mm} \times 204\text{ mm} \times 185\text{ mm}$, temperature zone II ($4^{\circ}\text{C}$) $\leq 131\text{ mm} \times 83\text{ mm} \times 34\text{ mm} \times 2$ ✓ Humidity: intravehicular humidity 30%~70%, which can be controlled automatically ✓ Air pressure: module pressure 0.8 atm~1 atm, which can be controlled automatically ✓ Microscopic imaging: 2592×1944 pixels (black and white), objective lens magnification 1~40 times/grade, adjustable ✓ White light illumination ✓ Photographing frequency: 1 photo/hour 	<ul style="list-style-type: none"> ● Recommendation: Use the present experiment module ● Support: Improvement based on present experiment module ● Feasibility: new experiment module be developed
<p>Special experiment module</p> 	<ul style="list-style-type: none"> ✓ Available space: $\leq 460\text{ mm} \times 545\text{ mm} \times 273\text{ mm}$, experiment unit size of the biomechanics experiment module: $169\text{ mm} \times 80\text{ mm} \times 32\text{mm}$ ✓ Temperature: biomechanics experiment $36.5 \pm 1^{\circ}\text{C}$, 12-way temperature measurement; protein and nucleic acid experiments $19^{\circ}\text{C} - 26^{\circ}\text{C}$ ✓ Humidity: intravehicular humidity (30%~70%), which can be controlled automatically ✓ Air pressure/gas: module pressure (0.8 atm~1 atm) 	<ul style="list-style-type: none"> ● Recommendation: Use the present experiment module ● Support: Improvement based on present experiment module ● Feasibility: new experiment module be developed.

3 Space Radiation Biology Exposed Payload

Space Radiation Biology Exposed Payload

- Life support for animals, plants, microorganisms and organic molecules
- In-situ measurement of extravehicular radiation environment



Experiment Interface

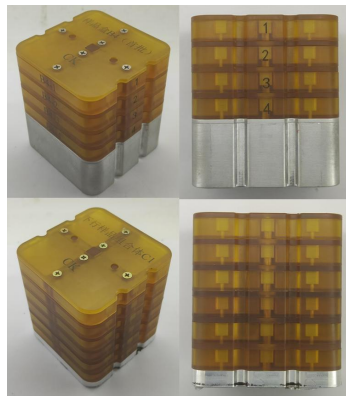
- ◆ Biological experiment unit consists of Aluminum Hermetic Outer Shell and Plant Experiment Container Assembly
- ◆ Plant Experiment Container Assembly (PECA) consists of 5/6 Plant Sample Layers(PSL) and 1Plant Breeding Box(PBB)
- ◆ PSL consists of 4 rice (or Arabidopsis thaliana) seed stack and 1 set of plant biological container installation tray and tray cover, the rice seed stack consists of 1 rice seed container ,1 solid nuclear track detector and N Thermo-Luminescent Detector

Experiment sample support	Biological sample type	Small animals : nematodes, and planarians), plant seeds, microbial spores and biological macromolecules, etc
	Type and number of experiment units	<ul style="list-style-type: none"> ✓ 12 standard biological experiment units ✓ Standard experiment units and ultraviolet transmission experimental units (1 position) ✓ Temperature :5° C - 20° C, adjustable ✓ Pressure :0.8 - 1atm ✓ No observation <ul style="list-style-type: none"> ✓ 1 microfluidic chip experiment unit ✓ Temperature :5° C - 20° C, adjustable ✓ Pressure :0.8 - 1atm ✓ Microscopic observation, Fluorescence microscopic observation : $\leq 2592 \times 1944$ pixels, imaging bands: $488 \pm 5\text{nm}, 507 \pm 5\text{nm}$, Spatial resolution: $\leq 3\mu\text{m}$

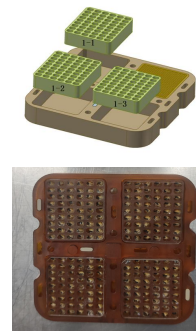
In-situ measurement of external space environment	Dose range (passive detector)	10 μGy - 10 Gy
	Dose sensitivity (passive detector)	$\geq 10 \mu\text{Gy}$
	Dose equivalent range (passive detector)	10 μSv to 10 Sv
	Dose equivalent sensitivity (passive detector)	$\geq 10 \mu\text{Sv}$
	Heavy ion positioning accuracy (solid state nuclear track detector)	$\geq 0.5 \text{ mm}$
	Neutron energy measurement range	0.025 eV - 10 MeV
	Neutron dose equivalent rate	1 $\mu\text{Sv/h}$ - 10 mSv/h
	Neutron dose equivalent sensitivity	$\geq 1 \mu\text{Sv/h}$
	Solar ultraviolet measurement	Wavelength range: 170 nm - 400 nm



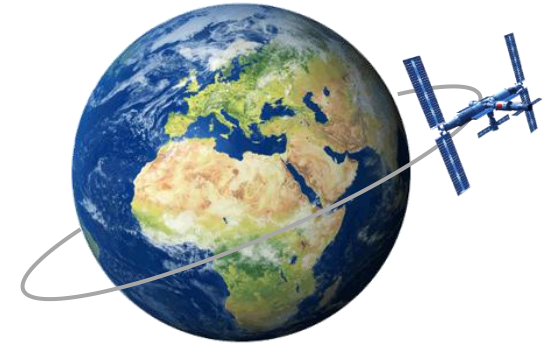
Biological experiment units



Plant Experiment Container Assembly



plant biological container

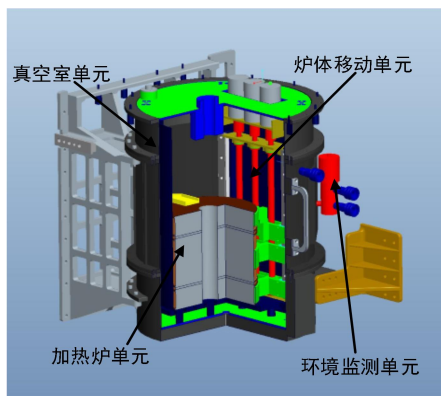


2 Experiment Interface-the Space Materials Science

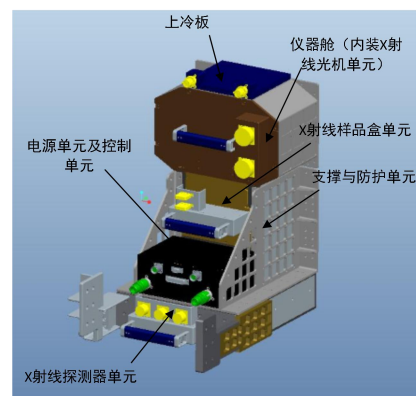
1 Material Furnace Experiment Rack (MFER)

Material Furnace Experiment Rack (MFER)

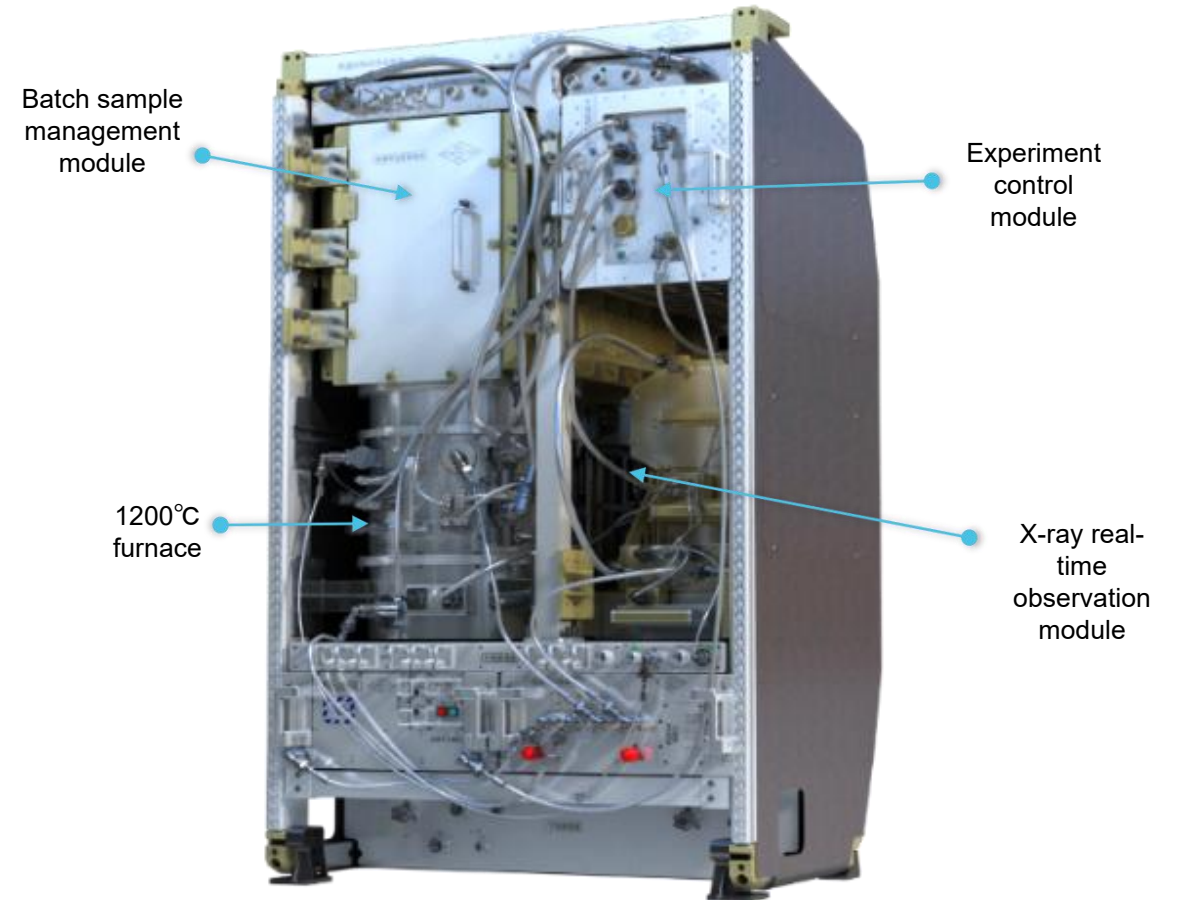
- Temperature: 1200°C
- Temperature field mode: isothermal, gradient, zone melting
- Rotating magnetic field actively controls melt flow
- X-ray real-time observation: better than 5um



High temperature furnace module

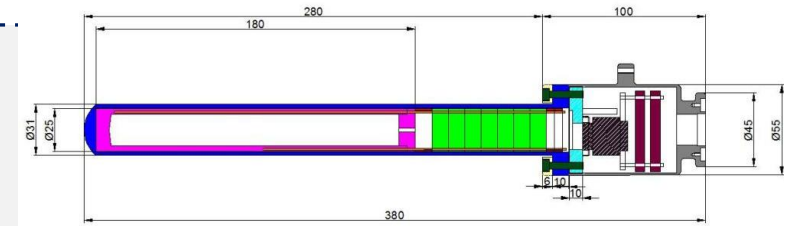


X-ray transmission imaging module



Experiment Interface

- Sample units **have the same mechanical interface** (including anti-misinsertion design), which can be matched with the batch sample management module. It uses a **sealed reinforcement design** to prevent cracking.
- The outer tube of the sample unit **uses high-temperature resistant**, high-purity alumina or niobium alloy with high-temperature resistant oxidation coating.
- For experimental scenarios below 1000 °C, **quartz glass** can also be used to make sample unit outer tubes, which can support **both conventional and rapid cooling** experiment.



High temperature material sample unit



Sample unit photo

Experiment Interface

➤ Type I sample unit

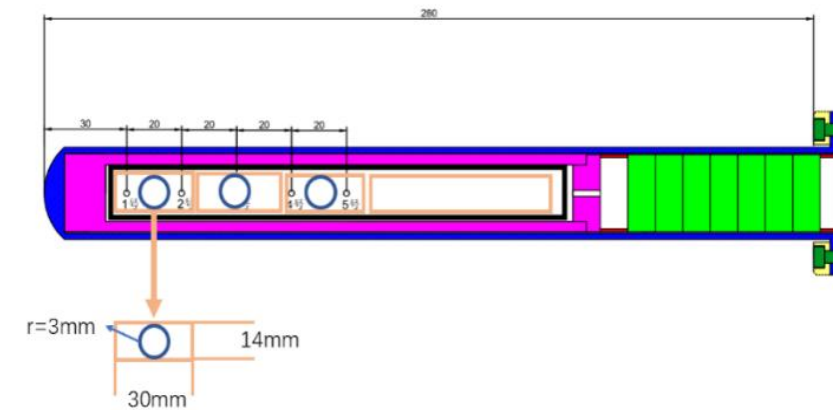
- **maximum sample size**: $\varnothing 25\text{mm} \times 160\text{mm}$
- **maximum size of sample unit**: $\varnothing 31\text{mm} \times 380\text{mm}$
- **temperature sensor interface**: 5-channel thermocouple temperature and 2-channel ambient temperature collection
- **Power supply interface**: 3.3V, 5V, 12V, maximum 20W

➤ Type II sample unit

- **maximum sample size**: $\varnothing 20\text{mm} \times 160\text{mm}$
- **maximum size of sample unit**: $\varnothing 26\text{mm} \times 380\text{mm}$
- **temperature sensor interface**: 3-channel thermocouple temperature and 2-channel ambient temperature collection
- **Power supply interface**: no



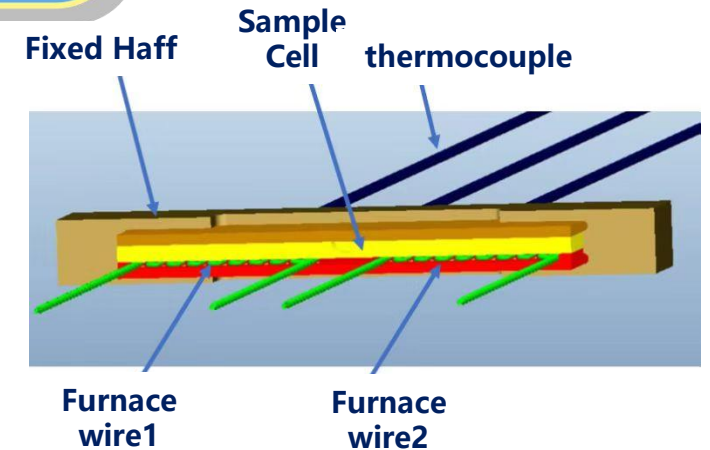
Thermocouple position



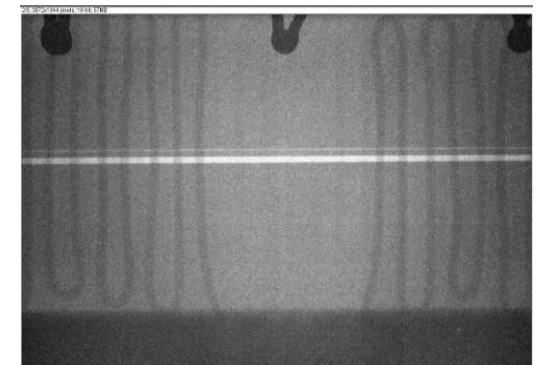
Placement of experimental samples

X-Ray Experiment Interface

- X-ray sample box is a square structure, maximum sample size: $\leq 140\text{mm} \times 140\text{mm} \times 40\text{mm}$
- temperature range 1
 - **sample cell size**: $20\text{mm} \times 5\text{mm} \times 0.5\text{mm}$
 - **imaging field of view**: $9\text{mm} \times 15\text{mm}$
 - **maximum temperature**: 700°C
 - **resolution**: $5\ \mu\text{m}$
 - The heating component is located on the lower side of the sample cell, with two sets of metal heating wires forming two heating zones located at both ends of the lower side of the rectangular sample cell.



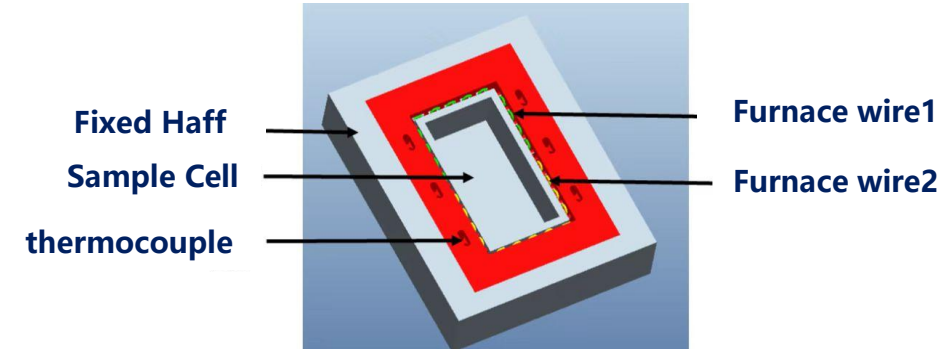
**X-ray sample box (range1)
internal structure**



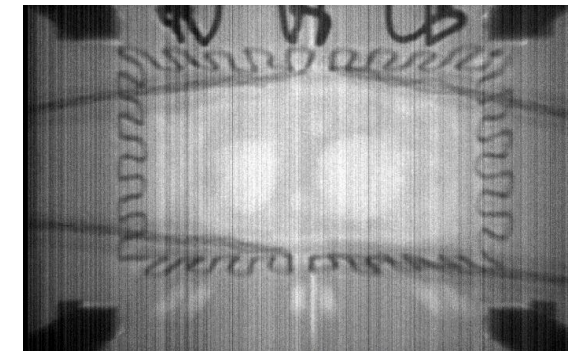
**X-ray transmission
Imaging (range1)**

X-Ray Experiment Interface

- temperature range 2
 - **sample cell size**: 20mm×10mm×6mm
 - **imaging field of view**: 20mm×30mm
 - **maximum temperature**: 1000°C
 - **resolution**: 10 μ m
 - The heating component is located on the side of the sample cell, with two sets of metal heating wires forming two heating zones located at both ends of the rectangular sample cell



X-ray transmission
Imaging (range2)

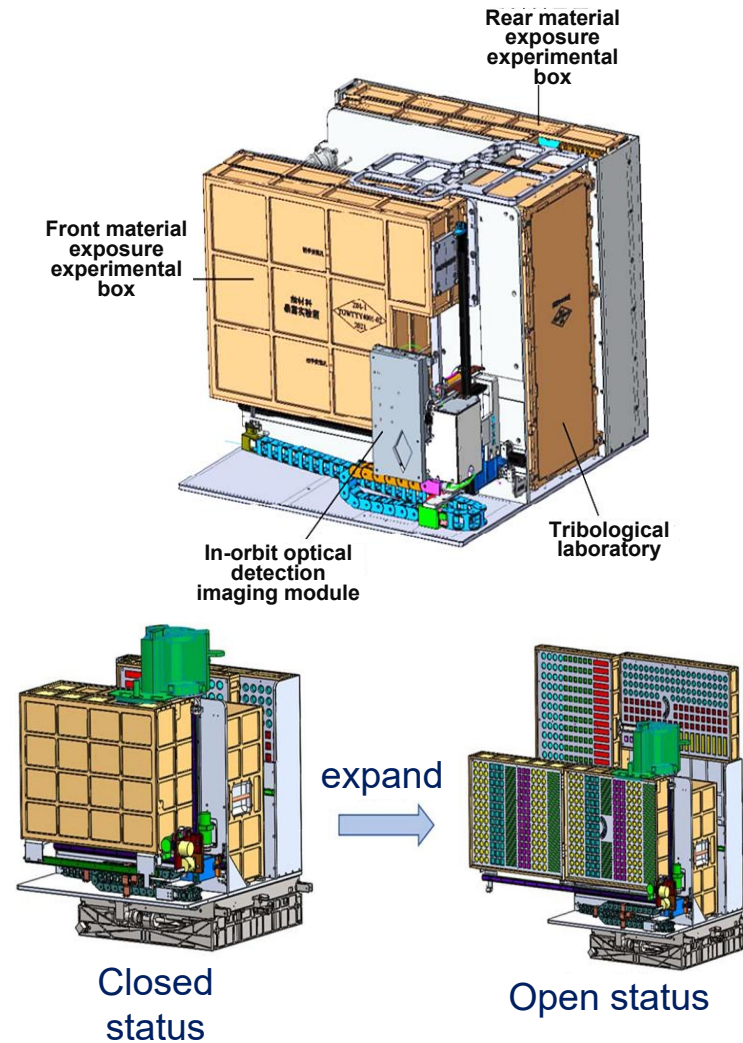


X-ray transmission
Imaging (range2)

2 Material Science Exposed Payload

Material Science Exposed Payload

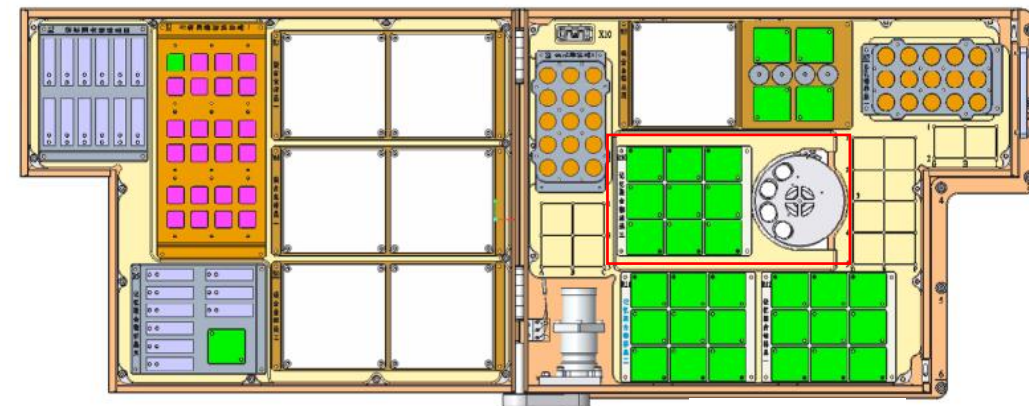
- Number of samples in a single batch: 200
- Online surface topography imaging of exposed samples
- Space exposed tribological experiment with lubricating materials



Experiment Interface

-front material exposure experiment box

- The sample units are installed on the panel with **M4 screws**.
- After unfolding, the samples are all **exposed to the wind** and can be **observed**.
- The effective exposure area for material experiments is **0.26m²**, the height of the sample unit is **15mm- 30mm**.
- Adjacent sample unit experimental areas can be **combined for use**, supporting the installation of **larger sample units** for experiments.
- **Multiple experimental samples** can be installed in the same sample unit.



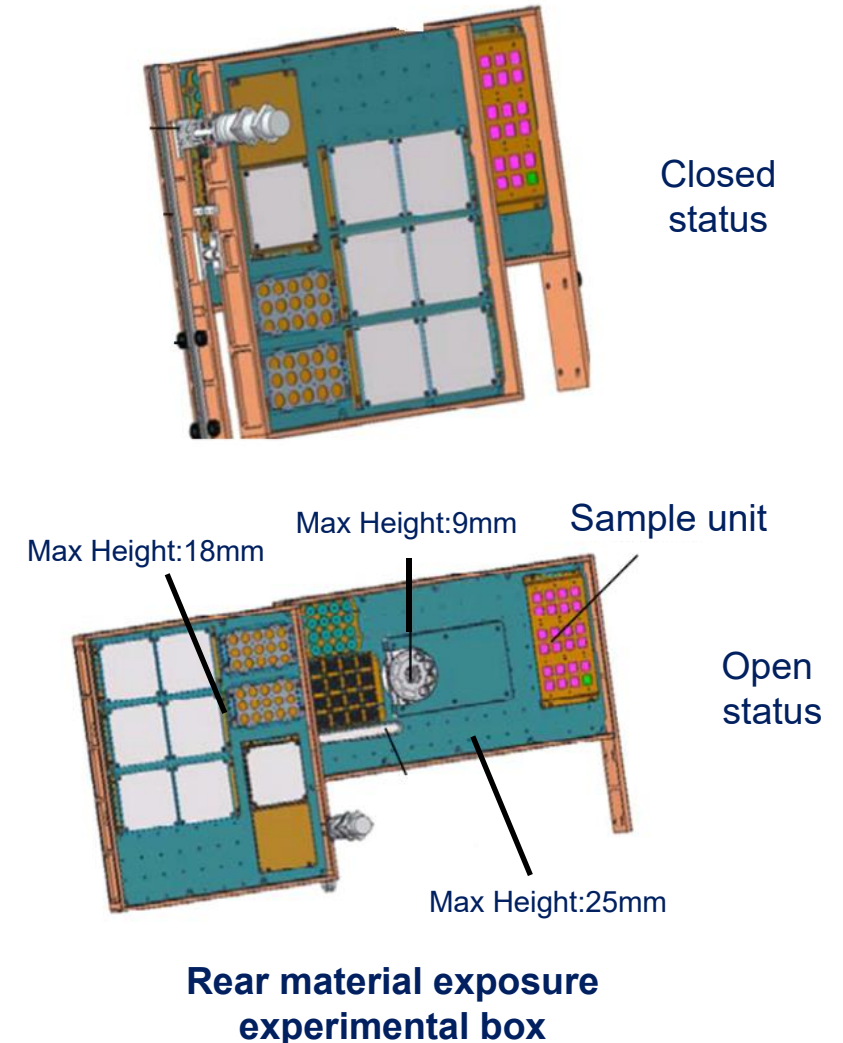
Open status

Open status

Front material exposure
experimental box

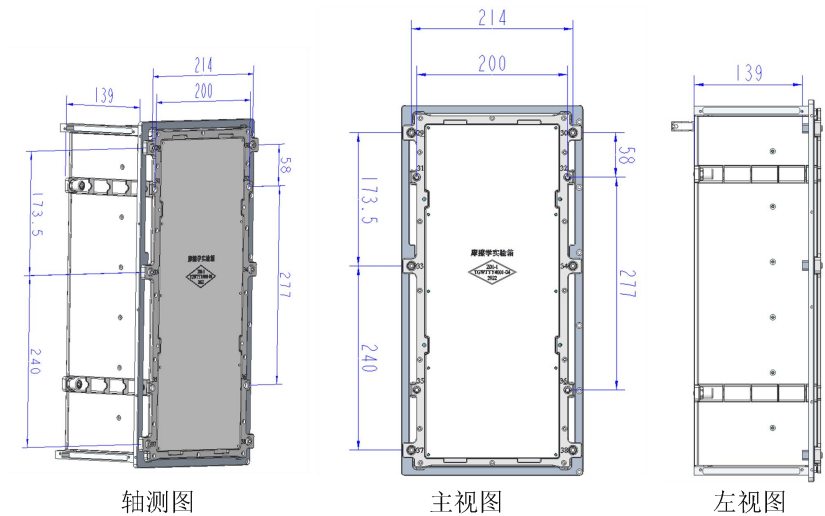
Experiment Interface -rear material exposure experimental box

- The sample units are installed on the panel with **M4 screws**.
- It can provide **two experimental positions: windward and leeward**, with effective exposure areas of 0.275m^2 each, totaling 0.55 m^2 .
- The **height of the sample unit** on the windward side shall not exceed 9mm/25mm/18mm, on the leeward side shall not exceed 20mm/25mm.
- Adjacent sample unit experimental areas can also be **combined for use**, supporting the installation of **larger sample units** for experiments.
- **Multiple experimental samples** can also be installed in the same sample unit.

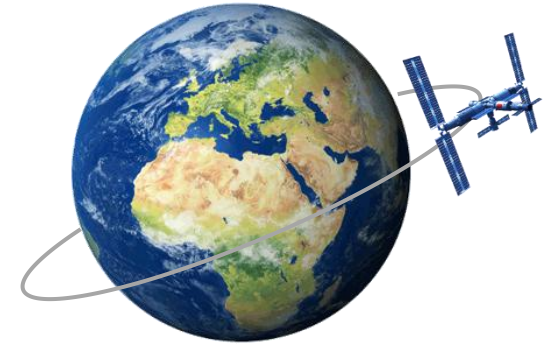


Experiment Interface -Tribology experimental box

- **Envelope size:** 461.4mm x 238mm x 163mm
- **Installation hole position:** connected to the main structure of the material device through 10 **M5 non loosening screws**
- **Power supply :** 1 channel 28V, max 50W; 1 channel 5V, max 10W
- **Thermistors :** 4, measuring range -100 °C to 100 °C, with an accuracy better than 0.5 °C
- **Data channel :** two RS422 channels
- **Telemetry channel :** one 0-5V analog telemetry









Tribology experimental box



3 Overview of Experiment Implementation

Main Engineering Implementation Process

-  Determine space experiment schemes, Propose preliminary scientific experiment requirements
-  Confirm the Experiment Requirements Document(Chinese national standard which specifies experiment interface)
-  Confirm the interfaces of mechanical, electrical, thermal and communication of module(IDS)
-  Develop experiment units/sample units and Carry out environmental test, ground matching test,Astronaut training, pass safety review
-  Confirm the space experiment process, the launch and retrieval plans for the experiment
-  Launch site sample preparation,Launch and Conduct space experiment, data transmission through uplink and downlink,sample retrieval and Sharing scientific achievements

INTERFACE CONTROL REQUIREMENTS

Scientific users provide

- **Experiment requirements Document(ERD)**
 - Sample type
 - Experiment unit/sample unit : size, weight, quantity
 - Temperature measurement and control : range, frequency, accuracy
 - Matching test
 - Environmental Test
 - Observation requirement: duration, frequency, resolution
 - Safety and medical requirement
 - Astronaut operation requirement
 - Launch site operation requirement
 - Retrieval requirement
- etc.....

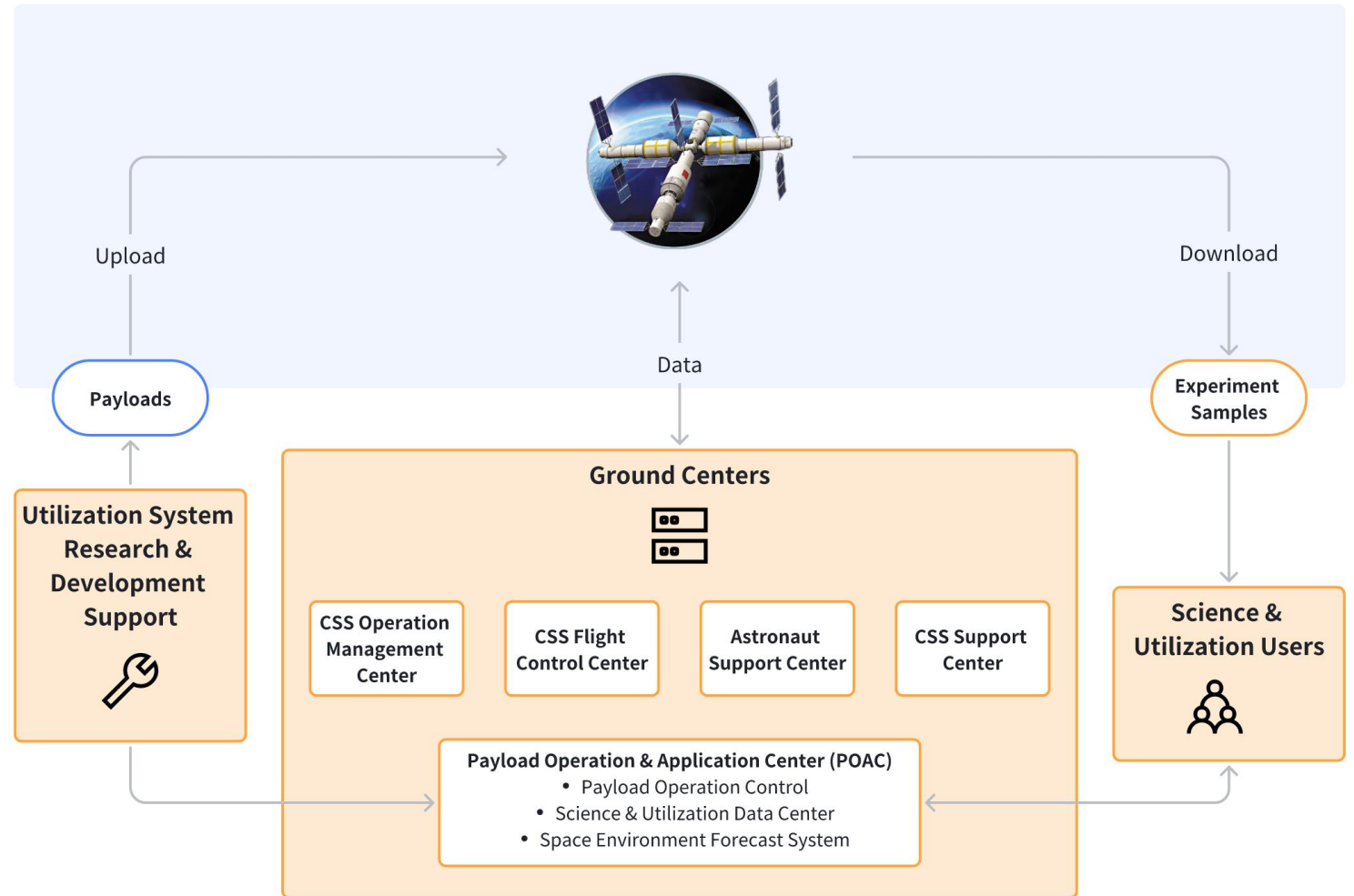
Provided to Scientific users

- **Cabin environmental data** : such as microgravity levels inside the cabin during the experiment
- **Experimental Data** : telemetry data, engineering data, and application data generated during the experiment
- **Load resources** : weight, volume, temperature environment, etc
- **Interface of payload** : mechanical, electrical, thermal, information, etc
- **Experimental Data** : temperature, atomic oxygen flux, pollutant deposition, and other data
- **Astronaut operation resources**: timing and human hours for astronaut operations
- **Upward and downward resources** : volume, weight, etc

Operation Systems

Provide specialized technical support

- mid to long term mission planning
- mission analysis and simulation assesment
- resource management
- operation management
- monitoring & control
- on-orbit operation support
- data processing & sharing
- space environment forecast



How Astronauts Are Trained for Experiments

- ✓ Submit an ergonomic evaluation application when the project conditions are met (no later than 3 months before the launch)
- ✓ Prepare the relevant experiment hardware to carry out the ergonomic evaluation work
- ✓ Only after obtaining a qualified conclusion of ergonomic evaluation (no later than 2 months before the launch), the Astronaut training documents be submitted, and prepare the hardware to conduct the astronaut training activity

Standard of International Cooperation Projects of CSS

□ **Chinese national standard: Requirements Analysis for Space Science Experiment**

✓ This standard specifies the basis, principles, processes, contents, and ERD establishment requirement of the requirements analysis for space science experiments.

□ **CSU standard: Environmental Test Requirement for Payload**

✓ This document specifies the requirements for environmental adaptability test items, test scales, test sequences, allowable deviations, etc., providing environmental adaptability design basis. It is applicable to determine the environmental adaptability of engineering components and flight units.

□ **CSU standard: Safety and Medical Requirements for Payload and Scientific Experiment on China Space Station**

✓ This document specifies the safety and medical requirements to guarantee the in-orbit safety and stable operation of the international cooperation projects of China Space Station (including payload and scientific experiment projects), and this document will be deemed as a basis for implementing relevant safety and medical requirements throughout the process of international cooperation projects of Space Station including development, delivery and in-orbit experiments.



Thank you

Website: <http://www.csu.ac.cn>

Address: Technology and Engineering Center for Space Utilization, Chinese Academy of Sciences, No. 9, Deng Zhuang South Road, Haidian District, 100094