



Experimental Module Manipulator (EMM): 1 Year of Chinese Robotic Arm on the China Space Station

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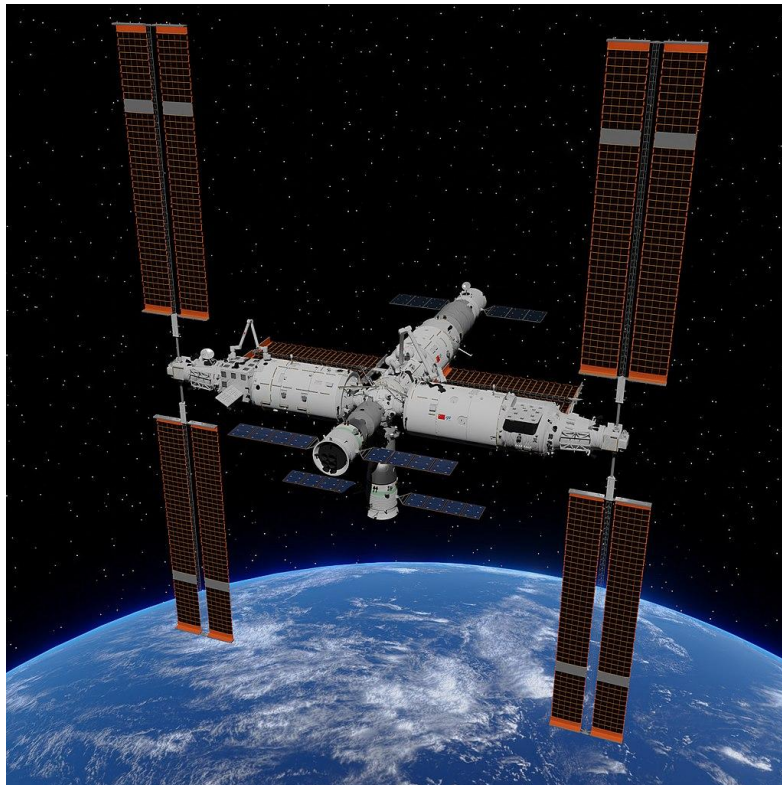
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Overview

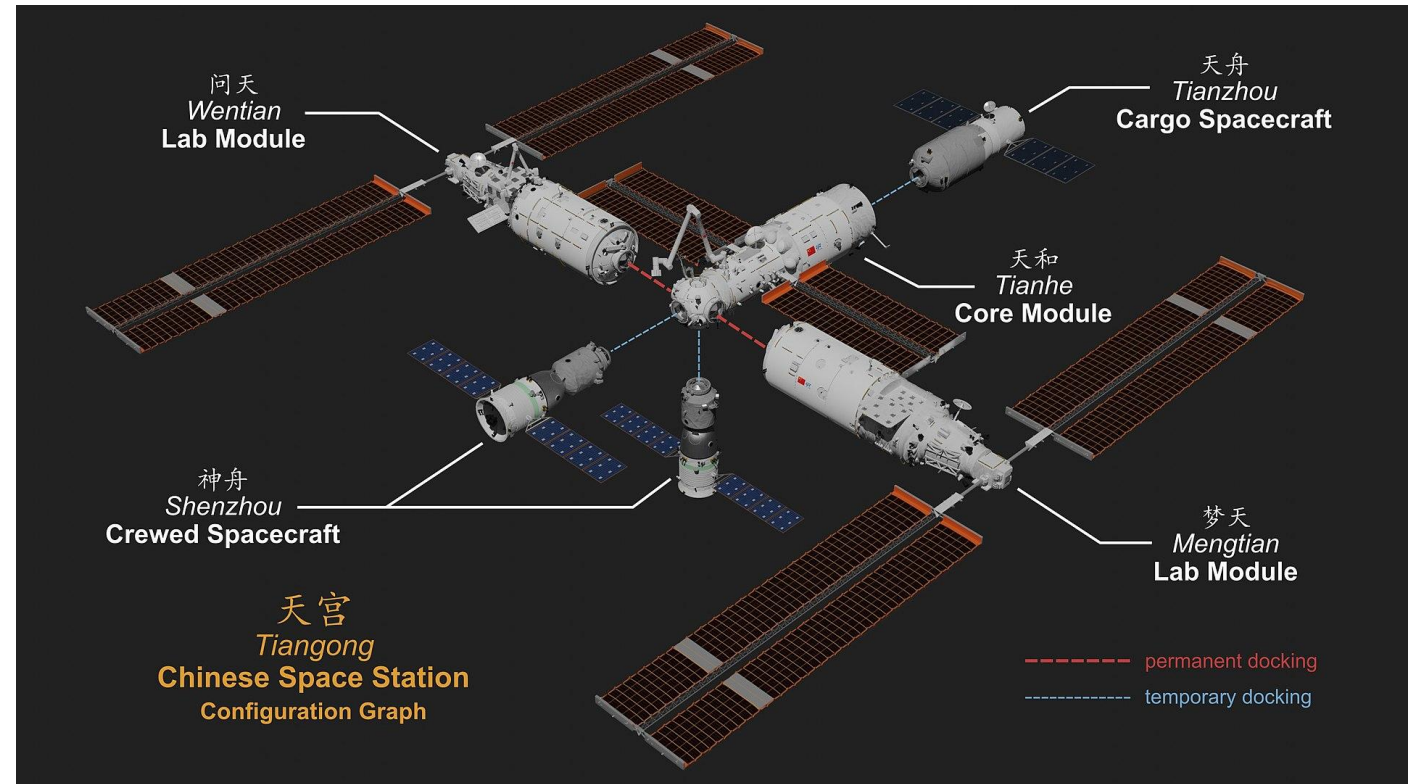
- 1. EMM for China Space Station**
- 2. EMM System Description**
- 3. Testing, Integration, and Launch**
- 4. Perform Tasks**

1. EMM for China Space Station

- With the launch of the Shenzhou-15 mission on Nov 29, 2022 the **China Space Station** has entered the stage of application and development, which will last for more than 10 years.



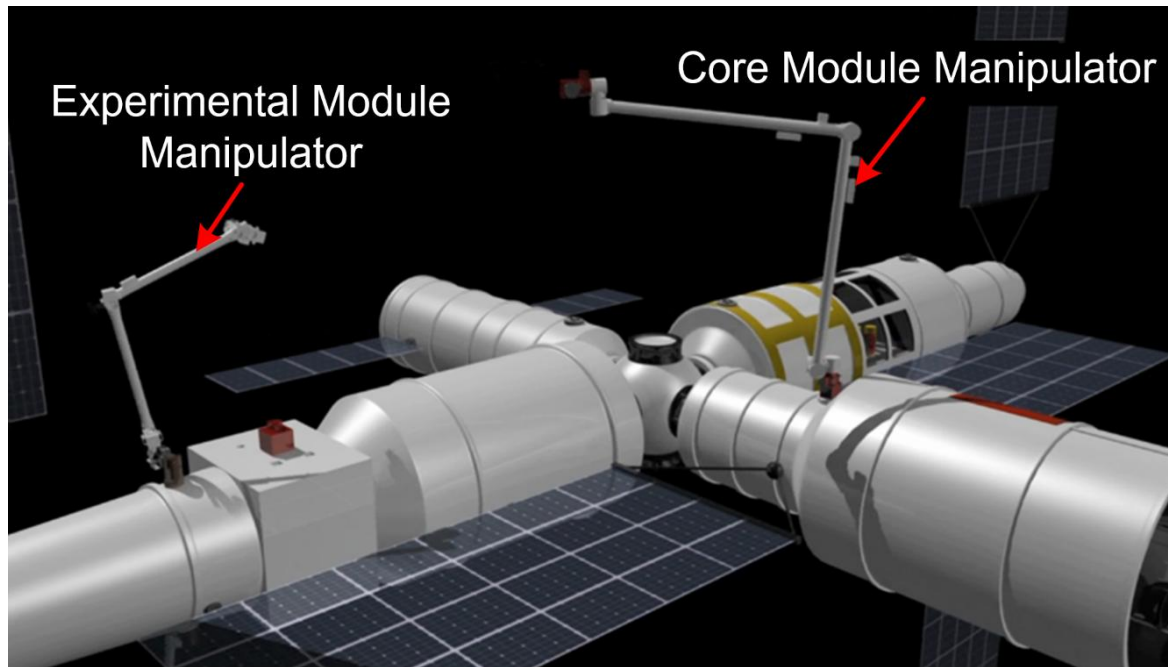
China Space Station



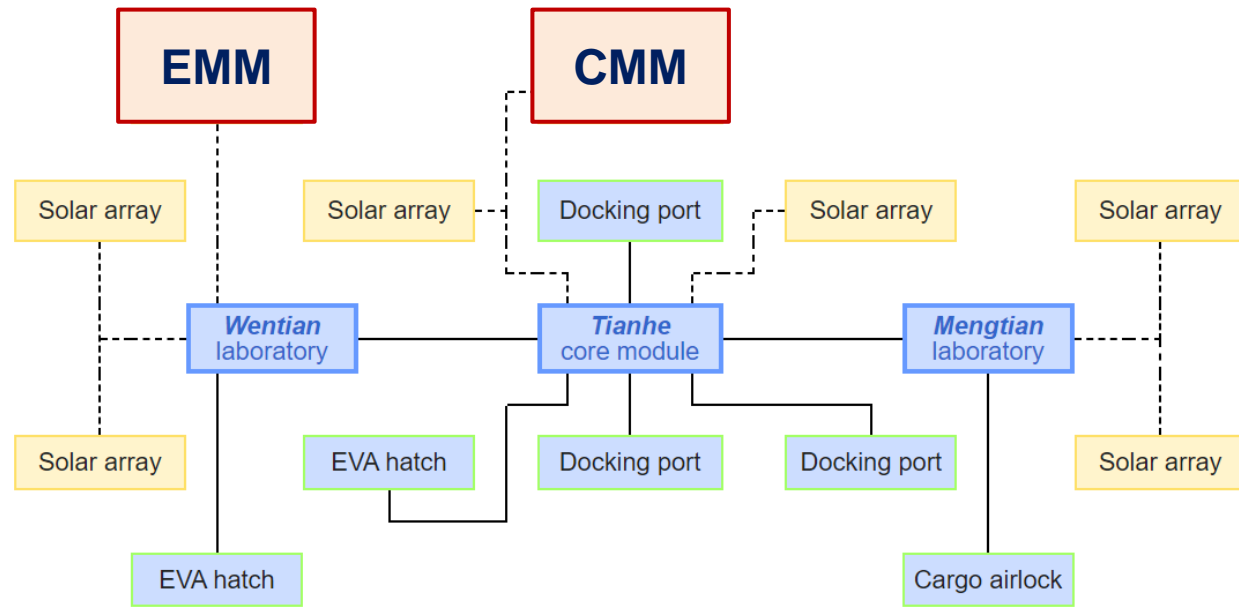
Completed a T-shaped configuration In May 2023

1. EMM for China Space Station

- The China Space Station Remote Manipulator System (CSSRMS) consists of a Core Module Manipulator (CMM) and an Experimental Module Manipulator (EMM).

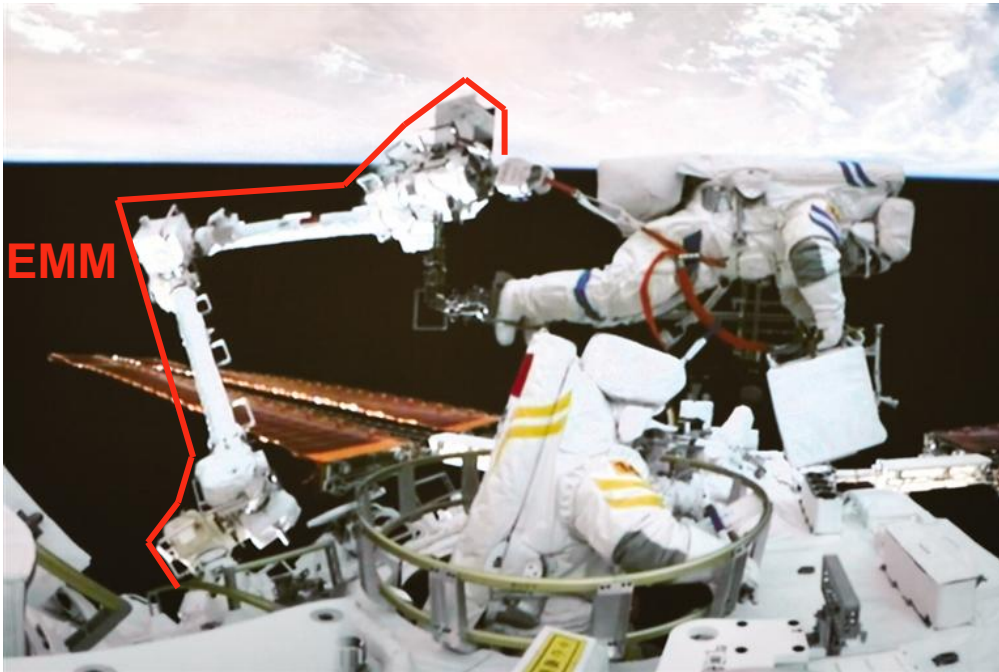


The EMM is mounted on the Wentian Lab Module



1. EMM for China Space Station

- The EMM can perform operations with greater precision and can also be held with the CMM to form a combined arm, which can perform extravehicular operations with a larger range.



The EMM on board the Wentian assisted astronauts Chen Dong (Top), and Liu Yang in conducting EVAs. (1/9/2022)

The main tasks of the EMM:

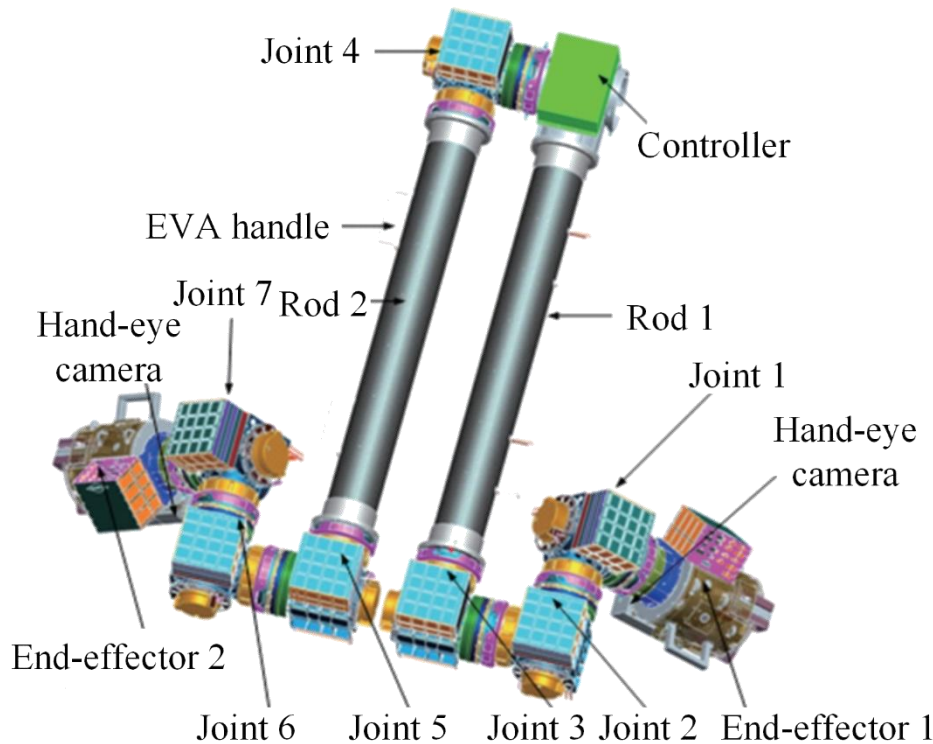
- ✓ Payload care for space exposure experiments
- ✓ Optical platform care
- ✓ Workhorse for astronaut EVAs
- ✓ Inspection of the space station exterior
- ✓ Extravehicular servicing of payloads and equipment

Overview

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2. EMM System Description

- The EMM is a 7-DOF robot arm system with 3 DOFs for each wrist joint and 1 DOF for the elbow.



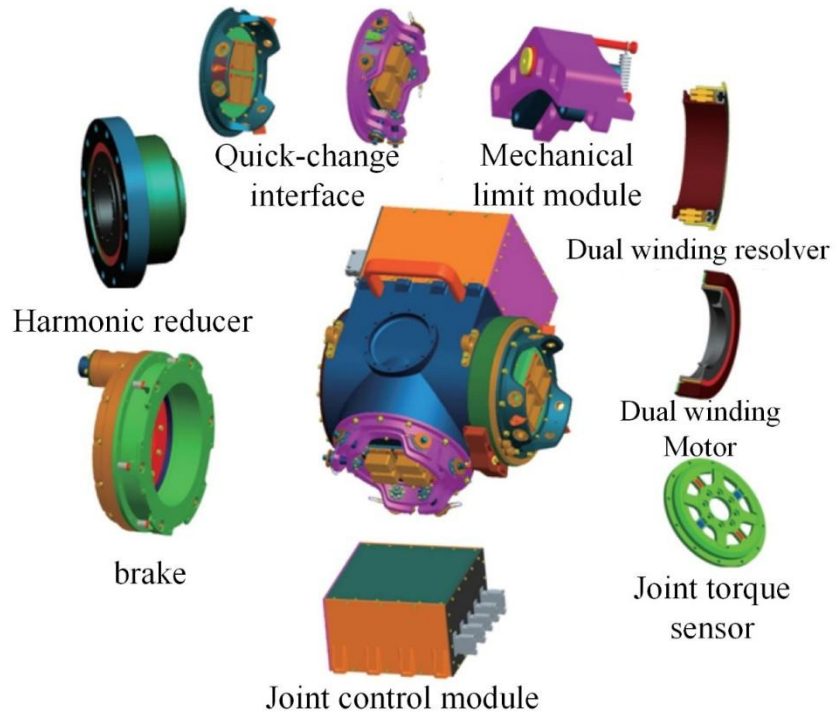
Configuration of the EMM

Specifications of the EMM:

- ✓ One end-effector is used for connection between the EMM and Wentian Lab Module as the work base
- ✓ The other end-effector is used as the tool for payload operation and can be also used for docking with the CMM to compose a 15-meter series-connected arm
- ✓ Both end-effectors are configured with hand-eye cameras and elbow cameras
- ✓ The controller is placed on the main body of the EMM and moves with it

2. EMM System Description

- Joints are the core components of the movement of the EMM, consists of a brushless DC motor, a harmonic reducer, a joint torque, an angle sensor, a thermal control system, and so on.



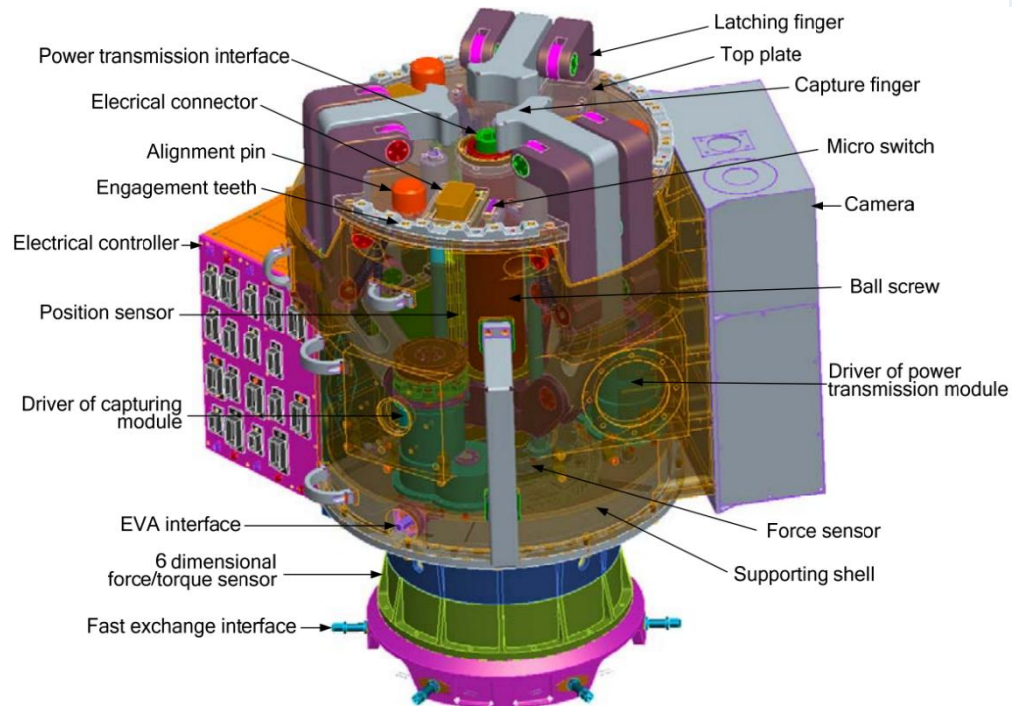
The major components

Multiple functions of the EMM joint include:

- ✓ Providing a standard interface for on-orbit applications
- ✓ Collecting joint information by answering or sending it periodically, and transmitting it to the EMM controller
- ✓ Supporting active thermal control of joints, astronaut control drive, and on-orbit replacement of joints
- ✓ Equipped with a mechanical interface for launch locking

2. EMM System Description

- The end-effector subsystem is installed on each end of the EMM, one serves as the base point through grappling the cooperative grapple fixture, and the other conducts various operation tasks with the operation tools.

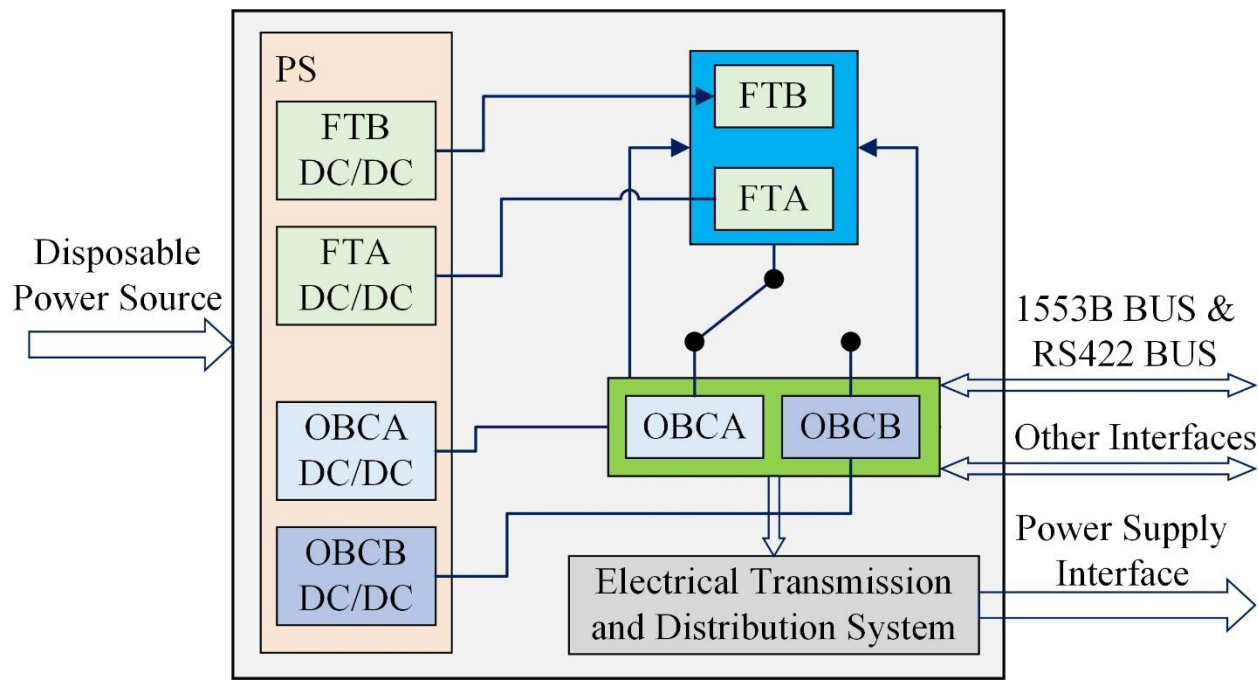


Functions of the end-effector include:

- ✓ **Self-relocation:** the EMM can perform an inchworm-like movement on the China Space Station
- ✓ **Payload handling:** one end-effector acts as a shoulder base, while the other end-effector acts as a hand
- ✓ **Power transmission:** transmit torque to drive the attached tool to accomplish certain on-orbit servicing tasks

2. EMM System Description

- The controller subsystem is an important part of the EMM, which mainly completes the communication, control, power management and other tasks.



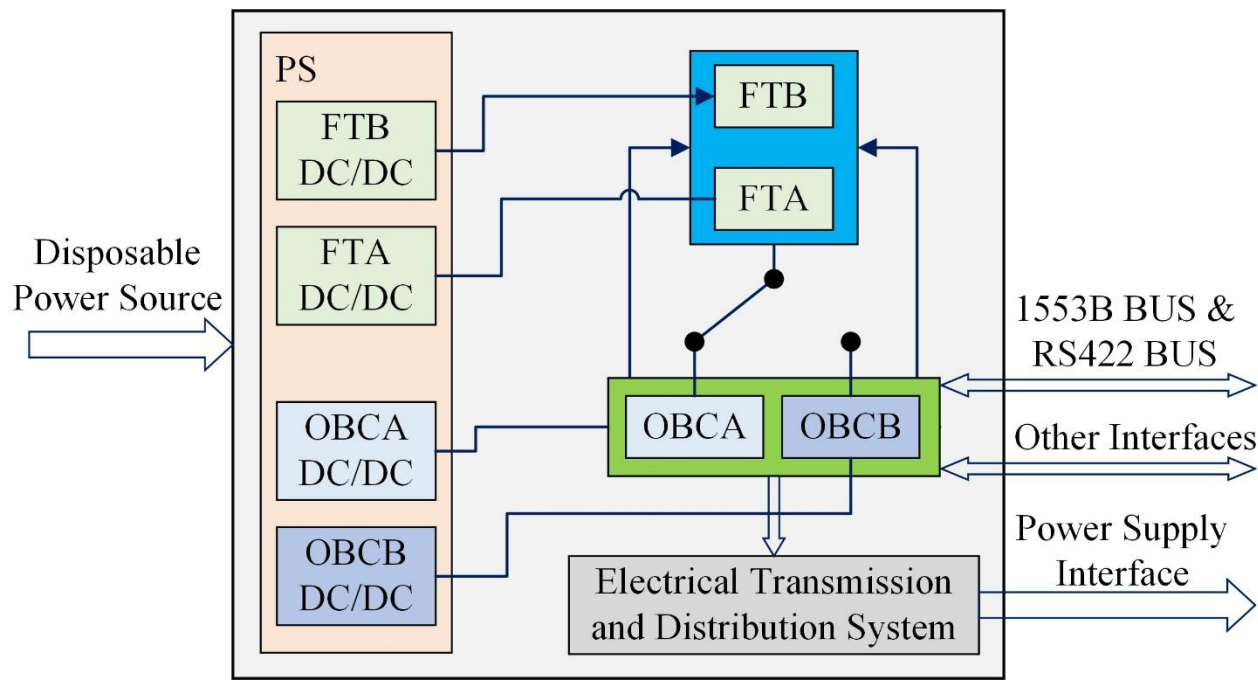
The configuration of the controller

Installed on the outer surface of the EMM and consists of:

- ✓ On-board controller (OBC)
- ✓ Fault Tolerance (FT)
- ✓ Switching power supply and distribution module
- ✓ Secondary power module

2. EMM System Description

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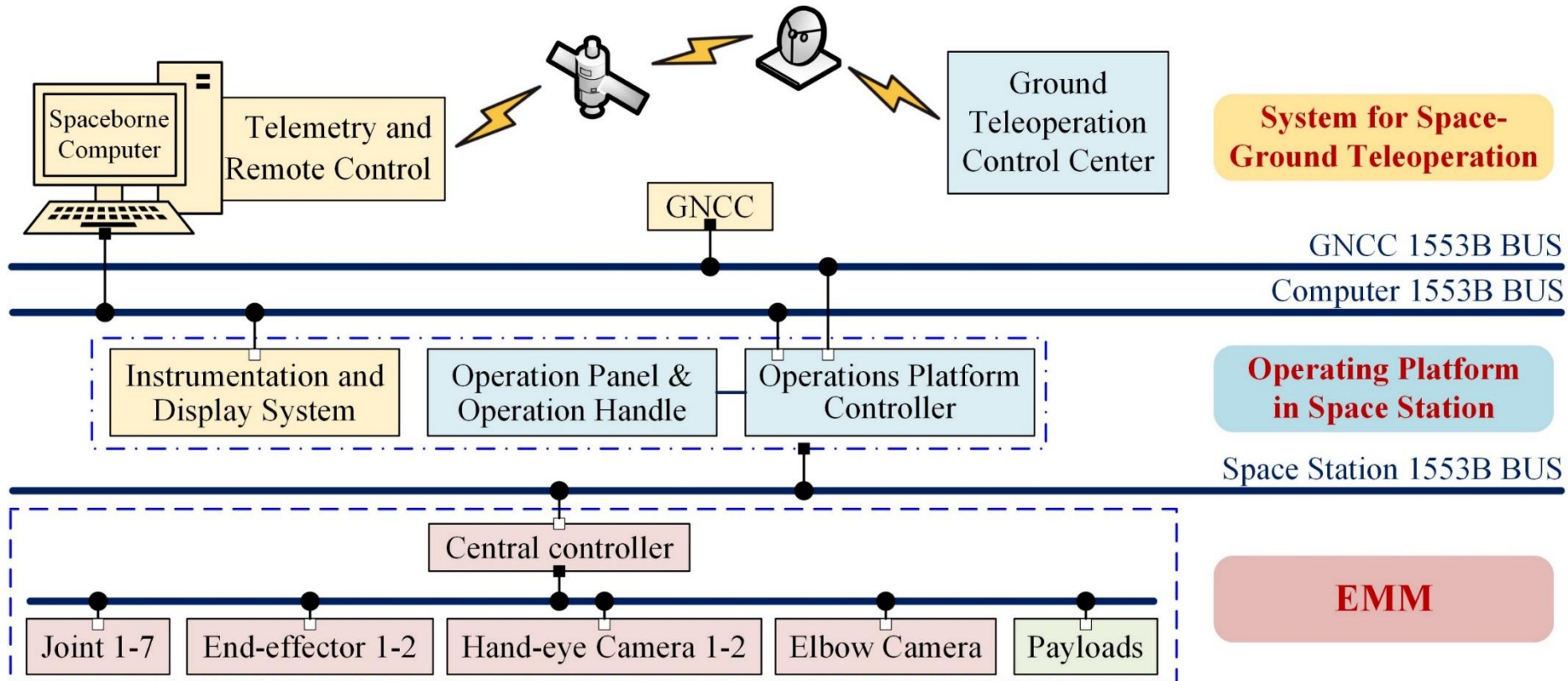
The configuration of the controller

The controller subsystem architecture:

- ✓ Secondary power supply
- + Computer OBC dual-mode cold standby
- + Fault-tolerant dual-mode cold and hot standby
- + Power supply and distribution switching

2. EMM System Description

- Astronauts can switch to the ground teleoperation mode (default state) through the button on the operation platform in Wentian or through ground commands.



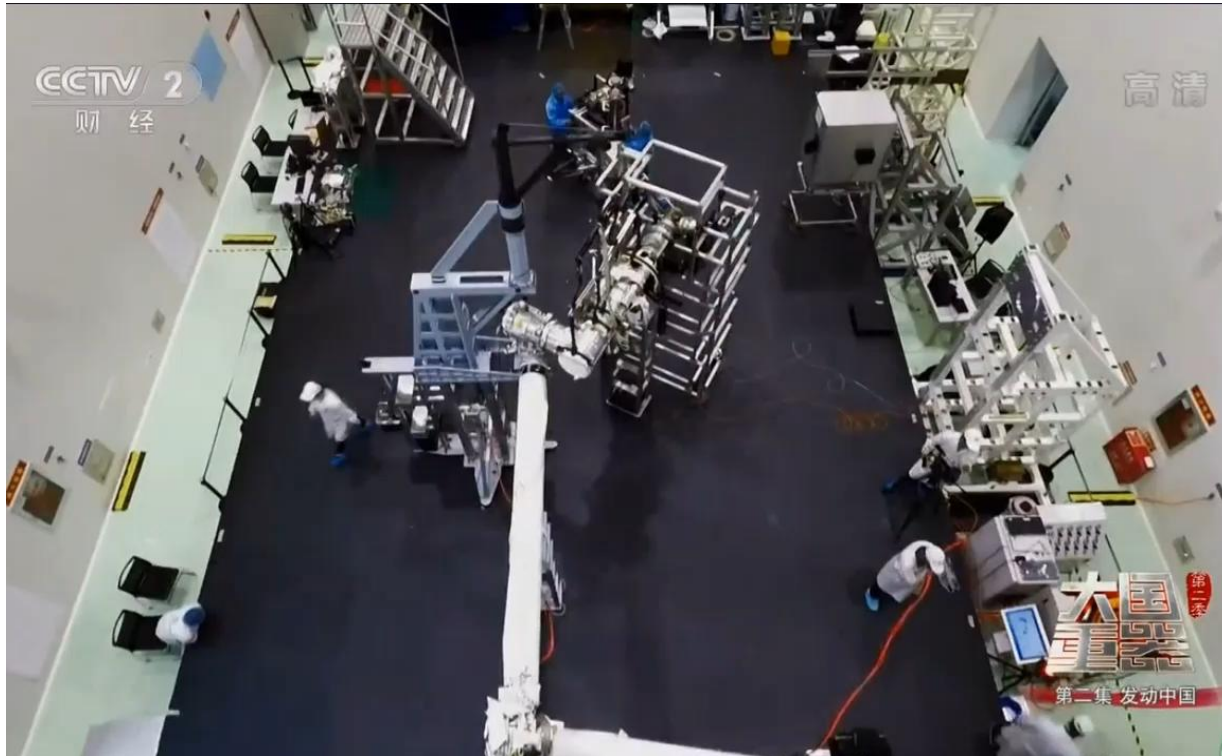
The system structure of on-orbit operation and ground teleoperation

Overview

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3. Testing, Integration, and Launch

- The EMM is meant to work in an environment with low or no gravity, it can't handle missions on Earth where gravity is strong. We set up **ground experiment supporting system** based on an air-bearing table.



Verify the validity of the EMM's design scheme:

- ✓ Conventional performance parameters test
- ✓ Sine vibration test
- ✓ Random vibration test, etc.

3. Testing, Integration, and Launch

- The integration operation phase is a vital stage for the EMM.



Following individual ground experiments, the EMM was shipped to the cleanroom and mated with Wentian Lab Module

3. Testing, Integration, and Launch

- **Launch** : after the integration process was completed



The rocket took off at 2:22 p.m. Beijing Time on July 24, 2022, from the Wenchang Spacecraft Launch Site

24 July 2022

- ✓ **Wentian Lab Module was launched into orbit**

24 July 2022

- ✓ **Successfully docking with Tianhe Core Module forward port**

25 July 2022

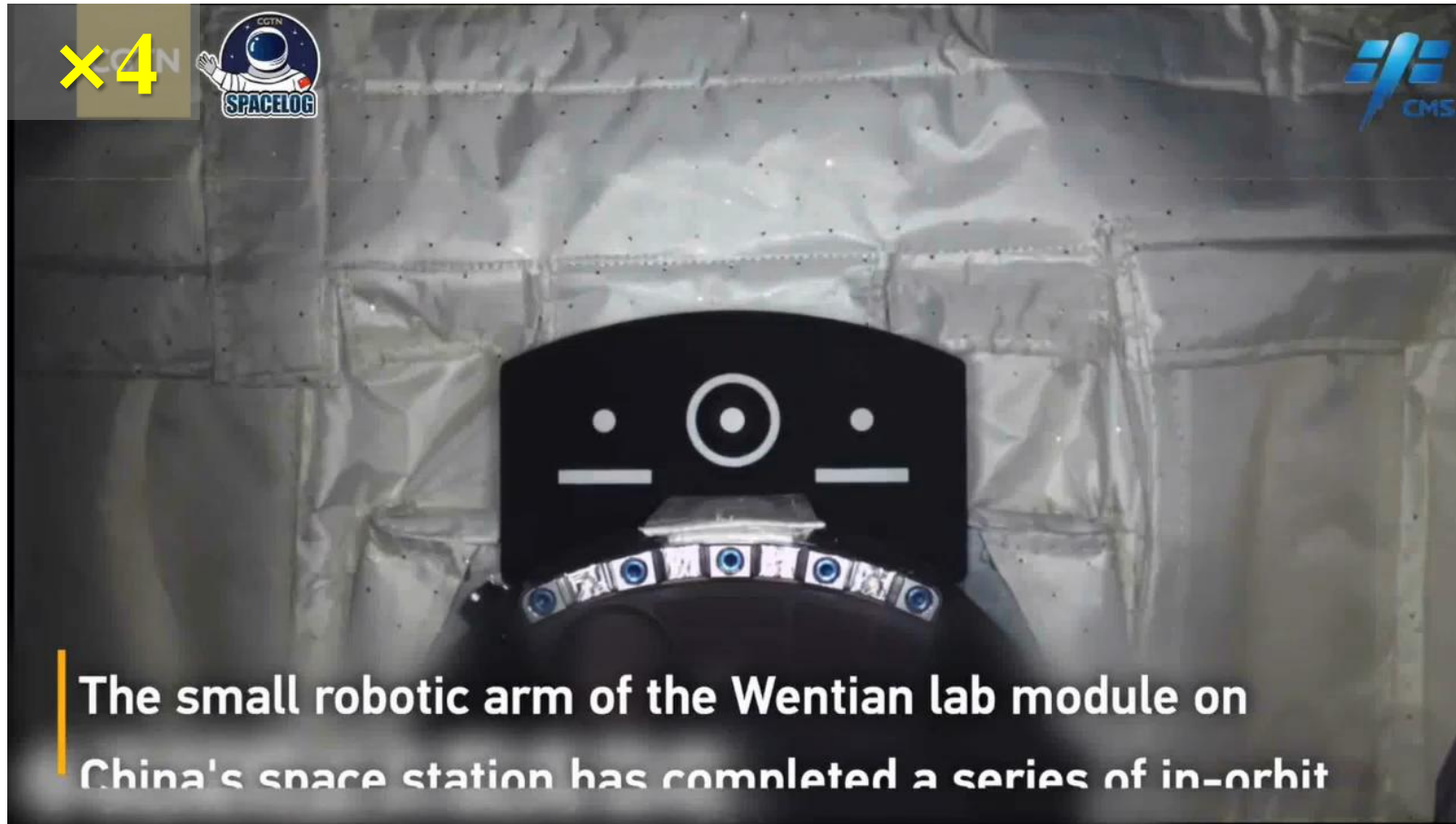
- ✓ **The crew of Shenzhou 14 opened the hatch and entered the module for the first time**

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4. Perform Tasks

- The astronauts unfolded the EMM in Wentian Lab Module and completed a series of performance tests.



Test items include:

- ✓ Unlocking of aerospace pyrotechnic devices
- ✓ Self-inspection
- ✓ Single joint deployment
- ✓ Confirmation of crawling ability
- ✓ Disengage from the base
- ✓ Inspection of adapters, solar array, exit hatches
- ✓ Joint test

4. Perform Tasks

- With the help of the EMM, Shenzhou-14 astronauts Chen Dong and Liu Yang went outside the cabin and returned safely to Wentian Lab Module after completing the scheduled tasks.



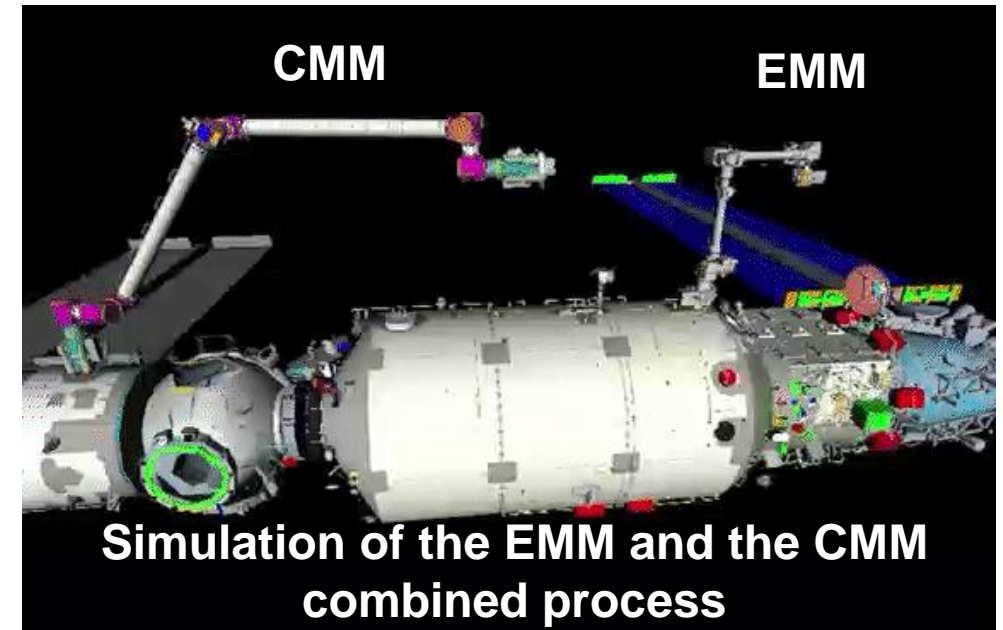
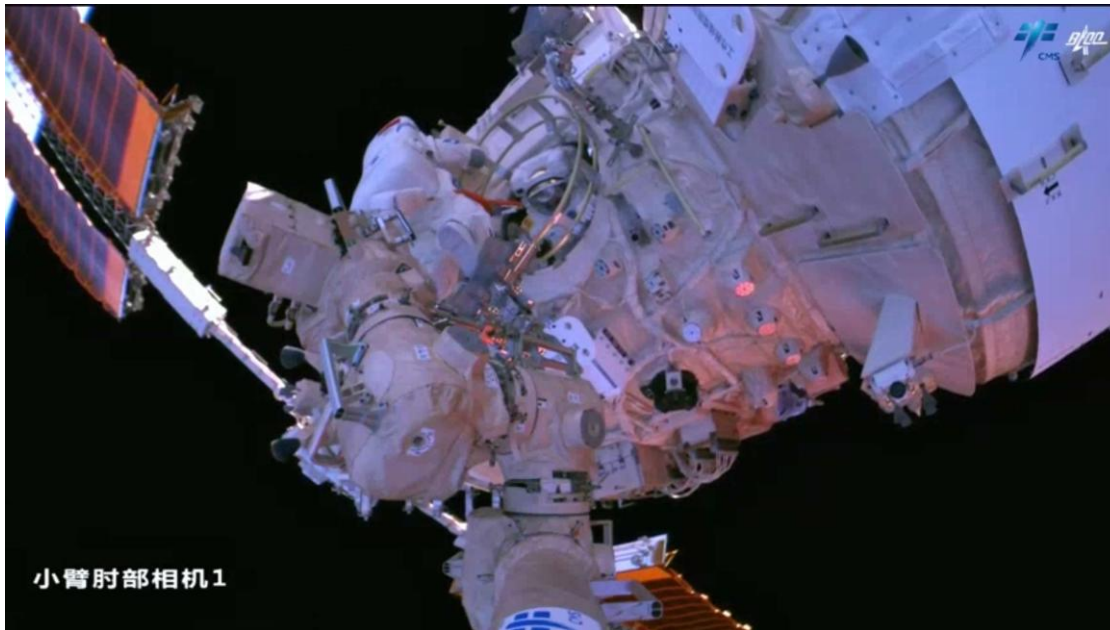
Support to EVA astronauts:

- ✓ Install foot limiters
- ✓ Fixing an astronaut at the end-effector of EMM
- ✓ An astronaut is lifted to the operating position to install pumps
- ✓ The astronauts return to the interior of Wentian Lab Module

September 2, 2022, was the day of Wentian's first spacewalk, which lasted about six hours.

4. Perform Tasks

- On July 20, 2023, with the assistance of the combined arm, astronauts Jing Haipeng, Zhu Yangzhu and Gui Haichao completed all set tasks during the eight-hour spacewalk.



During the spacewalk, the astronauts completed tasks including bracket installation and lifting of panorama camera B of the Core Module and the unlocking and lifting of panorama cameras A and B of the Mengtian Lab Module

4. Perform Tasks

- Inspection of the exterior is critical for China Space Station.



The EMM's elbow and hand-eye camera can be used to inspect the exterior of CSS

The camera can be used to accomplish several functions:

- ✓ **Track changes in external conditions:** surface anomalies, damage, material degradation, etc.
- ✓ **Configuration verification:** module installation and transfer, deployment of the solar arrays, etc.
- ✓ **Anomaly status detection and monitoring:** torn solar arrays, air leak, etc.

4. Perform Tasks

■ Conclusions

- ✓ **Space robots can adapt to the extreme environment, break through the limits of human space exploration, and greatly improve the safety and economy of space operation and control.**
- ✓ **The EMM has been successful over its 1-year life and met its design requirements of the China Space Station.**

4. Perform Tasks

■ Conclusions

Three characteristics of the EMM:

- 1. The EMM improves astronauts' ability to operate in the harsh environment of space**
- 2. The application of the EMM is beneficial to extend the on-orbit servicing life of the China Space Station**
- 3. The application of the EMM can reduce astronaut EVA risk to obtain more economic returns**

Acknowledgements

- I would like to take a moment to express my heartfelt gratitude. None of this research would have been possible without the incredible efforts of our dedicated team at **Experimental Module Manipulator**.





**Thank you all for your
attention and engagement!**

If you have any further questions or would like to discuss our research in more detail, please feel free to reach out.

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