Fukushima Daiichi Nuclear Power Station Unit 2 PCV Internal Investigation/ Status of Fuel Debris Trial Retrieval

July 30, 2026

International Research Institute for Nuclear Decommissioning
Tokyo Electric Power Company Holdings, Inc.

1. PCV internal investigation and trial retrieval plan overview

- In order to guarantee work safety and prevent the spread of contamination, the following equipment will be installed at the penetration to the Unit 2 primary containment vessel (hereinafter referred to as, "X-6 penetration") that will be used for the PCV internal investigation and also as a preparatory stage of trial retrieval.

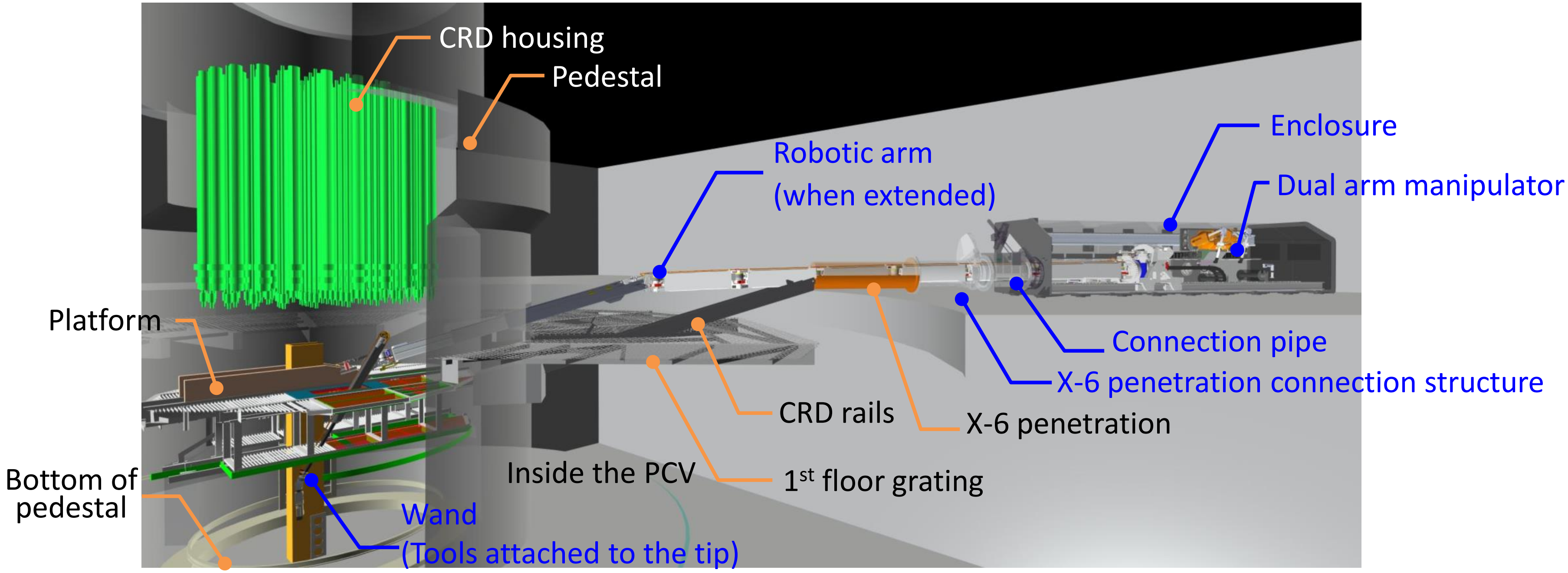
  ＜Already installed＞

  - The X-6 Penetration connection structure isolates the inside of the PCV from the outside
  - The connection pipe shields radiation

  ＜To be installed going forward＞

  - A metal box that contains the robotic arm (enclosure)

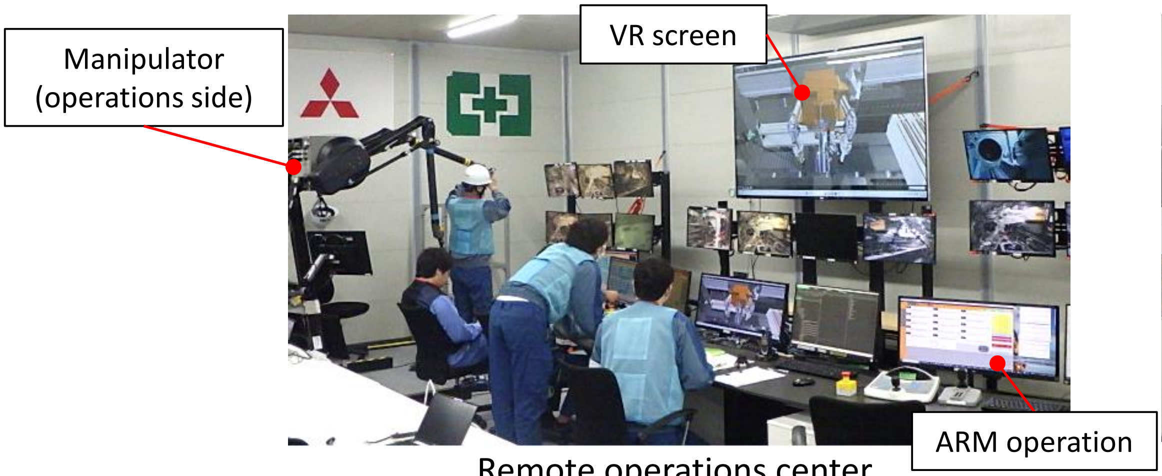
- After installation of the aforementioned equipment, the robotic arm shall be fed into the PCV through the X-6 penetration to remove obstacles inside the PCV while also conducting internal investigations and moving forward with the trial retrieval of fuel debris.



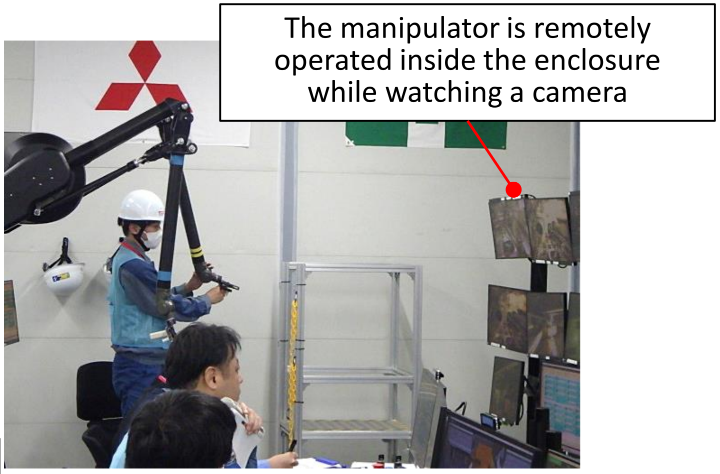
Unit 2 internal investigation/trial retrieval plan overview

2-1. Installation status of the robotic arm (function checks to confirm integrity)

- Function checks are underway to confirm the integrity of the robotic arm.
- TEPCO operators will operate the robotic arm and manipulator from the remote operations center.
- Arm and manipulator operation will be checked with the isolation valve of the X-6 penetration connection structure, which is the PCV boundary, closed.

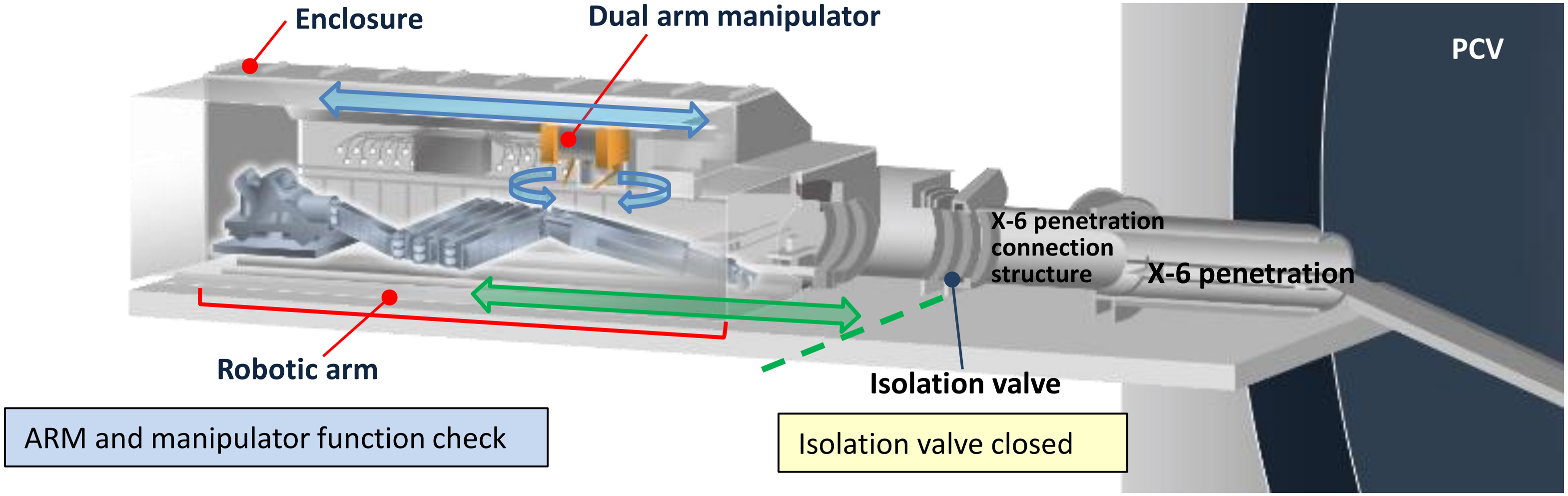


Remote operations center



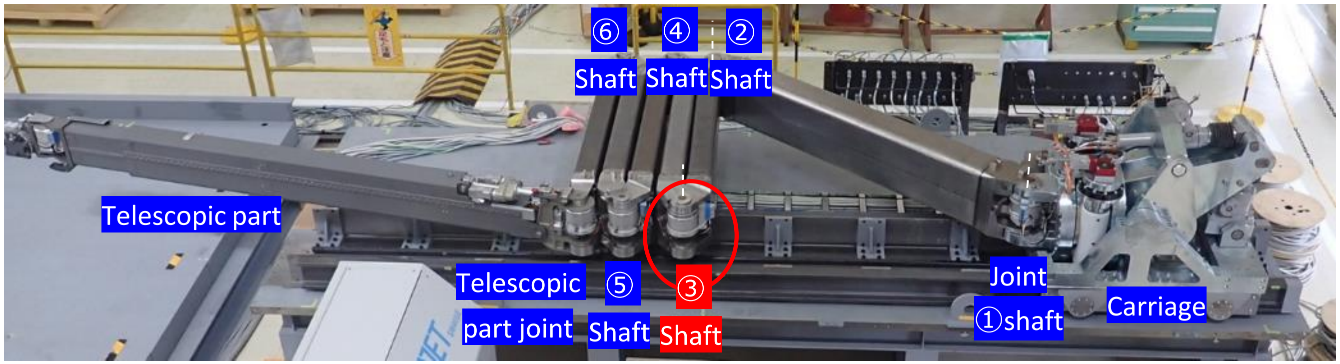
Manipulator function check

<Overview of the function check to confirm integrity>



2-2. Robotic arm function check (Joint ③ shaft drive malfunction)

- During the arm function check, we were unable to disengage the position retention mechanism for the arm joint ③ shaft drive (There were no abnormalities with any of the other joints)
  - The electrical system was checked and no problems were found
  - The arm joint shaft drives (motor and reducer unit) were replaced during maintenance performed at the Naraha test center ※2
  - Unit function tests were performed during maintenance and function tests were performed after the arm was assembled, and integrity was confirmed

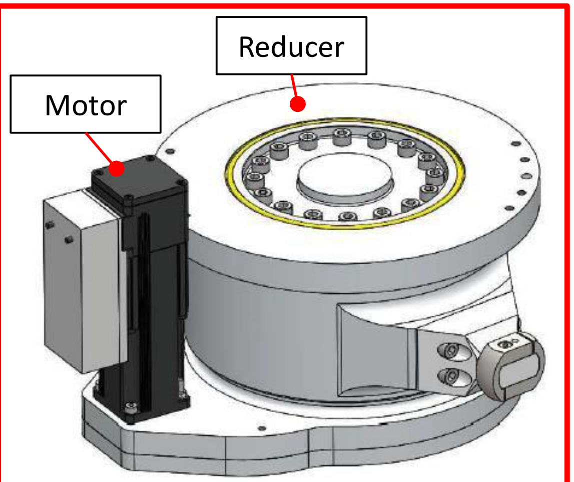


Robotic arm overview

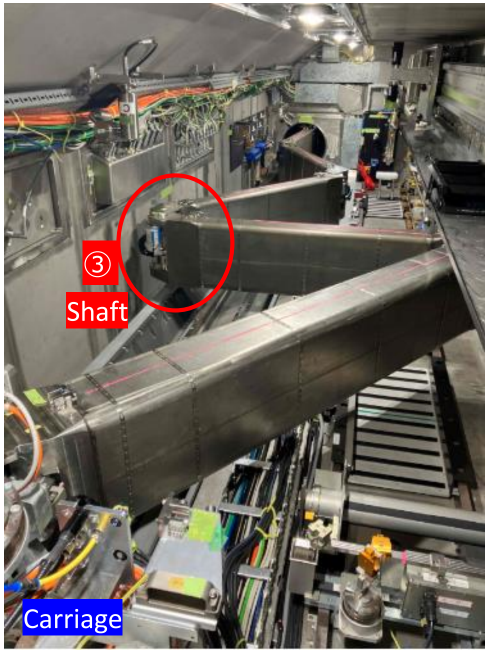
※1 Brake mechanism that stops motor rotation in order to maintain arm position

※2 Verification tests performed at the JAEA Naraha Remote Technology Development Center

Arm joint shaft



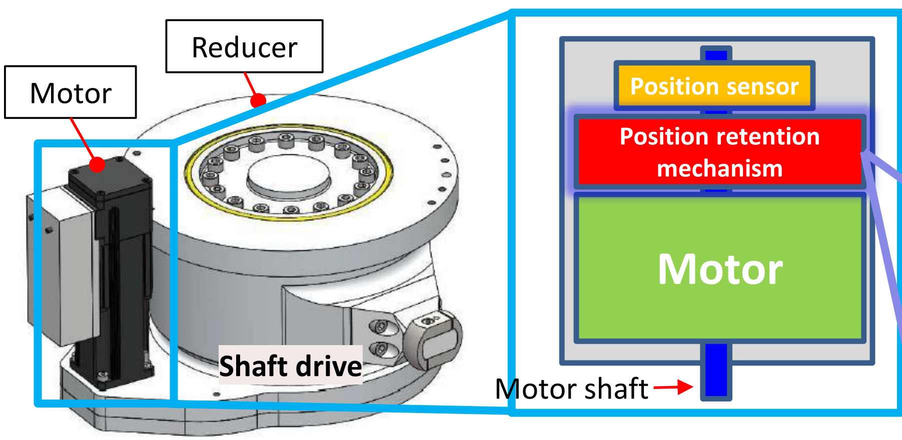
Shaft drive



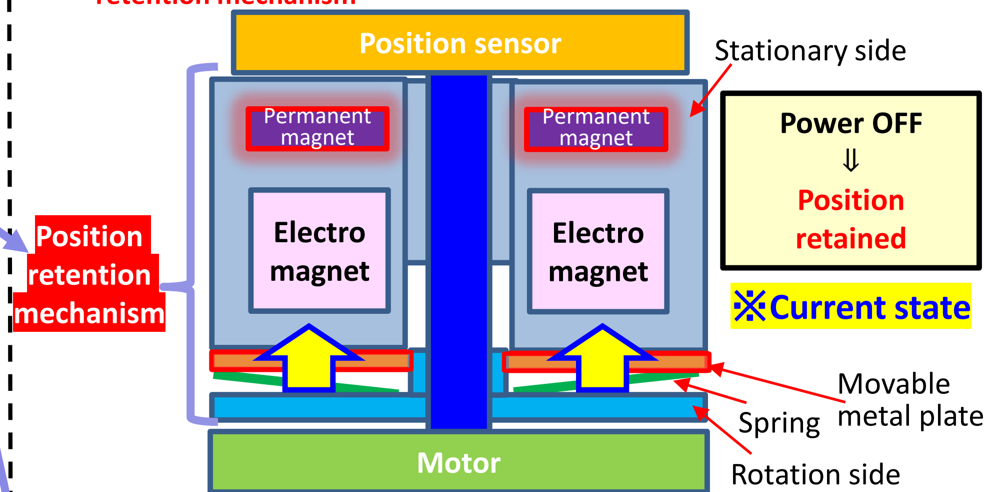
Robotic arm functions (During testing at Naraha)

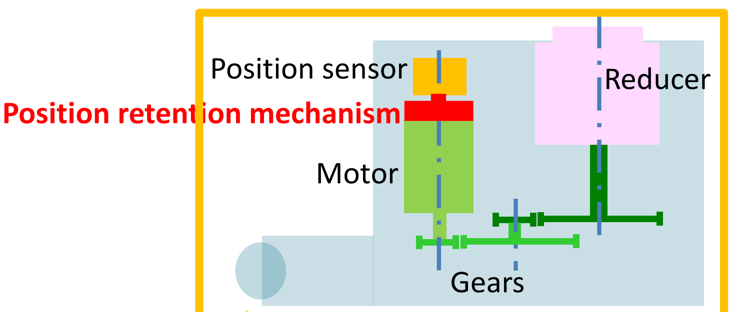
[Reference] Robotic arm function tests (Joint ③ shaft drive structure)

- The following shows the shaft drive motor structure
  - The unit is made up of a motor, a **position retention mechanism**, and a position sensor

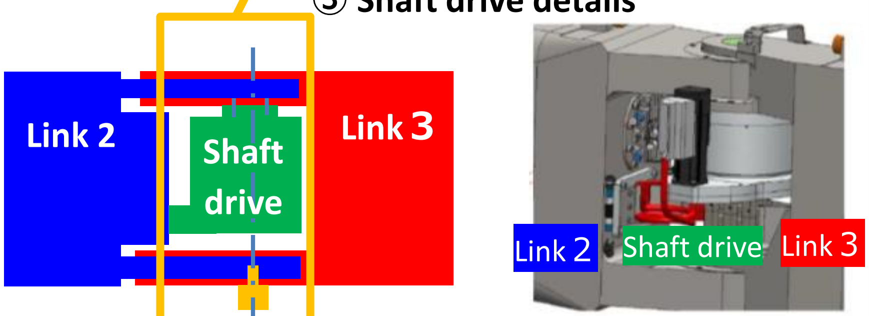


- When the power is off, the movable metal plate is secured to the stationary side by the permanent magnet thereby **securing the position retention mechanism**

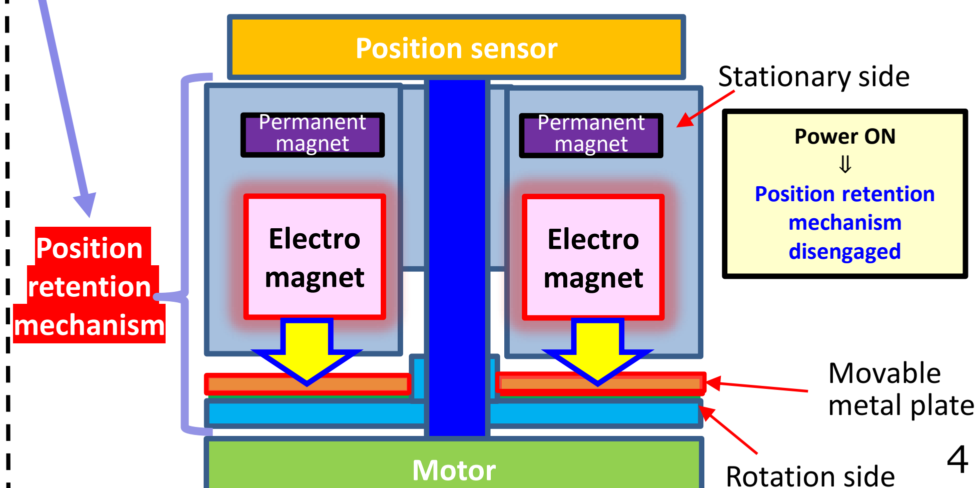




③ **Shaft drive details**



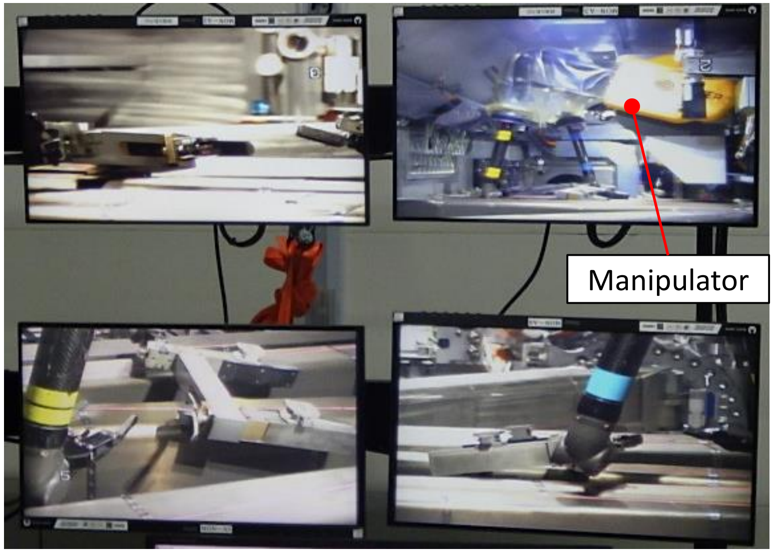
- When the power is on, voltage is applied to the electromagnet which cancels the magnetic field of the permanent magnet thereby allowing the movable metal plate to be pulled by the spring and away from the stationary side **which disengages the position retention mechanism**



2-3. Robotic arm function test status (Status of the investigation into the cause of the malfunction)

- The following investigations were implemented on the electrical and mechanical systems.
- Each investigation showed that there are no problems with the electrical system, so we assume the cause is the mechanical system.
- It was determined that the shaft motor needs replacing, so we are deliberating replacement of the aforementioned motor.

Target	Possible problem	Investigation result
Electrical system	Control system errors or bugs	• It was confirmed that commands are being outputted from the control system
	Severed or damaged cables	• Resistance measurements between cables from the control panel to the position retention mechanism revealed no problems
	Power to disengage the position retention mechanism is not being applied	• Voltage measurements taken between the control panel and position retention mechanism revealed no problems
	Voltage to disengage the position retention mechanism is low	• It was confirmed that there are no problems with insulation resistance between the control panel and the position retention mechanism, and also that the position retention mechanism failed to disengage even when high voltage was applied
Mechanical system	Position retention mechanism damage	• The inside of the unit has not been inspected but it is unlikely that damage was incurred by vibration during transport
	Movable parts of the position retention mechanism are stuck or jammed	• External force , such as vibration, was applied to the shaft ③ drive motor, but it did not disengage



Performing an investigation with the manipulator
(Monitors showing the camera feed from inside the enclosure)

Performing checks inside the enclosure

3. Work schedule

- Since verification tests at Naraha have concluded, the robotic arm will be transported to 1F. After that it will be brought into the Unit 2 reactor building via remote control and connected to the X-6 penetration connection structure and connection tube, and cables will be laid. Function tests to confirm integrity are currently underway.
- During the arm function check, we were unable to disengage the position retention mechanism for the arm joint ③ shaft drive motor.
- As a result of the investigation it was determined that the shaft drive ③ motor needs replacing, so we are deliberating replacement of the aforementioned motor.
- We are currently reviewing repair schedule and the schedules for commencing PCV internal investigations and trial fuel debris retrieval

		FY 2026			
		Q1	Q2	Q3	Q4
Robotic arm	Inspection/maintenance, etc., and any additional development required based upon once-through tests/test results				
	Arrival at the Fukushima Daiichi Nuclear Power Station	▽			
	Installation preparation, etc./ access route construction				
	Internal investigation/debris sampling				

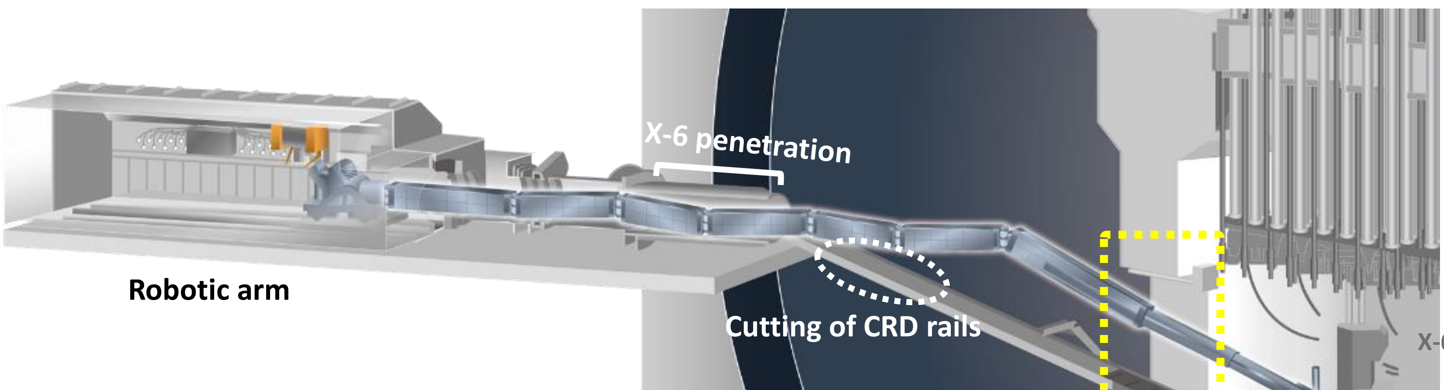
: Completed

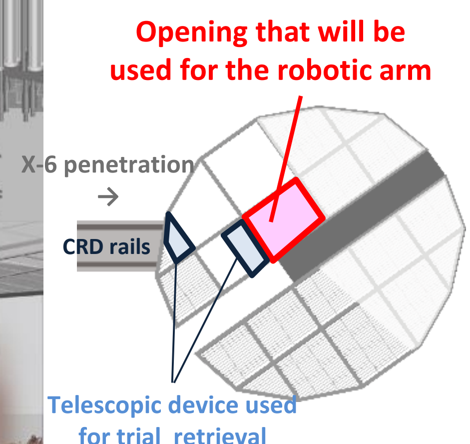
: Commencement and completion dates under review

[Reference] Objective of PCV Internal investigation/fuel debris trial retrieval

- A robotic arm will plan to be inserted through the PCV's X-6 penetration to perform internal investigations and retrieve fuel debris samples
- Objectives
  - **To build an access route**※ by removing obstructions with the telescopic device that may hinder the insertion of the large robotic arm
  - **To acquire 3D model data and footage from inside the PCV** in order to confirm the adequacy of work plans and the design of retrieval device to be used as the scale of fuel debris retrieval is gradually enlarged
  - To verify that a digital environment (virtual reality) can be used for **fully remote operations** and also **verify that device can be used for long periods of time in high dose environments**

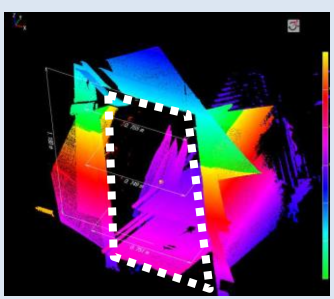
※ Removal of obstructions inside the PCV





Top view of platform

Pedestal opening



3D model data acquisition

Creation of digital environment (virtual reality)

[Reference] Process of PCV internal investigation and trial retrieval

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- The process is as follows: **Access route construction, 3D model data acquisition**, **debris sampling, acquisition of other data**
- Of these steps, **access route construction** and the **acquisition of 3D modeled data** inside the pedestal for verifying precise device design and adequacy as well as verifying operations and making them more efficient shall be prioritized. **The entire process will take approximately six months**

Prioritized processes

Access route construction ⇒ 3D model data acquisition ⇒ Debris sampling ⇒ Footage data ⇒ Gamma ray dose measure-ments ⇒ Neutron count

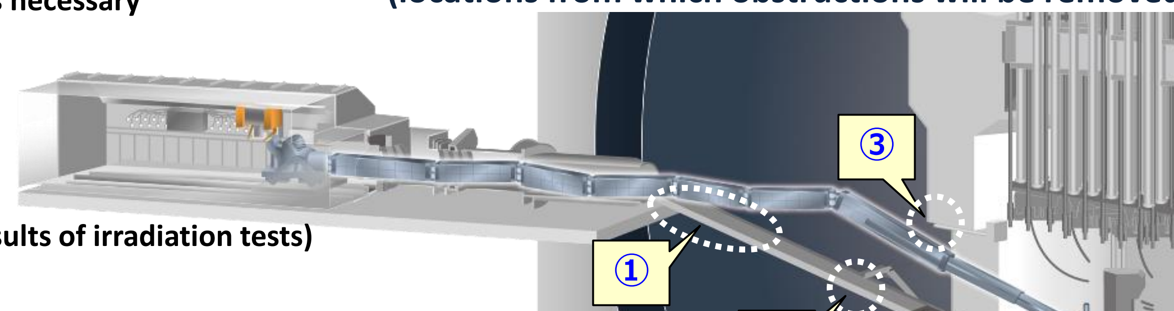
Approx. 3~4 months

To be added to the aforementioned process as necessary

+ Camera replacement | Minor nonconformities, etc.

(Camera replacement is included based on the results of irradiation tests)

■ **Access route construction (locations from which obstructions will be removed)**



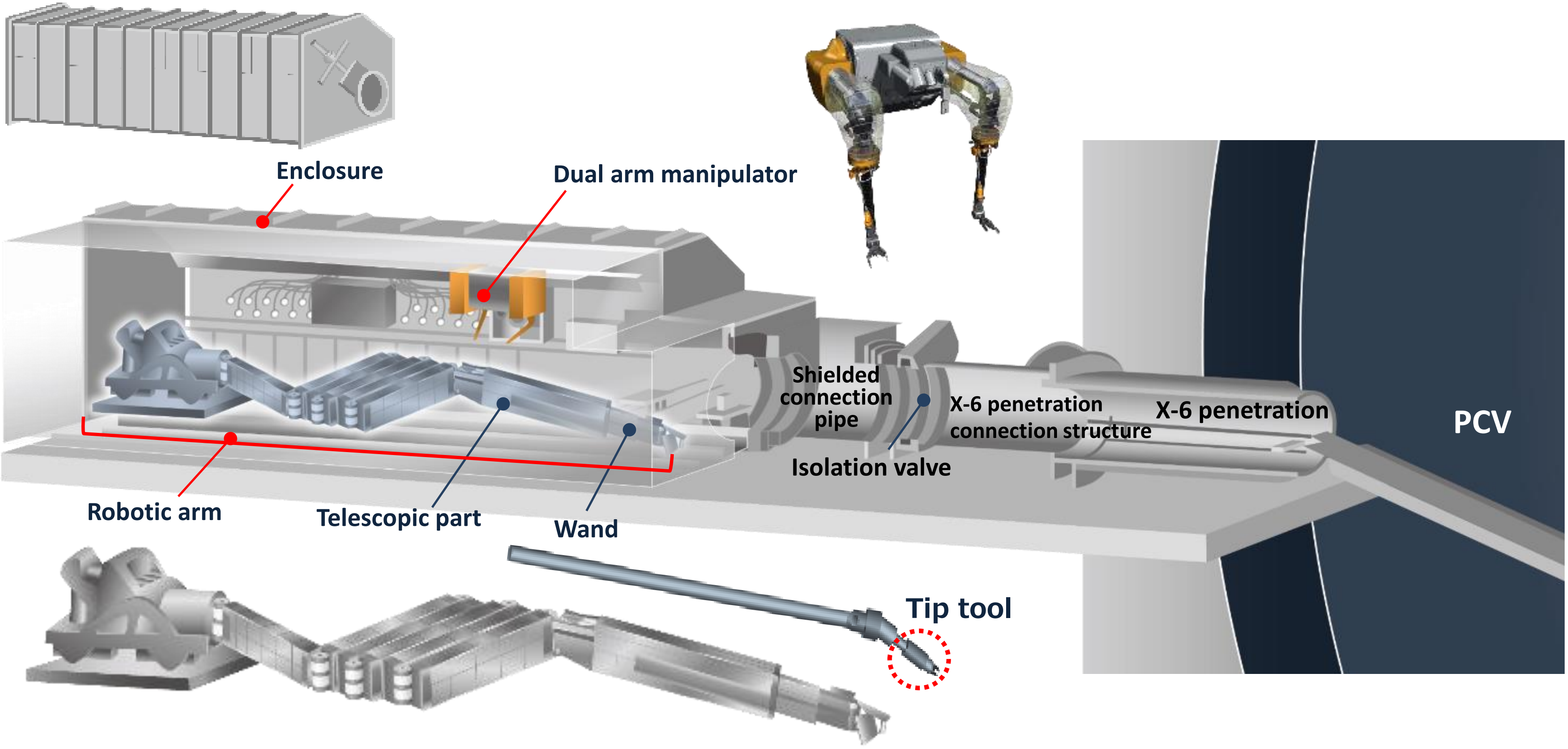

①Cutting of CRD rails


②CRD rails hoisting jig


③ Electrical wire conduits

[Reference] Robotic arm structure

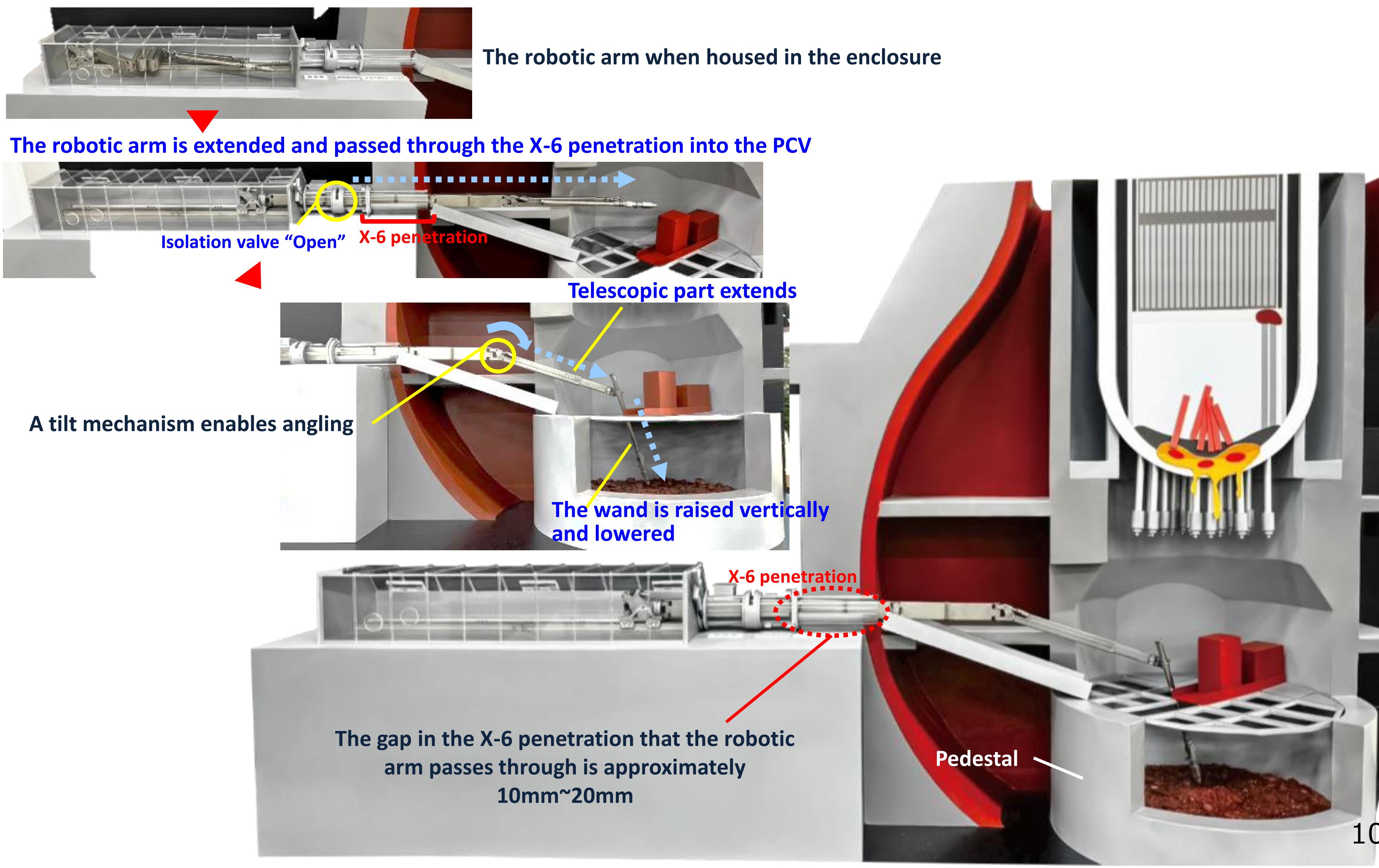
- The **robotic arm** and **dual arm manipulator** are housed inside an **enclosure** that serve as a PCV boundary.
- The dual arm manipulator is used **to perform maintenance, such as replacing cameras and switching out the end jigs on the robotic arm, and also to put the sampled fuel debris into containers**. The robotic arm is also equipped with a **wand** used to affix tip tools.



- **Robotic arm: total length: Approx. 22m (approx. 18m without the wand)/Weight: 4.6t**
- **Enclosure dimensions: Approx. 2.4m x Approx. 8.8m x H: Approx. 2.0m/Weight: Approx. 30t (including the arms and dual arm manipulator)**

[Reference] Robotic arm movements

- The robotic arm is extended from the enclosure and inserted into the PCV through the X-6 penetration. The telescopic part then lower and extends while raising the wand vertically as it approaches the bottom of the pedestal.

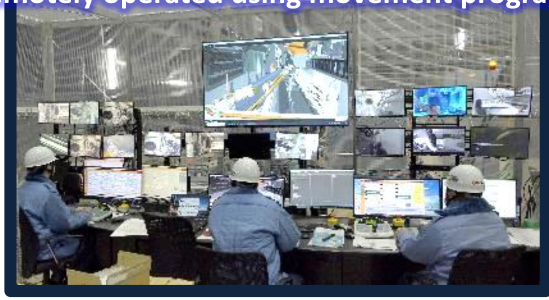


[Reference] Remote operation of the robotic arm

- Differing from the telescopic device that required direct manual position adjustment on site, the robotic arm used for this project will be operated using a **program created based on repeated accessibility verification tests** using actual size pipes, etc. (X-6 penetration mock-ups, etc.). By using this **verified program that ensures that there are no structures or obstructions in the vicinity we will be able to engage in remote operations that ensure safety and are reproducible**.

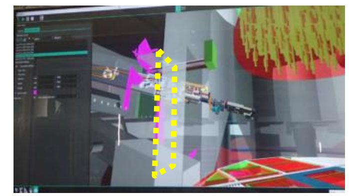
Robotic arm operations

Remotely operated using movement programs

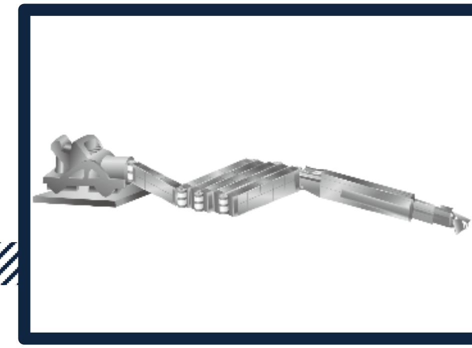


Control system (program)

VR



Robotic arm



A mouse is used to move the arm while checking arm joint angle and movement speed as well as the details of the program.
In addition to camera footage, a virtual space that reflects 3D model data will be used to confirm the positional relationship between the robotic arm and structures in the vicinity.

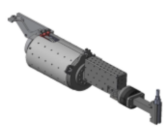
- There are multiple tip tools that can be attached to the wand of the robotic arm in accordance with the task to be performed. The **dual manipulator inside the enclosure is operated remotely to switch out these tip tools.**

Dual arm manipulator

Remote manual operation

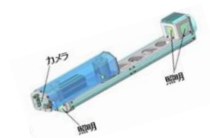
Remote operations room

<Tip tools>



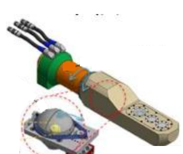
Cutting tool

3D model data



Footage data

Trial retrieval

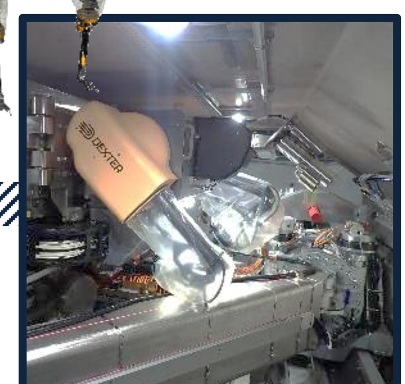


Gamma dose measurements

Metal brush

Vacuum container

Dual arm manipulator

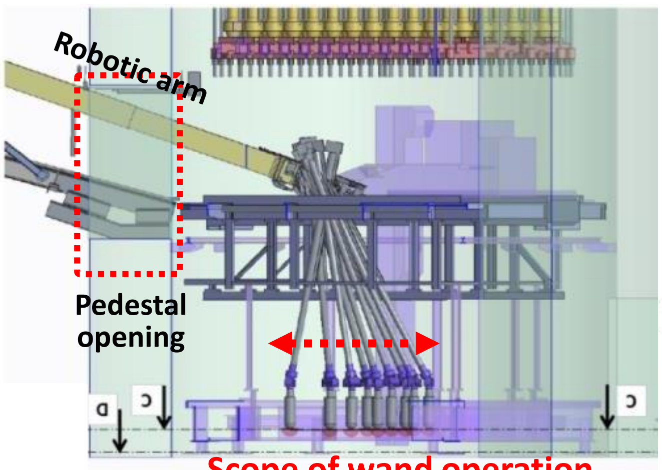


Inside the enclosure

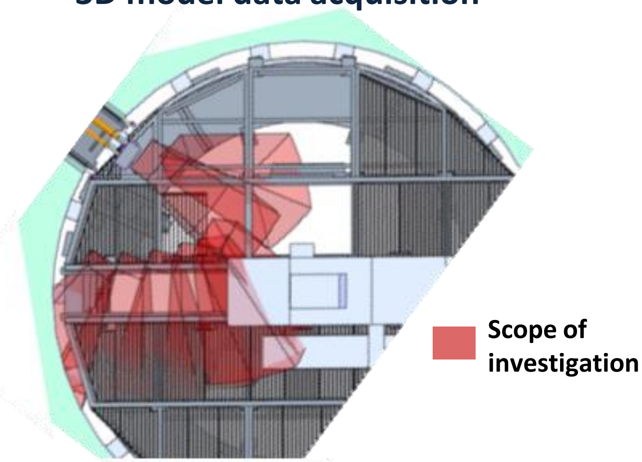
[Reference] Scope of access and operational policy of the robotic arm

- Compared with the telescopic device the robotic arm **can access a larger area inside the PCV.**
- Multiple types of tip tools will be attached to the wand to remove obstructions and perform internal investigations of the PCV.

When sampling debris

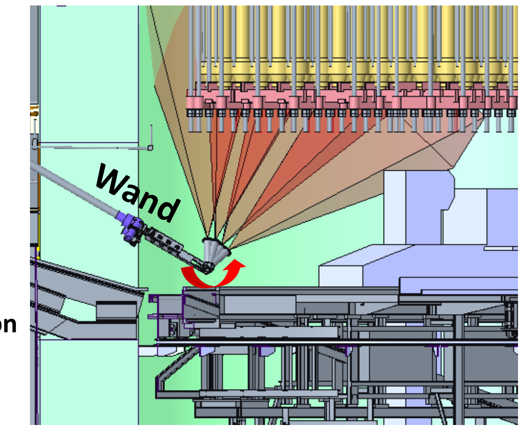


3D model data acquisition



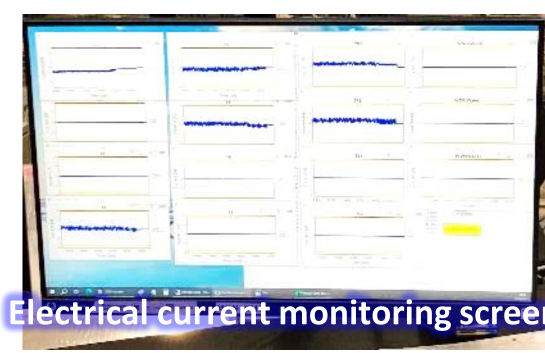
Scope of investigation required for inserting the robotic arm

Camera investigation



Investigation of the bottom of the reactor pressure vessel

- In preparation for application in the field a risk assessment was conducted and **maintenance on components** is being performed in order to reduce the risk of malfunction caused by degradation.
- **Predictive management**, such as monitoring the electrical current of motors that operate robotic arm joints, is being performed to detect abnormalities thereby enabling the device to be withdrawn to the enclosure for function checks before any malfunctions occur.



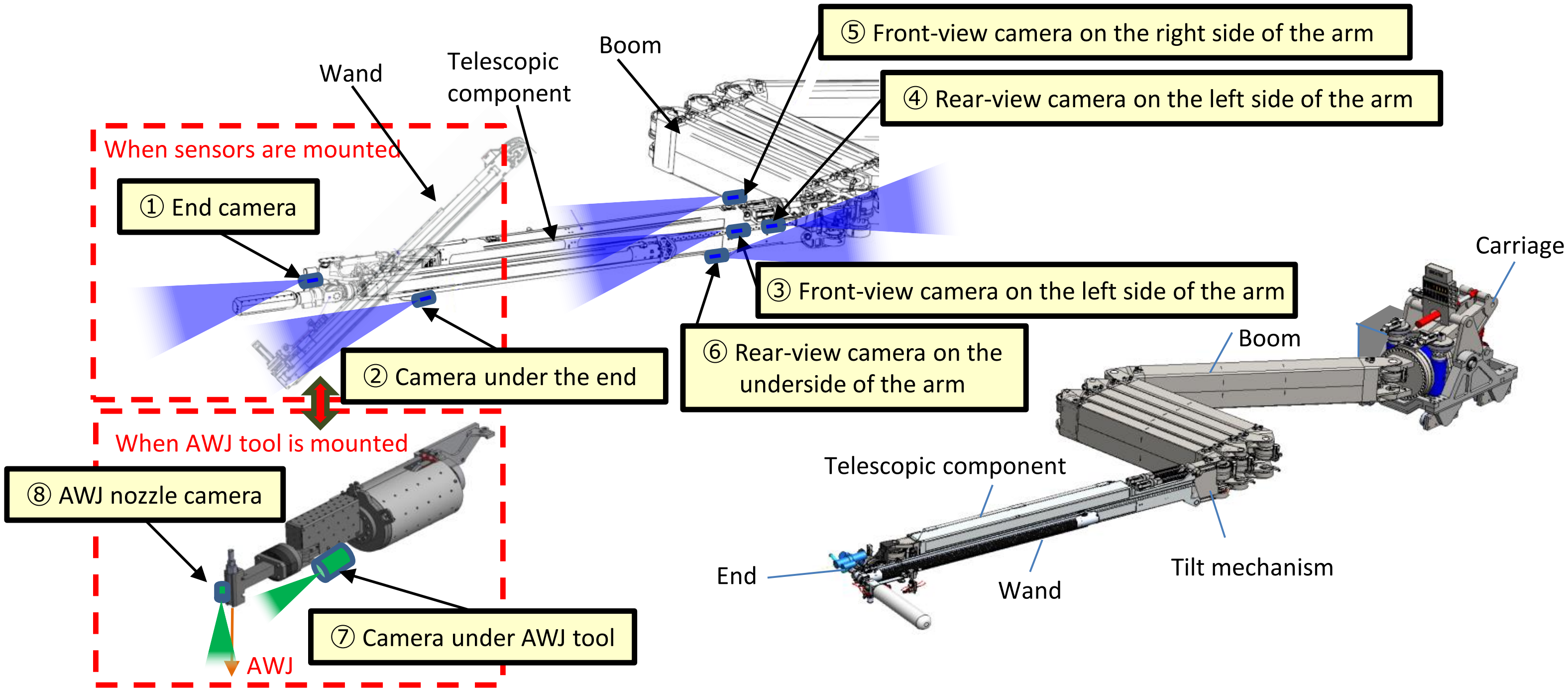
Electrical current monitoring screen

In particular, the electrical current and line resistance of "arm" and "dual arm manipulator" motors are monitored to detect abnormalities

[Reference] Cameras mounted on the robotic arm (horizontal deployment of the telescopic device)

IRID TEPCO

- In light of the camera malfunctions on the telescopic device, irradiation tests of the cameras mounted on the robotic arm was implemented.
- We were unable to confirm the radiation resistance as noted in the manufacturer's specifications. Since it has been impossible to acquire spare cameras, we have changed the cameras that was subjected to high accumulated doses during field work to ones that have been adopted in our previous works.
- The radiation resistance of the replaced cameras was confirmed to be in line with the manufacturer's specifications. However, since the radiation resistance was lower than the planned dose for on-site work, they will be replaced remotely using a manipulator as needed, and operations will continue.
- Currently, additional tests are being conducted at the mockup facility, such as checking visibility following camera changes and using a manipulator to replace cameras.
- In addition, during the test, it was confirmed that even if all the cameras mounted on the robotic arm stopped, the arms could be retrieved to the enclosure using the control program and VR.



Cameras mounted on the robotic arm

[Reference] Anticipated major risks and countermeasures

- The following chart shows the major anticipated risks (malfunctions with the arm, wand, dual manipulator, or cameras, which are the main components of the robotic arm), as well as preventative measures procedures to be implemented when malfunctions occur.
- **If the robotic arm malfunctions it will be withdrawn into the enclosure for arm function tests.**

＜ Anticipated major risks and countermeasures ＞

Malfunction	Preventative measures	Action to be taken when a malfunction occurs
Arm joint motor malfunction	・Perform maintenance, such as component replacement, etc. and perform function tests after assembly ・Perform predictive management on-site to quickly detect nonconformities ・Revise work teams and lengthen daily work periods so as to reduce the amount of time spent inside the PCV (accumulated dose reductions) ・Verify methods for withdrawing the arm if it malfunctions and replacing the manipulator ・When remaining inside the PCV, straighten the arm inside the PCV to enable easy recovery in the event of an emergency ・Perform irradiation tests in advance to confirm actual radiation resistance	Perform maintenance on parts that cannot be replaced remotely on site in order to reduce risks
		Handle in accordance with the symptoms detected during predictive management
		If the arm malfunctions it will be recovered and tests of movement and control systems performed
Arm tip (wand) motor malfunction		If the tip of the arm malfunctions the tip shall be cut away and the arm recovered (It will be impossible to continue the investigation thereafter)
Manipulator control communications error		If a manipulator control system error occurs the device will be reset or the power turned on and off
Manipulator motor malfunction		Deliberate manipulator replacement (This will require a lot of time)
Arm malfunction ＋manipulator malfunction		If the arm cannot be recovered or the manipulator cannot be operated remotely we will deliberate cutting away the arm and recovering the rest of the system (This will require a lot of time)
No feed from arm camera	・Verify methods for recovering footage if the cameras shut down	If it is deemed that precise operations are impossible the arm will be withdrawn into the enclosure and the cameras replaced
	・Have spare cameras on hand	It will be confirmed that the system can be withdrawn into the enclosure even if all the arm cameras shut down

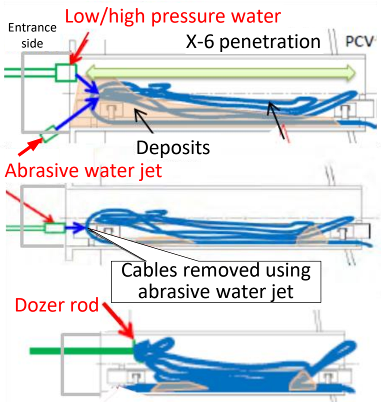
[Reference] Field Preparation Work Progress
Primary Steps of the Fuel Debris Trial Retrieval (Internal Investigations/Debris Sampling)

1. Isolation chamber installation

2. Opening of the X-6 penetration hatch

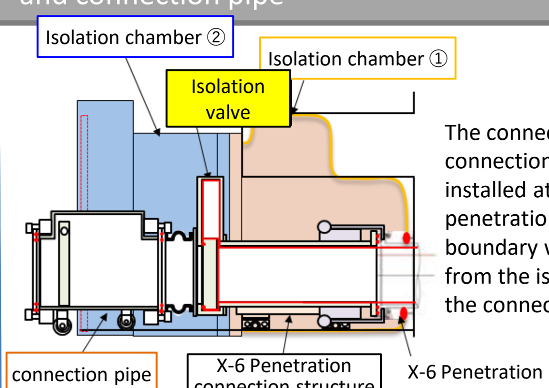
3. Removal of deposits from inside the X-6 penetration

Removing deposits/cables from inside the X-6 penetration



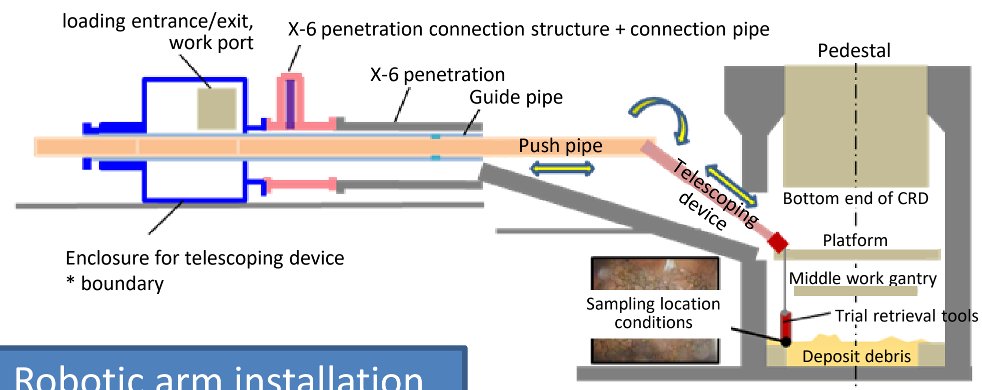
- Deposits pushed with low/high-pressure water
- Cables removed with Abrasive water jet
- Cables pushed with dozer rod

4. Installation of X-6 penetration connection structure and connection pipe

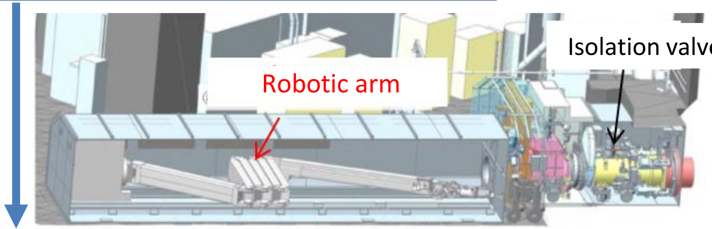


The connecting structure and connection pipe will be installed at the X-6 penetration and the boundary will be changed from the isolation chamber to the connection structure.

5. Installation of telescopic device
6. Trial retrieval (debris sampling using telescopic device)

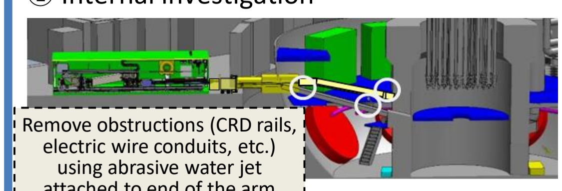


7. Robotic arm installation

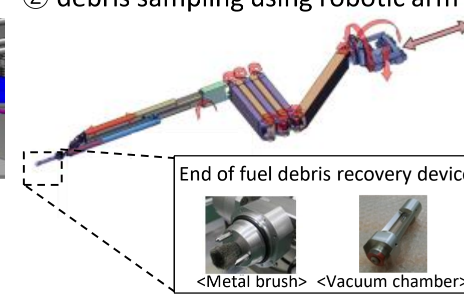


8. Internal investigation/debris sampling using robotic arm

① Internal investigation



② debris sampling using robotic arm



(Note)

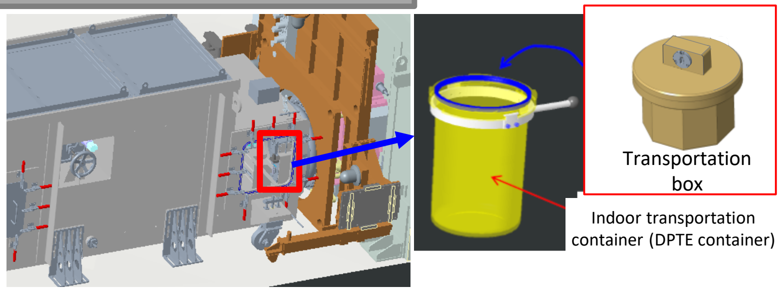
Isolation valve: Valve installed to separate the inside of the PCV from the outside

Abrasive Water Jet: Combines high pressure water with an abrasive to improve cutting ability

Primary Steps of the Fuel Debris Trial Retrieval (Internal Investigations/Debris Sampling)

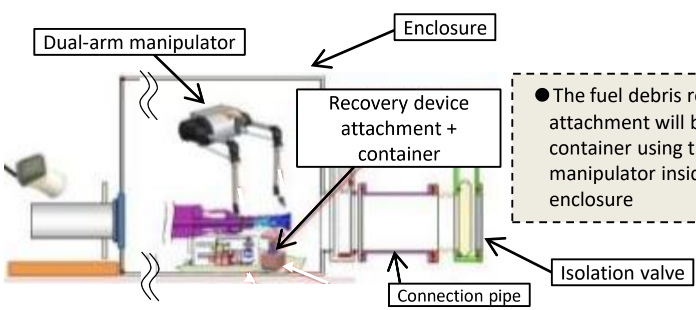
(From Step 6 on the previous slide)

9-1. Collection of fuel debris

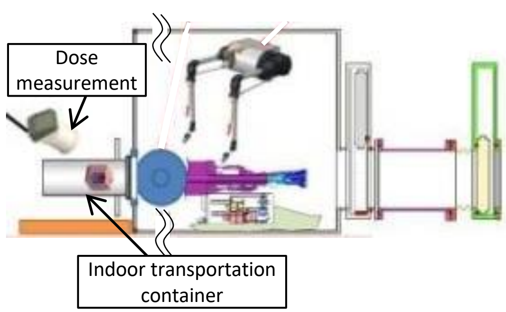


(From Step 8 on the previous slide)

9-2. Inserting the fuel debris recovery device attachment into a container, Inserting into an on-site transportation container/Dose measurements

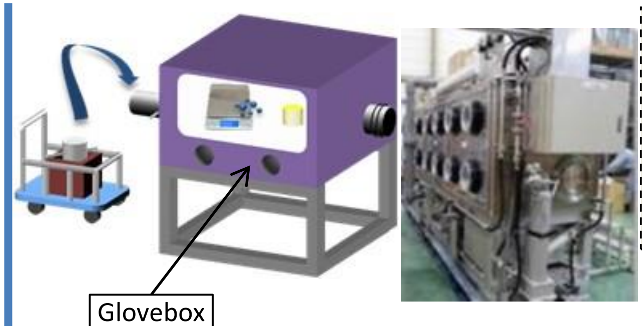


- The fuel debris recovery device attachment will be put into a container using the dual-arm manipulator inside the enclosure



- Inside the enclosure, the attachment will be put into an on-site transportation container after taking dose measurements
- This will be removed while attempting to prevent the spread of contamination

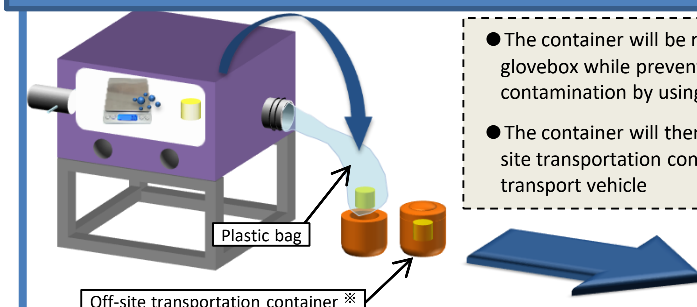
10. Insertion into glovebox/Measurement



<Exterior view of glovebox>

- The collected samples will be put into a negative pressure glovebox
- The samples will be subjected to various measurements inside the glovebox and then put into a container

11. Container removal/Insertion into transportation container /Removal from premises



- The container will be removed from the glovebox while preventing the spread of contamination by using a plastic bag
- The container will then be inserted into an off-site transportation container and loaded onto a transport vehicle

※ Prior to transport, the surface dose/contamination density, etc. of the container shall be measured to ensure that it meets legal requirements

12. Off-site transport and off-site analysis

(Note)
DPTE Container is an abbreviation of “Double Porte pour Transfert Etanche”.
By opening/closing the lid of the container and double door of the glove box at the same time, it allows the items to be transferred while maintaining a sealed environment.