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

February 26, 2026

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

1-1. Status of robotic arm tests (performance tests)

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- Tests using a mockup of the Fukushima Daiichi on-site (combined once-through tests) were completed at the Naraha mockup facility in February 2025.
- The comprehensive inspection of the robotic arm, including replacement of parts that were found during testing to have deteriorated with age and other similar parts, has been completed as planned.
- Movement checks that were commenced after completion of the comprehensive inspection are underway.
- Furthermore, in addition to robotic arm developing, we are also confirming this technology applicability to the actual worksite by looking at procedures that simulate actual work tasks, operator operability, and equipment reliability.

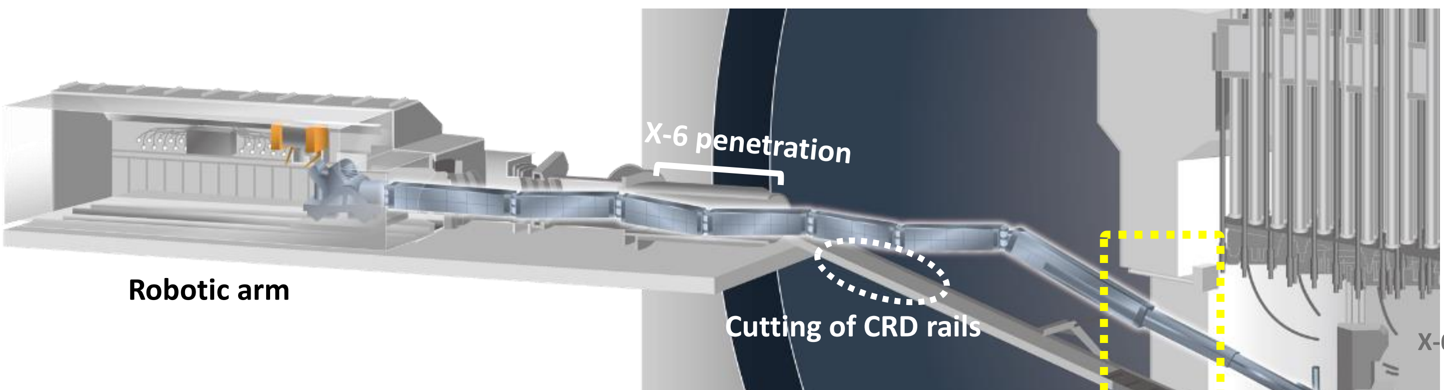
Performance tests

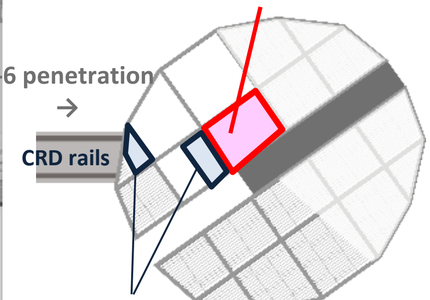
Test category	Test	JAEA Naraha
Robotic arm-related	Ability to pass through the X-6 penetration	Completed
	Removing obstructions at the exit for the X-6 penetration using the AWJ	Completed （Work efficiency being examined）
	Function tests (deflection measurements, etc.)	Completed
	Ability to access the inside of the PCV (accessing the top and bottom of the pedestal)	Completed
	Removing obstructions inside of the PCV (Cutting obstructions inside the PCV after passing through the X-6 penetration)	Completed （Work efficiency being examined）
Dual arm manipulator-related	Connecting sensor tools to the arms	Completed
	Connecting/removing the external cables to/from the arms	Completed
	Bringing in and removing sensor tools	Completed
	Removing the fixed arm jig	Completed
	Replacing arm cameras/lighting	Completed
	Changing the position of the enclosure camera	Completed
	Forced withdrawal of the arm	Completed
Combined once-through tests (robotic arm + dual arm manipulator)	Sensors/external cables, tools/Installing external cables at the arm	Completed
	Investigation of the top of the pedestal (sensors and wand are installed)	Completed
	Investigation of the bottom of the pedestal (sensors and wand are installed)	Completed
	Constructing an access route (removing obstructions using the AWJ)	Completed
Comprehensive inspection	Comprehensive inspection (maintenance)	Completed
Combined verification tests	Movement checks after comprehensive inspection (maintenance)	Underway

1-2. 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**

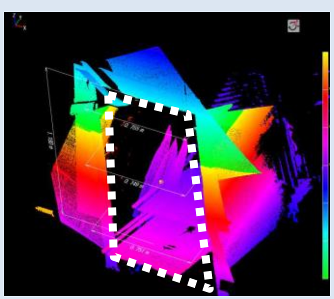
※ Removal of obstructions inside the PCV





Top view of platform

Pedestal opening



3D model data acquisition

Creation of digital environment (virtual reality)

1-3. Process of PCV internal investigation and trial retrieval

- 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

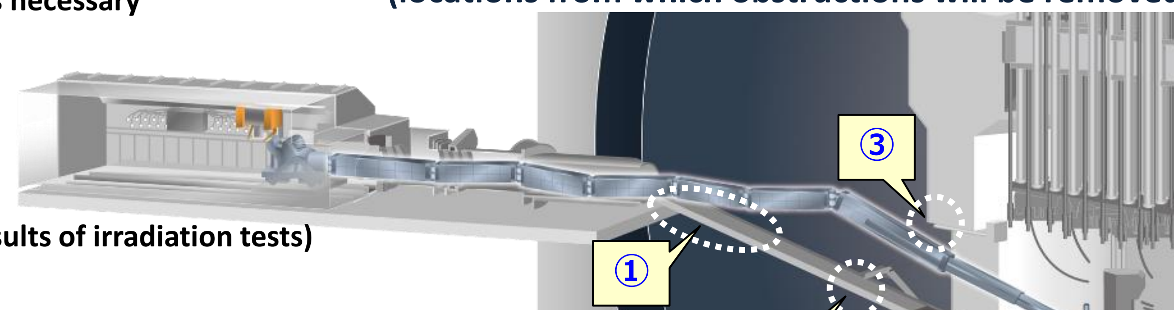
Approx. 3~4 months

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)**



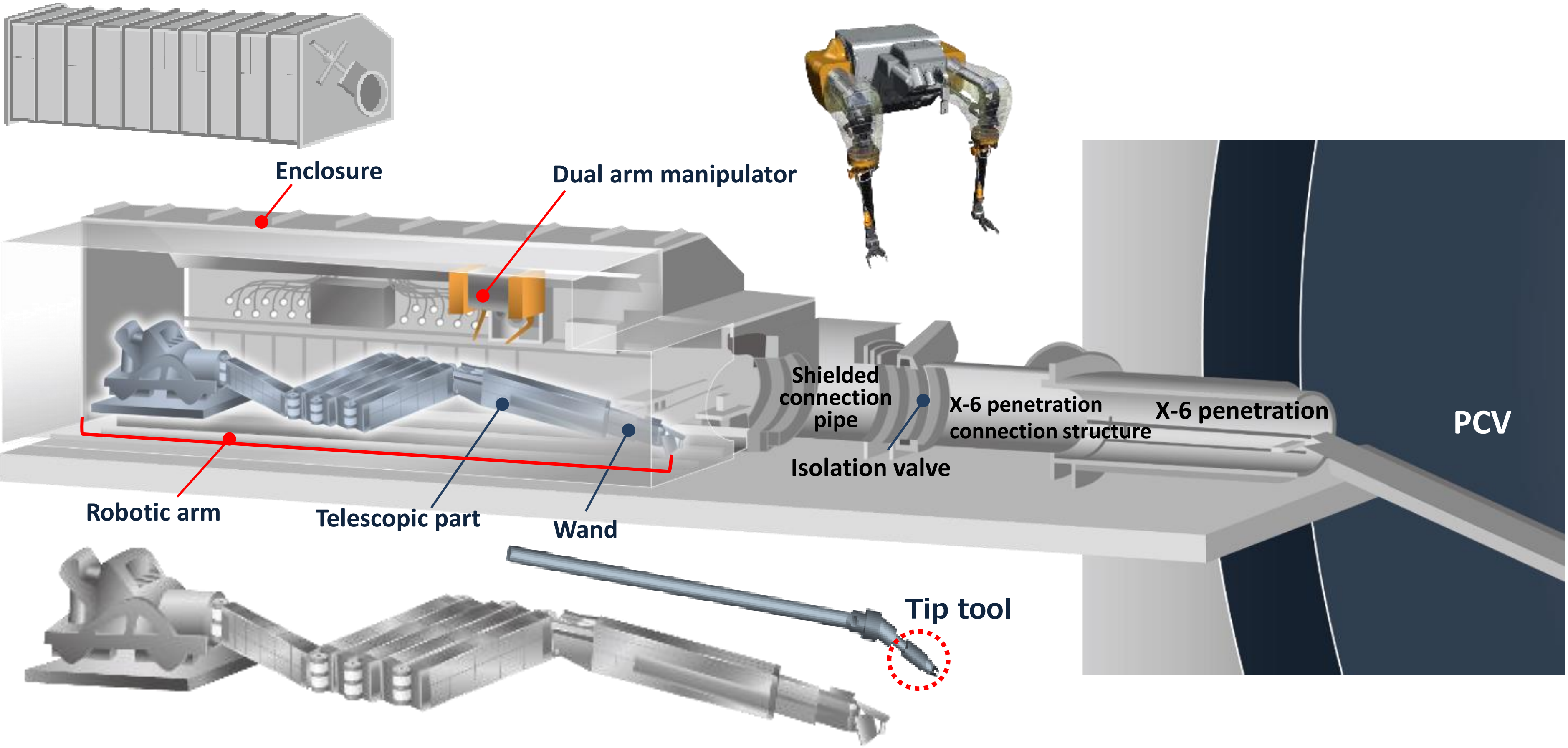
①Cutting of CRD rails

②CRD rails hoisting jig

③ Electrical wire conduits

1-4. 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.



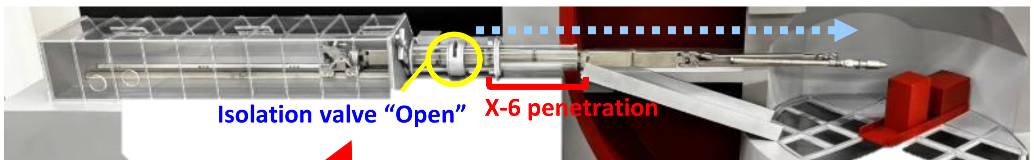
- **Robotic arm: total length: Approx. 22m (approx. 18m without the wand)/Weight: 4.6t**
- **Enclosure dimensions: Approx. 2.4m x Approx. 8.8m x H: Approx. 2.0m/Weight: Approx. 30t (including the arms and dual arm manipulator)**

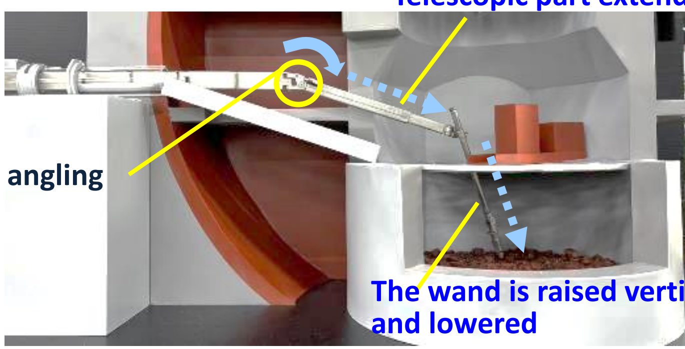
1-5. Robotic arm movements

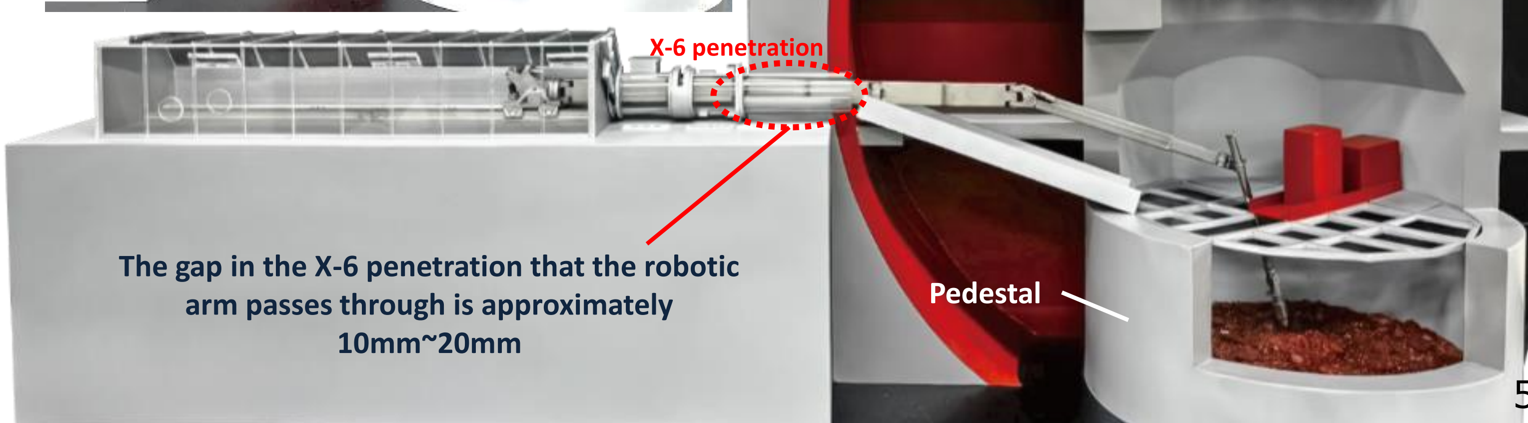
- The robotic arm is extended from the enclosure and inserted into the PCV through the X-6 penetration. The telescopic part then lower and extends while raising the wand vertically as it approaches the bottom of the pedestal.

The robotic arm when housed in the enclosure

The robotic arm is extended and passed through the X-6 penetration into the PCV





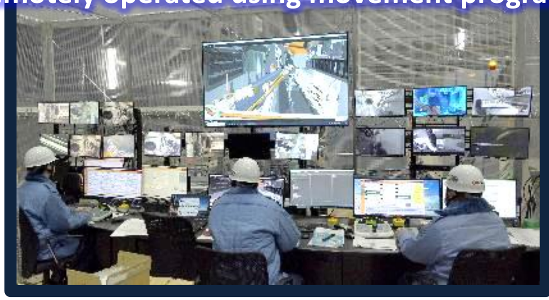


1-6. Remote operation of the robotic arm

- 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**.

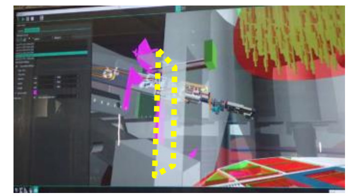
Robotic arm operations

Remotely operated using movement programs

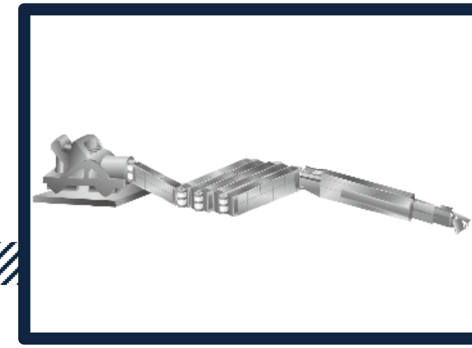


Control system (program)

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

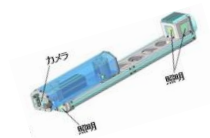
Remote manual operation

Remote operations room

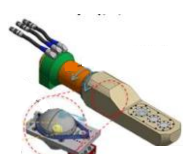
<Tip tools>

Cutting tool

3D model data



Footage data



Gamma dose measurements

Trial retrieval

Metal brush

Vacuum container

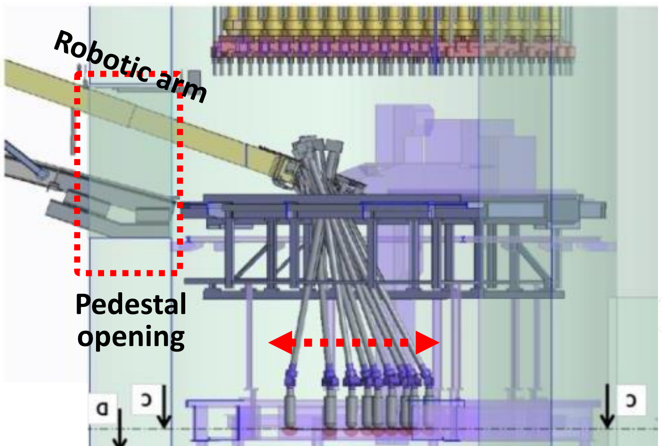
Dual arm manipulator

Inside the enclosure

1-7. Scope of access and operational policy of the robotic arm

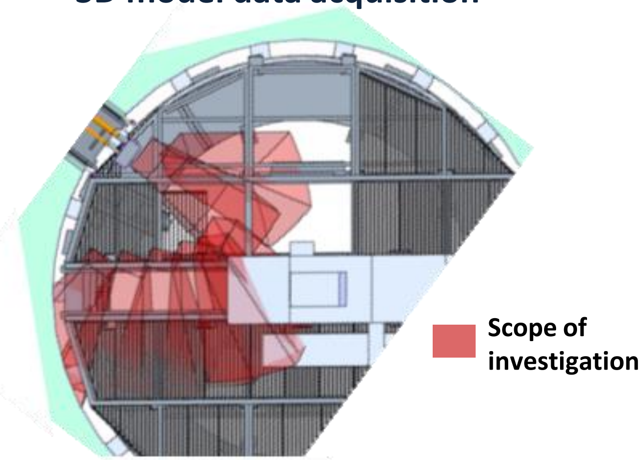
- Compared with the telescopic device the robotic arm **can access a larger area inside the PCV.**
- Multiple types of tip tools will be attached to the wand to remove obstructions and perform internal investigations of the PCV.

When sampling debris



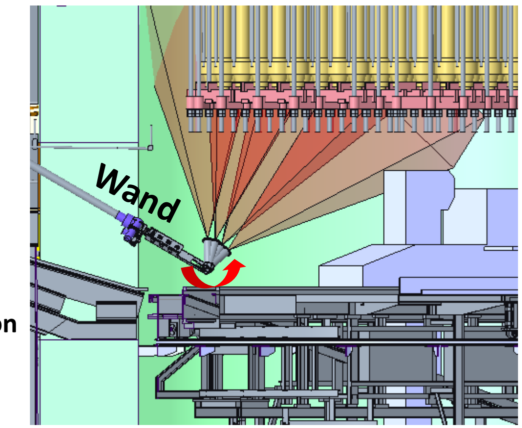
Scope of wand operation

3D model data acquisition



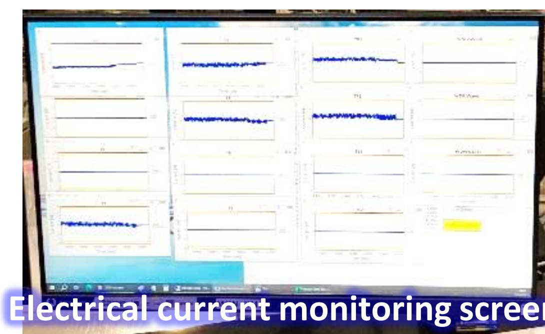
Scope of investigation required for inserting the robotic arm

Camera investigation

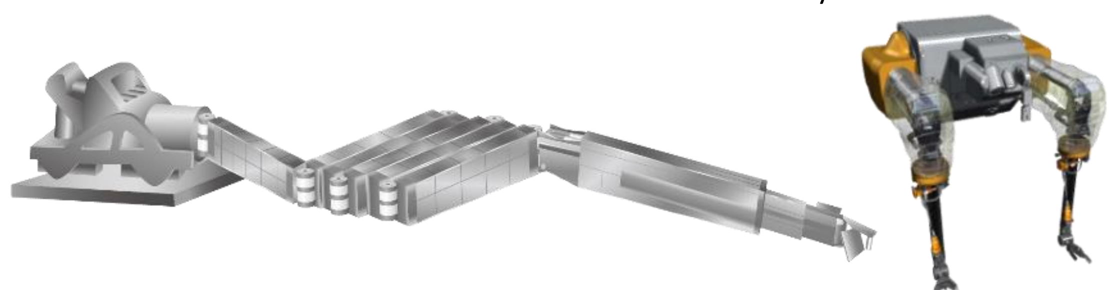


Investigation of the bottom of the reactor pressure vessel

- 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

2. Work schedule

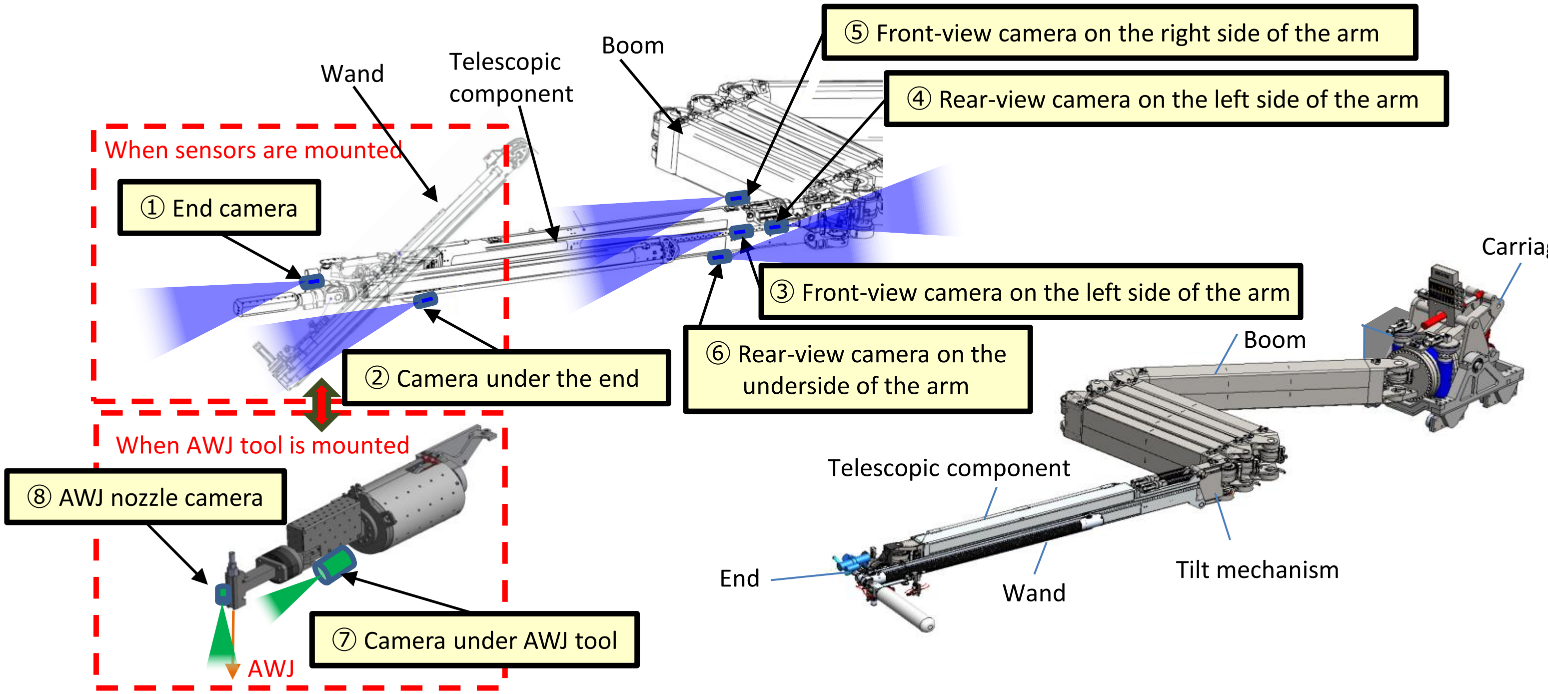
- In light of the camera malfunctions on the telescopic device, irradiation tests of the cameras mounted on the robotic arm are being implemented.
- We were unable to confirm the radiation resistance as noted in the manufacturer's specifications. Since it has been impossible to acquire spare cameras, 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.
- On-site work will be performed using large devices that are completely remotely operated, and the difficulty level of the work is extremely high, so maintenance tasks are being performed on a mockup of the facility that assumes the risks.
- Currently, visibility during camera replacement is being checked, and training on using the manipulator to replace the cameras, as well as operations to withdraw the camera in the event of emergency, are under way. Furthermore, based on the telescopic device troubles, a simulated environment is being used to conduct training on robotic arm and ancillary equipment installation.
- Verification tests will continue and the robotic arm will be transported to Fukushima Daiichi Nuclear Power Station at the end of March 2026. Thereafter, approximately three to four months will be required for installation. We plan to commence PCV internal investigations and debris sampling during the summer of 2026.

		FY2025	FY2026			
		Q4	Q1	Q2	Q3	Q4
Robotic arm	Inspection/maintenance, etc., and any additional development required based upon once-through tests/test results					
	Installation preparation, etc./ access route construction	▽				
	Internal investigation/debris sampling					
	Inspection/maintenance, etc., and any additional development required based upon once-through tests/test results					

▭ : Completed ⬚ : Commencement and completion dates under review

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

- 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 >

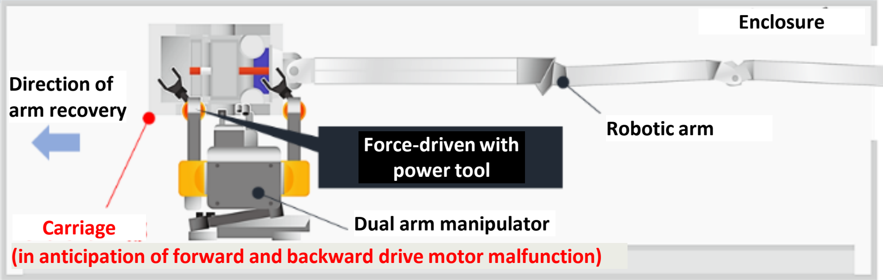
Malfunction	Preventative measures	Action to be taken when a malfunction occurs
Arm joint motor malfunction	・Perform maintenance, such as component replacement, etc. and perform function tests after assembly ・Perform predictive management on-site to quickly detect nonconformities ・Revise work teams and 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 No feed from arm camera		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) If it is deemed that precise operations are impossible the arm will be withdrawn into the enclosure and the cameras replaced
	・Verify methods for recovering footage if the cameras shut down	
	・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] Examples of anticipated risks and countermeasures

- **If the arm malfunctions it will be withdrawn into the enclosure** and tests of movement and control systems performed.

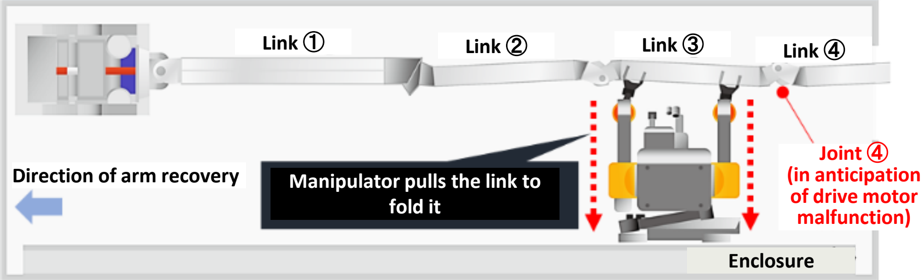
- Forced withdrawal (emergency recovery) tests of the arm were implemented in anticipation of an arm motor malfunction during the internal investigation.

Emergency recovery test in anticipation of carriage (forward and backward drive motors) malfunction



- The dual arm manipulator will use a power tool to force-drive the malfunctioning motor thereby bringing the carriage backward to recover the arm.
- **We believe that it will be possible to withdraw the arm into the enclosure this way.**

Emergency recovery test in anticipation of link (joint ④ axis drive motor) malfunction



- The clutch of link ④ (joint) will be disabled via remote operation after which the other operable joints will be remotely operated while pulling the malfunctioning link ④ with the dual arm. Manipulator (folding) **thereby enabling the arm to be withdrawn inside the enclosure.**

[Reference] Anticipated risks and countermeasures

- In light of the lessons learned from the incident involving the telescopic device when mistakes were made with the pipe order, **a mockup of device transport and installation,** which will be one of the preparations for this investigation**, was created in order to thoroughly train workers on how to implement the task.**

Enclosure transport

Ancillary equipment transport

Cable rack installation

Cable laying

[Reference] Field Preparation Work Progress

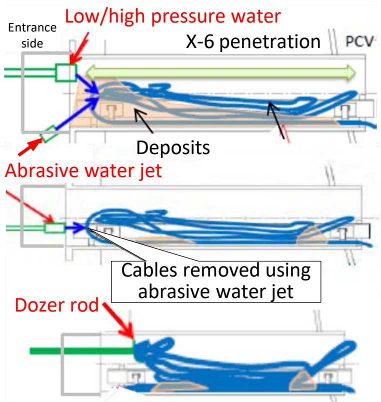
Primary Steps of the Fuel Debris Trial Retrieval (Internal Investigations/Debris Sampling)

1. Isolation chamber installation

2. Opening of the X-6 penetration hatch

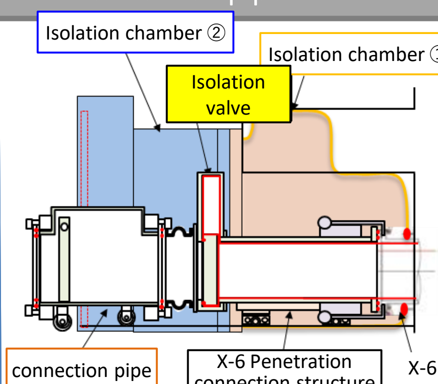
3. Removal of deposits from inside the X-6 penetration

Removing deposits/cables from inside the X-6 penetration



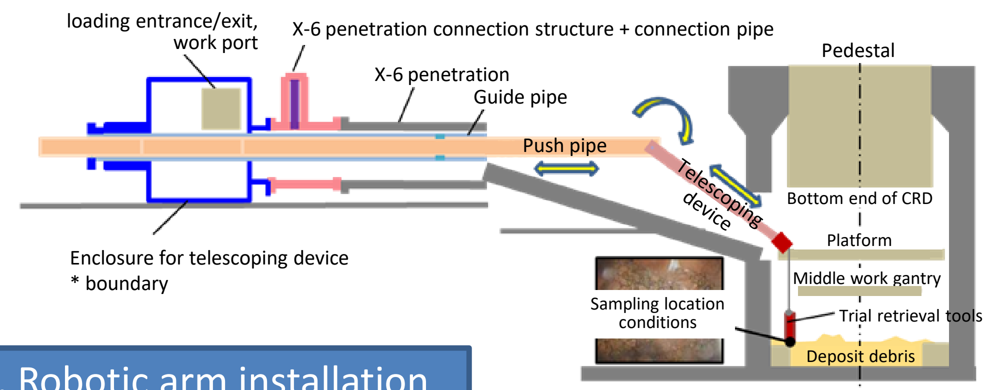
- Deposits pushed with low/high-pressure water
- Cables removed with Abrasive water jet
- Cables pushed with dozer rod

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

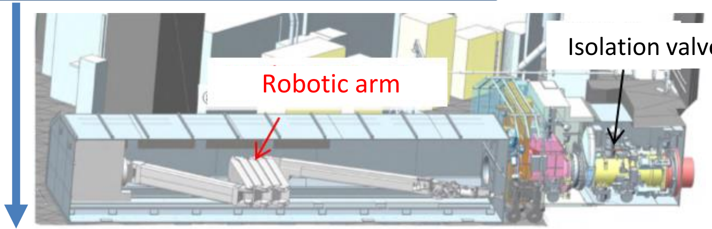


The connecting structure and connection pipe will be installed at the X-6 penetration and the boundary will be changed from the isolation chamber to the connection structure.

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

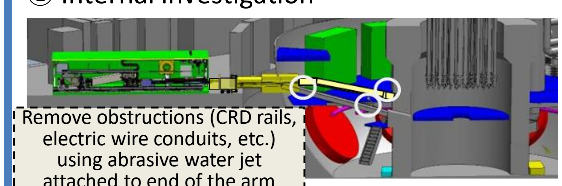


7. Robotic arm installation

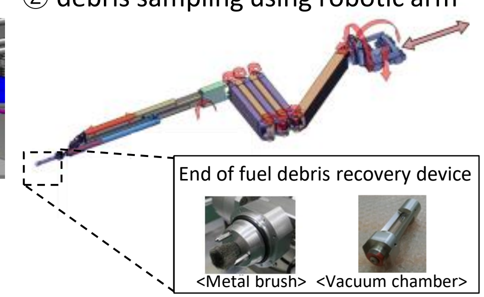


8. Internal investigation/debris sampling using robotic arm

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

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

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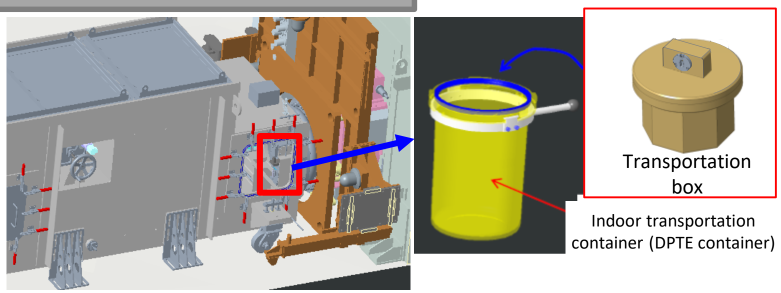
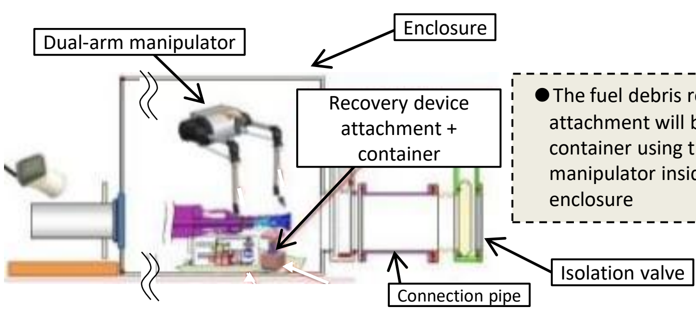
(From Step 6 on the previous slide)

9-1. Collection of fuel debris

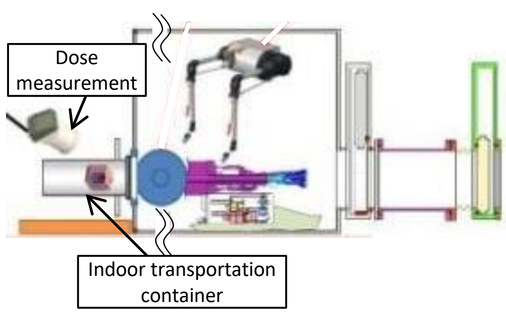


(From Step 8 on the previous slide)

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

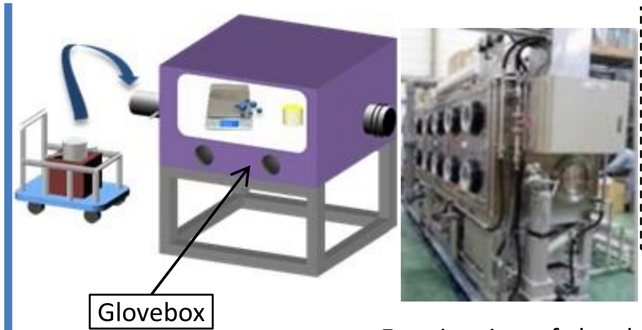


- The fuel debris recovery device attachment will be put into a container using the dual-arm manipulator inside the enclosure



- 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

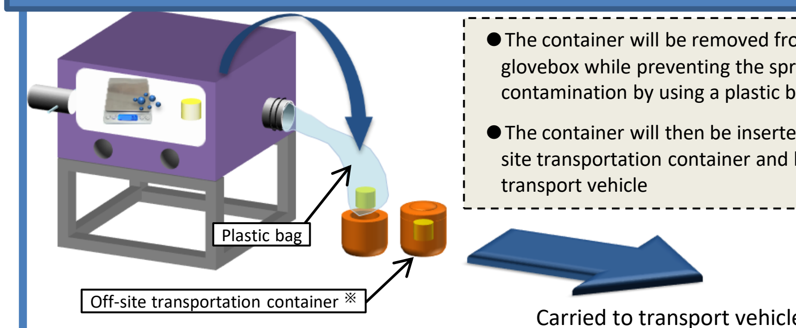
10. Insertion into glovebox/Measurement



<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.