Current Status and Challenges of R&D for Decommissioning of Fukushima Daiichi Nuclear Power Station

November 14, 2023

Senior Manager Planning and Administration Department

International Research Institute for Nuclear Decommissioning (IRID)

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2. Development of Investigation Technology for inside PCV
3. Development of Technology for Fuel Debris Retrieval
4. Nuclear Safety Enhancement

PCV: primary containment vessel

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PCV: primary containment vessel

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Outline of IRID

1. Name

International Research Institute for Nuclear Decommissioning (IRID)

https://irid.or.jp/en/

2. Date of Establishment

August 1, 2013

3. Membership (19 organizations)

2 research institutes

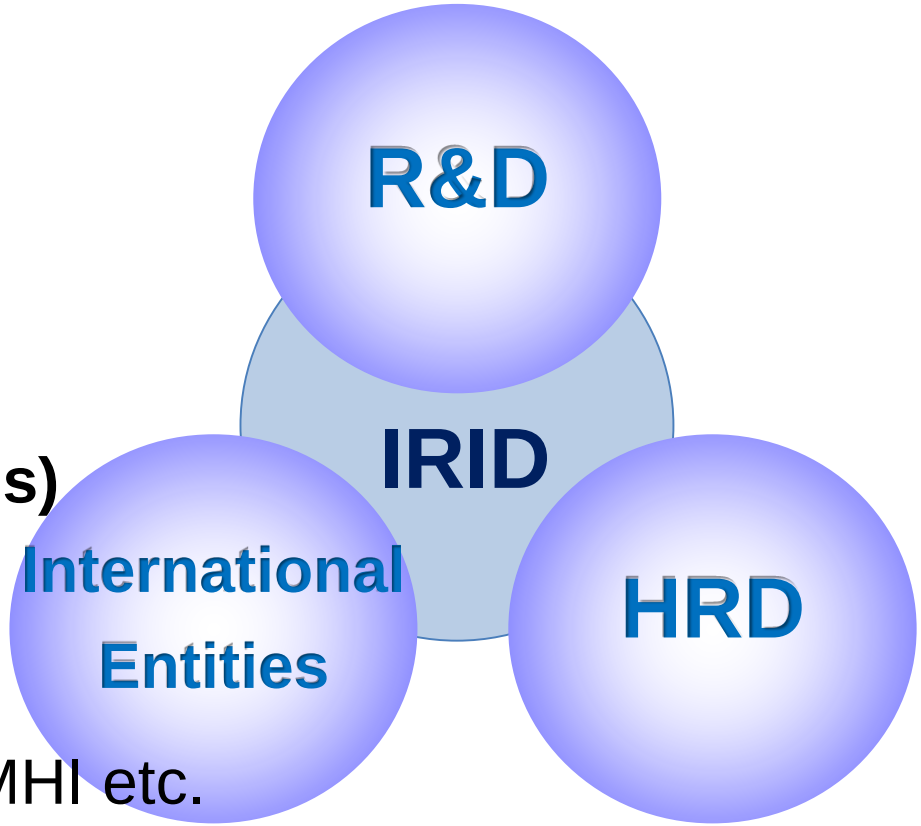
JAEA etc.

4 manufacturers

Toshiba ESS, Hitachi-GE,MHI etc.

13 electric utilities, etc.

TEPCO Holdings etc.



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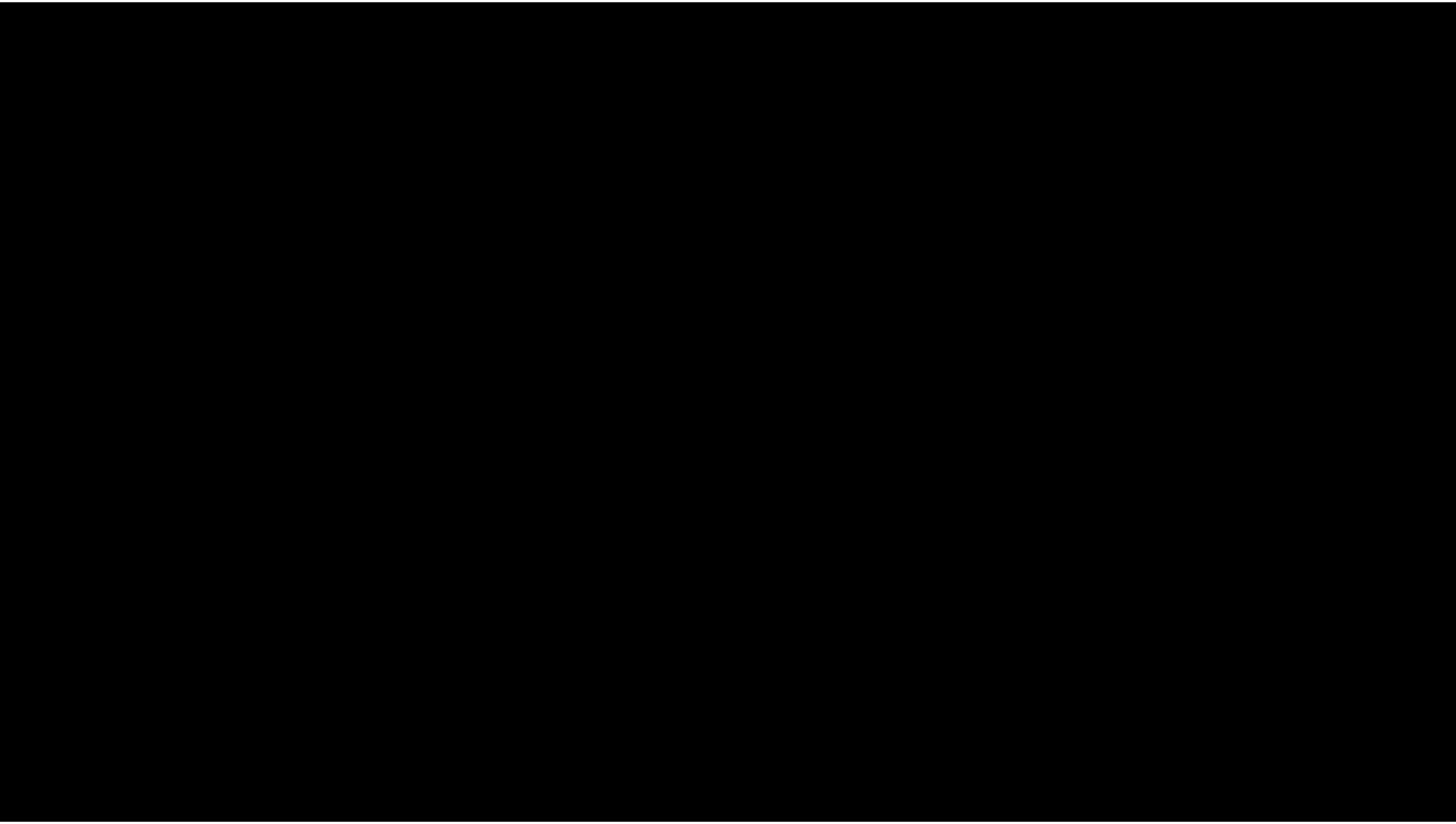
Video: Introduction of IRID



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Introduction: R&D projects conducted by IRID

1. R&D for fuel removal from spent fuel pool

Evaluation of Long-term Structural Integrity of Fuel Assemblies Removed from Spent Fuel Pool — Completed in March 2016

3 R&D for Radioactive Wastes

- Technology for Proceeding Process Methods of Radioactive Wastes
- Treatment and Disposal of Solid Radioactive Wastes

Completed in March 2019

2 R&D for Fuel Debris Retrieval

Technology for Decontamination and Dose Reduction

- Remotely Operated Decontamination Technology in R/B

Completed in March 2016

Fuel Debris Retrieval Technology

Retrieval Technology for Fuel Debris and Internal Structure: Criticality Control/Fundamental Technology/ Small Neutron Detector

Completed in March 2019

- Development of Retrieval Technology and Method For Fuel debris and Internal Structures
- Dust collection System for Retrieval of Fuel debris and Internal structures
- Technology for Containment, Transfer And Storage of Fuel Debris
- Development of Safety System for fuel Debris retrieval

Technology for Environmental Improvement

<Ensuring of the stable state>

- Corrosion Control Technology in RPV/PCV

Completed in March 2018

- Full-scale test for Repair Technology for PCV Leak Points

Completed in March 2018

- Full-scale Test for Water Circulation Technology in PCV

Completed in March 2019

Investigation and Analysis Technology

<Indirect Investigation> <Direct Investigation>

- Fuel debris detection Technology for RPV

Completed in March 2018

- Upgrading for Identifying Conditions Insides the Reactor

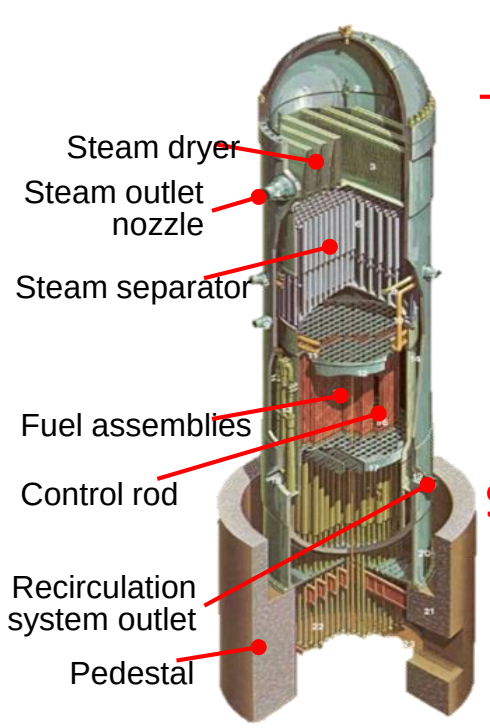
Completed in March 2018

- Technology for Detailed Investigation Inside PCV

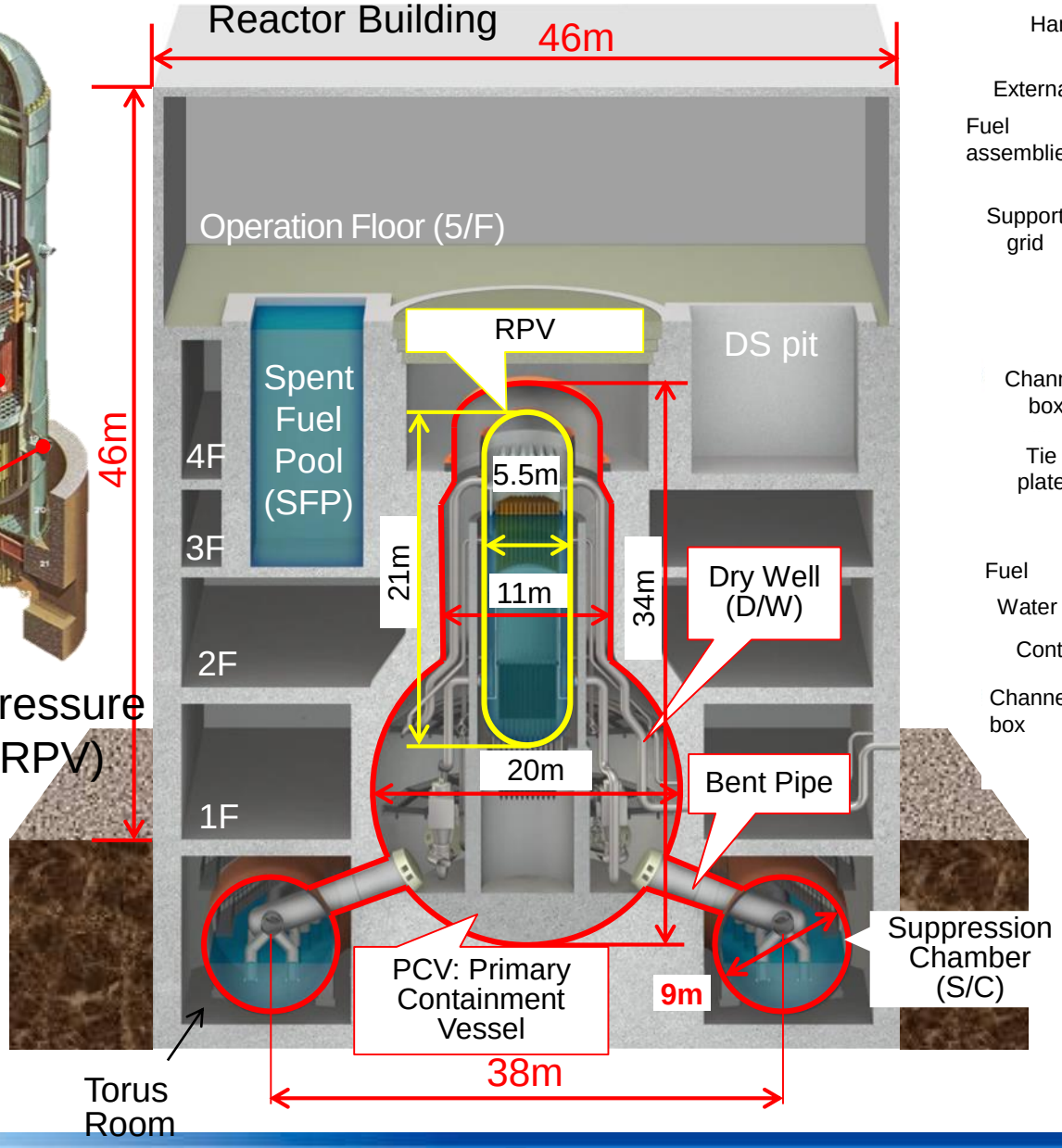
Completed in March 2019

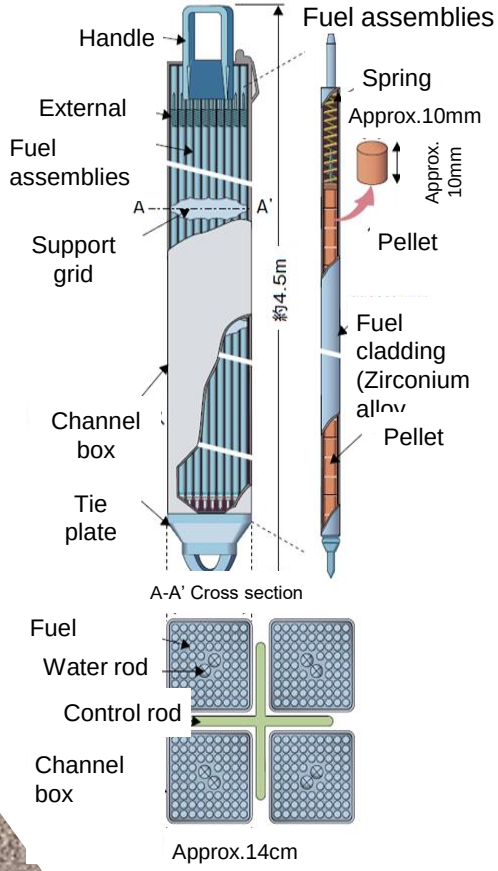
- Investigation Technology Inside the RPV
- PCV detailed Investigation: Demonstration Through X-6 penetration
- PCV Detailed Investigation: Demonstration of Sediments
- Fuel Debris Characterization and Analysis
- Fuel Debris Sampling Technology/ /Increase of Retrieval Scale for Fuel Debris

Boiling Water Reactor (BWR)



Reactor Pressure Vessel (RPV)





Fuel Assembly

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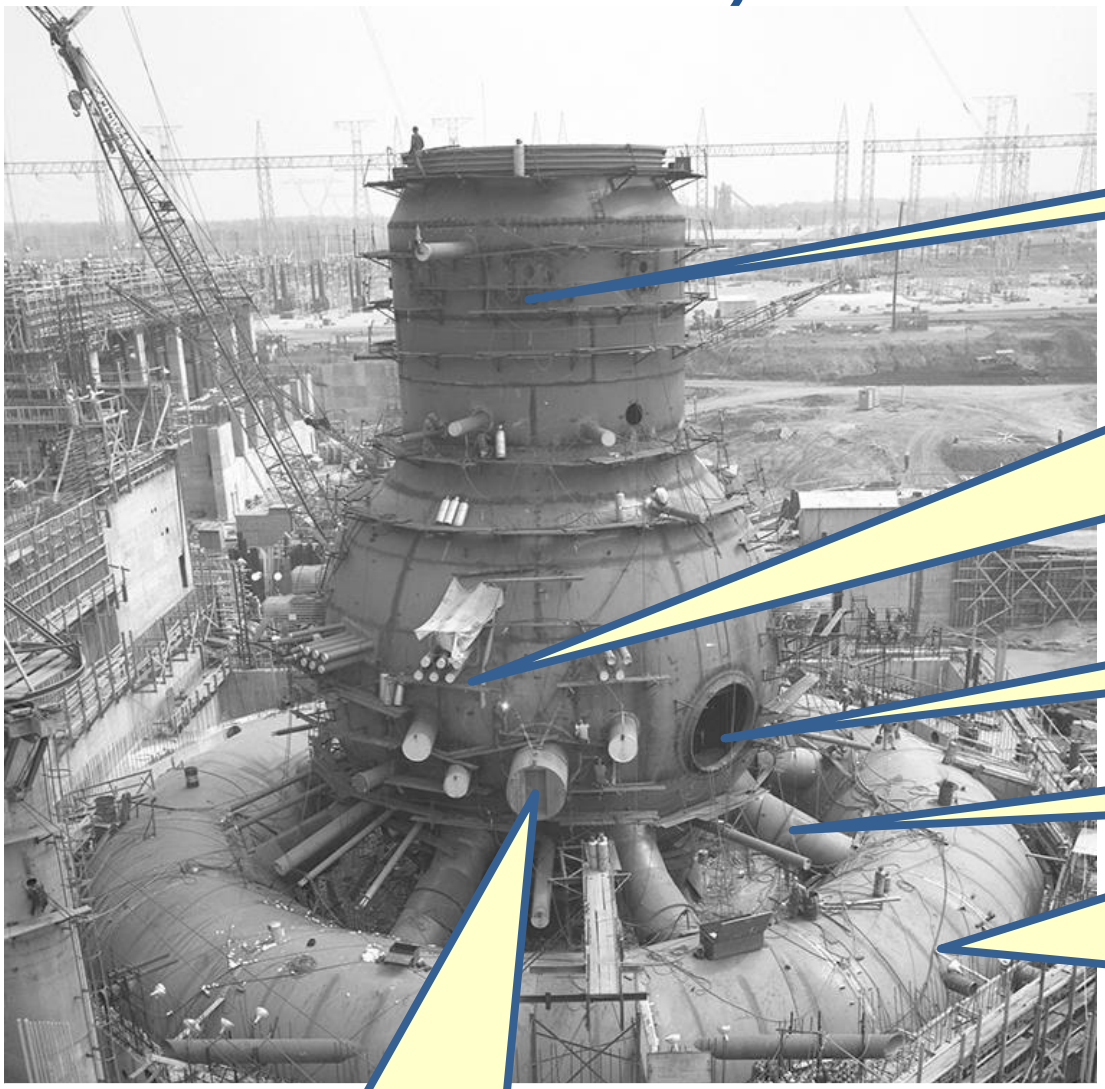
Appearance of Primary Containment Vessel (PCV) (Photo of PCV under construction)



Dry well (D/W): Upper part of PCV above the S/C

PCV penetration : Penetrations of piping and electric wiring, etc.
Unit 1: Approx. 150 penetrations
Unit 2: Approx. 200 penetrations
Unit 3: Approx. 190 penetrations

Equipment hatch: Carry-in/out port of large equipment

Vent pipe: Connection pipe between D/W and S/C

Suppression Chamber (S/C): The S/C condenses water vapors generated when an accident occurs to suppress the increase of pressure in PCV.

Air lock: Entrance and exit for humans

"*Browns Ferry Unit 1 under construction 1966.Sep.*"
Tennessee Valley Authority – TVA's 75th Anniversary webpa

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PCV: primary containment vessel

Muon Transmission Measurement

- Muons are secondary cosmic rays, which generate when radiation from space collides with the atmosphere of the Earth. The cosmic ray muons are high-energy particles and can pass through materials.

- Muon tomography can measure the number of muons that pass through the reactor building to image the density of materials such as X-ray. It can be used to image the distribution of fuel debris in the reactor pressure vessel (RPV). (Smaller number of muons will pass through high density regions so higher density regions show dark shadow).

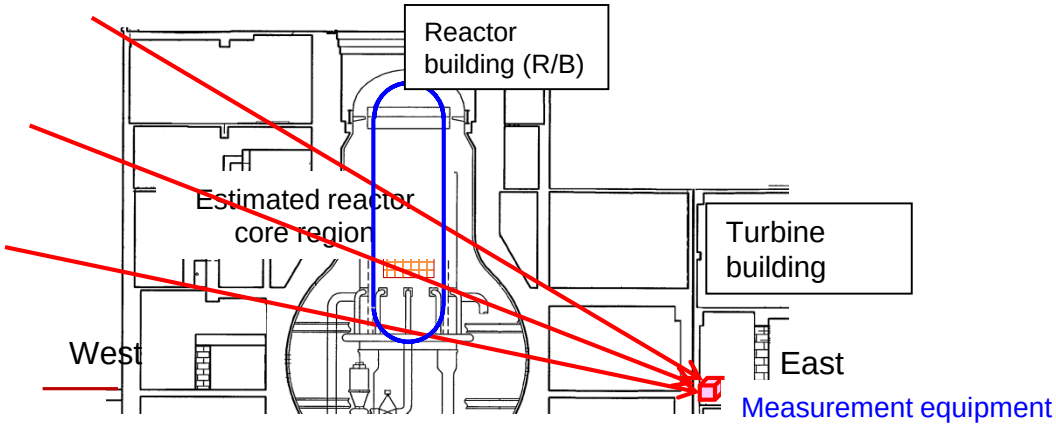


Illustration of measuring muons passing through the reactor building (horizontal cross section)

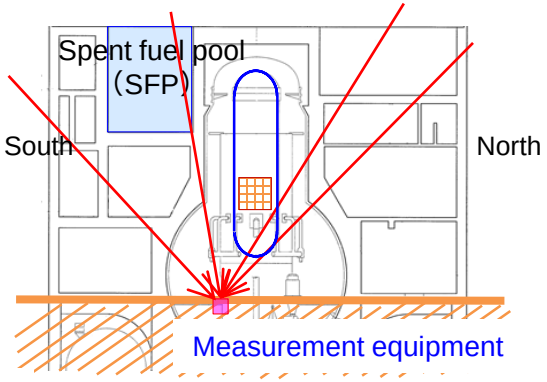
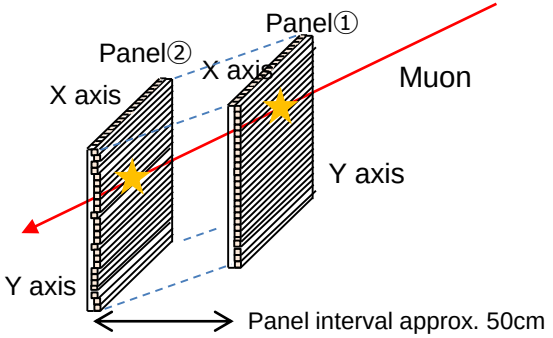


Illustration of measuring muons passing through the reactor building (vertical cross section)

<Measurement principle of the muon transmission method (illustration)>

Two panel detectors (plastic scintillator) that are placed in the measurement equipment can detect muons falling from space and calculate their trace on where they have passed through from the coordinates (X and Y axes) on the panel.



Quoted from a material of TEOCO Holdings, Inc. website

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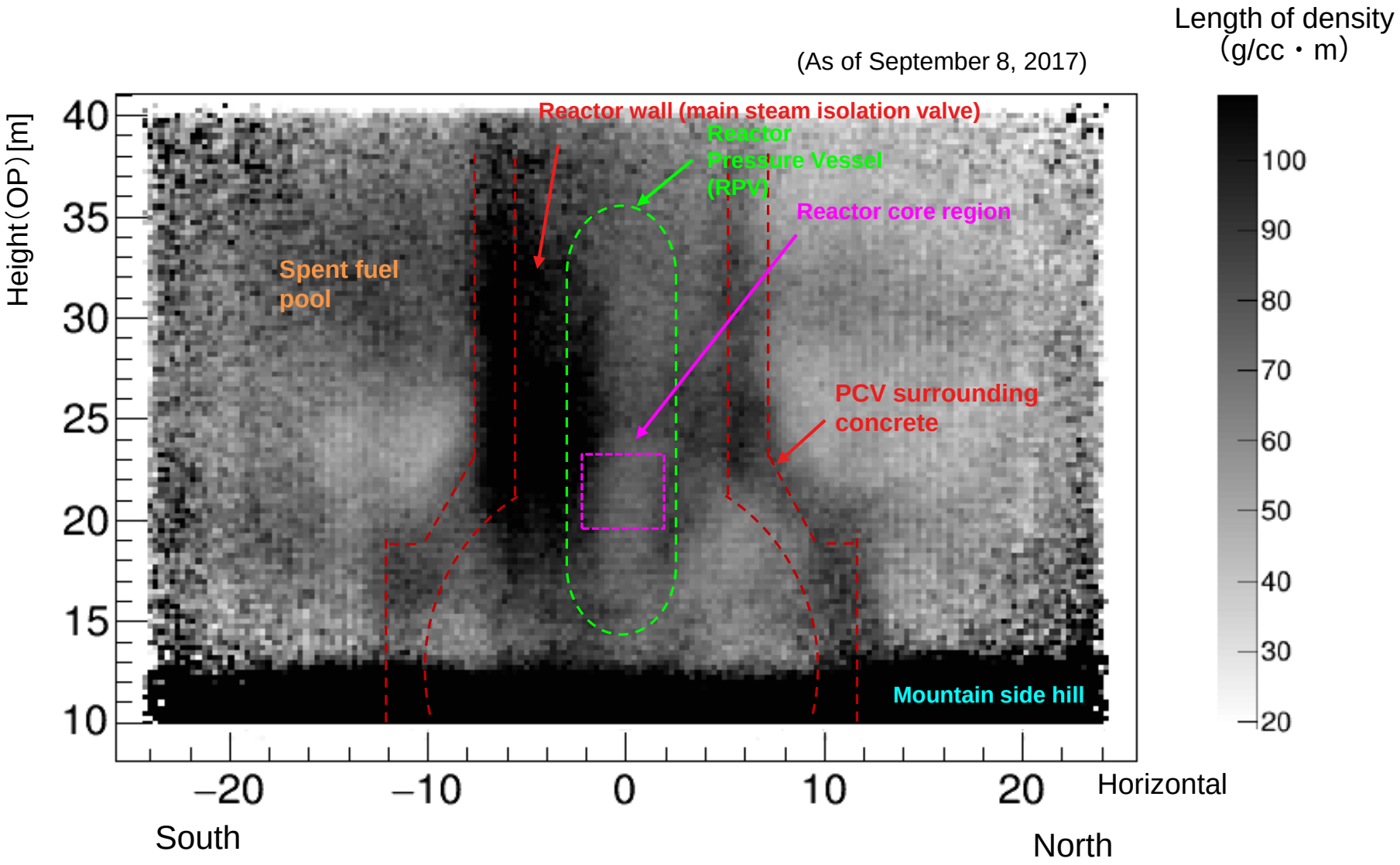
Measurement Result of the Muon Transmission Method for Unit 3



Quoted from report released from the TEPCO Holding Inc. website.

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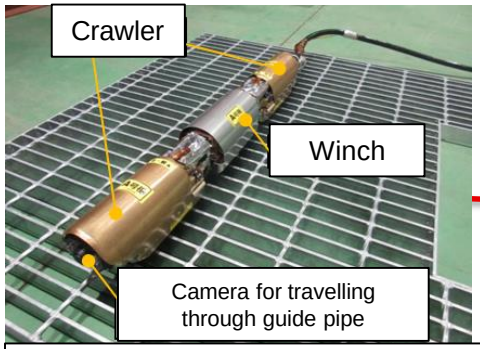
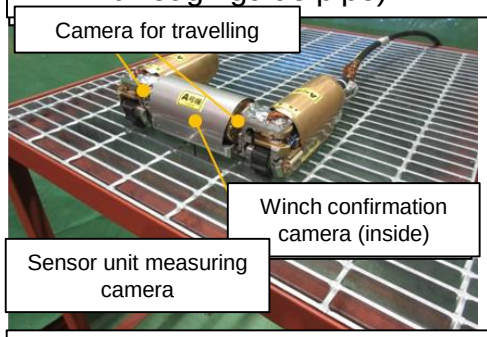
Robot Investigation of the PCV interiors

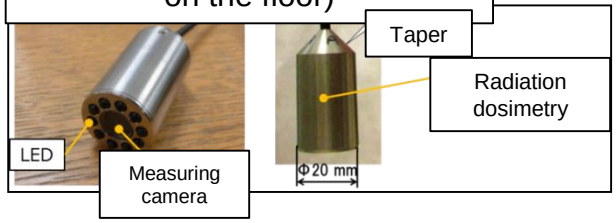
Investigation of outside the pedestal (Unit 1)



Type Ⅰ (when travelling through guide pipe)

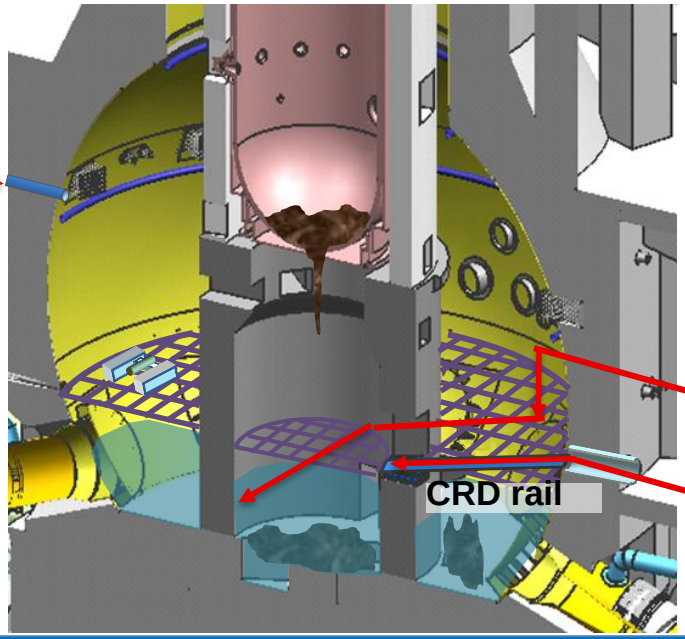


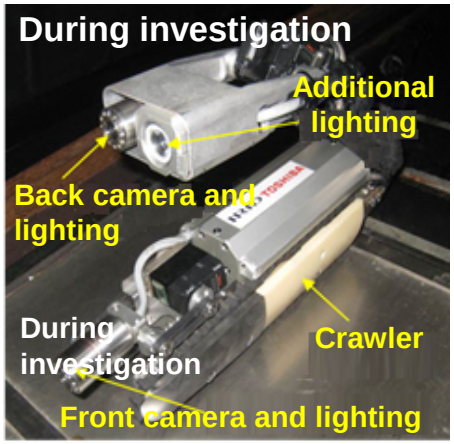
U-shape type (when travelling on the floor)



Investigation of inside the pedestal (Unit 2)

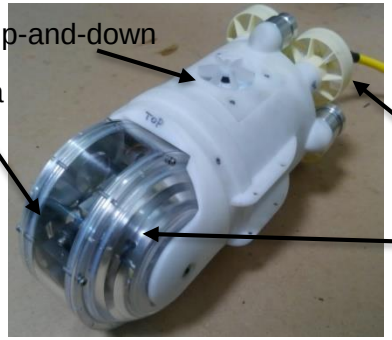
○ Remote-operated crawler robot for investigation





○Suspension type investigation equipment (A2' investigation)

Investigation of inside the pedestal (Unit 3)



○Submersible Crawling Robot

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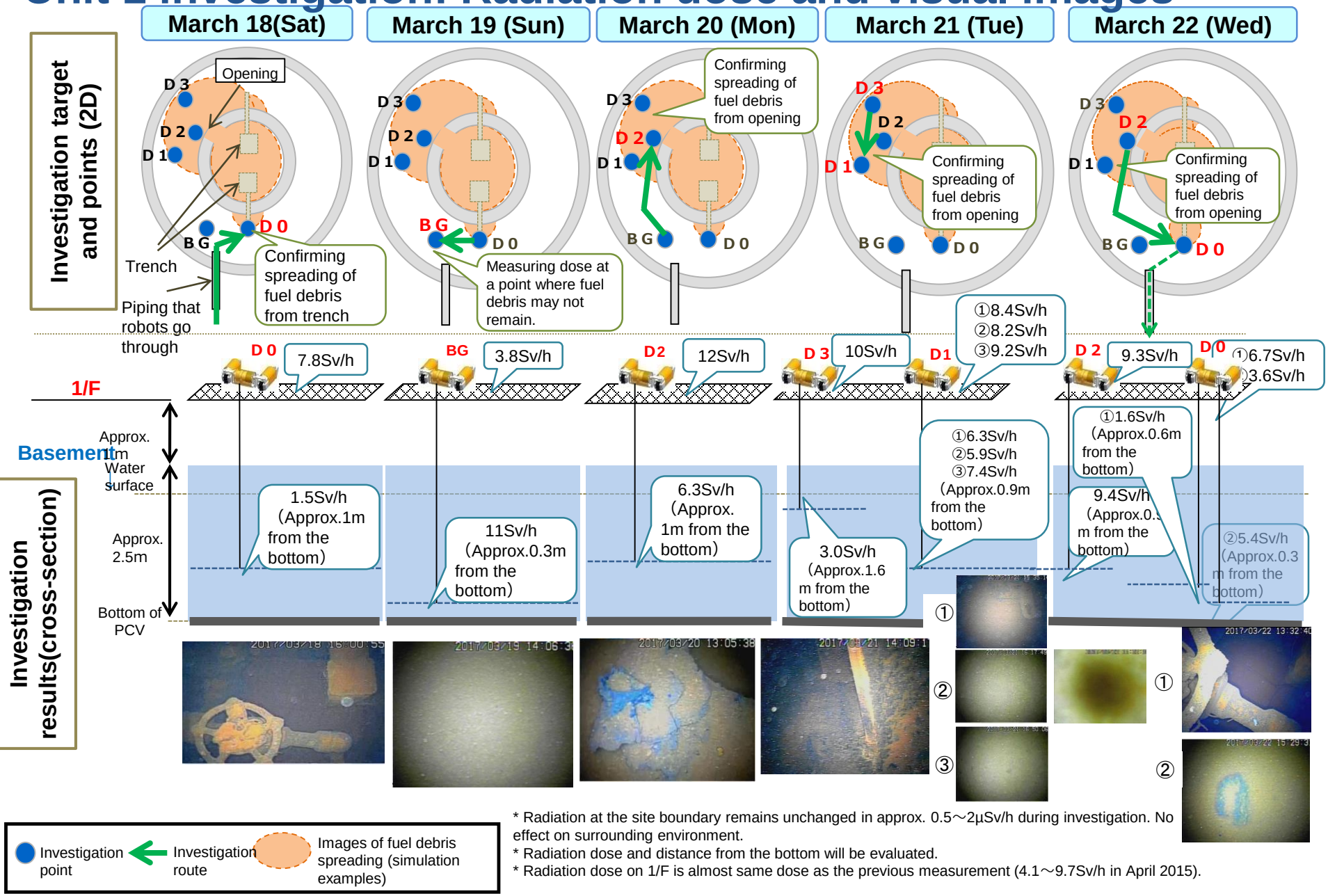
Unit 1 investigation: Radiation dose and visual images



* Radiation at the site boundary remains unchanged in approx. 0.5～2μSv/h during investigation. No effect on surrounding environment.
* Radiation dose and distance from the bottom will be evaluated.
* Radiation dose on 1/F is almost same dose as the previous measurement (4.1～9.7Sv/h in April 2015).

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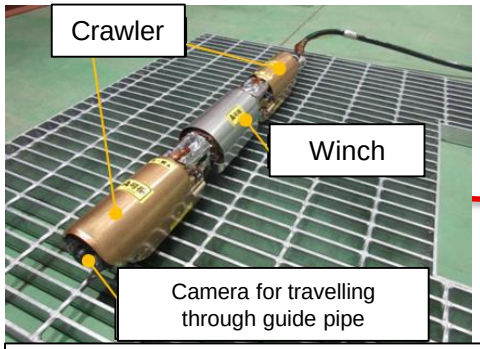
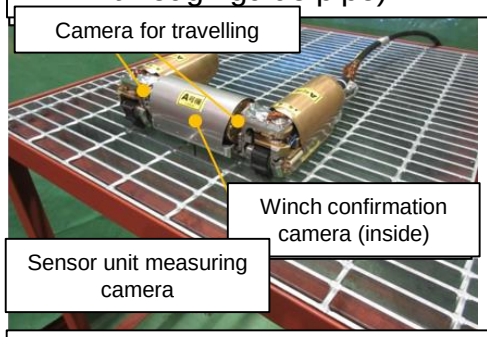
Robot Investigation of the PCV interiors

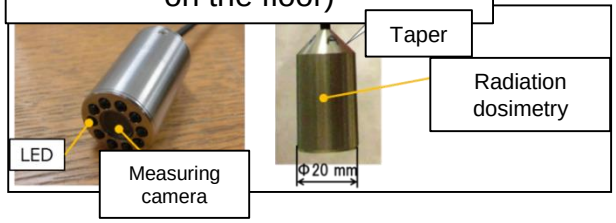
Investigation of outside the pedestal (Unit 1)



Type Ⅰ (when travelling through guide pipe)

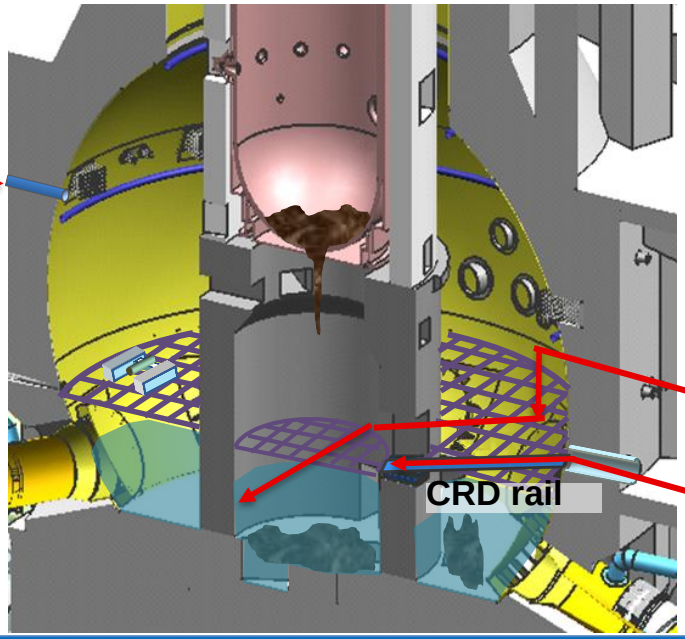


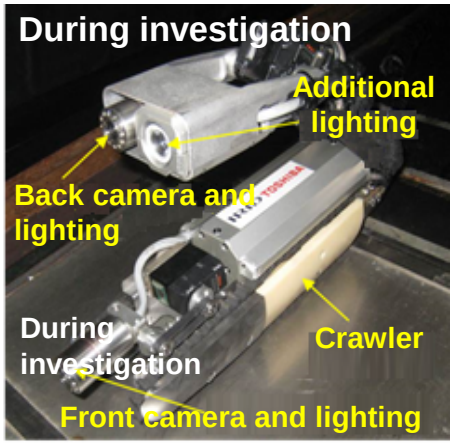
U-shape type (when travelling on the floor)



Investigation of inside the pedestal (Unit 2)

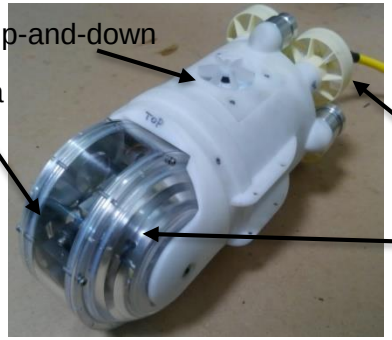
○ Remote-operated crawler robot for investigation





○Suspension type investigation equipment (A2' investigation)

Investigation of inside the pedestal (Unit 3)



○Submersible Crawling Robot

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Investigation of the Unit 2 upper pedestal interior

(A2 investigation: January – February 2017)

【Investigation method】

- Photographing by camera

【Implementation period】

- Jan. – Feb. 2017

Investigation procedure

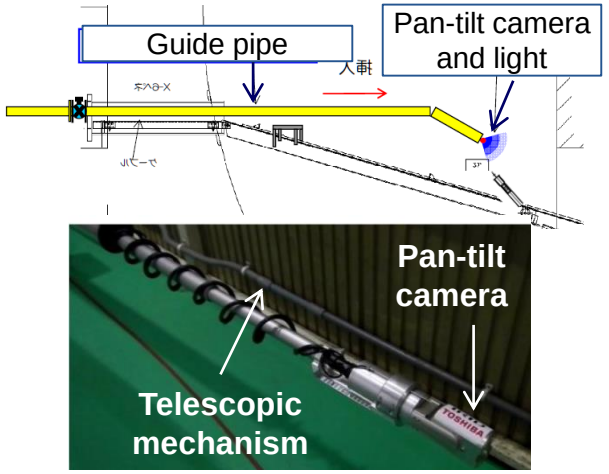
Pre-confirmation for the penetration interior

1.Pre-confirmation for the pedestal interior — Conducted on 30 Jan. 2017

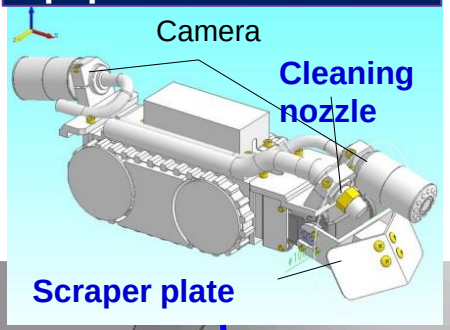
2. Removal of deposition on the rail — Conducted on 9 Feb. 2017

3. A2 investigation — Conducted on 16 Feb. 2017

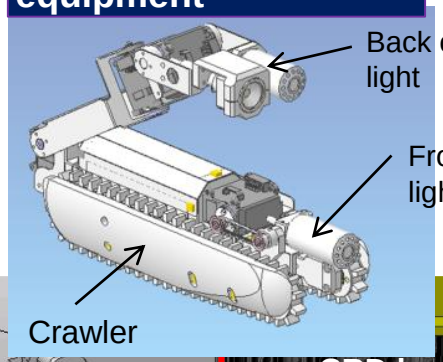
1. Pre-confirmation system

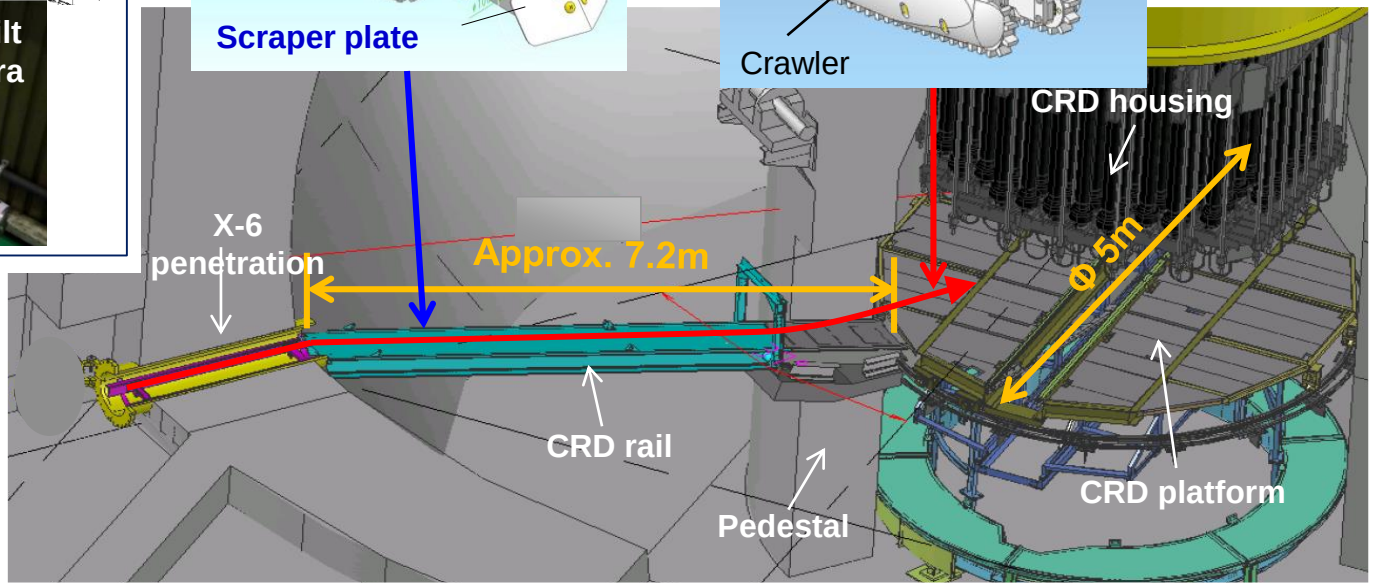


2. Deposition removal equipment



3. A2 investigation equipment





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Investigation of the Unit 2 upper pedestal interior

(A2 investigation: January – February 2017)

Upper pedestal interior (after image processing)

Investigation of the lower pedestal interior

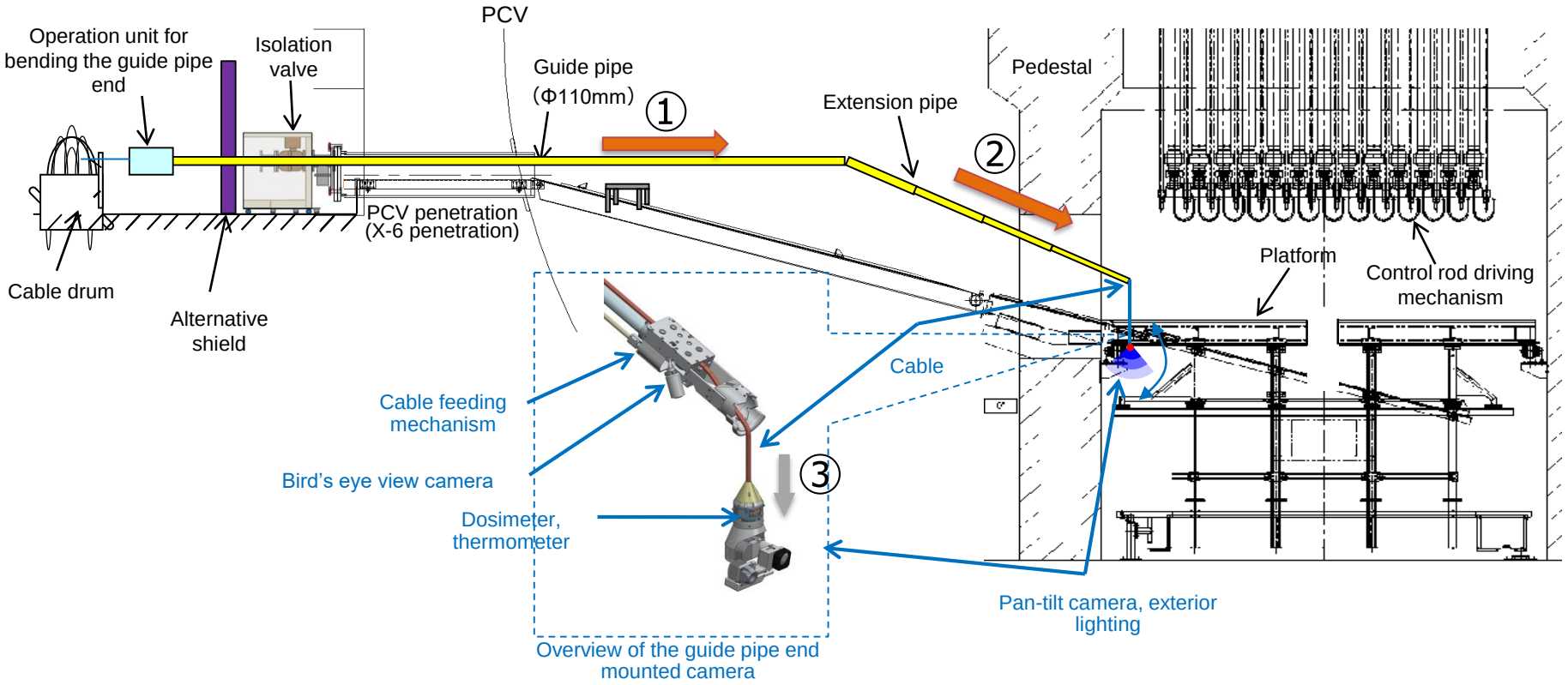
(A2' investigation in January 2018)

■ Purpose of investigation

Confirmation of the state below the platform

■ Investigation procedure

①Inserting a guide pipe ⇒ ②Extending a pipe ⇒
③Suspending a pan-tilt camera ⇒ ④Investigation



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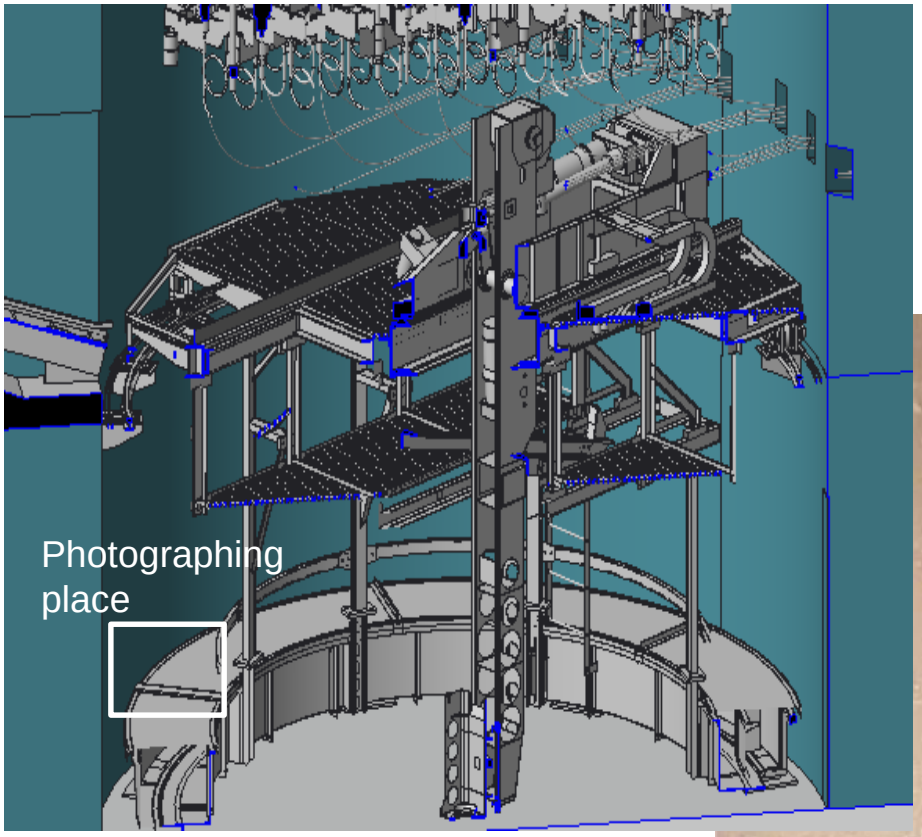
Unit 2 investigation: Pedestal Floor



Bottom of the Unit 2 PCV
(An overhead image)

Pedestal floor and wall
Fuel debris? and a fuel assembly handle

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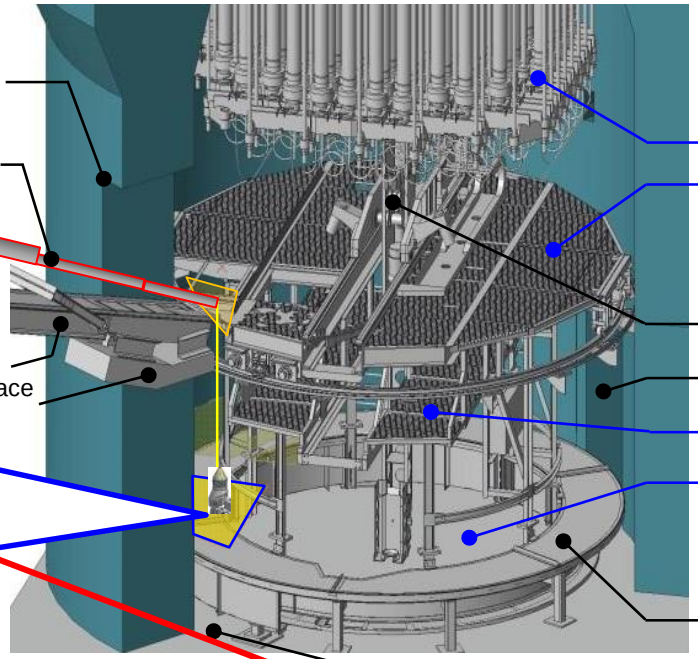
Investigation of the Lower Pedestal Interior

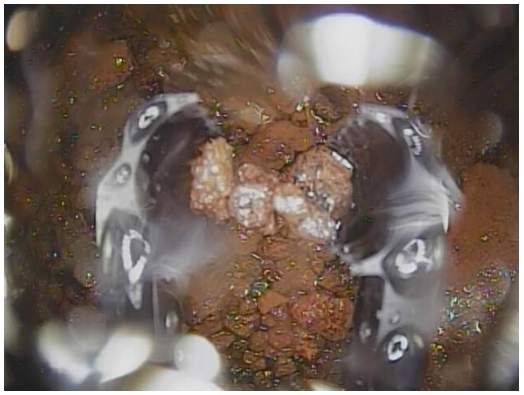
(A2' investigation in February 2019)

Direction to the pedestal center

*Investigation point is tentative.
Investigation area (A photo taken in Jan. 2018)



Before touching deposition



Touching deposition

After touching deposition

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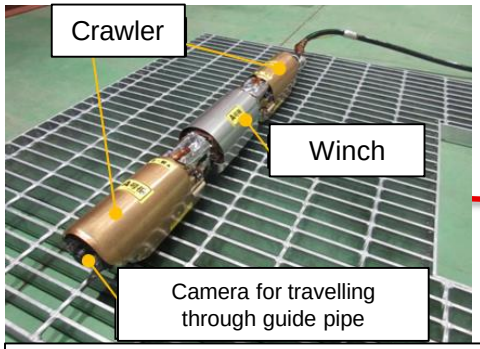
無断複製・転載禁止 東京電力ホールディングス株式会社

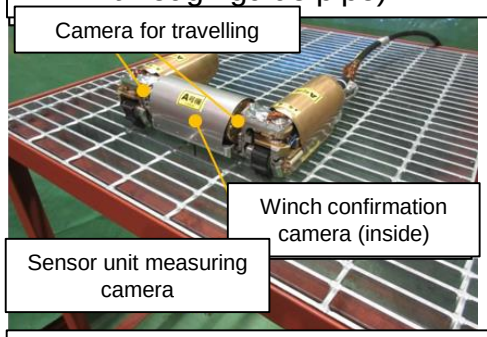
Source: TEPCO Holding Inc. website

Robot Investigation of the PCV interiors

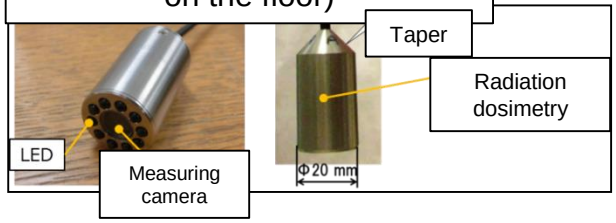
Investigation of outside the pedestal (Unit 1)



Type Ⅰ(when travelling through guide pipe)

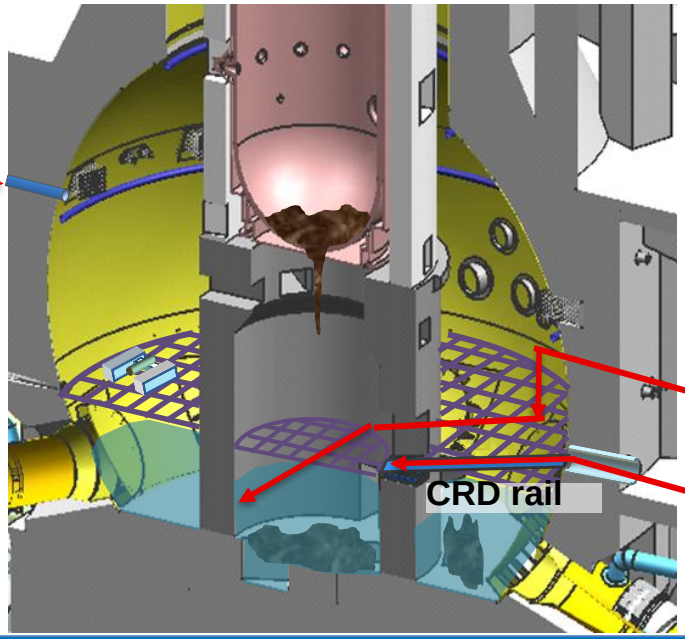


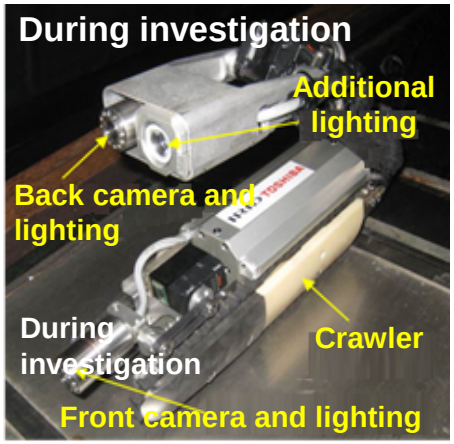
U-shape type (when travelling on the floor)



Investigation of inside the pedestal (Unit 2)

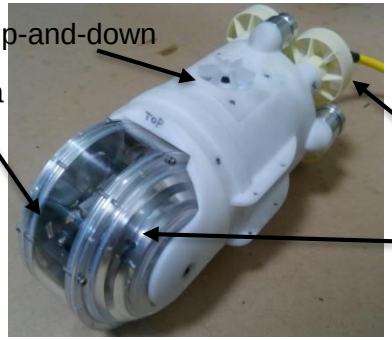
○ Remote-operated crawler robot for investigation





○Suspension type investigation equipment (A2' investigation)

Investigation of inside the pedestal (Unit 3)



○Submersible Crawling Robot

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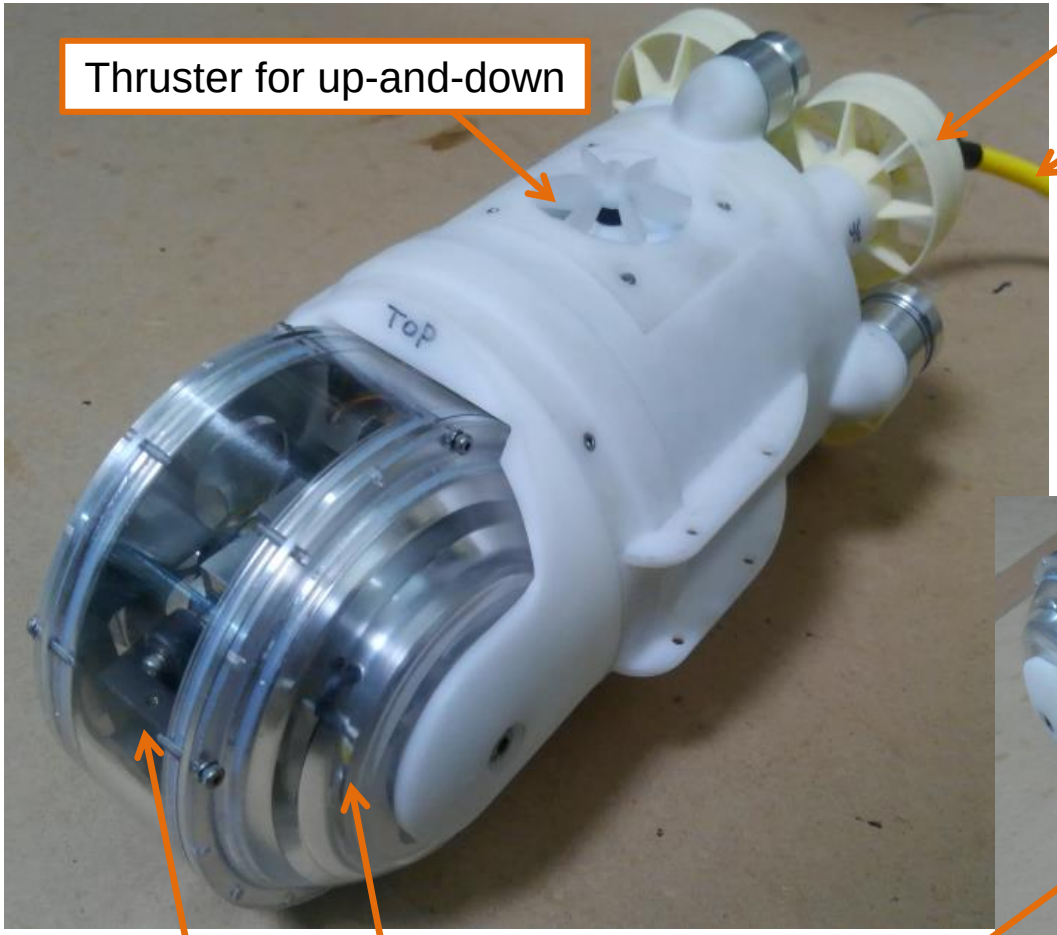
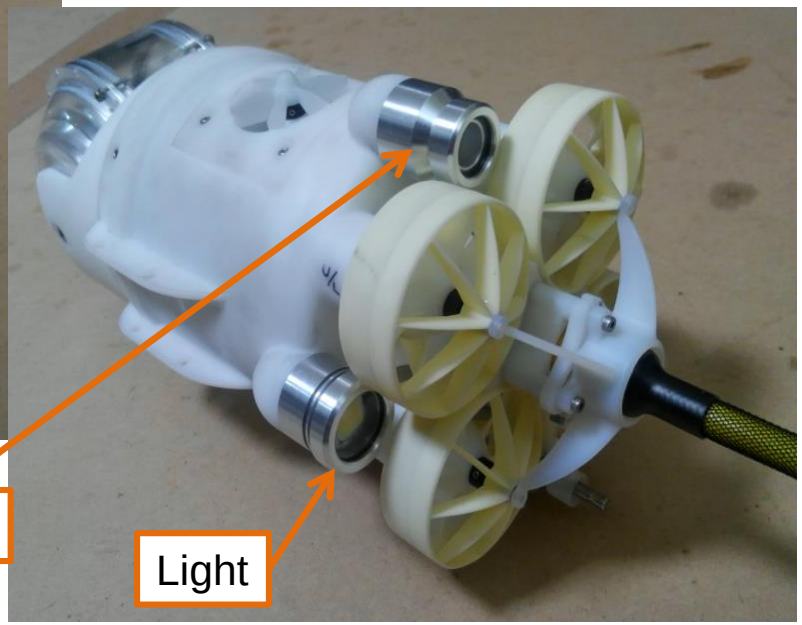
Submersible Remote Operated Vehicle (ROV) (mockup vehicle)



Items	Specifications
Outer size	Outer diameter：φ125mm Overall length：Approx.300mm
Weight	Approx. 2000g (in air)
Radiation resistance	200Gy



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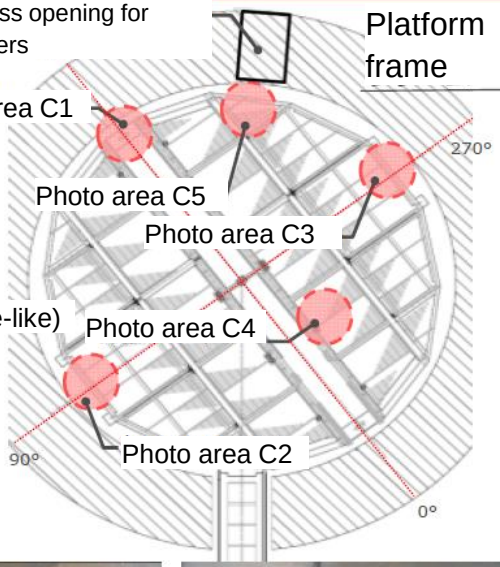
Results of investigation for the Unit 3 PCV

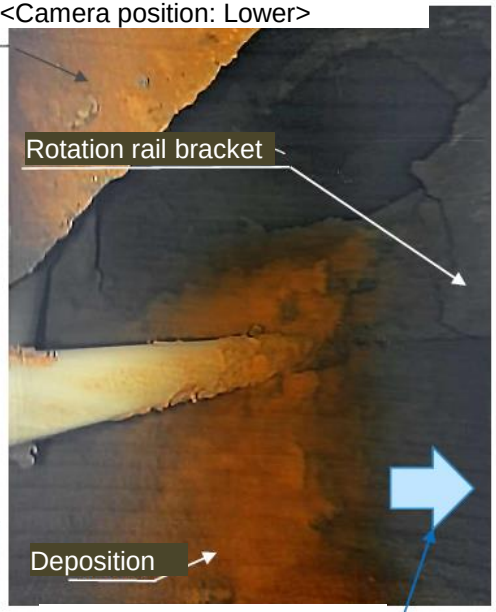
2. Investigation results
2.3. The lower pedestal

Area C1 where a photo was taken
<Camera position: Lower>

Deposition (pebble-like)



Area C5 where a photo was taken
<Camera position: Lower>



Area C2 where a photo was taken
<Camera position: Horizontal>

Area C3 where a photo was taken
<Camera position: Upper>

Area C4 where a photo was taken
<Camera position: Lower>

- The investigation has revealed that deposition in sandy, pebble-like and massive form has accumulated.
- The access opening for workers was not confirmed visually (deposition was visually seen nearby).

「3号

* Reference: Investigation result of the Unit 3 PCV interior (report of the 48th Team Meeting and Countermeasures for Decommissioning and Contaminated Water Treatment Conference on Nov. 30, 2017)

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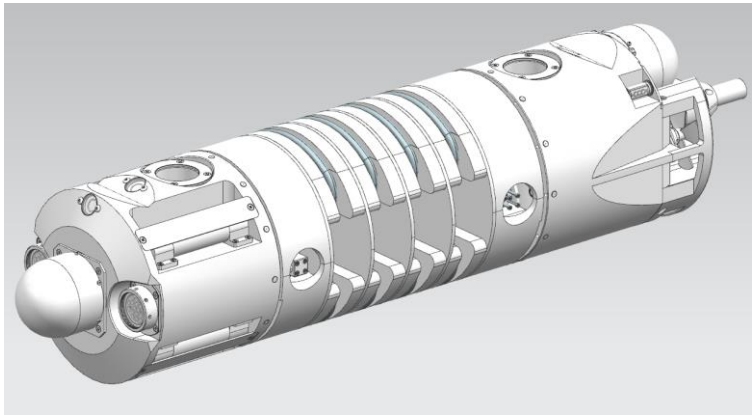
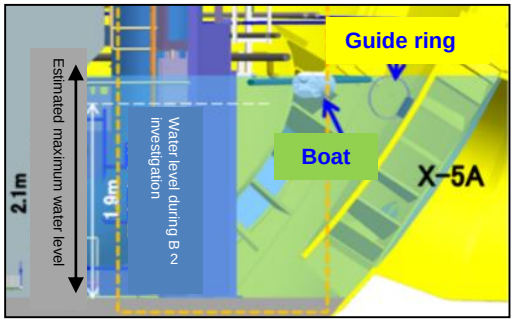
Boat Type Access Equipment

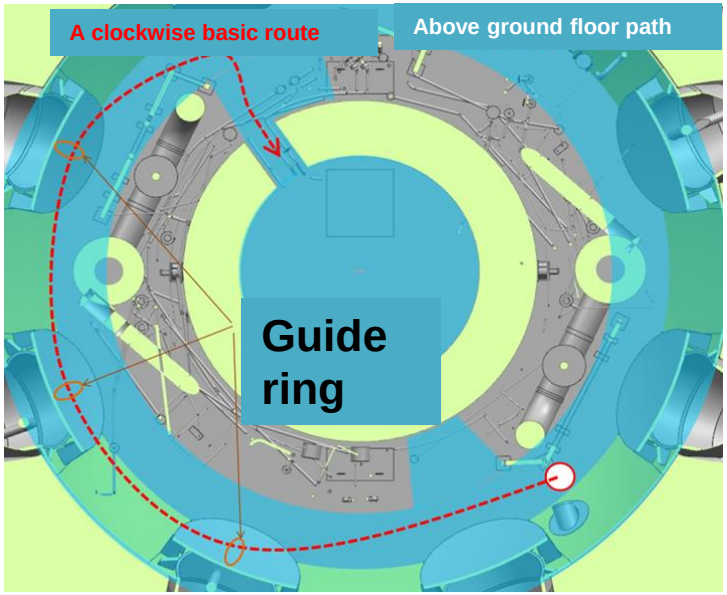
- Boat type access equipment which can move on a wide range of the water surface in the primary containment vessel (PCV) was developed.



Example: Guide ring installation
- Diameter: φ25cm
- Length: Approx. 1.1m
- Thrust: Over 25N

Appearance of the boat type access equipment





Travelling line of the equipment

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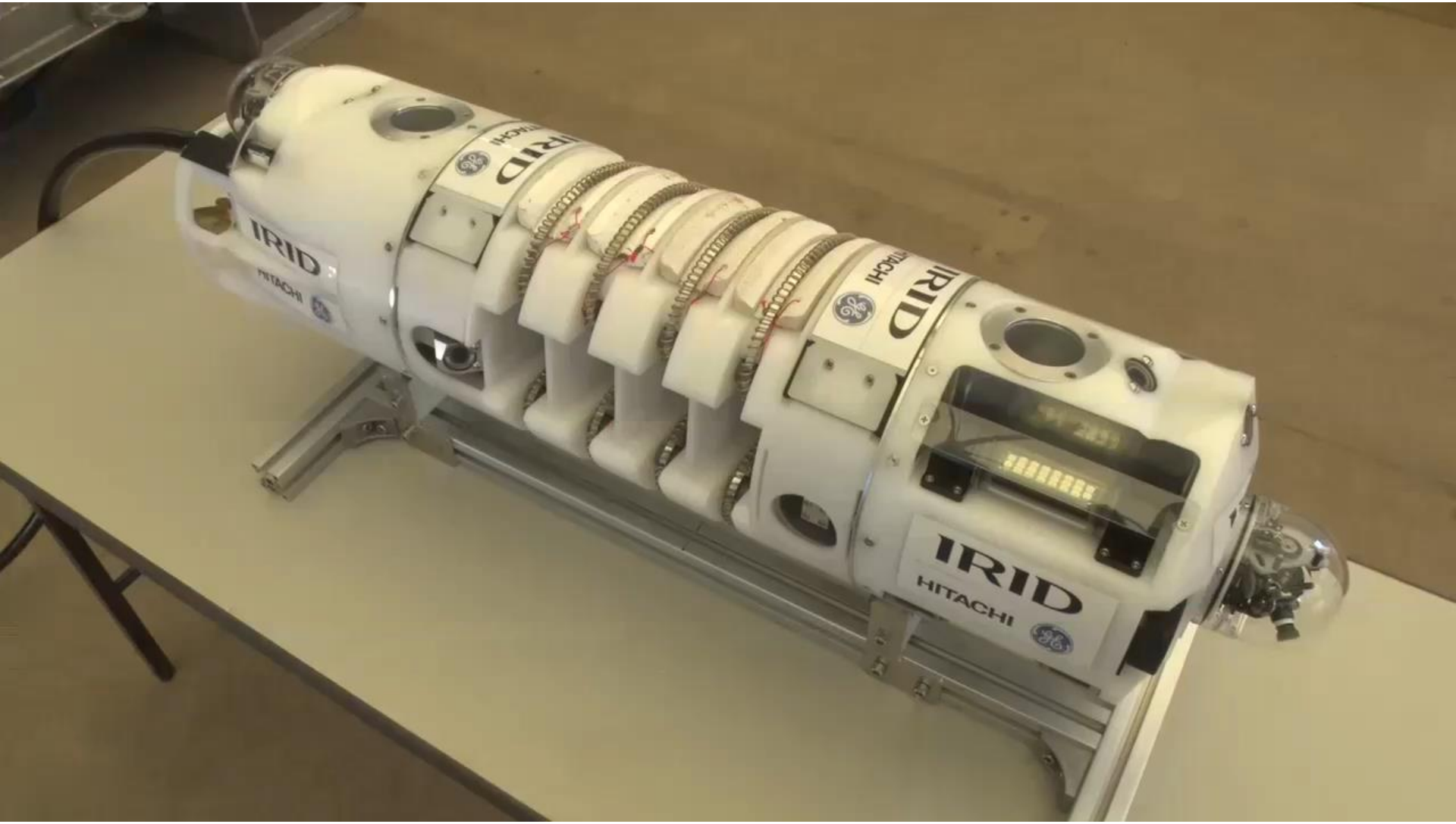
Boat Type Access Equipment (Video)



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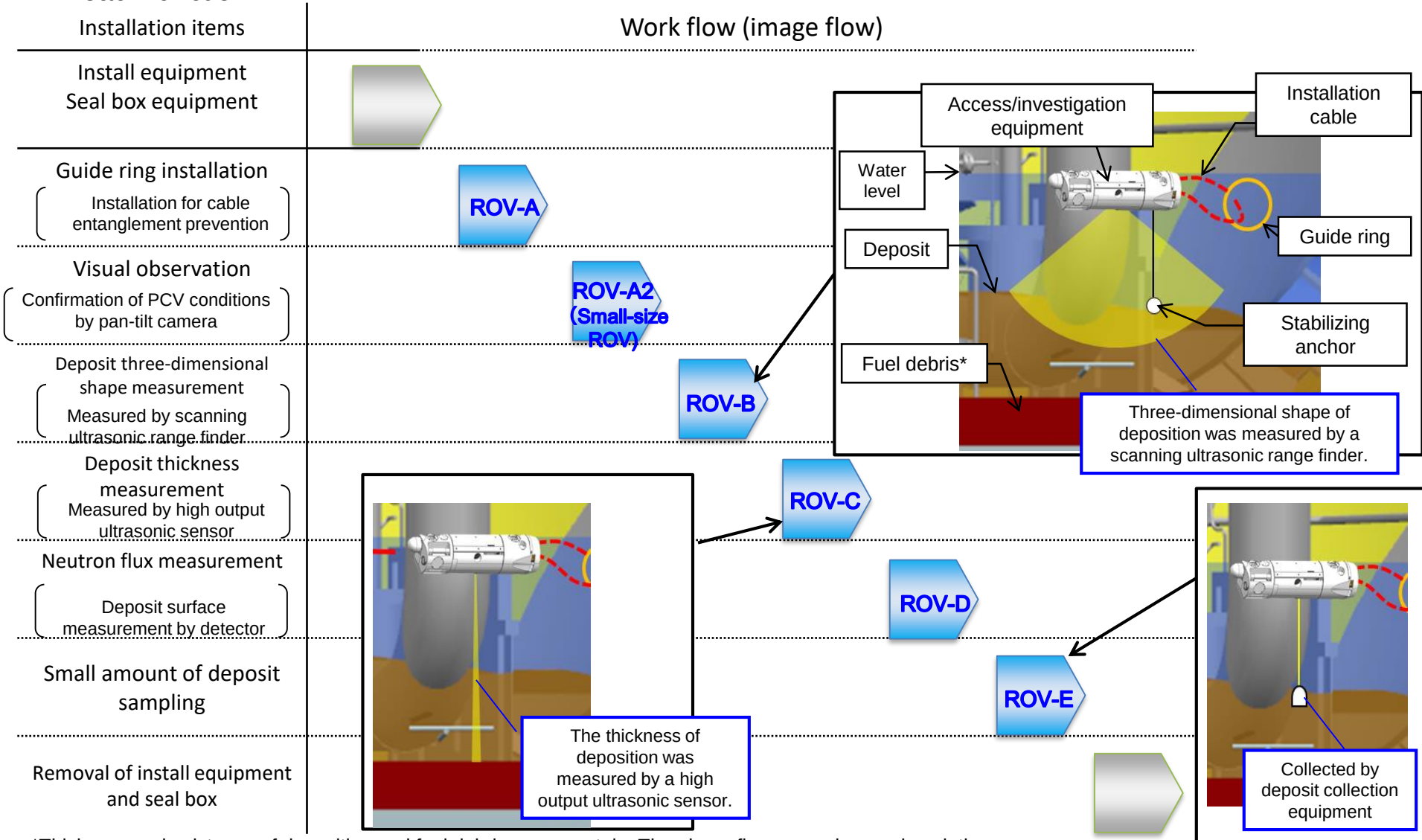
Boat Type Access Equipment (Investigation inside PCV through X-2 penetration)

- Six kinds of boat type access and investigation equipment with submersible functions will be prepared for each function.



*Thickness and existence of deposition and fuel debris are uncertain. The above figures are image descriptions.

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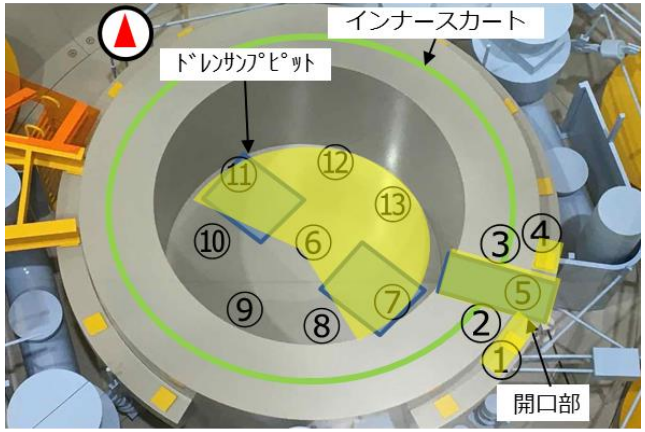
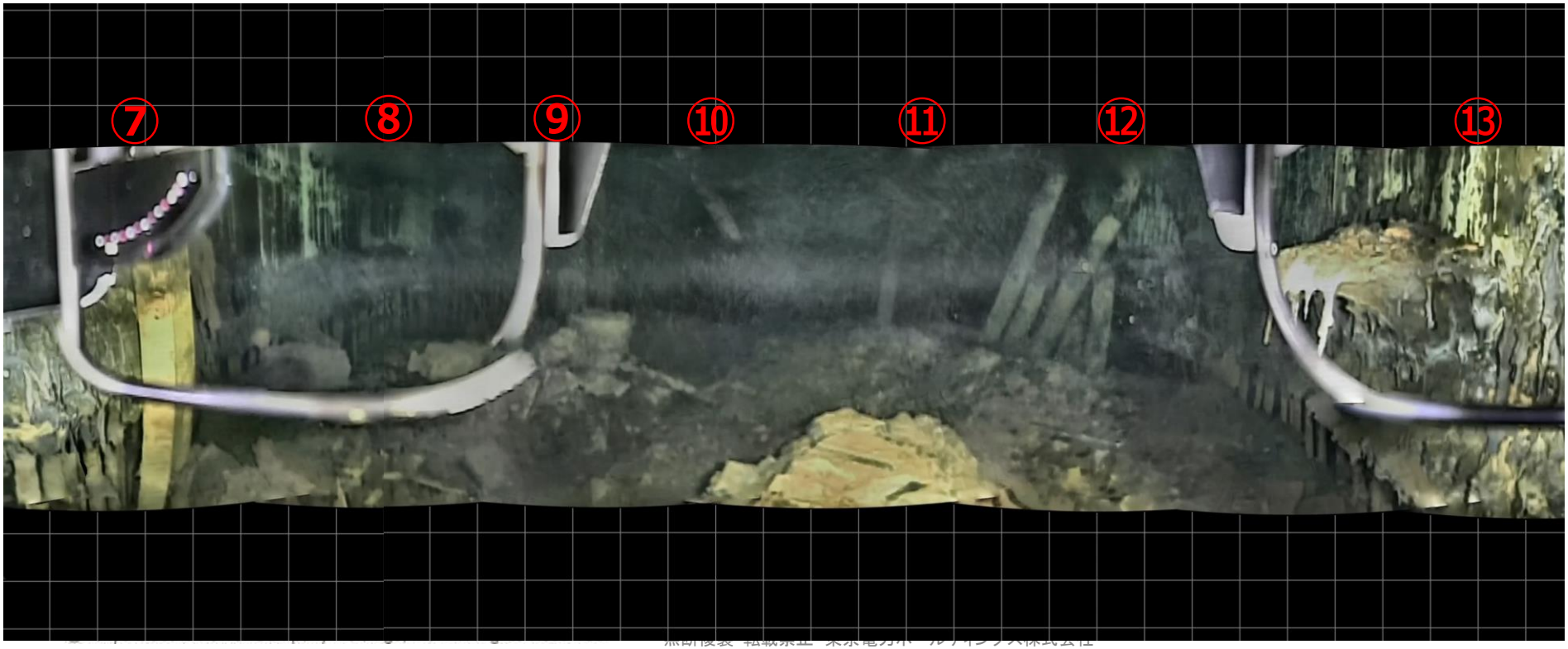
【Reference】Panoramic photo images taken from the pedestal opening



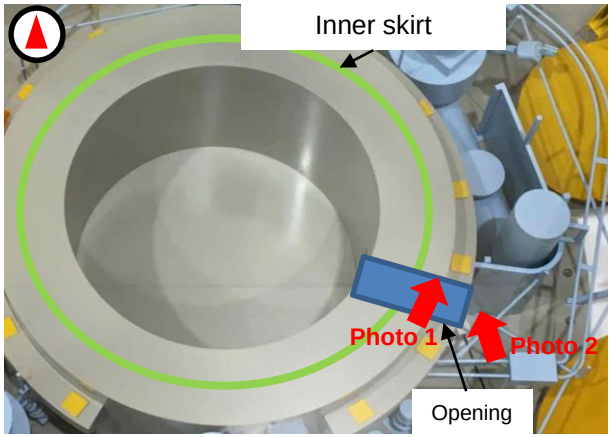


無断複製・転載禁止 東京電力ホールディングス株式会社

Image processing by TEPCO Holding, Inc.

【Reference】Concrete remains of the right pedestal opening (1/2)

- Tokyo Electric Power Company (TEPCO) Holdings, Inc. investigated the Unit 1 pedestal to confirm the concrete that likely remain outside the pedestal (Bolts that were installed before the accident were confirmed to be fixed). The investigation on March 2023 confirmed the inside of the pedestal wall.
- TEPCO assumes that the lost concrete of the pedestal outer wall opening in right side would be limited.
- The investigation found that reinforcing steels of the outside pedestal have remained 7 pieces in the right opening part and 11 pieces in the left side. The earthquake resistance should be evaluated based on 64° that is equivalent to the angle in accordnce with the opening angle.



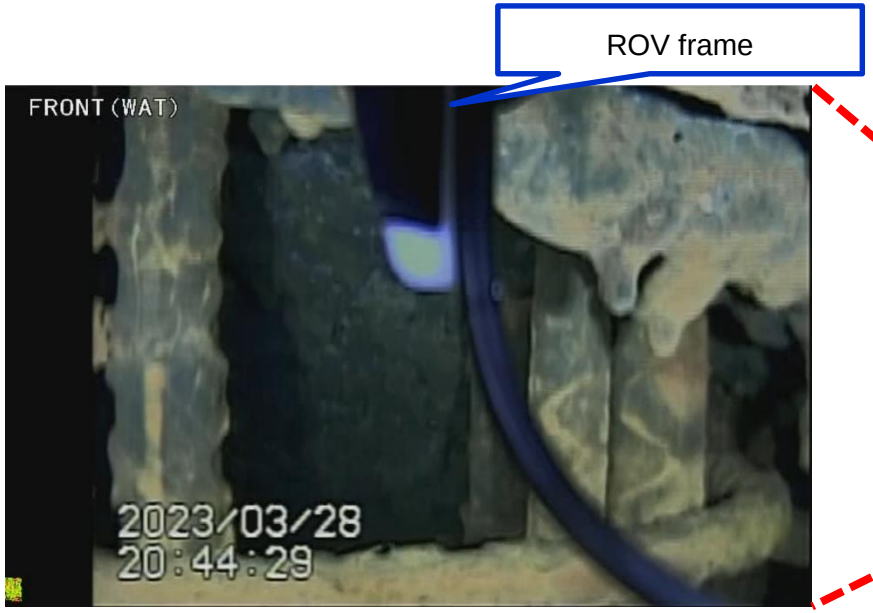


Photo 1: Concrete remains can be seen from the pedestal opening

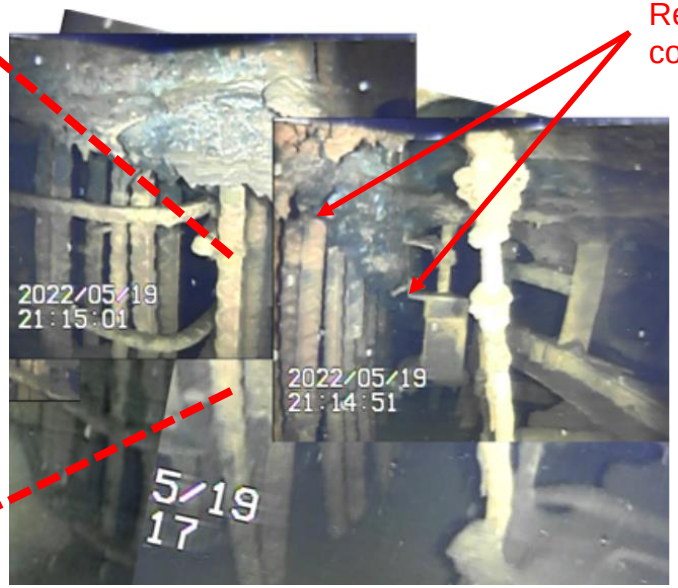


Photo 2: Concrete remains can be seen from the pedestal opening

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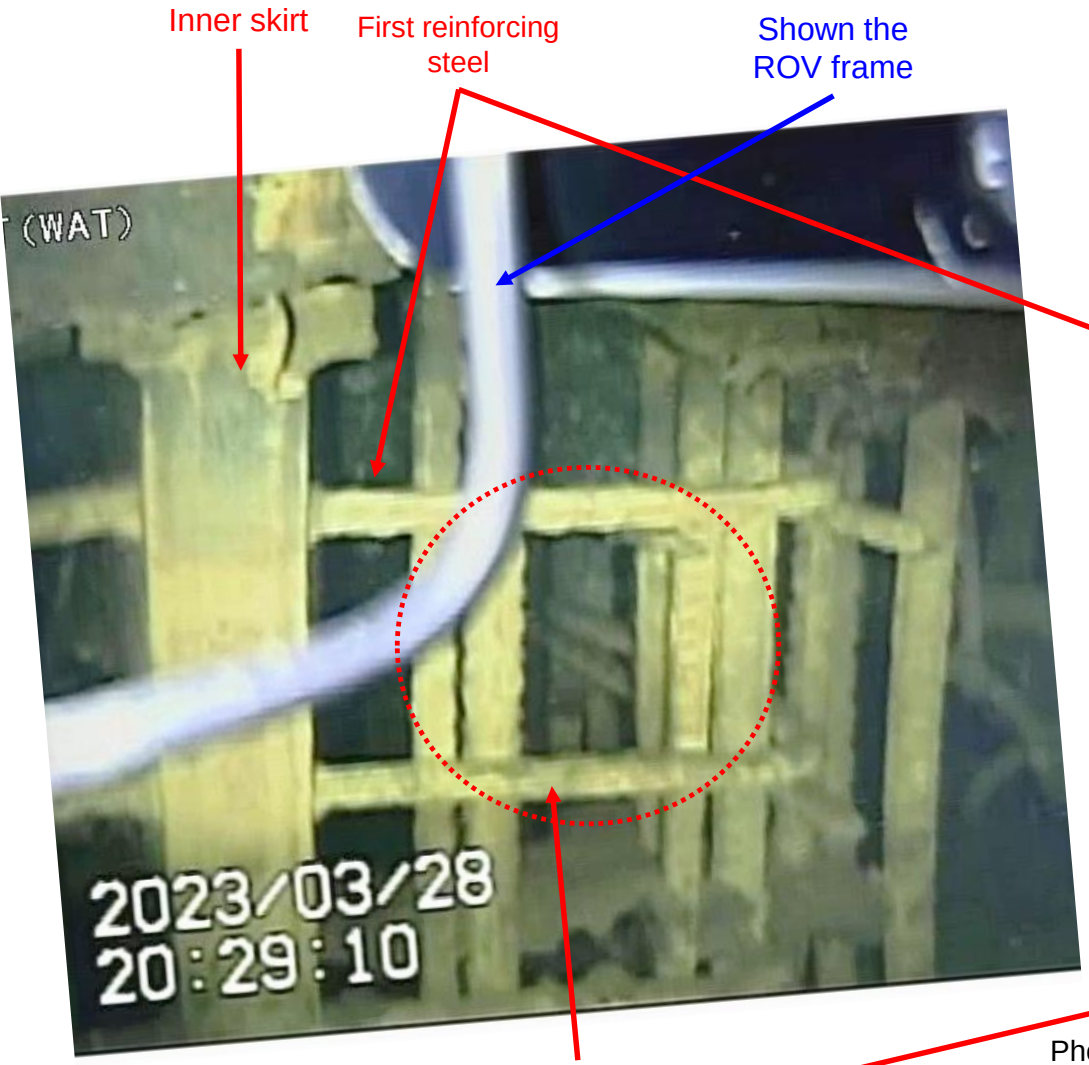
Photos processed by TEPCO Holdings Inc.

【Reference】Concrete remains of the right pedestal opening (2/2)



*The brightness of the original image is increased by 30%.

Figure 1: Remains of the pedestal outer wall of the right opening

*The brightness of the original image is increased by 50%.

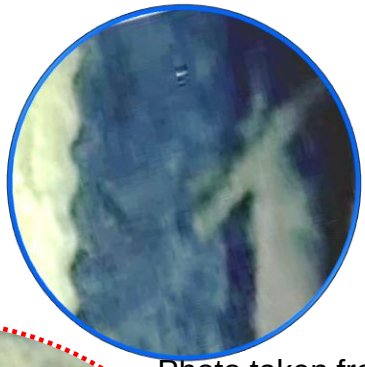
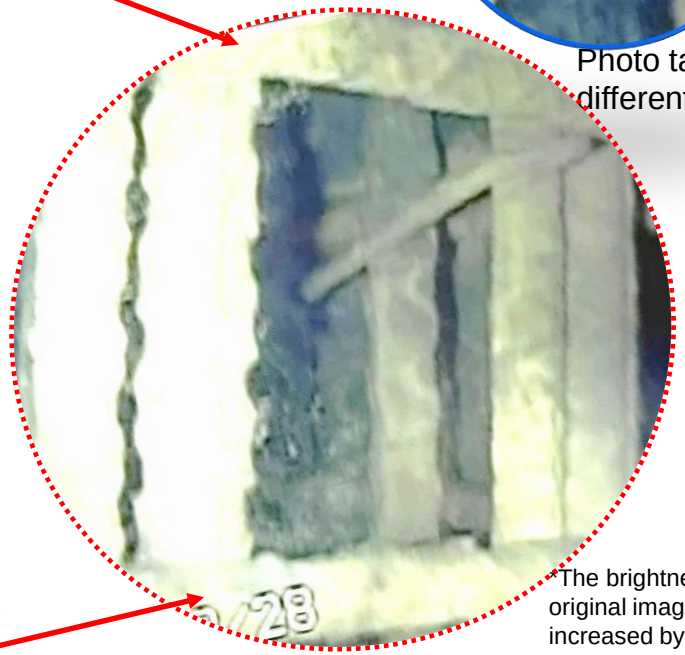


Photo taken from different angle



*The brightness of the original image is increased by 50%.

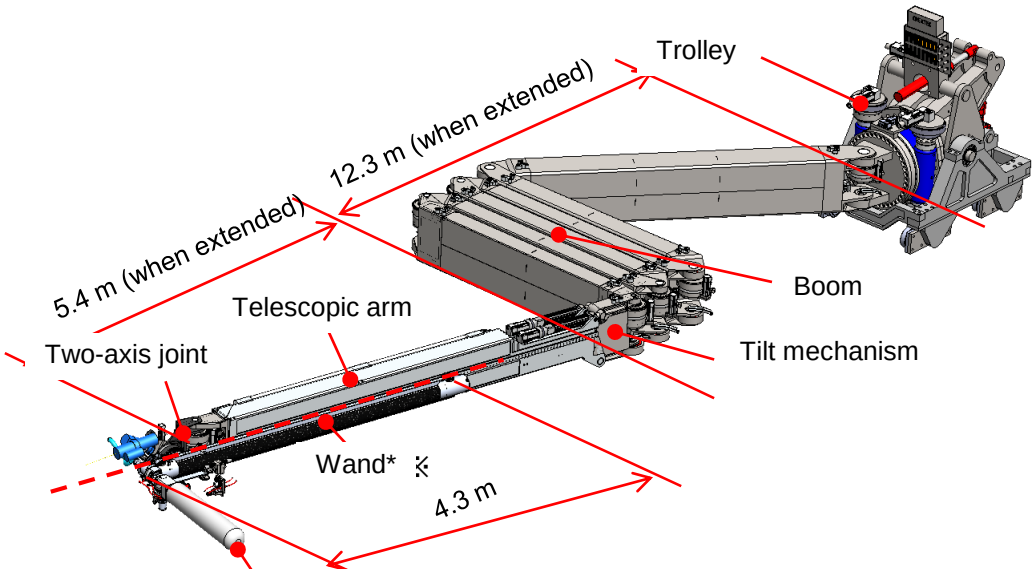
Photo of left red-circled part taken from different angle

Figure 2: Visual image taken from different angle of the remains

Photos processed by TEPCO Holdings Inc.

Arm Type Access Equipment

- The arm type access equipment was manufactured which can access on a wide range through the PCV penetration for maintenance of control rod drive mechanism.
  - Total length of the arm: Approx. 22m
  - Investigation equipment up to 10kg can be loaded.



*The wand can be replaced an alternative tool.

Arm type access equipment

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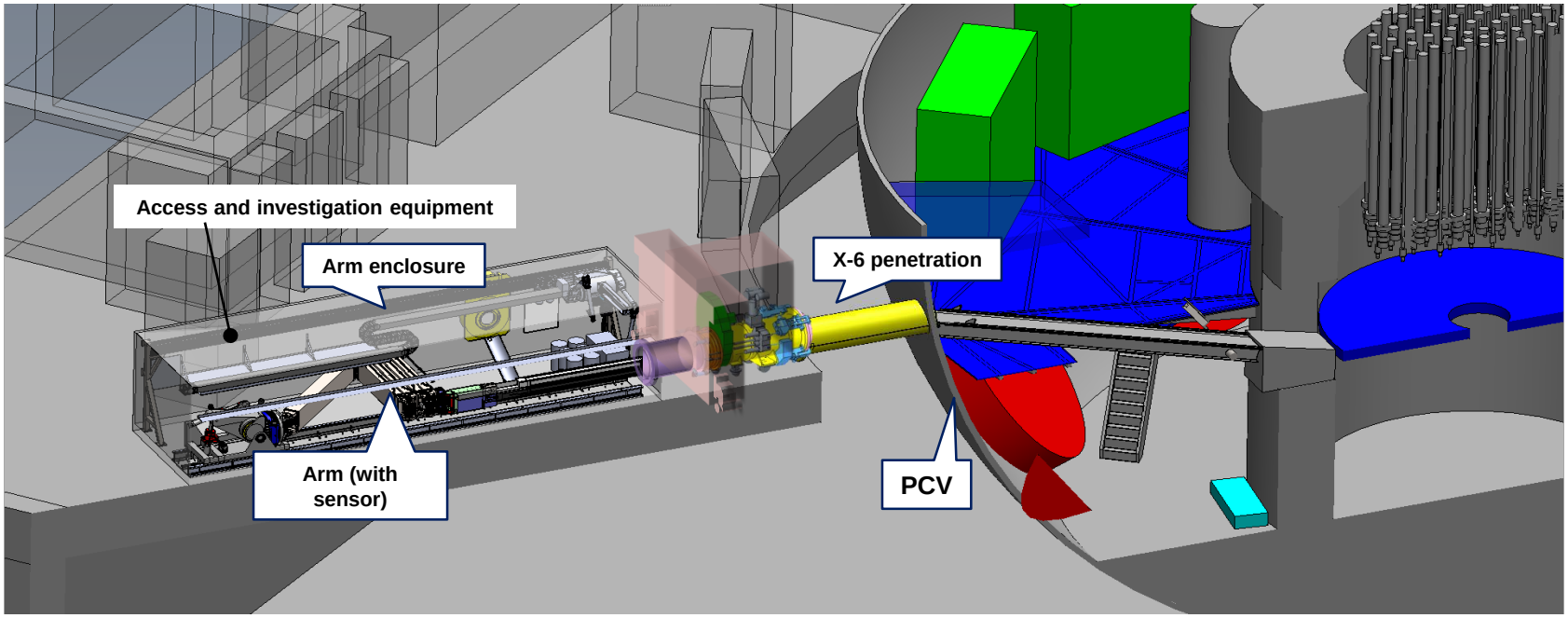
Configuration of Access Equipment



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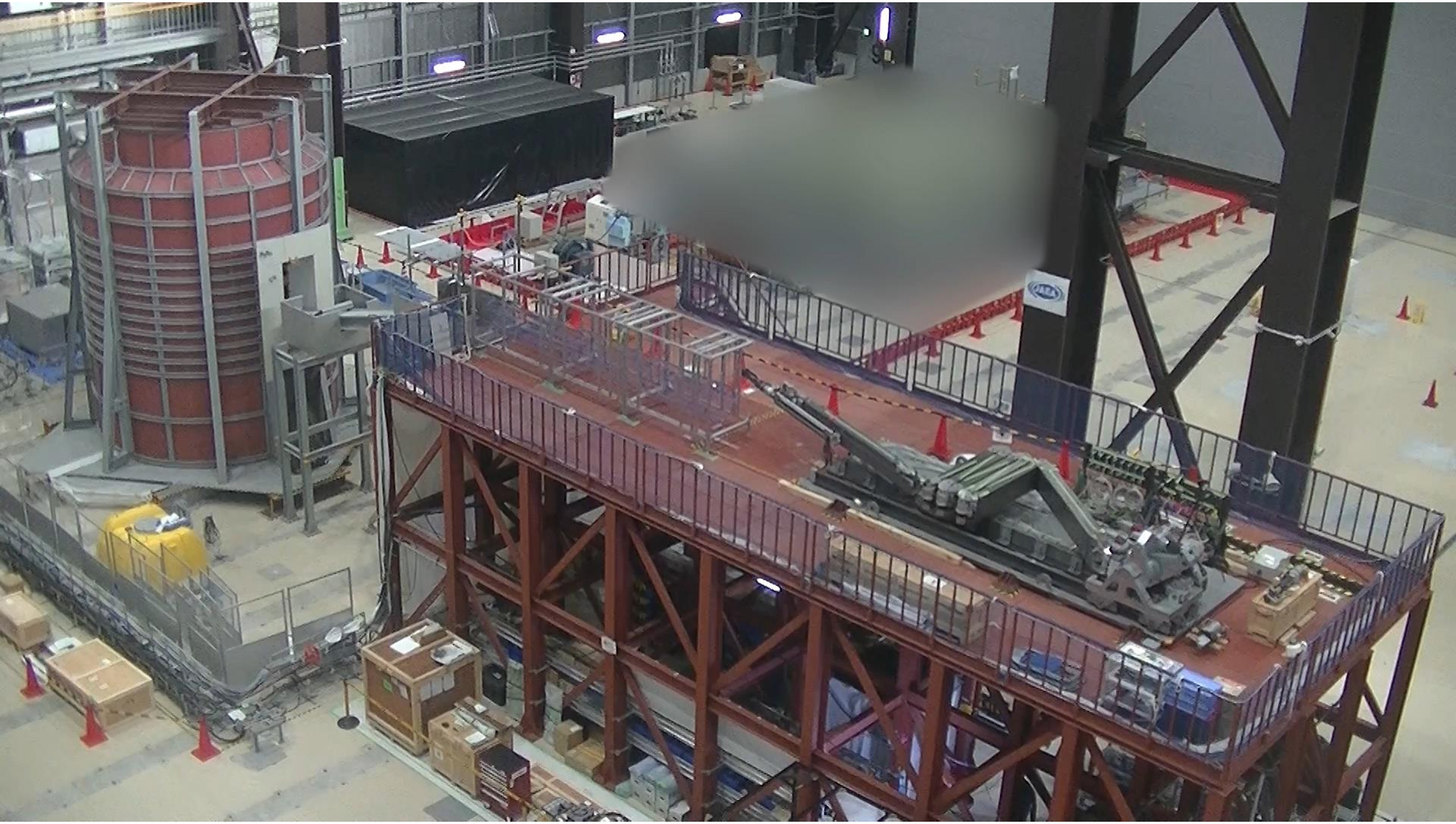
Arm Type Access Equipment (video)



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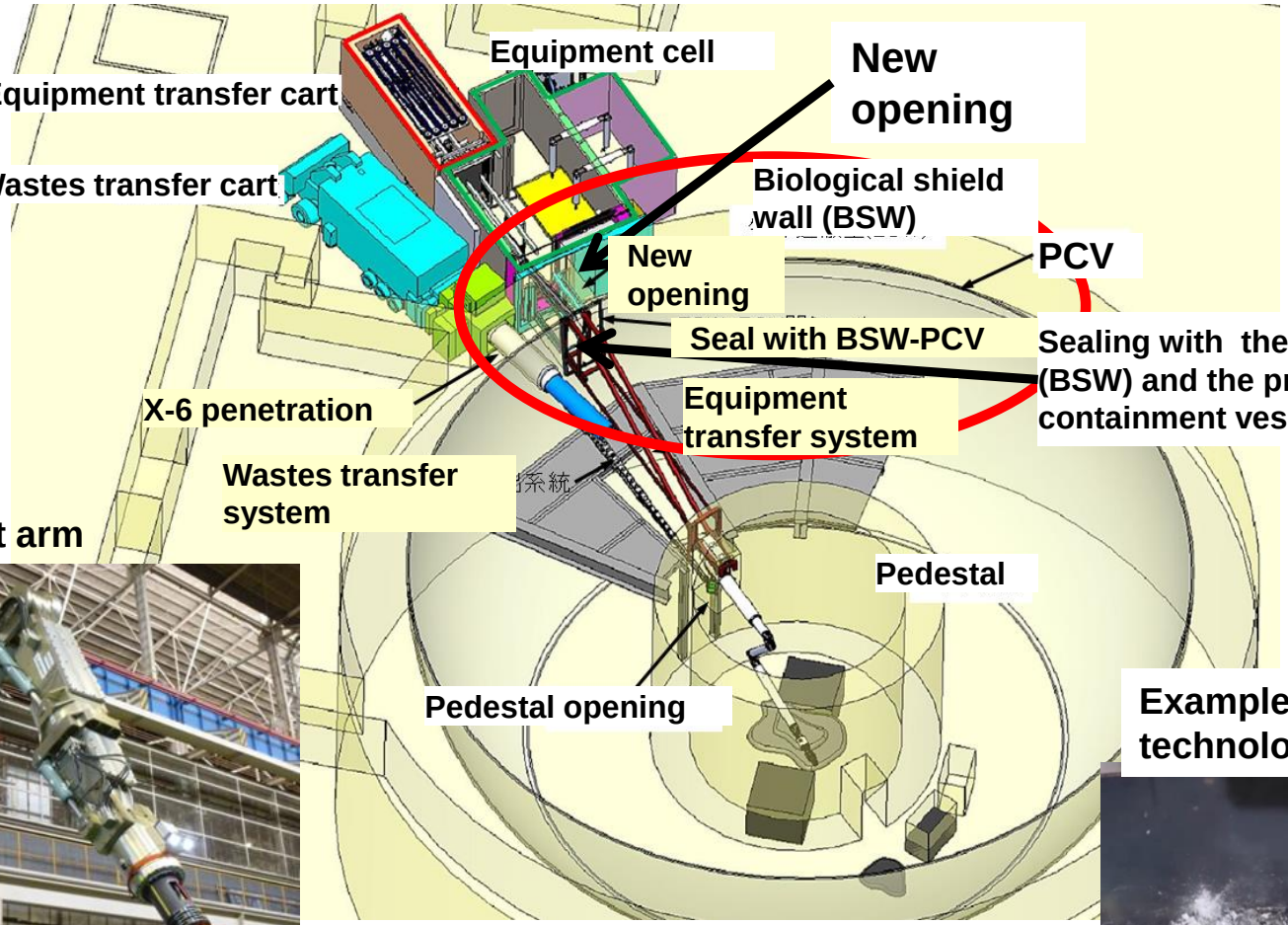
PCV: primary containment vessel

Fuel Debris Retrieval Technology



Example of robot arm

Example of cutting technology (Chisel)

Example of the side access method (illustration)

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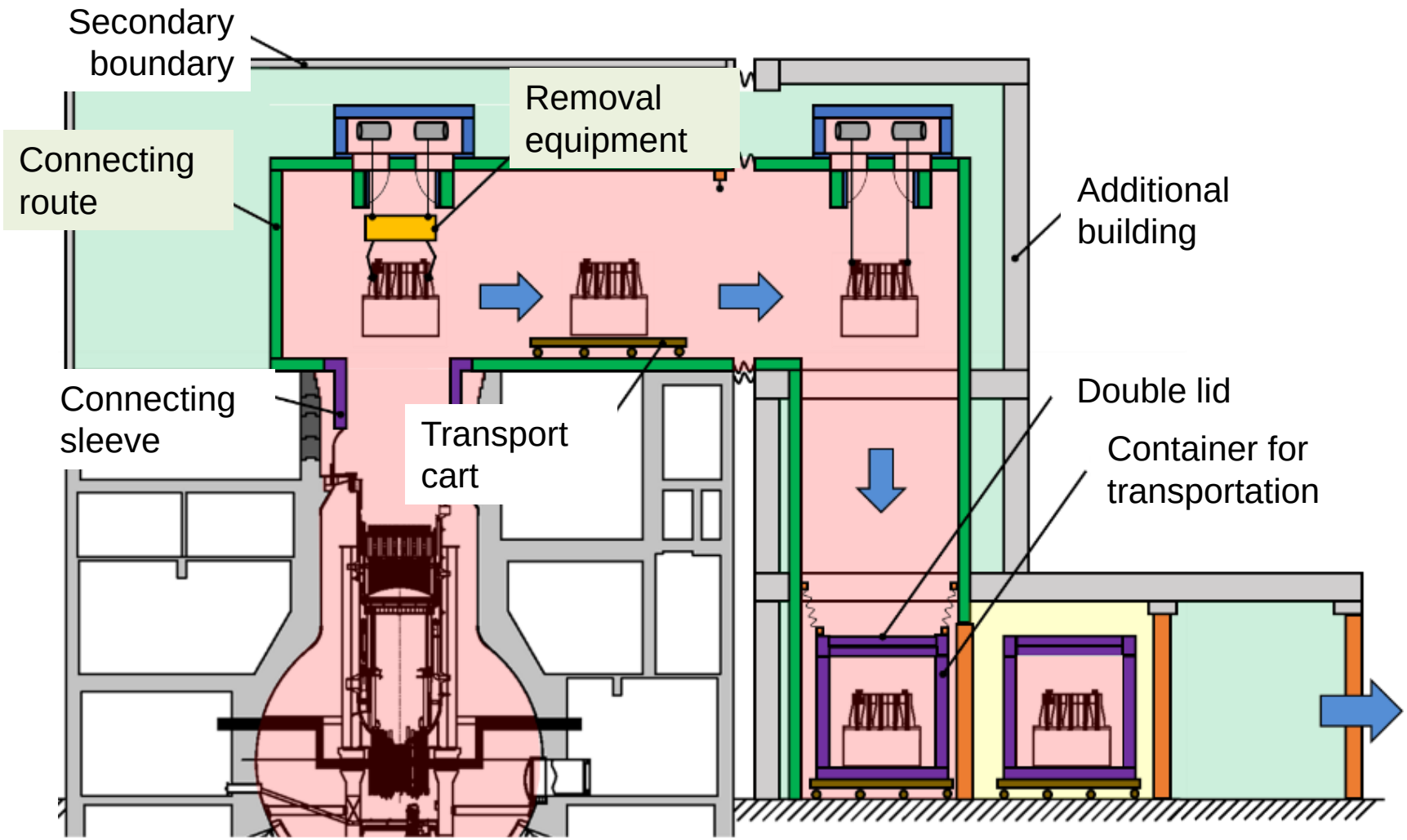
【Example of the top-access method】: Methods for Removing and Transporting the Entire Structures



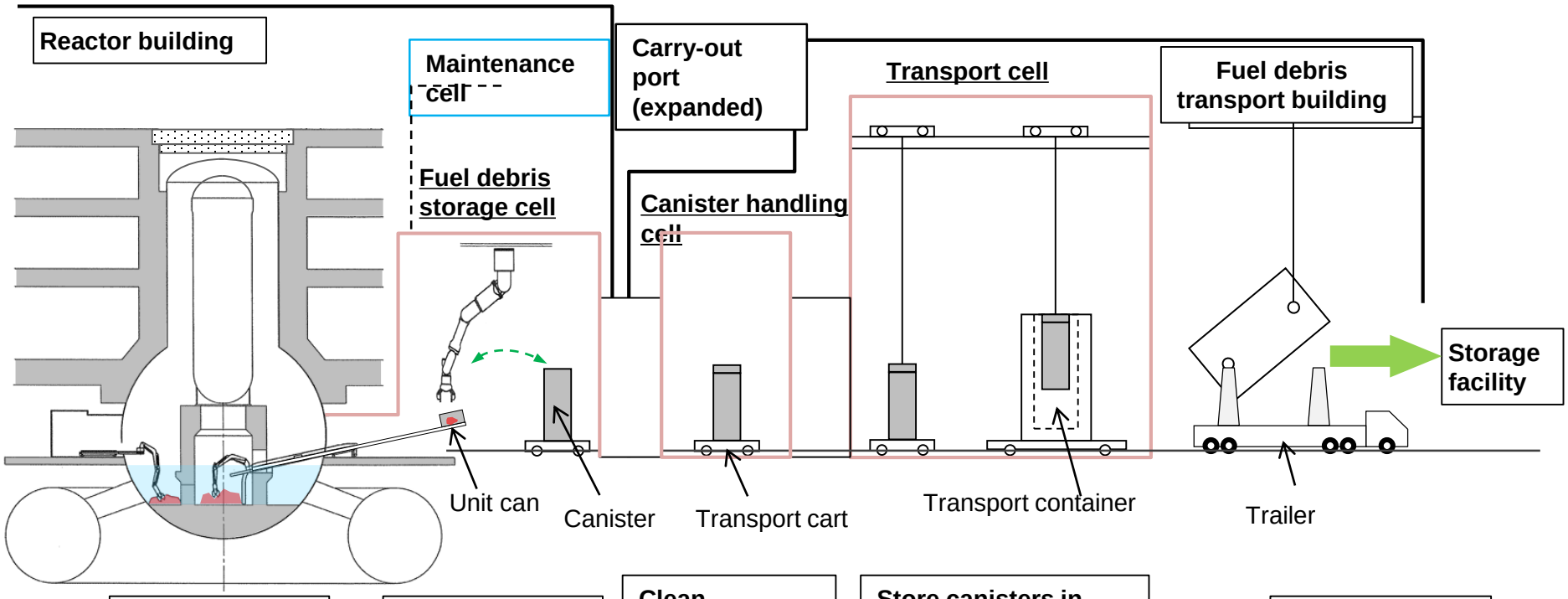
Technology for Containing, Transferring and Storing Fuel Debris

Design of canister

⇒**Responding to issues specific to the Fukushima Daiichi**

- High-burnup and the enrichment→ **High reactivity**
- Molten products mixed with concrete→ **Hydrogen generation** caused by radiolysis of moisture containing concrete
- Molten products with sea water injected and instrumental cables,etc. → Impact of **salt** and contamination of **impurities**

Transport method (Ex. Partial submersion side-access method



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PCV: primary containment vessel

Ensuring the Safety When Retrieving Fuel Debris

Risks necessary to be considered

1. Cooling
   ・・・Decay heat has decreased over a long time after the accident, however it must be cooled for a certain period of time. There is a risk of losing its functions.

1. Confinement
   ・・・There is a risk of releasing dust to be generated when cutting and chipping debris.

2. Fire and explosion (inactivation)
   ・・・There is a risk of fire and hydrogen explosion when cutting and chipping debris.

3. Criticality
   ・・・There is a risk of criticality caused by changing the shape of debris during fuel debris retrieval.

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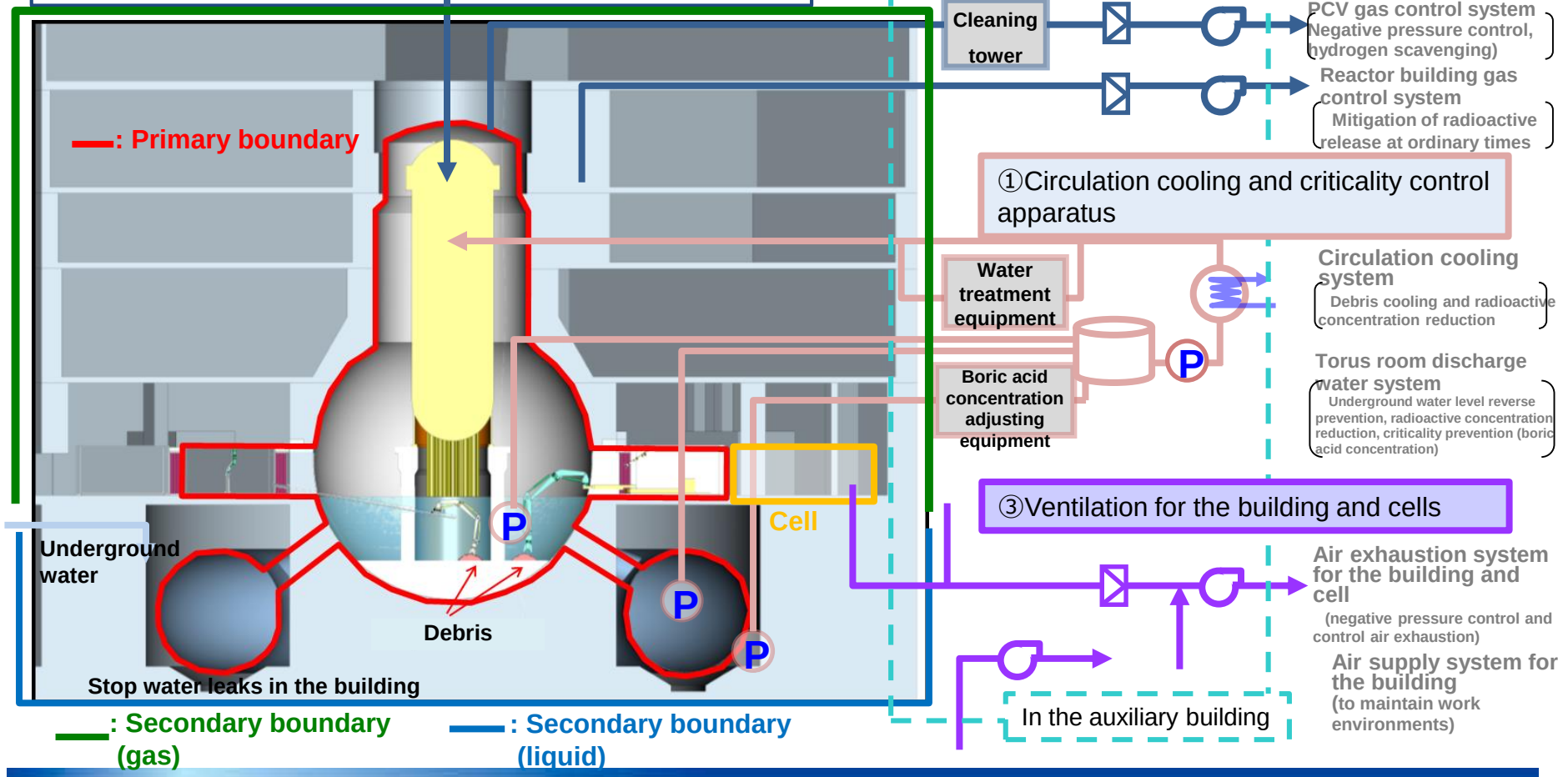
Ensuring the Safety When Retrieving Fuel Debris

Necessary safety functions

1. Cooling
2. Confinement (negative pressure and water level control of the torus room)
3. Inactivation (fire and explosion prevention)
4. Sub-criticality



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End of presentation

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