Overview of IRID R&D
-Focusing on Debris Investigation-

28th April, 2017

Atsufumi Yoshizawa

Executive Director

International Research Institute for Nuclear Decommissioning (IRID)

This achievement is obtained from the Subsidy Project of Decommissioning and Contaminated Water Management by Ministry of Economy, Trade and Industry (METI).

Contents

1. Introduction
2. Approach to Confirm Unit 1 Debris Distribution
3. Approach to Unit 2 & 3
4. Lessons and Future Plan

Contents

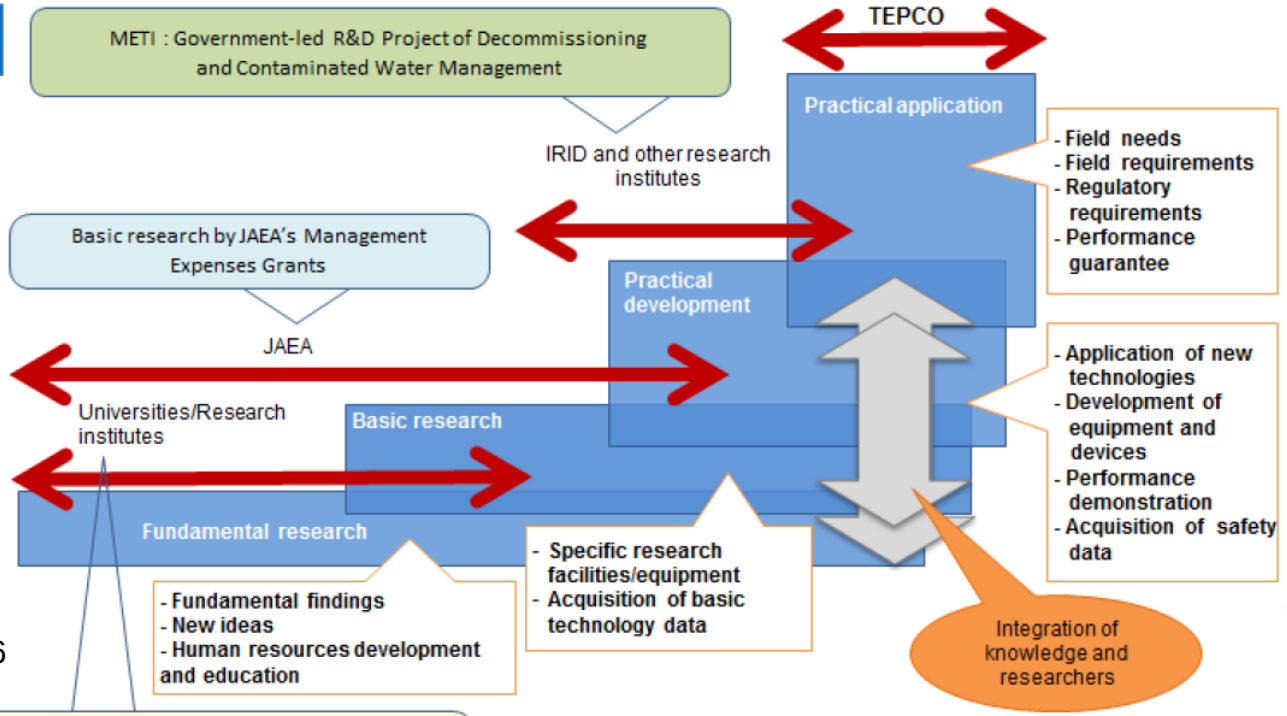
IRID R&D Scope

Decommissioning Work

- Maintaining cold shut-down of the reactor
- Accumulated water treatment (contaminated water management)
- Reduction of radiation dose and prevention of spreading contamination for a whole plant
- Fuel removal from spent fuel pool
- Fuel debris retrieval
- Solid waste management (storage) and disposal (treatment) plan
- Decommissioning plan for nuclear facilities

R&D is led by IRID

Overview of R&D



Resource: NDF strategy plan 2016

IRID R&D Projects (Overview)

1.R&D for fuel removal from spent fuel pool (1PJ)

Evaluation of **Long-term Structural Integrity** of the Fuel Assemblies Removed from Spent Fuel Pool

2 .R&D for Preparation of Fuel Debris Retrieval(12PJ)

Technology for Decontamination and Dose Reduction

- **Remotely Operated Decontamination Technology in R/B**

Completed in March 2016

Repair and Water Stoppage Technology

- Technology for **Repair and Water Stoppage** For PCV Leakage Points
- **Full-scale test** For Repair Technology for PCV Leak Points

Fuel Debris Retrieval Technology

<Ensuring of Stability>

- **Corrosion Control** Technology in RPV/PCV
- **Technology for Seismic Resistance** Impact Assessment in RPV/PCV
- **Criticality Control** Technology for Fuel Debris <Fuel Debris Retrieval>

Investigation and Analysis Technology

<Direct Investigation>

- **Investigation Technology** Inside the PCV
- **Investigation Technology** Inside the RPV

<Indirect Investigation>

- **Detection Technology in R/B For Fuel Debris**
- Upgrading For **Identifying Conditions Insides the reactor**
- **Characterization** Of Fuel Debris

- **Approach and System** For Retrieval of Fuel Debris and Internal Structures
- **Fundamental Technologies** For Retrieval of Fuel Debris and Internal Structure
- Technology for **Collection, Transfer And Storage** of Fuel Debris

3 R&D for Radioactive Wastes(1PJ)

- **Treatment and Disposal of Solid Radioactive Wastes**

14 Projects

Background/Purpose

In order to determine the policy and method of fuel debris retrieval, **it is essential to ascertain** the distribution of fuel debris, **inside the reactor, etc.**

Direct Observation

- Investigation inside RPV
- Investigation inside PCV

Indirect Measurement

- Muon imaging

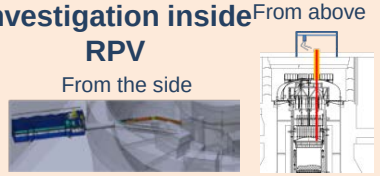
Feed back process

Estimation/evaluation of fuel debris distribution (position/quantity/composition, etc.) from **accident progress analysis** and actual data, etc.

Investigation inside RPV

From the side

From above



Investigation inside PCV

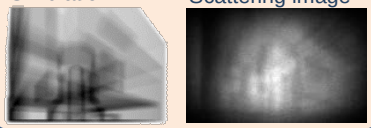
Pedestal exterior

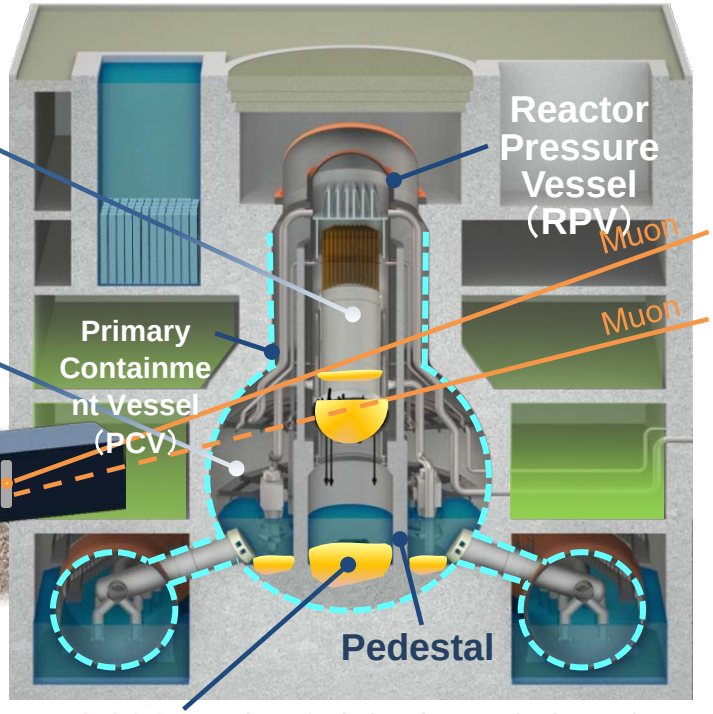
Pedestal interior

Visualizing RPV interior using cosmic ray muons

Simulation

Scattering image



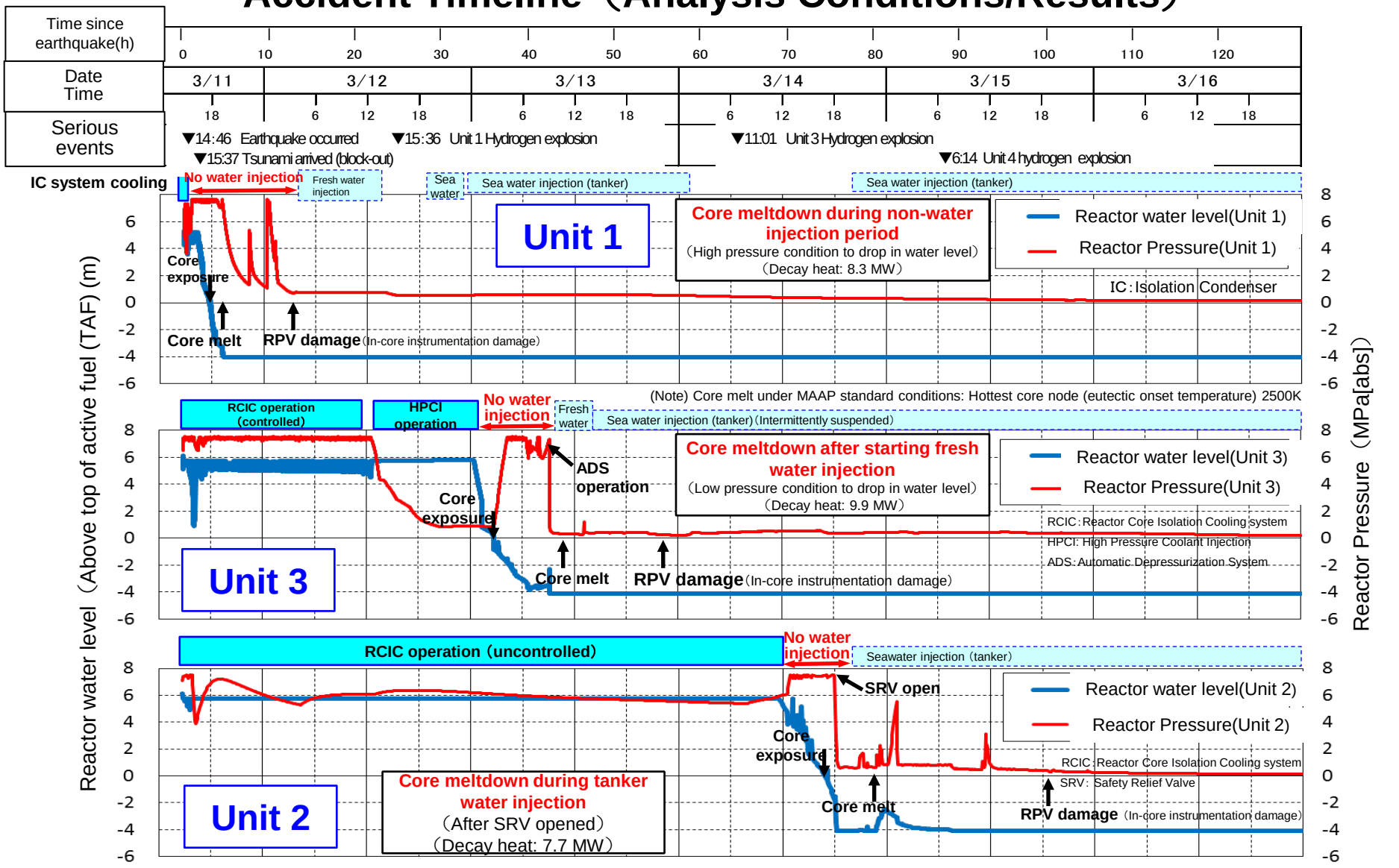


Fuel debris: Nuclear fuel that has melted together with part of reactor internal structure due to the loss of reactor coolant and then solidified again

Providing information that contributes to decommissioning work

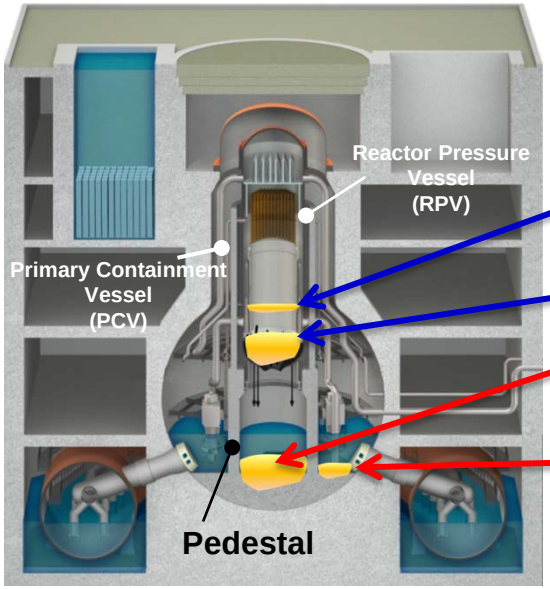
Analysis Result Overview

Accident Timeline（Analysis Conditions/Results）



Upgrading for identifying overall conditions of inside the reactor

Reactor Building (R/B)



: Inside the RPV : Outside the RPV (unit: ton)

	Unit 1	Unit 2	Unit 3
Location	Representative value*	Representative value*	Representative value*
Reactor Core	0	0	0
RPV bottom	15	42	21
Inside the Pedestal	157	146	213
Outside the Pedestal	107	49	130
Total	279	237	364

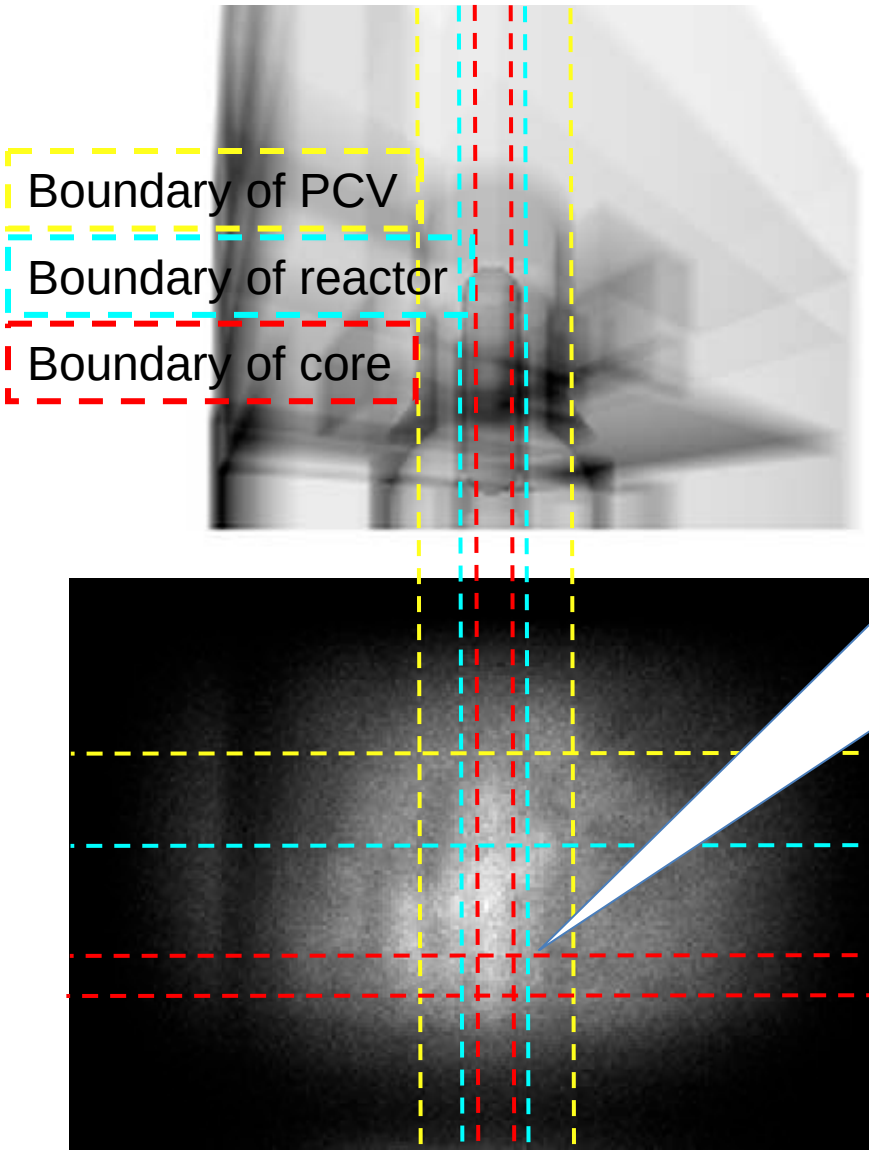
“Representative value”: a value that is most likely to be certain as of now.
“Assumed weight”: fuel + melted and solidified structural materials (including concrete component)

- Comprehensive analysis and evaluation based on analysis results and actual investigation data (temperature data, measurement through Muon technology, investigation inside the PCV and etc.).

Most of debris exists in the **bottom of pedestal** (more than 80%).

Contents

Detection of Fuel Debris using cosmic ray MUON



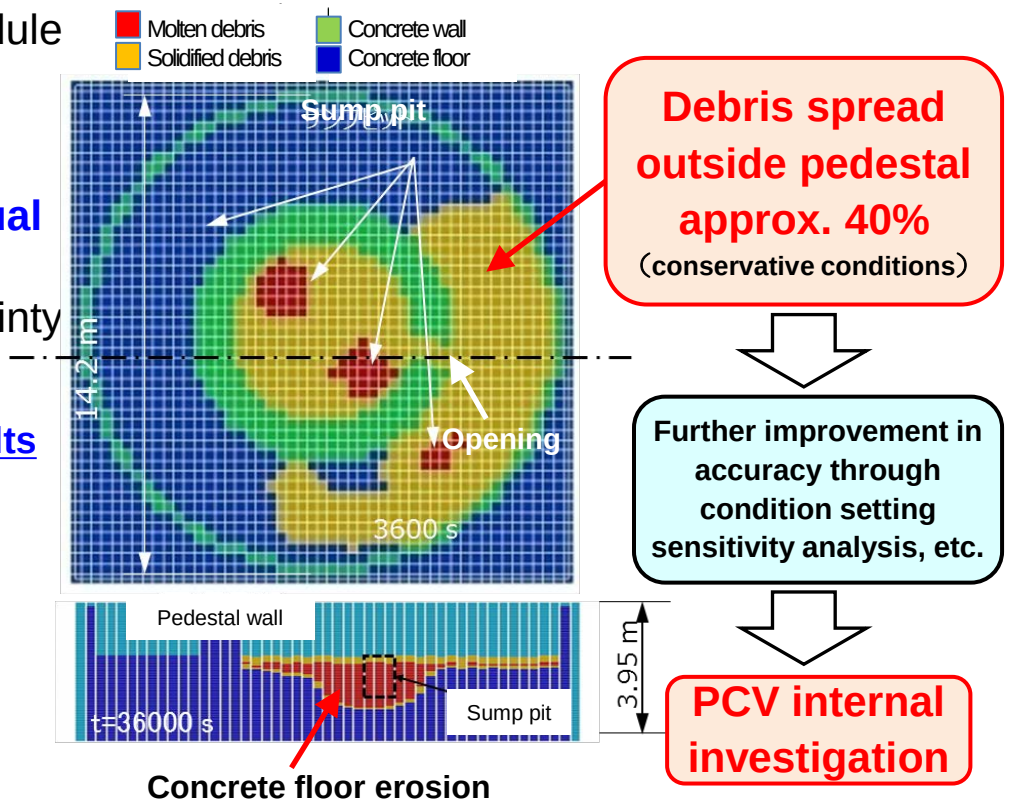
High density material (fuel) was not detected at the area where the reactor core had been originally located.

Unit 1 Analysis/Evaluation Results

（Molten Core Concrete Interaction（MCCI）Analysis Result）

- **Eroded concrete convection flow/spread model added to** highly versatile DSA module in SAMPSON code
- **Validation through MCCI test results**
- **Evaluation of MCCI evaluation in actual sump system and determine spread of debris in PCV**（Supplements the uncertainty in MAAP analysis）

MCCI assessment/Evaluation of fuel debris spread in PCV

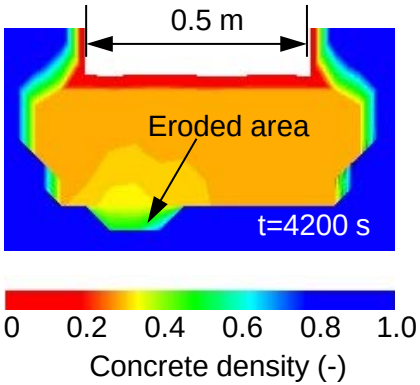


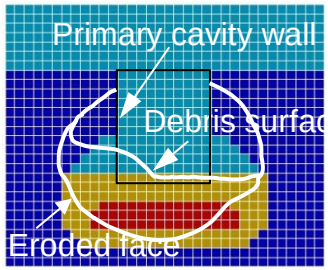
⇒ Leakage from sand cushion drain pipe has been confirmed; possibility that fuel debris has flowed out to the drywell side. (However, from PCV pressure behavior after the accident, it is assumed that possibility of large-scale shell attack is small)

Validation through OECD/MCCI CCI-2 test results

Final surface form of debris

predicted within 13% accuracy





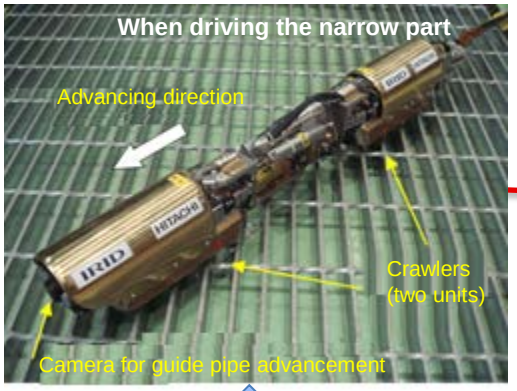
White line: test observation data

Melted debris　Solid debris
Concrete

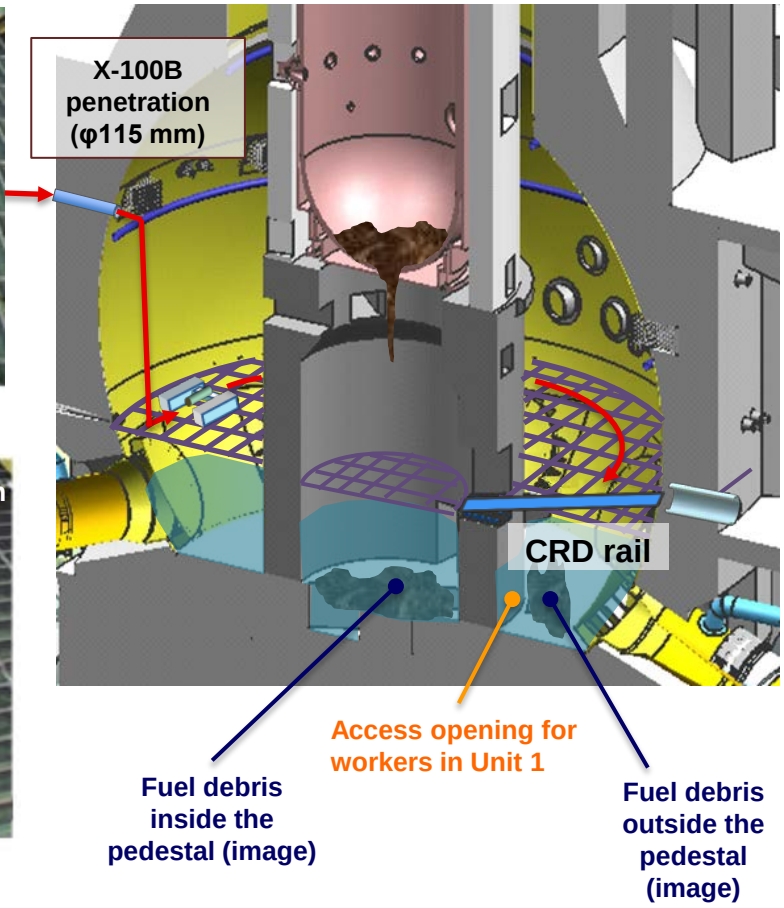
Development of technology for investigation of inside the PCV —Investigation robot—

Investigation of outside the pedestal (unit 1)

○ **Shape-changing robot (B2 investigation)**



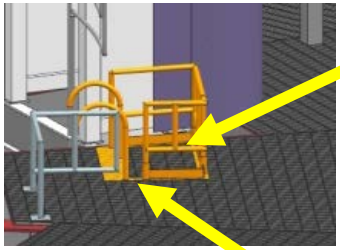
(Note): the robot in B1 investigation is shown in the above photo.



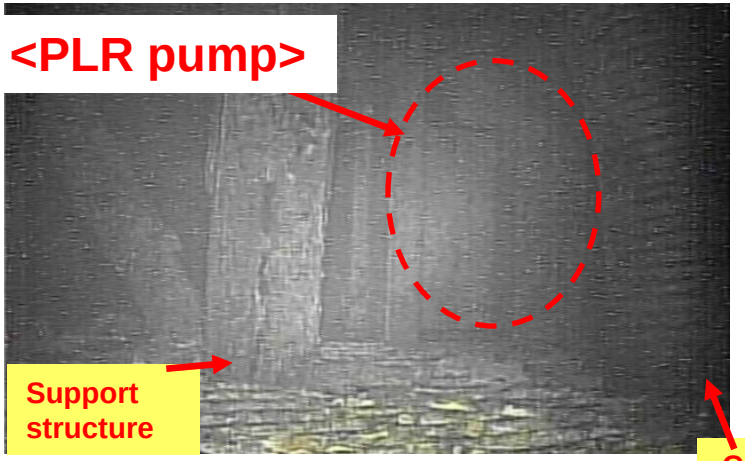
Achievements of the investigation in 2015

Item	Observed result
Opening on grating to the lower floor	**<Potential access path>** to the lower floor during next step investigation **No interference around the opening**
CRD rail	**<Potential access path>** to the inside of pedestal **Could not be observed well** (difficult access due to narrow access route)
General observation	**<Existing components>** **No serious damage** (PLR pump & piping, pedestal wall, HVH, etc.,) **<measurement results at 12 locations>** **Temperature 17.8~21.1 ℃** **Dose rate 4.7~9.7 Sv/hr**

<Opening>



<PLR pump>



<CRD rail>

(Mock up facility)

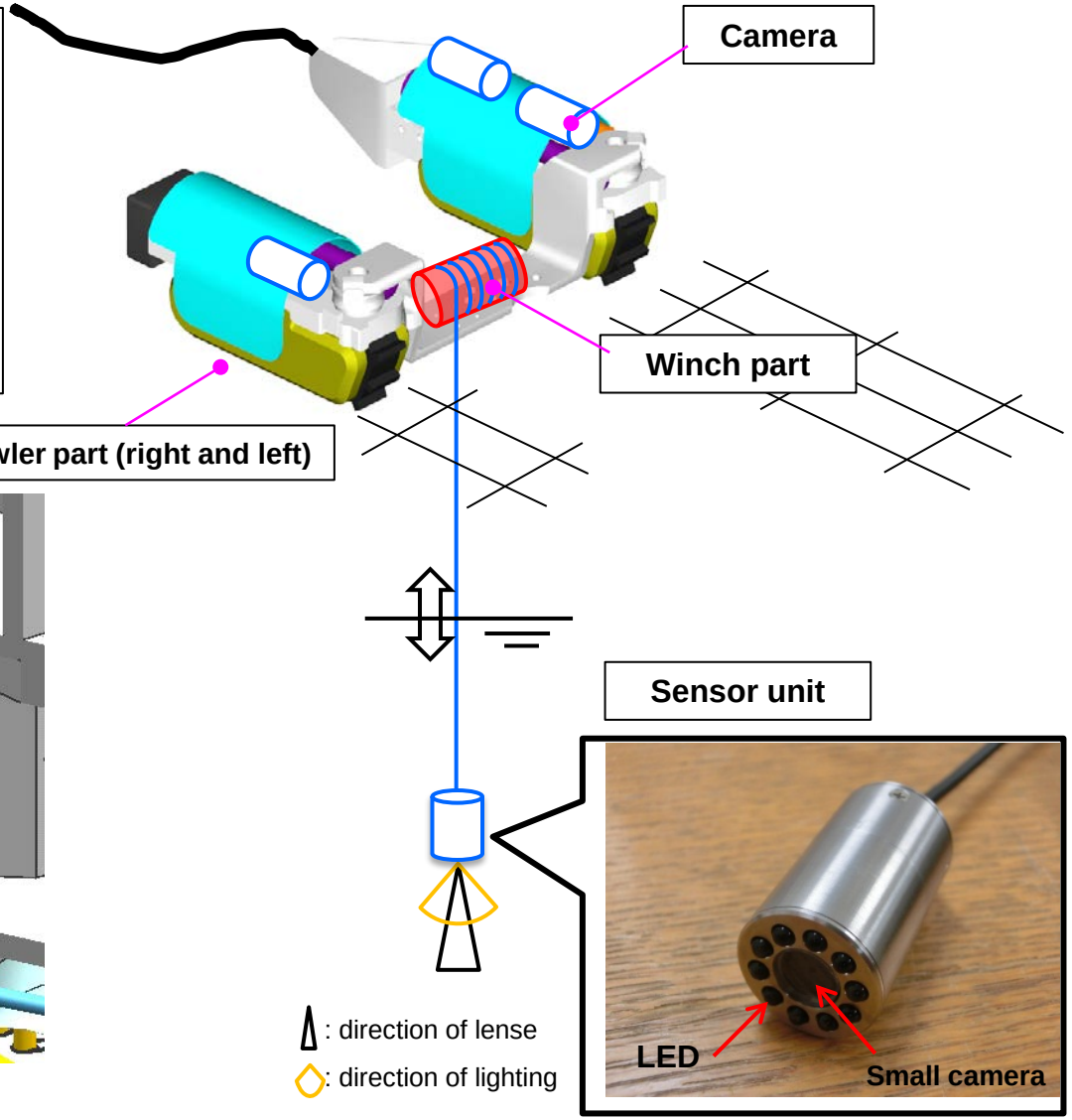
Investigation of outside the pedestal in 2017

[Investigation methods]

- Three-dimensional measurement of dose rate
- Photo shoot by underwater camera

[Commencement]

- March 2017 (completed)



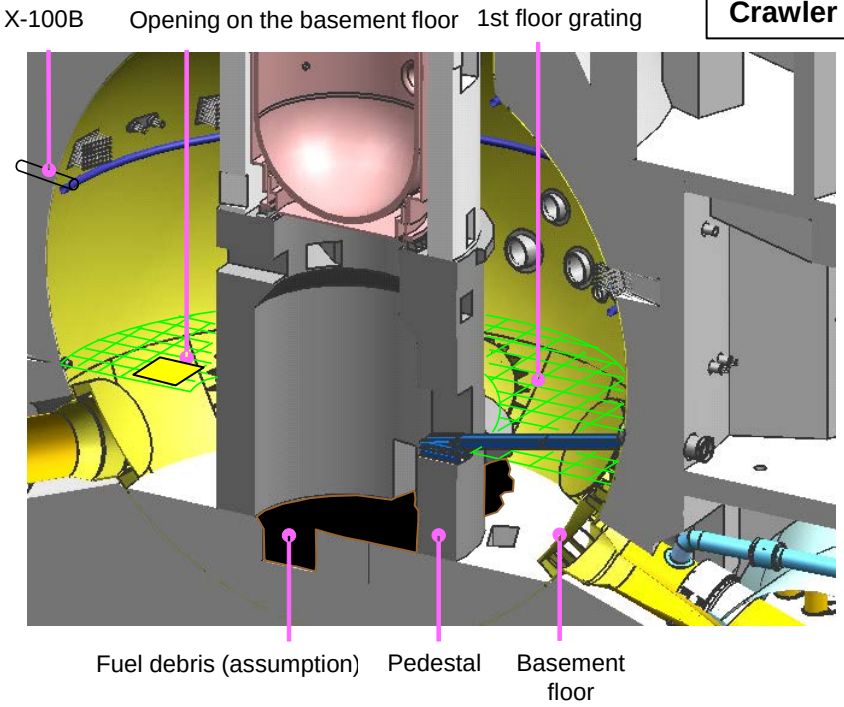
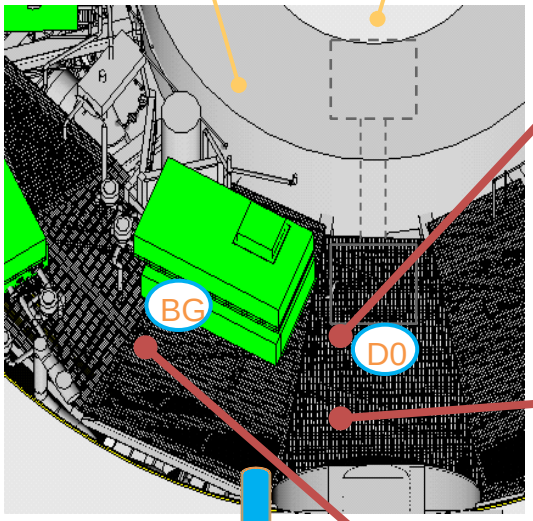


Image measurement results (1/2)

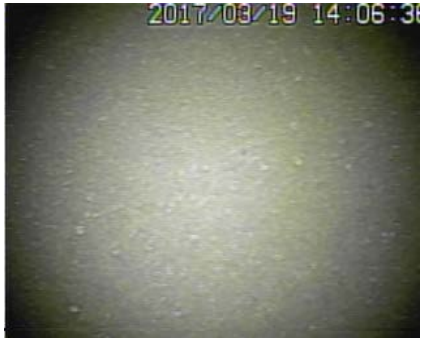
- Typical images captured



3/18 D0① Image near lowest point

3/22 D0② Image near lowest point

3/22 D0③ Image near lowest point



3/19 BG Image near lowest point

・Measurement point details are currently being evaluated

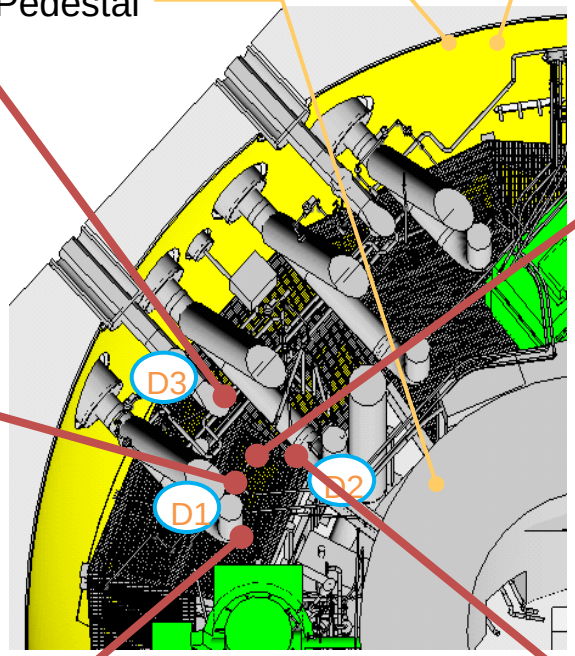
Image measurement results (2/2)

- Typical images captured

3/21 D3 Image near lowest point

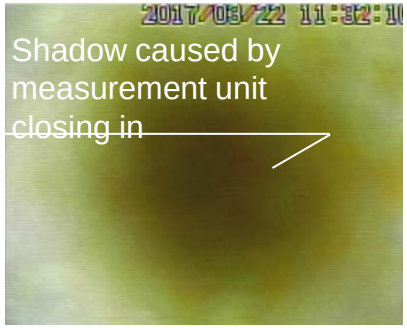
3/21 D1② Image near lowest point

3/21 D1① Image near lowest point



Cross-section of PCV 1st floor

・Measurement point details are currently being evaluated



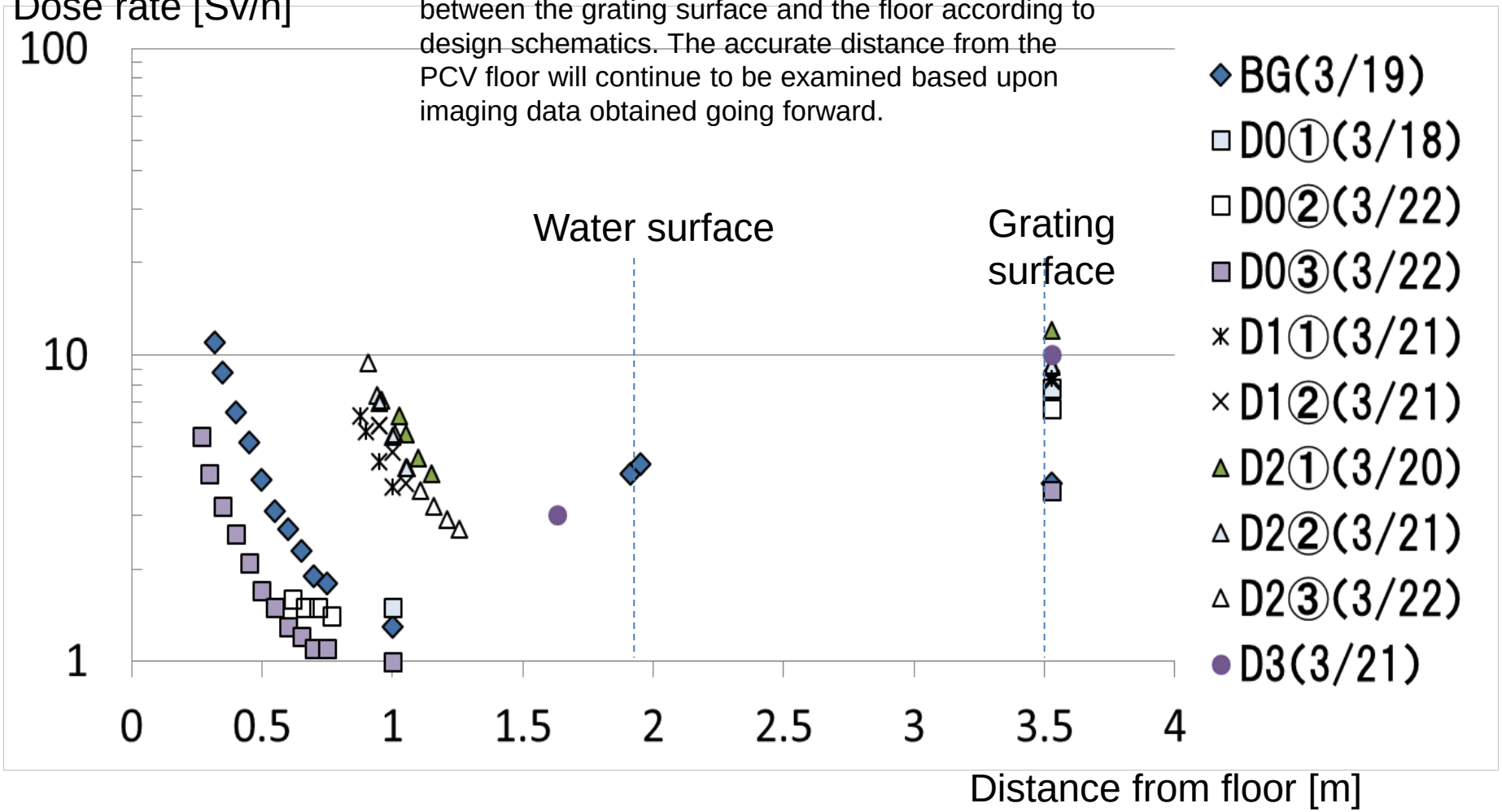
3/22 D2③ Image near lowest point

3/21 D2② Image near lowest point

3/20 D2① Image near lowest point

Dose measurement results

The data is calculated by subtracting the length of cable let out from the measuring unit from the distance between the grating surface and the floor according to design schematics. The accurate distance from the PCV floor will continue to be examined based upon imaging data obtained going forward.



Results of Unit 1 investigation

This was the first time that images were captured of conditions on the PCV floor near the pedestal opening.

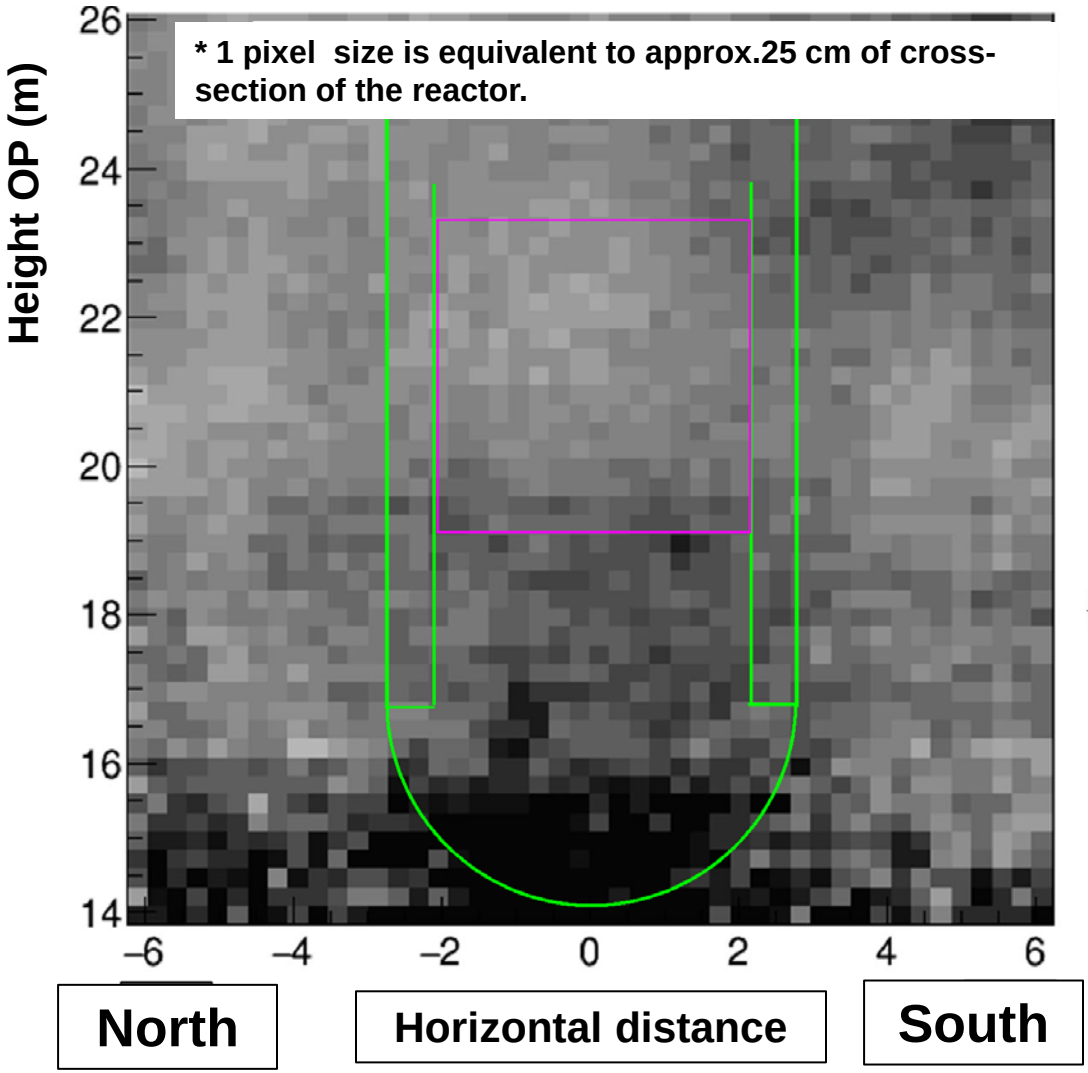
- No significant damage was found in the existing structures.
- Deposits were found at the bottom of the PCV and on piping, etc.
- The dose rate dropped when entering the water. However, it rose again when nearing the bottom of the PCV.
- Conditions on the PCV floor will continue to be examined based on image and dose rate data obtained going forward.

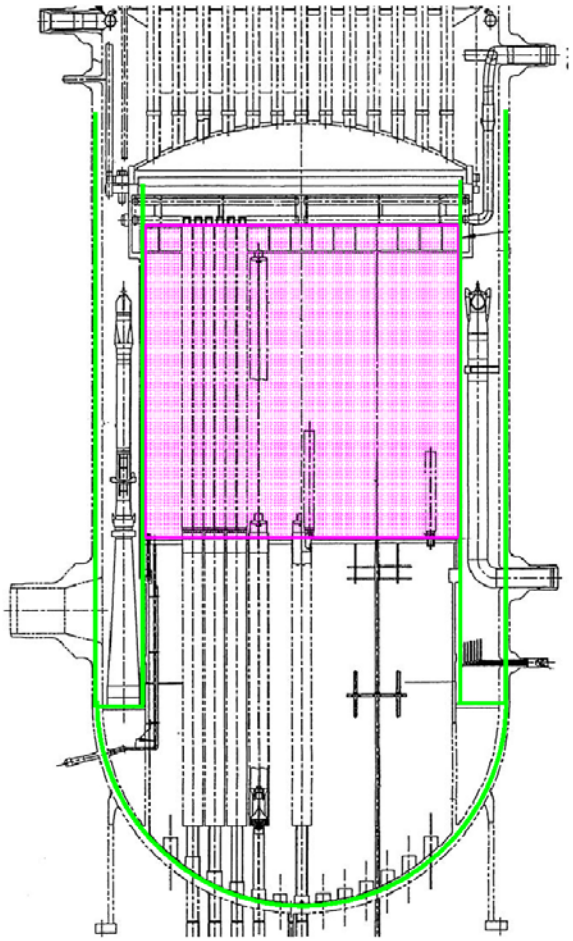
Contents

Investigation using MUONS at Unit 2

- **Confirming the high density material shadow that is assumed to be fuel debris at the bottom of RPV.**

(Measurement result: as of July 22, 2016)





Structure of lower part of RPV

Source: Publicized results by TEPCO Holdings, July 28, 2016

Investigation of the PCV Interior (Unit 2)

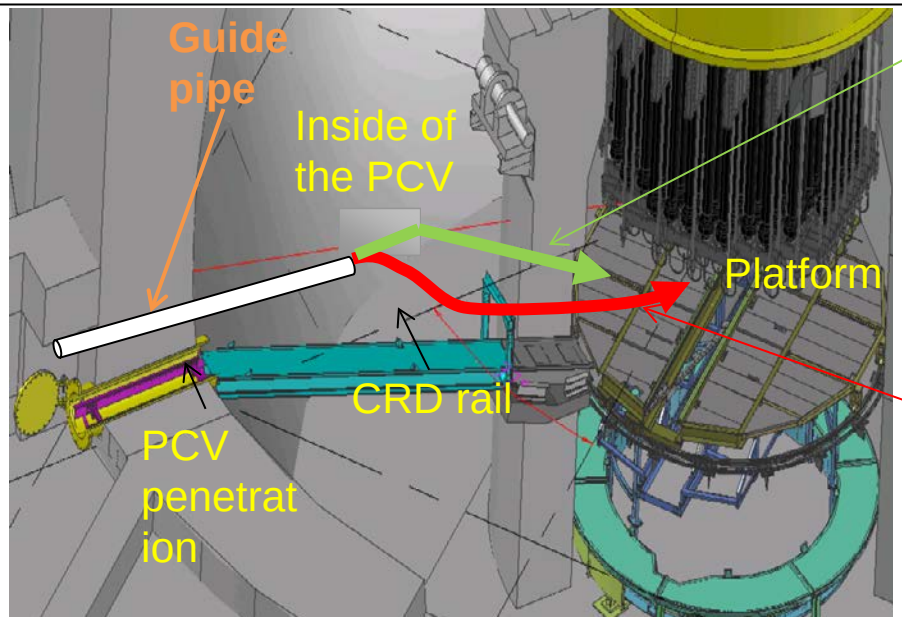
Jan.-Feb. 2017

[Investigated area] : - On the platform (Upper surface of platform, CRD housing)
- Basement floor

(1) Preliminary observation using telescopic camera before introducing the robot
- Insert debris visualization system, investigate inside pedestal.

(2) Introduce sediment removal robot to remove obstacles on the CRD rail if necessary
- Depending on the preliminary observation

(3) Investigation using crawler-type robot called “SASORI”
- SASORI means scorpion in Japanese.

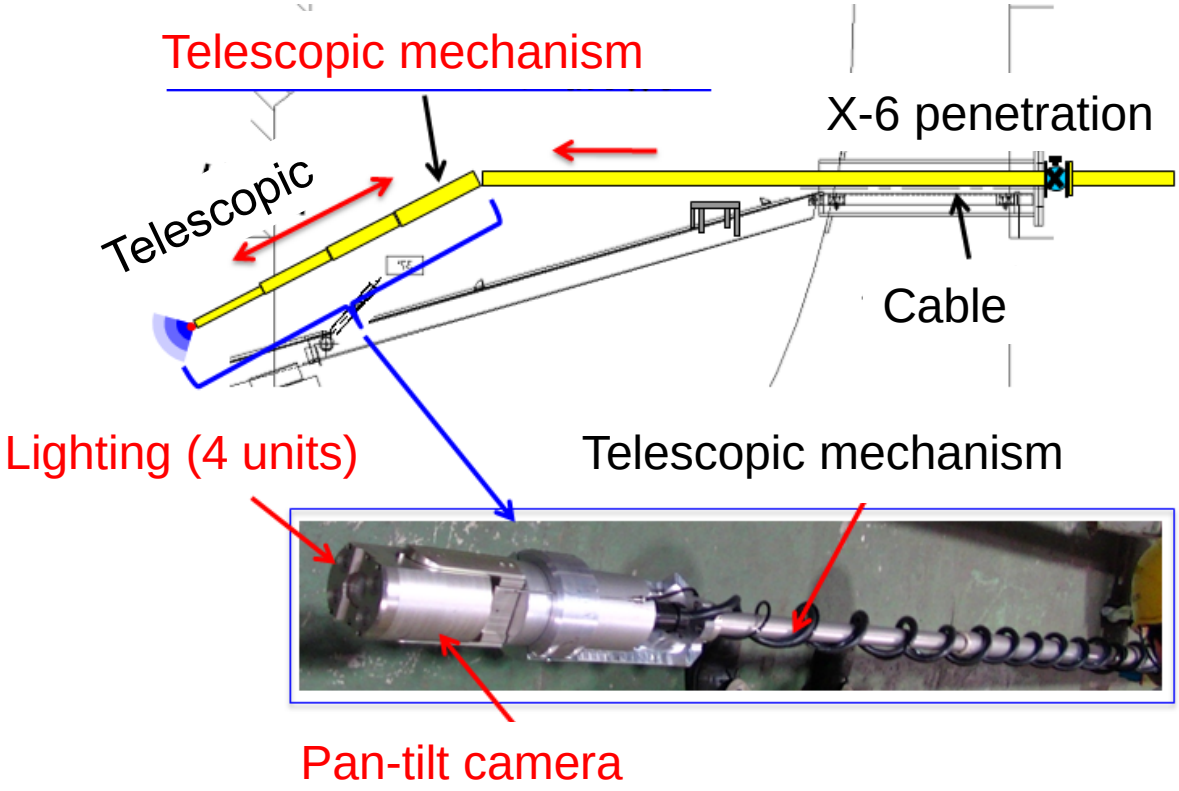


Access route to preliminarily confirm the pedestal interior

Access route for the crawler-type remotely-operated investigation robot

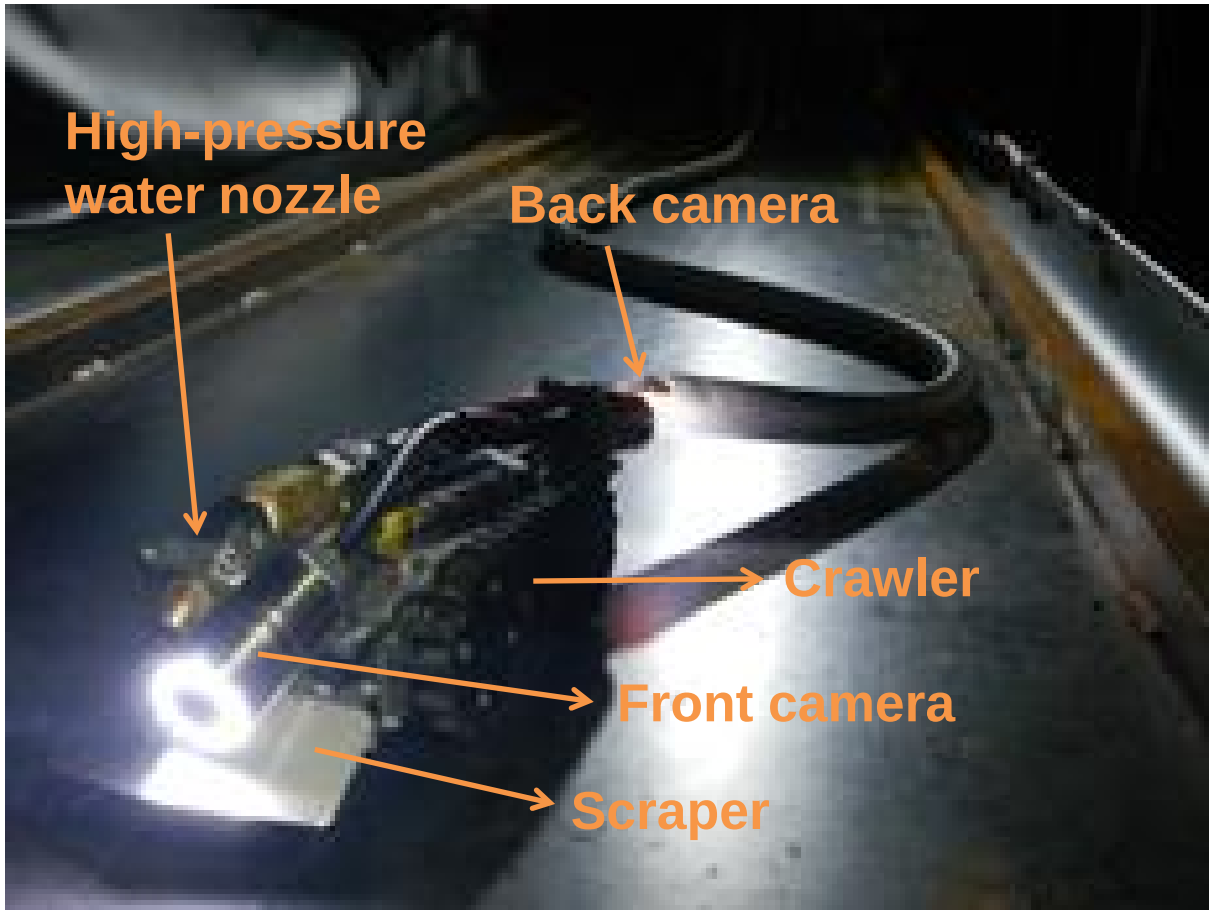
21

Preliminary observation

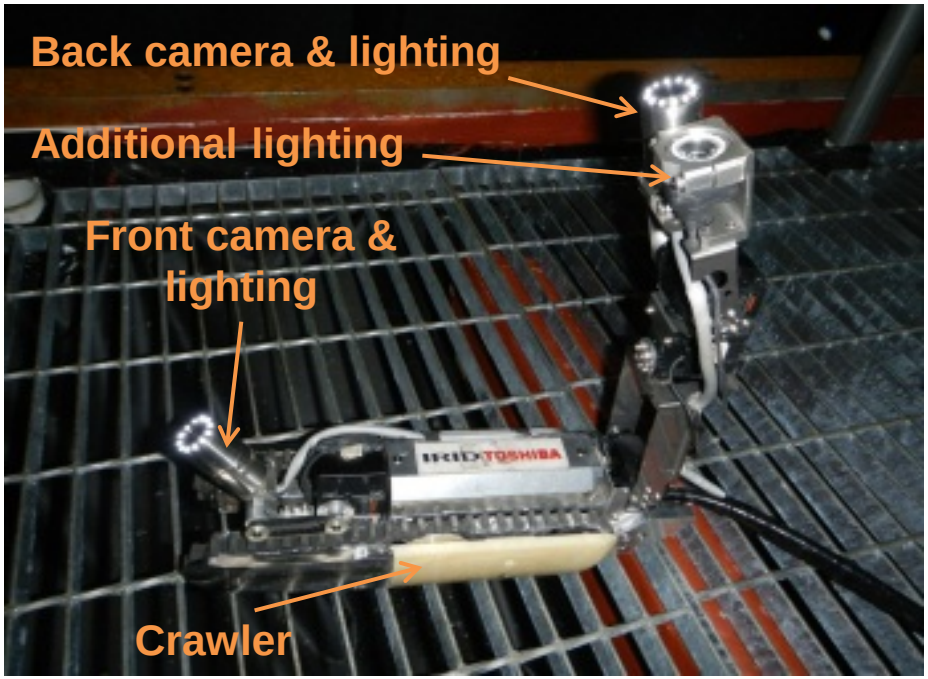


Equipment to preliminarily survey the pedestal interior

Sediment Removal Robot



Crawler-type remotely-operated investigation robot “SASORI: Scorpion”



・It has linear slender shape to go through a guide pipe with an inner diameter of about 100 mm.

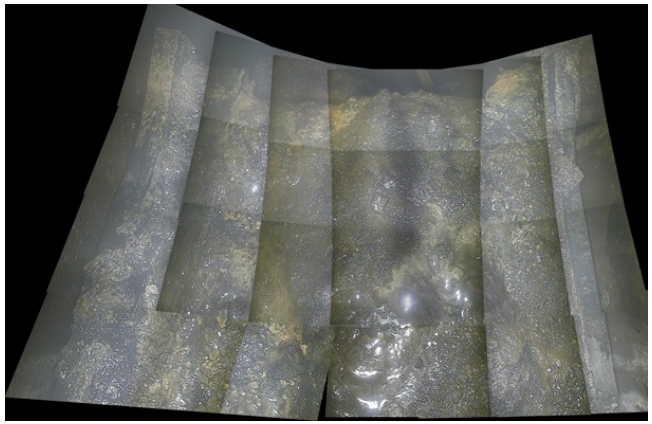
・Tail part of the body bends forward to obtain high spatial perception vision when investigation. (reason for calling SASORI)

・Cumulated radiation tolerance is 1000 Gy or more.

24

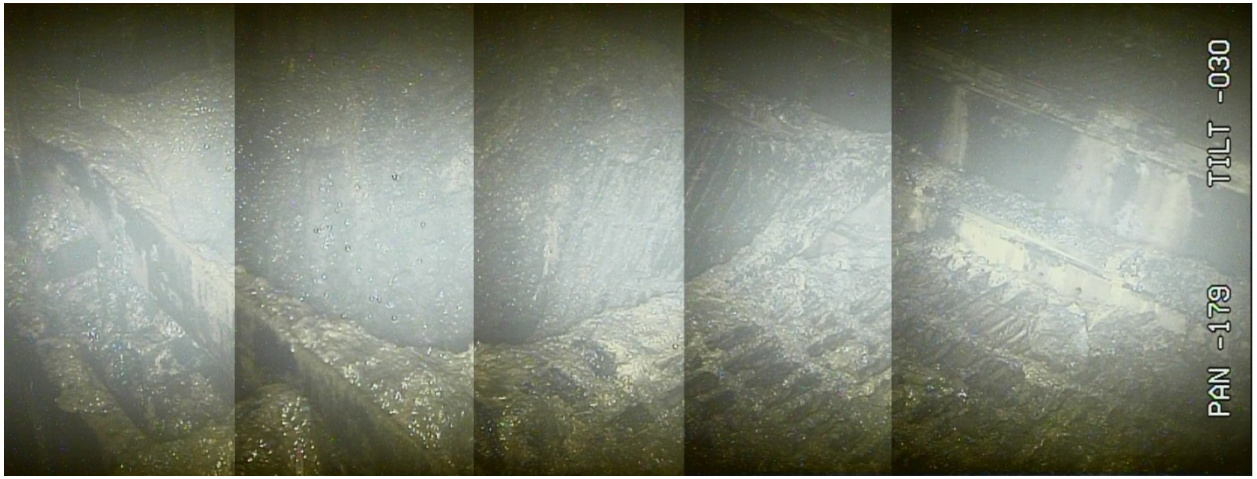
Images obtained by observation , 2017

Accretion of the grating



Sediments on CRD rail

Lack of platform grating



Deformed platform

Gap between platform and CDR rail

Inside pedestal (upper section of platform, middle-right side)

- As there are areas to the right of the TIP guide pipe support (28-27) that do not receive any light, it is difficult to identify individual cables. However, it is likely that there is less damage to cables here than on the left side.

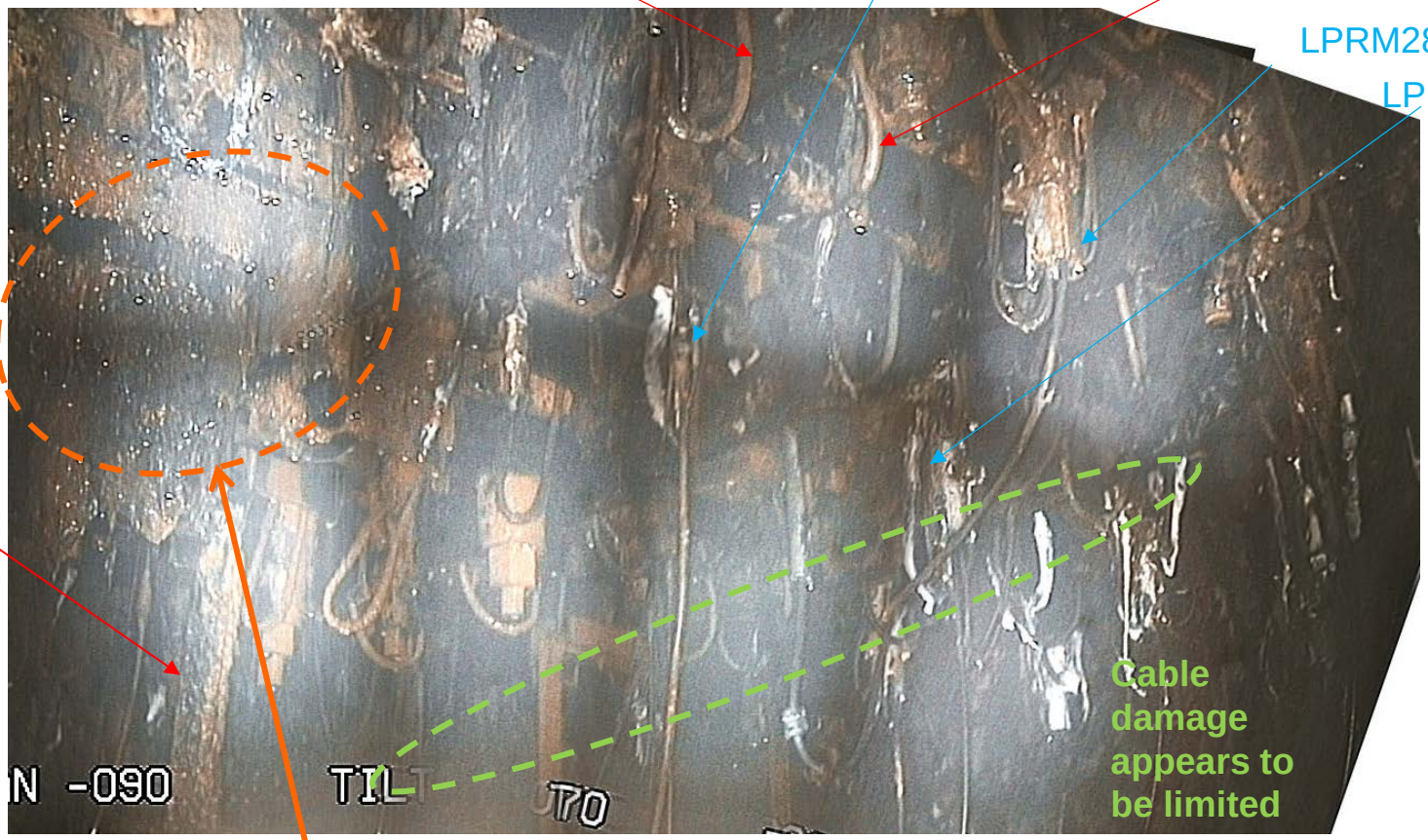
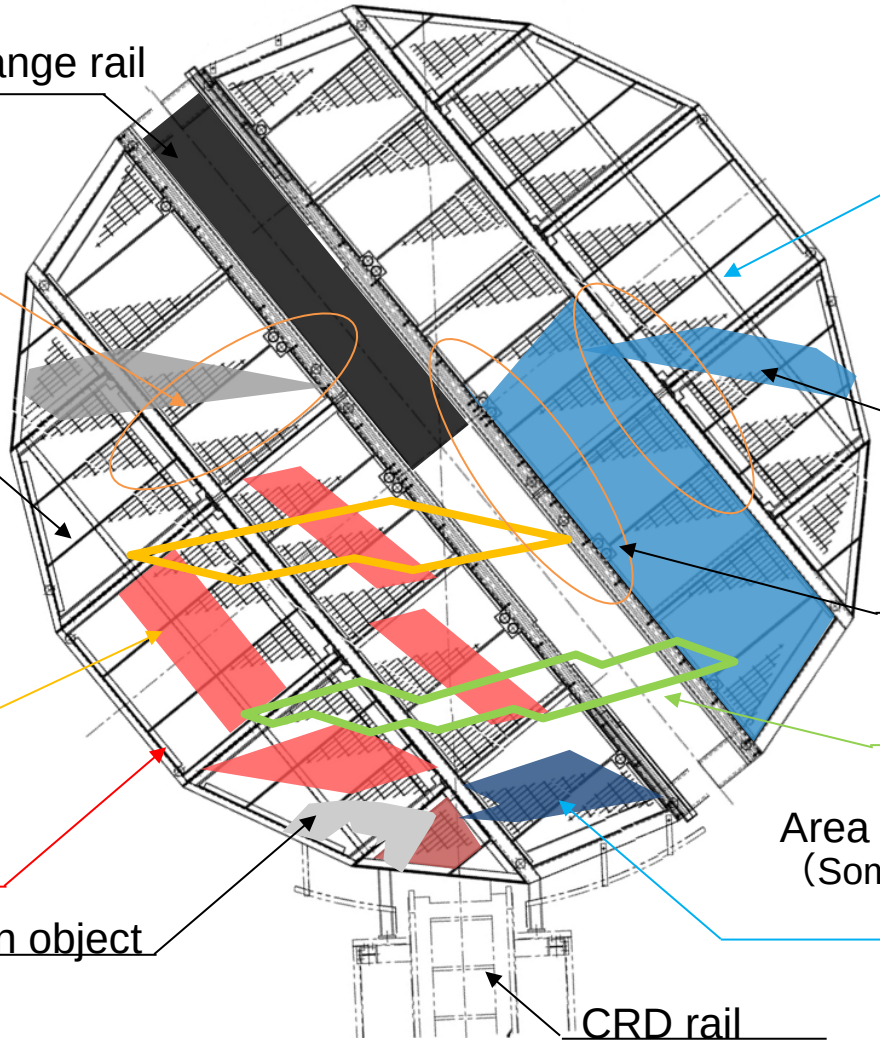


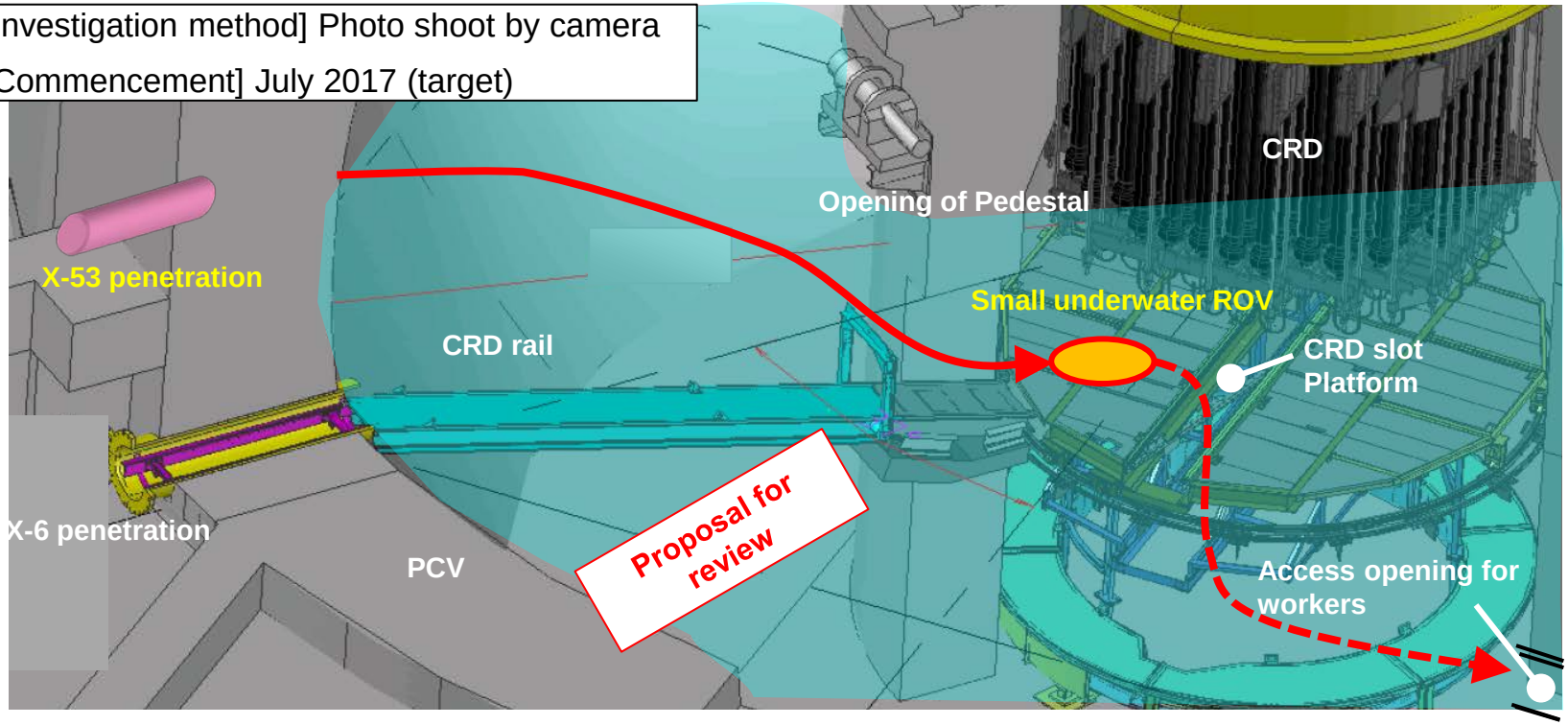
*Image processing: TEPCO Holdings

Currently confirmed results of investigation



Investigation of the inside the pedestal at Unit 3.

[Investigation method] Photo shoot by camera
[Commencement] July 2017 (target)



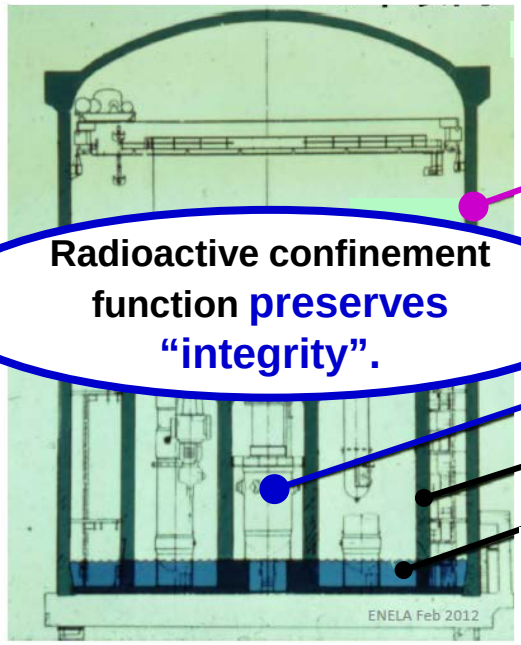
[Investigation route (proposal)]
(1) Access from the X-53 penetration.
(2) Going inside the pedestal.
(3) Checking the access route to the basement floor of pedestal.
(4) Entering the basement floor of the pedestal.

[Investigation Items (proposal)]
(1) Status of damage **on the platform and the lower CRD.**
(2) Presence of **obstacles at CRD slot opening.**
(3) Conditions of **debris accumulated at the bottom of pedestal.**
(4) Conditions **of debris** from the access opening for workers to the outside pedestal.

Contents

What are difficulties of fuel debris retrieval in 1F?

TMI-2



Reactor Building (PCV)

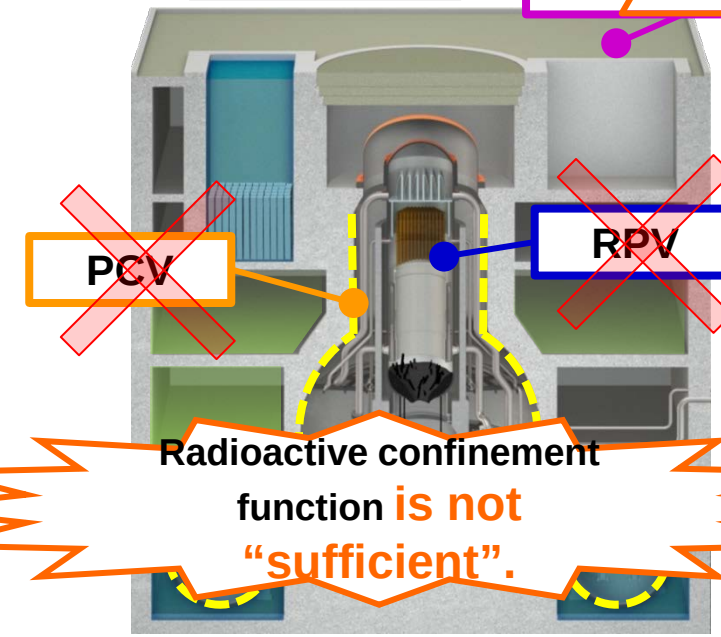
Radioactive confinement function **preserves "integrity".**

RPV

Shield Wall

Contaminated Water

1F-1,2,3



Reactor Building

PCV

RPV

Radioactive confinement function **is not "sufficient".**

TMI-2		1F-1,2,3
Approx.133 ton	Total Amount of Debris	Approx.880 ton（3units）
Mostly in RPV, partly in piping	Range of Debris distribution	Fallen in pedestal bottom and caused concrete erosion
（Dose on operation floor）After decontamination/shielding※ :Approx.1mSv/h	Radiation dose	（Dose on operation floor）Current rate :Dozens～hundreds mSv/h

※：Right after the accident: Dozens mSv/h

Conclusions

- ✓ Each PCV internal survey has been progressing.
- ✓ The existence of debris is still mainly evaluated based on analysis and the indirect method.
- ✓ We have studied the development of new kinds of detectors and introduction of new robotics technologies.
- ✓ We will consider ways to obtain detailed internal information more accurately and faster.