IRID

WECC 2015
Kyoto, Japan

Research and Development Programs for Decommissioning of Fukushima Daiichi Nuclear Power Station

International Research Institute for Nuclear Decommissioning

Executive Director

Kiichi Suganuma

Outline of IRID

1. Name

International Research Institute for Nuclear Decommissioning (IRID)

2. Location of Main Office

5F 3Toyo Kaiji Building, 23-1 Nishi-shinbashi 2-chome, Minato-ku
Tokyo 105-0003, Japan
website: http://www.irid.or.jp/en

3. Membership (18)

Research Institutes: Japan Atomic Energy Agency (JAEA),
National Institute of Advanced Industrial Science and Technology

Manufacturers, etc.: TOSHIBA Corporation, Hitachi-GE Nuclear Energy, Ltd.,
Mitsubishi Heavy Industries, Ltd., ATOX Co., Ltd.

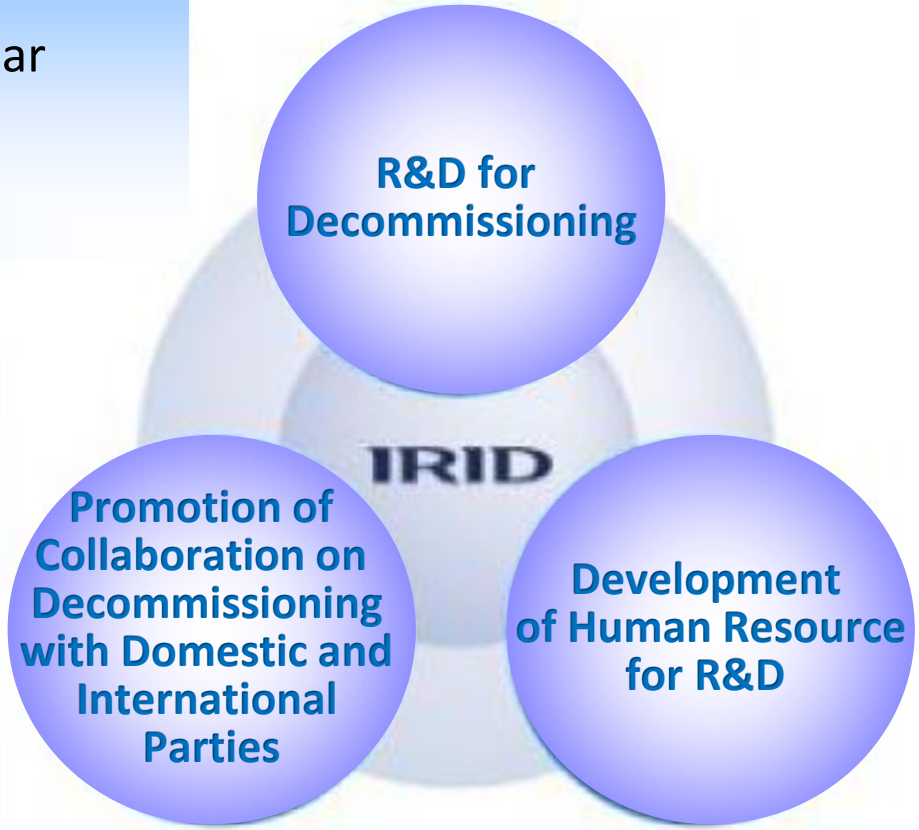
Electric Utilities, etc.: Hokkaido Electric Power Co., Inc., Tohoku Electric Power Co., Inc.,
Tokyo Electric Power Co., Inc., Chubu Electric Power Co., Inc.,
Hokuriku Electric Power Company, Kansai Electric Power Co., Inc.,
The Chugoku Electric Power Co., Inc., Shikoku Electric Power Co., Inc.,
Kyushu Electric Power Co., Inc., The Japan Atomic Power Company,
Electric Power Development Co., Ltd., Japan Nuclear Fuel Limited

Scope of Business

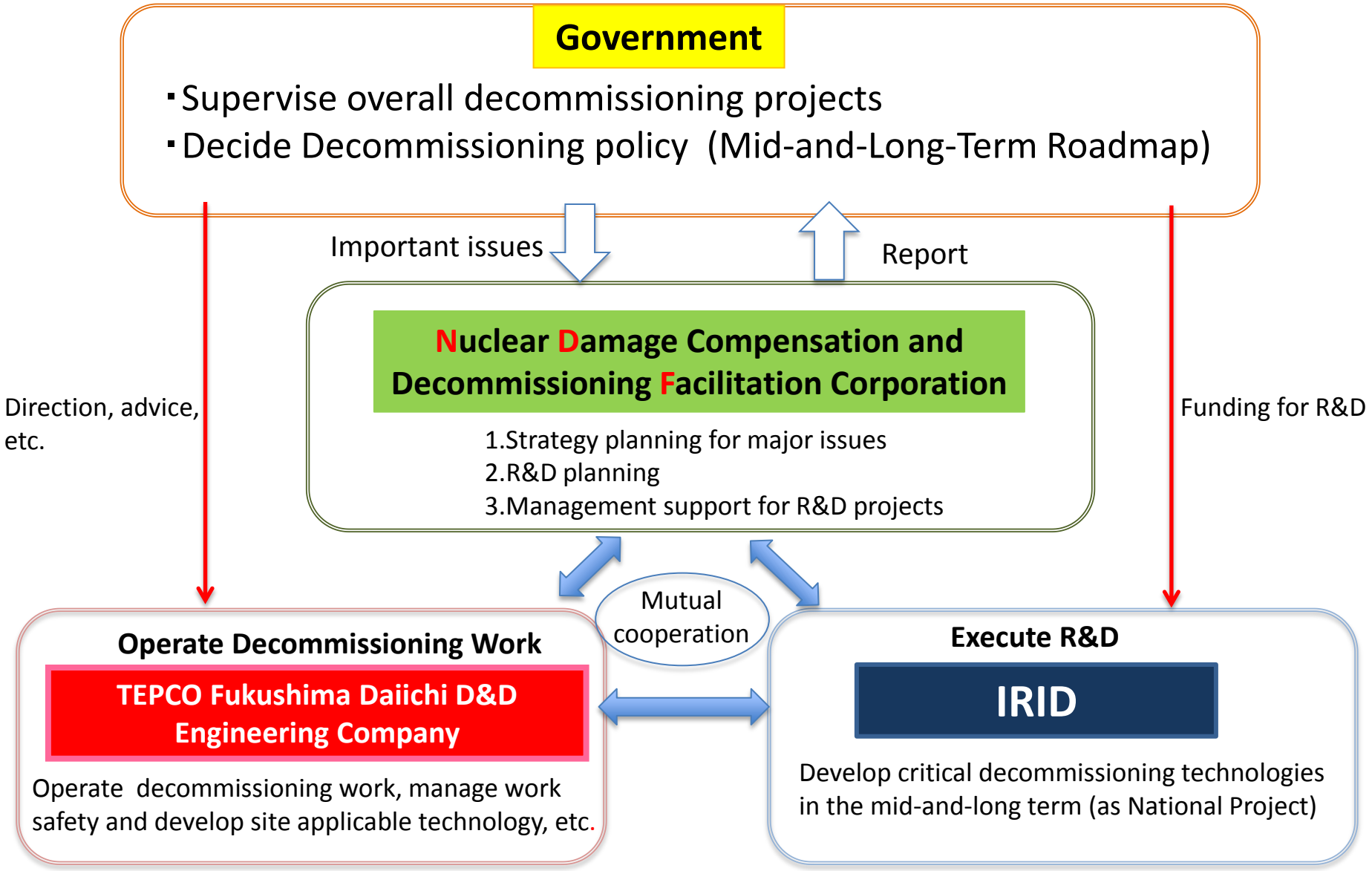
IRID gathers knowledge and ideas from around the world for the purpose of R&D in the area of nuclear decommissioning under the integrated management system.

R&D projects:

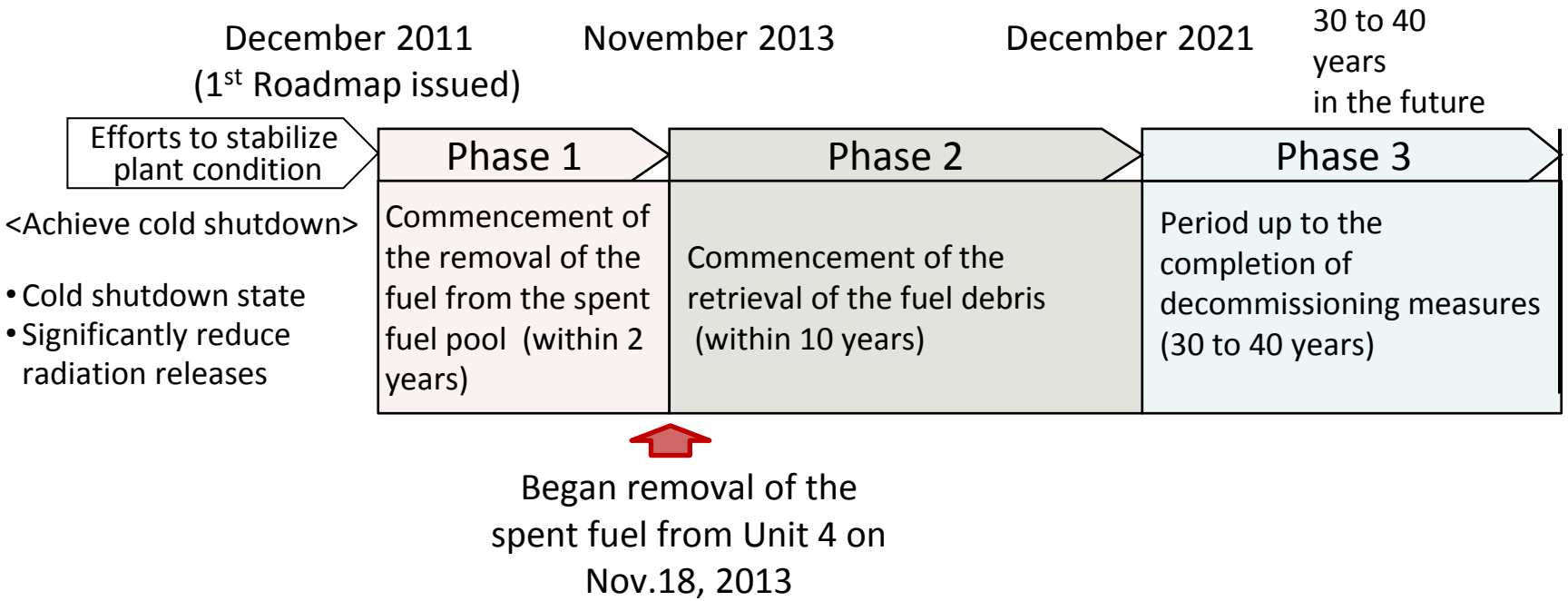
・Investigation of damaged PCV and preparation of repair tools
・Preparation for fuel debris retrieval
・Treatment and disposal of radioactive waste



Role of IRID in Decommissioning of Fukushima Daiichi Nuclear Power Station (NPS)



Mid-and-Long-Term Roadmap



The Mid-and-Long-Term Roadmap was amended on June 12, 2015, and the target time frames (milestones) were specified.

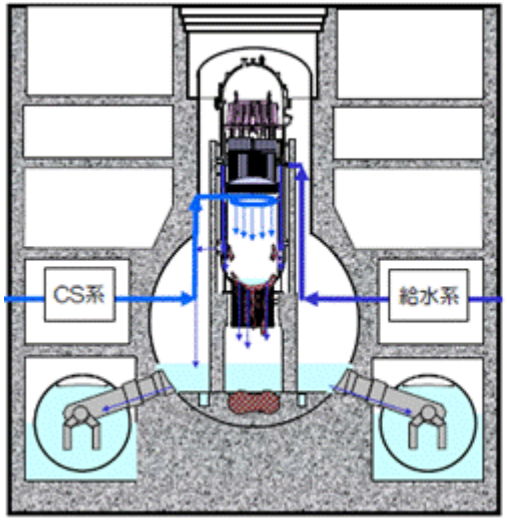
[Fuel Debris Retrieval]

- Decision of principle plan for fuel debris retrieval of each Unit — within 2 years
- Confirmation of fuel debris retrieval method for the initial Unit — by the first half of FY2018
- Commencement of fuel debris retrieval from the initial Unit — by December 2021

Current Condition of Each Unit at Fukushima Daiichi NPS

Based on the estimation about the PCV and reactor core conditions of Unit 1-3, priorities of R&D were decided as below

[Unit 1]

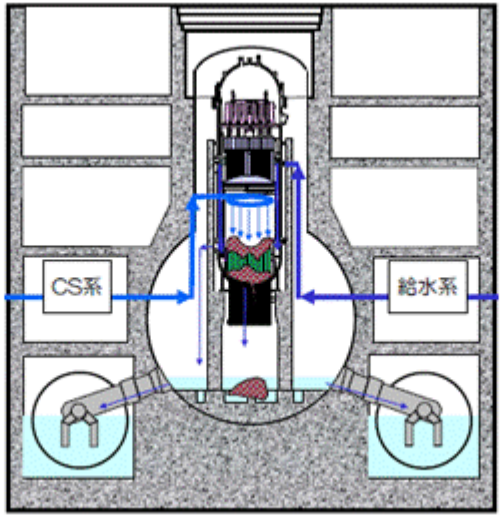


- Almost all melted fuel dropped to the RPV's lower part plenum, little is left in the reactor core

R&D priority

- Fuel debris possibly spread to the outside of the pedestal. Therefore, investigation on the outside of pedestal is the priority.

[Unit 2]

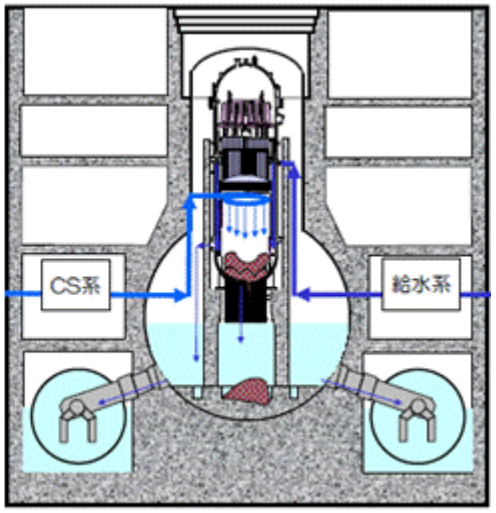


- A part of melted fuel dropped to the RPV's lower part plenum or PCV pedestal and a part of the fuel remains in the reactor core
- At Unit 3, more melted fuel than estimated might have dropped to the PCV

R&D priority

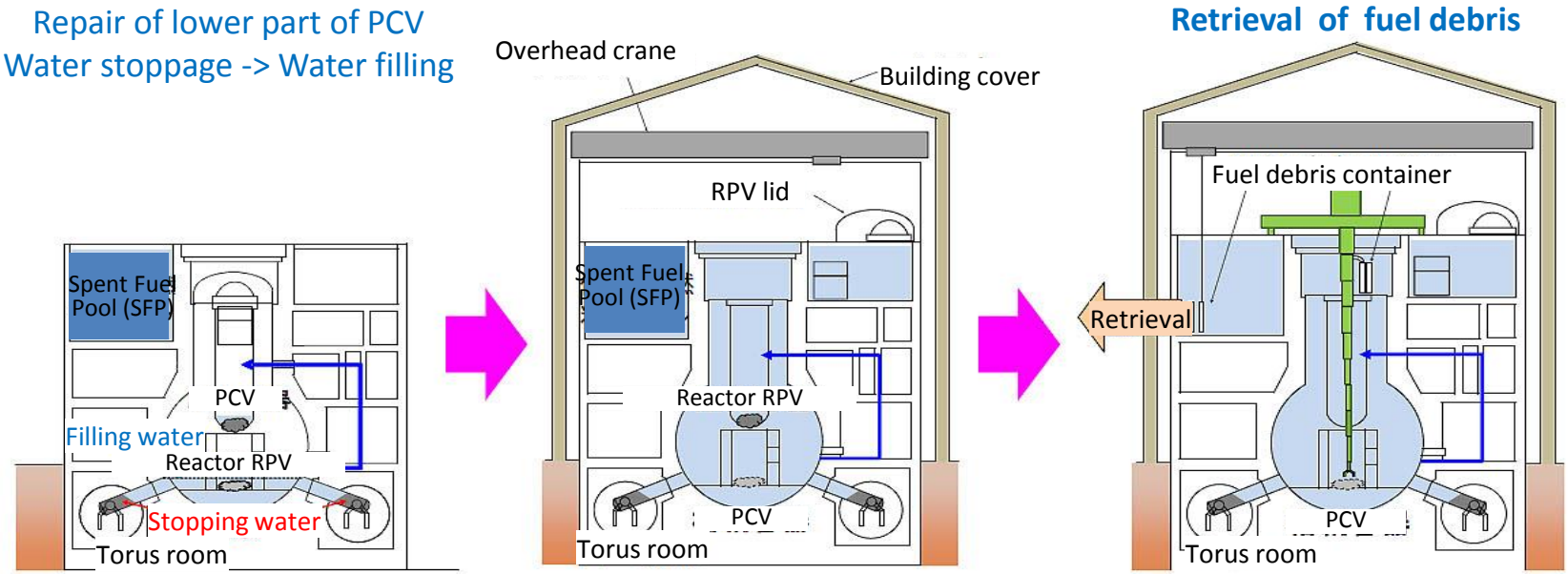
- Compare to Unit 1, it is less possible that fuel debris spread to the outside of the pedestal, so investigation the inside of pedestal is the priority.
- Regarding Unit 3 investigation, accumulated radioactive water level is higher than the height of the penetration which will be used for investigations of Unit 1 and 2. Therefore, it is necessary to use different penetration.

[Unit 3]



Concept Image of Work Steps for Fuel Debris Retrieval

- Retrieving the fuel debris submerged in water is a favorable approach from the viewpoint of minimizing radioactive exposure of workers.
- Investigation and repairing methods for filling the PCV with water have been studied
- Further R&D for collecting, transferring and storing of fuel debris is in progress.
- For each Unit, a retrieval method will be chosen from among candidate methods (submersion, in-air, upper-entry or side-entry) in the first half of FY2018.



IRID's R&D projects in FY2015

Evaluation of Long Term Integrity of spent fuel (FY 2015-2016)

Decontamination/ Dose Reduction

- Remotely Operated Decontamination Equipment (FY 2015)

Repair and Water Leakage Stoppage of PCV

- Water Stoppage Technology of PCV (FY 2015)
- Full-Scale Test (FY 2015)

Investigation/Analysis in the Reactor

Investigation

- Detection of Fuel Debris (FY 2015)
- Investigation Inside PCV (FY 2015)
- Investigation Inside RPV (FY 2015)

Characterization

- Accident Progression Analysis (FY 2015)
- Identifying Properties of Fuel Debris (FY 2015-2016)

Debris Retrieval

- PCV/RPV Integrity Evaluation (FY 2015)
- Fundamental Retrieval Technology for Fuel Debris & Reactor Internals (FY 2015-2016)
- Criticality Control in Fuel Debris Retrieval (FY 2015)
- Upgrading of Retrieval Method for Fuel Debris & Reactor Internals (FY 2015-2016)
- Collecting, Transferring and Storing of Fuel Debris (FY 2015-2016)

Radioactive Waste Treatment/Disposal

- Solid Waste Treatment and Disposal (FY 2015-2016)

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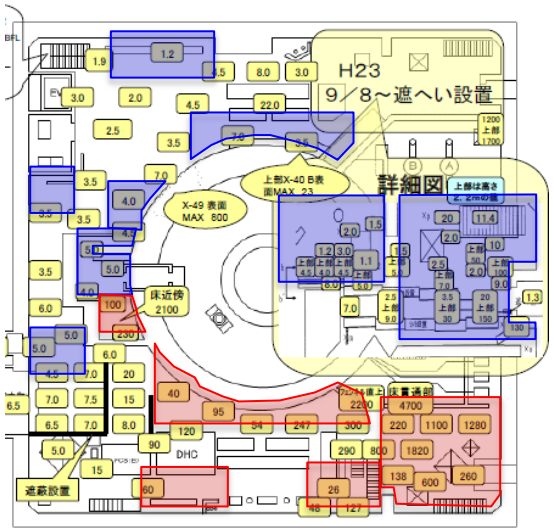
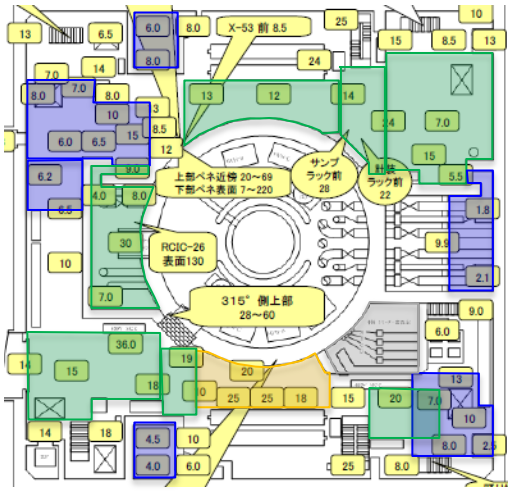
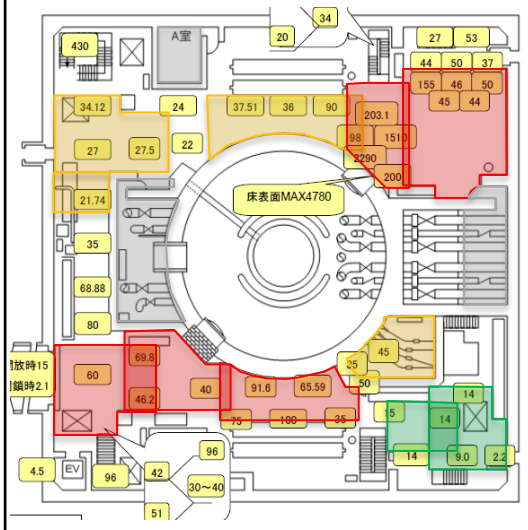
Dose Rate Goals after decontamination

◆ Dose rate reduction goals to be achieved using the decontamination equipment
(the necessity of PCV leakage investigation and repair work, and overall dose reduction scenario)

3 mSv/h for work area　　5 mSv/h for access route

	Unit 1	Unit 2	Unit 3
Necessity of dose reduction* and the dose rate			
Dose rate in the reactor building	Low as a whole: about 1-10 mSv/h Higher in south area and at some points in southeast area: 5,000 mSv/h	Before Oct. 2014: 2-60 mSv/h After Oct. 2014: about 5-10 mSv/h (Decontamination in lower/middle parts and shielding were conducted)	High as a whole: about 20-100mSv/h

* Mapping results of the dose rates at planned operation areas(with needs of dose reduction) derived from PCV investigation and repair project

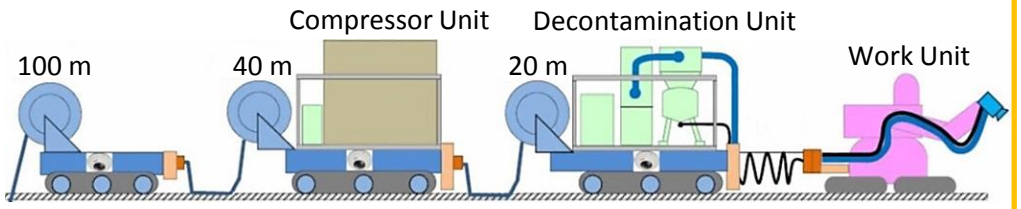
- 3 mSv/h to10mSv/h
- 10 mSv/h to 20mSv/h
- 20 mSv/h to 50mSv/h
- More than 50mSv/h
- Out of study due to the lack of data

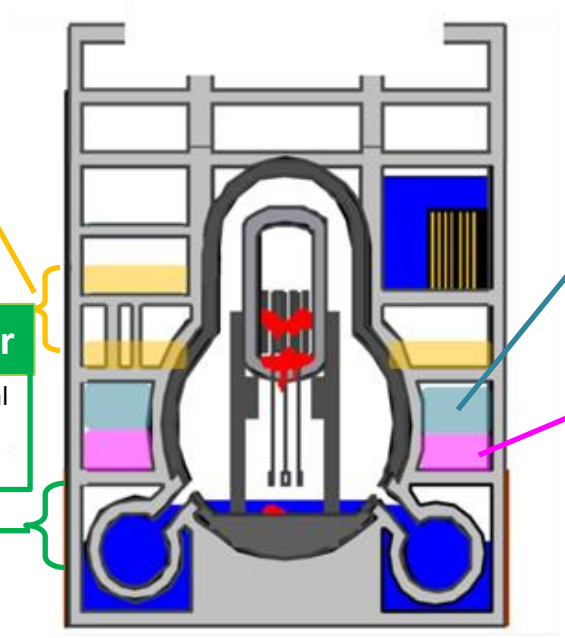
Results and Future Plan of Decontamination Equipment Development

Upper floors

・FY2013: design

・FY2014-2015 : production, verification test, applicability study of actual device





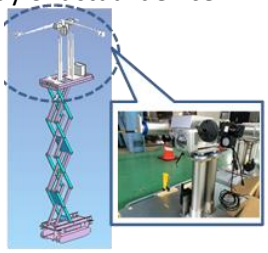
Underground floor

・FY2014 : Study of technical challenges, development planning

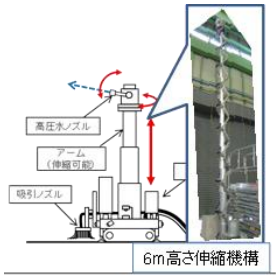
High places

・FY2013 : design, production

・FY2014-2015 : improvement, verification test, applicability study of actual device



Dry ice blast



High pressure water jet

Suction/Blast

Low places <Development completed>

・FY2011-2012 : design, production, test in 2F

・FY2013 : improvement, verification test (factory, 1F)

Suction/Blast

High pressure water jet

Dry ice blast

IRID's R&D projects in FY2015

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Investigation

Detection of Fuel Debris (FY 2015)

Investigation Inside RPV (FY 2015)

Investigation Inside PCV (FY 2015)

Characterization

Accident Progression Analysis (FY 2015)

Identifying Properties of Fuel Debris (FY 2015-2016)

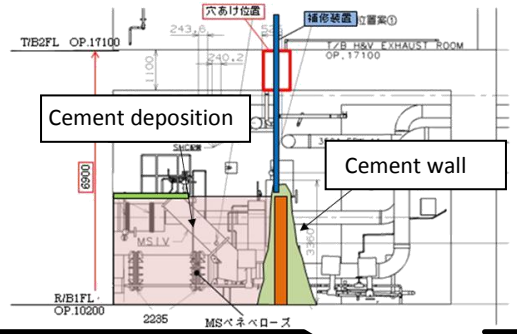
Radioactive Waste Treatment/Disposal

Solid Waste Treatment and Disposal (FY 2015-2016)

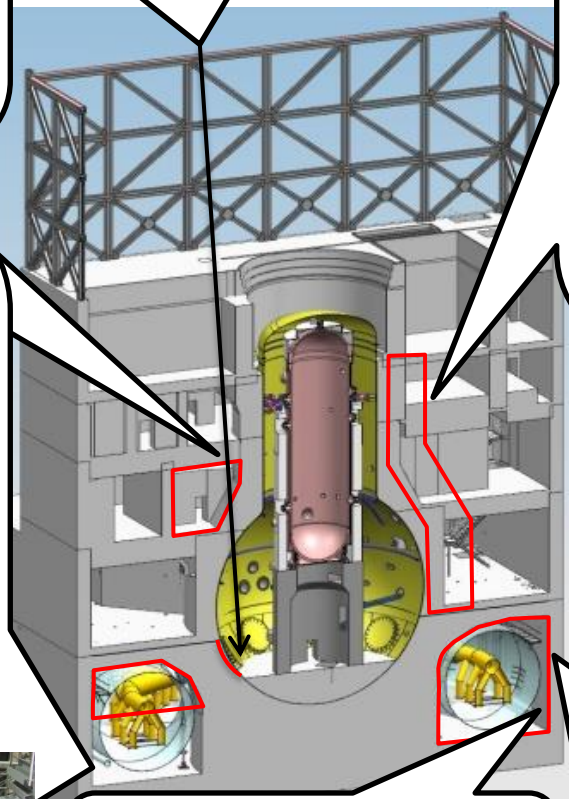
Target Areas for Water Leakage Stoppage at PCV

PCV Penetration (Small rooms)

Cement Depositing

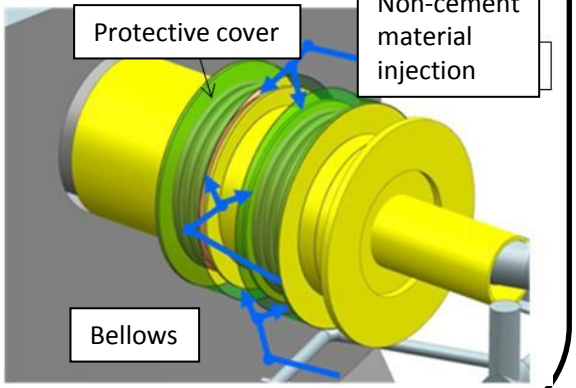


D/W Shell (repair)



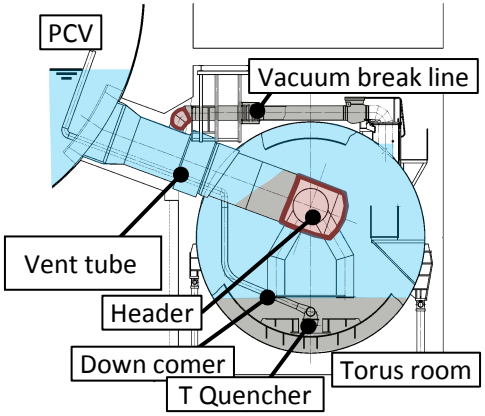
PCV Penetration (Open spaces)

Non Cement (temporal)
Cement (Long term)



Vent Piping, Down Comer

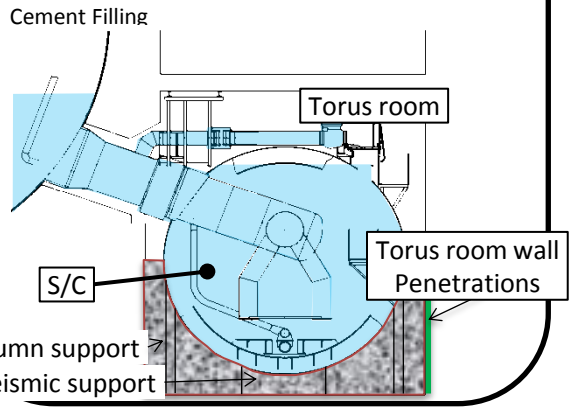
Cement Filling



A half-scale test

S/C Support, Torus Room Penetrations

Cement Filling



PCV Connecting Piping in torus room

Cement Depositing

IRID's R&D projects in FY2015

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Investigation/Analysis in the Reactor

- **Detection of Fuel Debris (FY 2015)**

Investigation

- Investigation Inside RPV (FY 2015)
- Investigation Inside PCV (FY 2015)

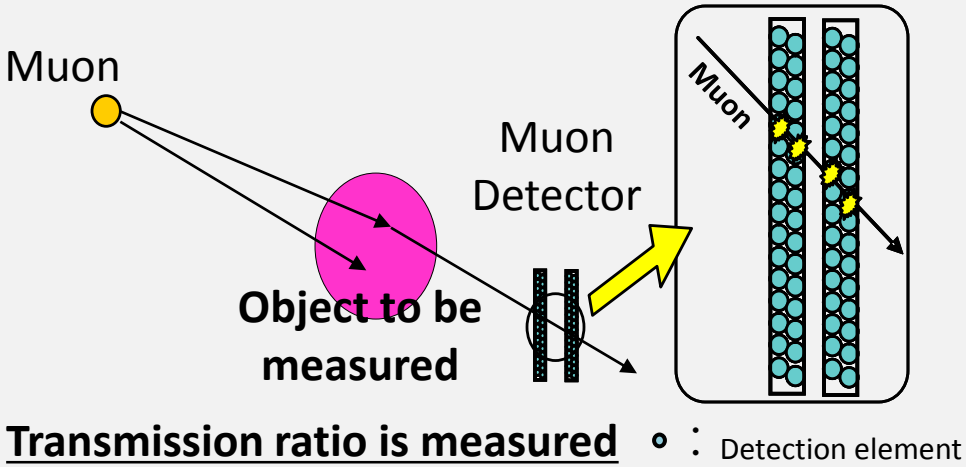
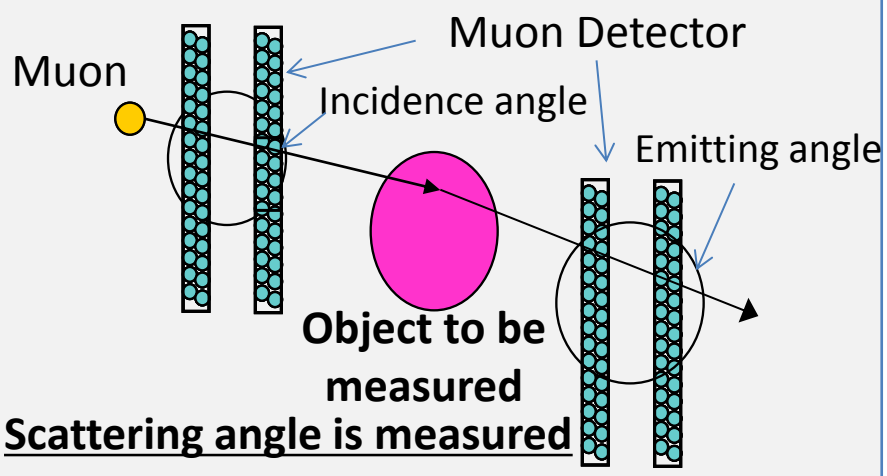
Characterization

- Accident Progression Analysis (FY 2015)
- Identifying Properties of Fuel Debris (FY 2015-2016)

Radioactive Waste Treatment/Disposal

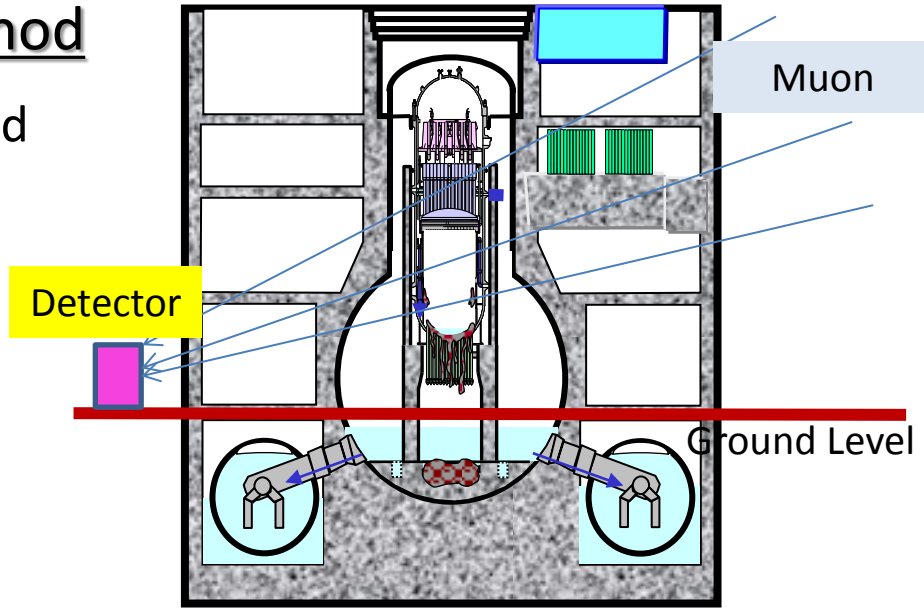
- Solid Waste Treatment and Disposal (FY 2015-2016)

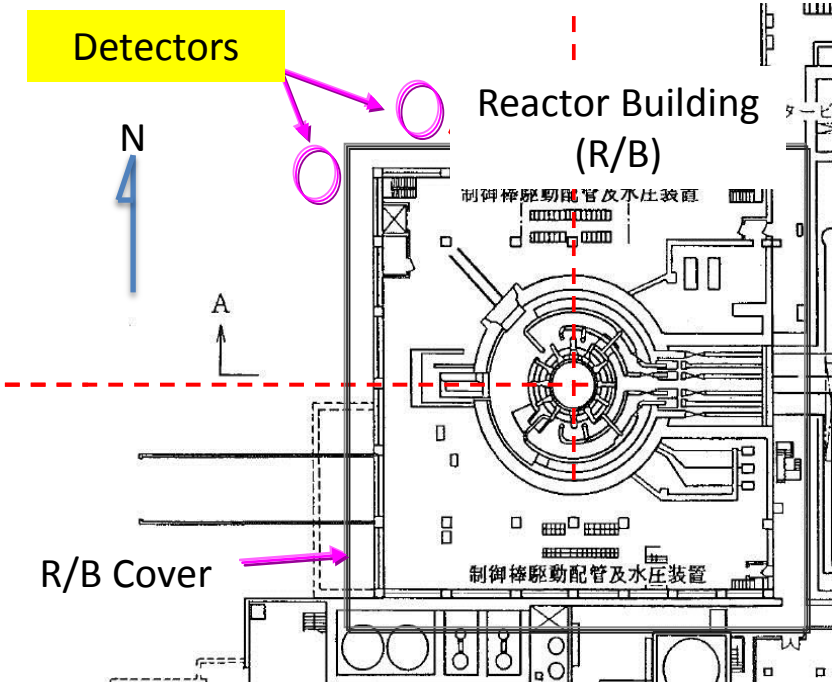
Assessing Conditions inside Reactor by Muon Observation Technology

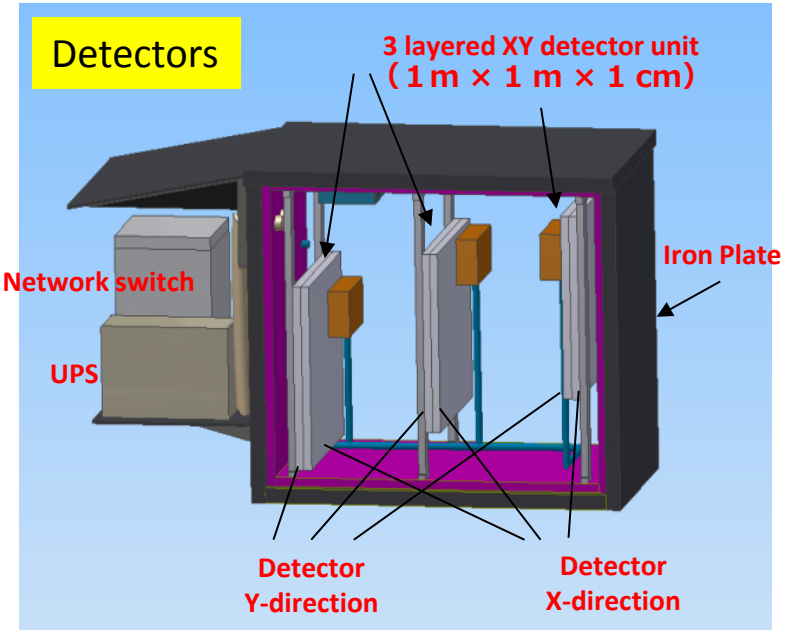
Transmission Method	Scattering Method
	
Can detect existence/non-existence of an object on Muon flying direction (two-dimensions)	**Can detect existence/non-existence of an object at Muon scattering area (three-dimensions)**
Can image fuel debris at a spatial resolution of about 1 m	**Can Image fuel debris at a spatial resolution of about 30 cm**
Detector: One small-size detector (easy installation and quick application)	Detector: One pair of large-size detectors (needs wider space and longer time to install)
	Can distinguish heavy element such as Uranium

Measurement by Transmission Method

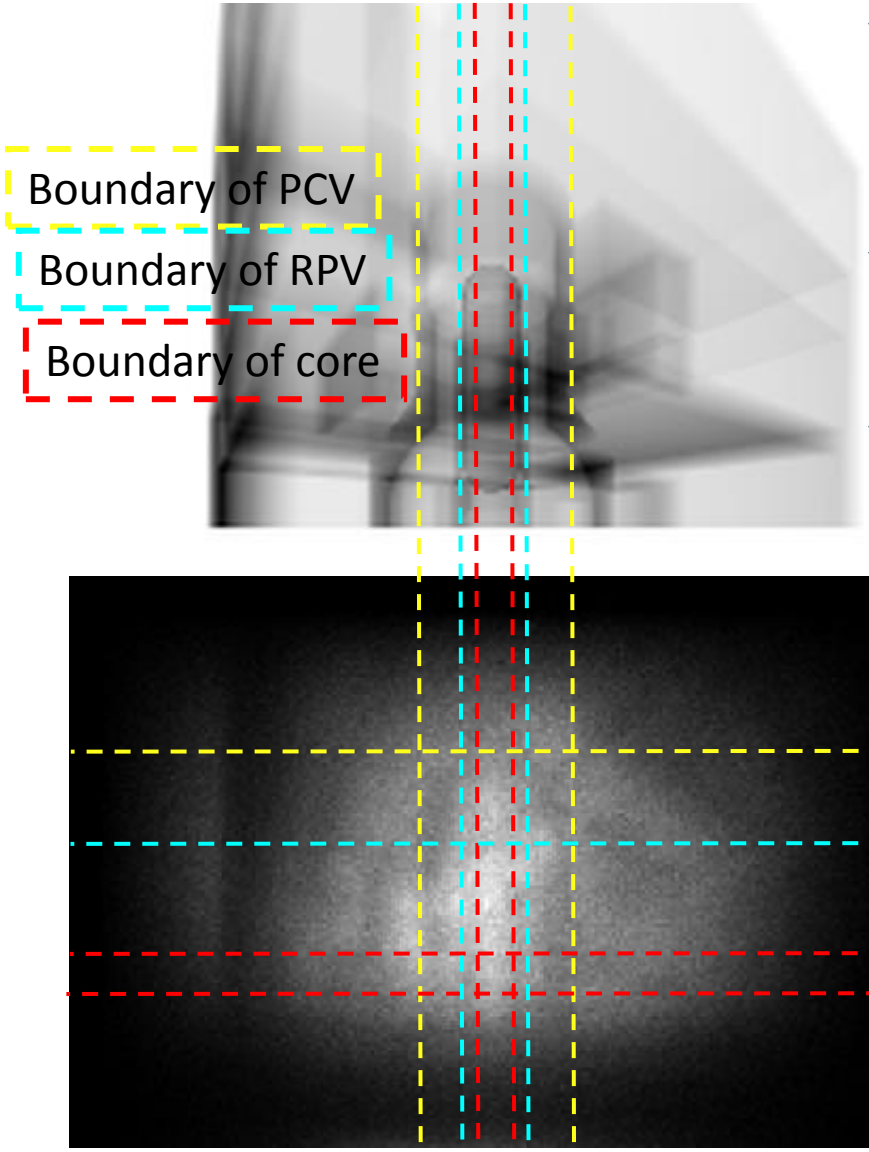
- Detectors were installed at the north and north-west corners of Unit 1 reactor building (late January, 2015)
- Measured from February through May
- Detectors were shielded by 10 cm thick iron plates







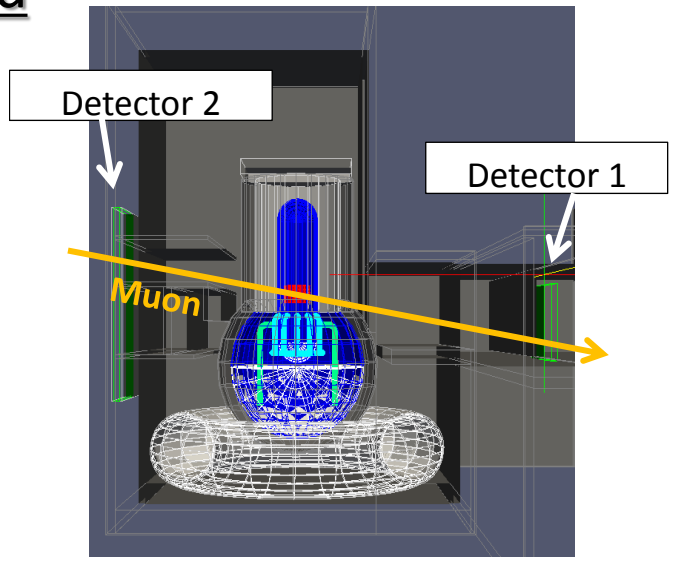
Estimation of Fuel Debris Location Based on Comparison between Design Image and Measurement

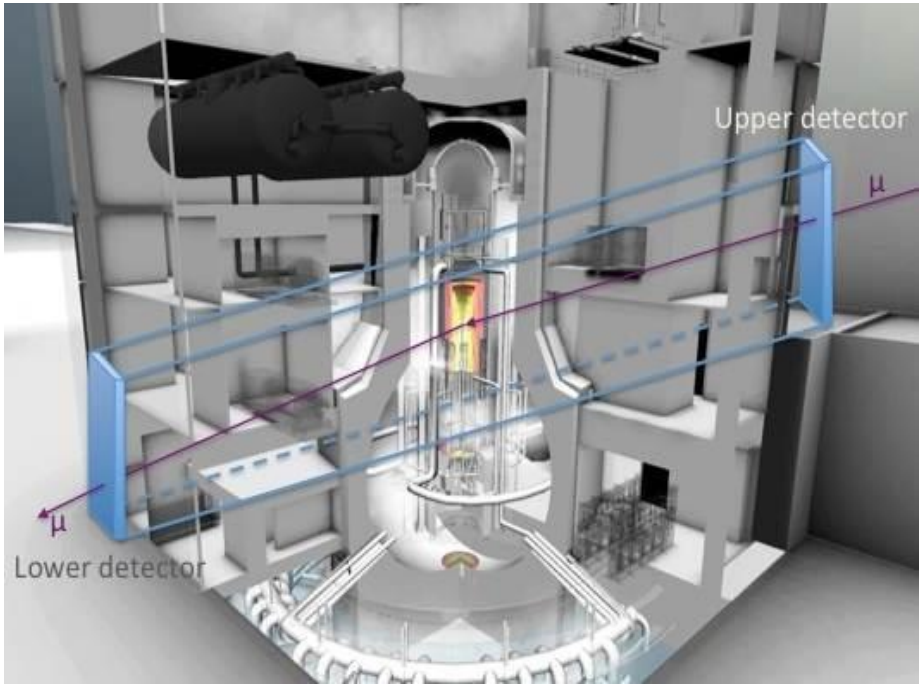


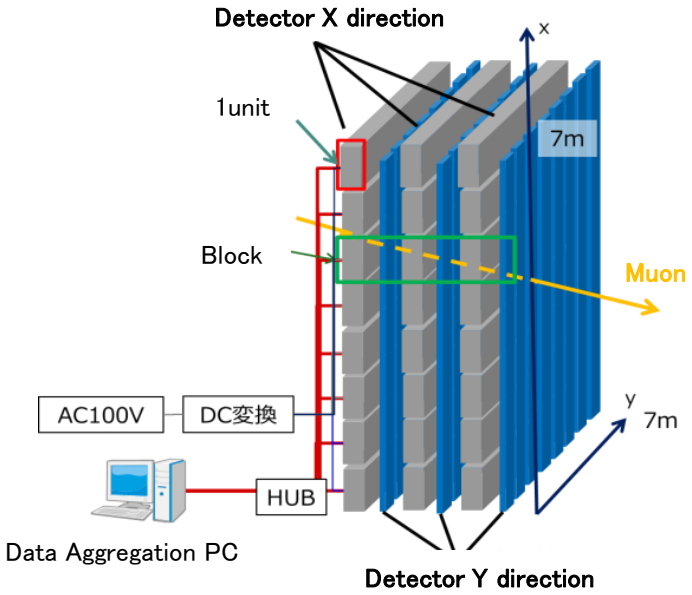
- Measured data, though it does not clearly indicate, shows that equipment, etc. are detected at locations where they are supposed to exist based on the design documents
- The boundaries of the PCV and the RPV in the image acquired from measurement matches those in the image drawn from design data.
- High density material (fuel debris) is not detected at the area where fuel assemblies are originally installed.

Measurement by Scattering Method

- Detectors will be installed in front of the R/B and 2nd Floor in T/B (Operation Floor) at Unit 2
- Background radiation should be eliminated by shielding and algorism
- The detector in front of the R/B should be shielded by 8 cm thick iron plates
- The detector on the second floor of the T/B will not be shielded because of low background radiation







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Investigation inside the PCV (Unit 1)

[Investigated area] 1st floor grating outside the pedestal

[Steps for investigation and device development]

(1) Investigation from X-100 penetration (FY 2015)

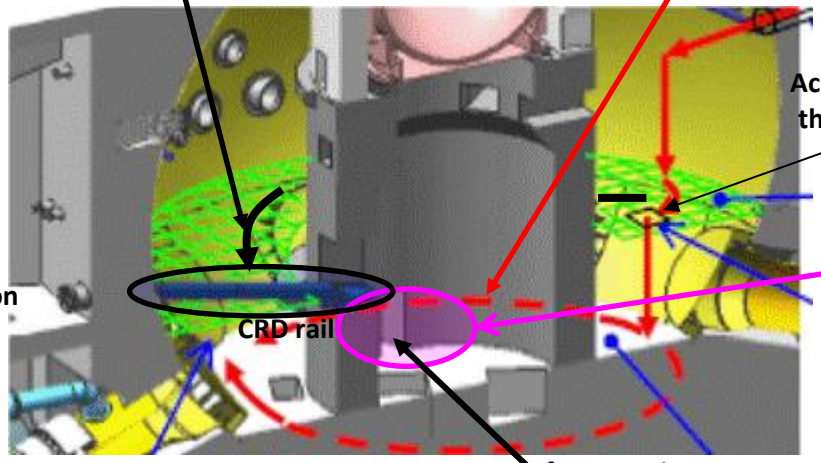
1. Acquire information about the grating area on the 1st floor (access point to the basement, etc.): B1 (finished)
2. Acquire images showing the outside of the pedestal on the basement floor (esp. access entrance and nearby vent tube) following the results of investigation at the torus room using a small boat in November 2013: B2 (planning)

(2) Investigation from X-6 penetration (FY 2016-2017) (after decontamination around the X-6 penetration)

1. Acquire further information about outside the pedestal on the basement floor by using fuel debris shape measurement apparatus: B3

B1. Investigation outside the pedestal on 1st floor grating (completed in April 2015) : from X-100B penetration

B2. Investigation outside the pedestal on the basement floor (planned to be done in FY 2015) : from X-100B penetration



Necessity of further investigation will be decided according to the results of B2

B3. Investigation outside the pedestal on the basement and access entrance (FY 2016-2017) : from X-6 penetration

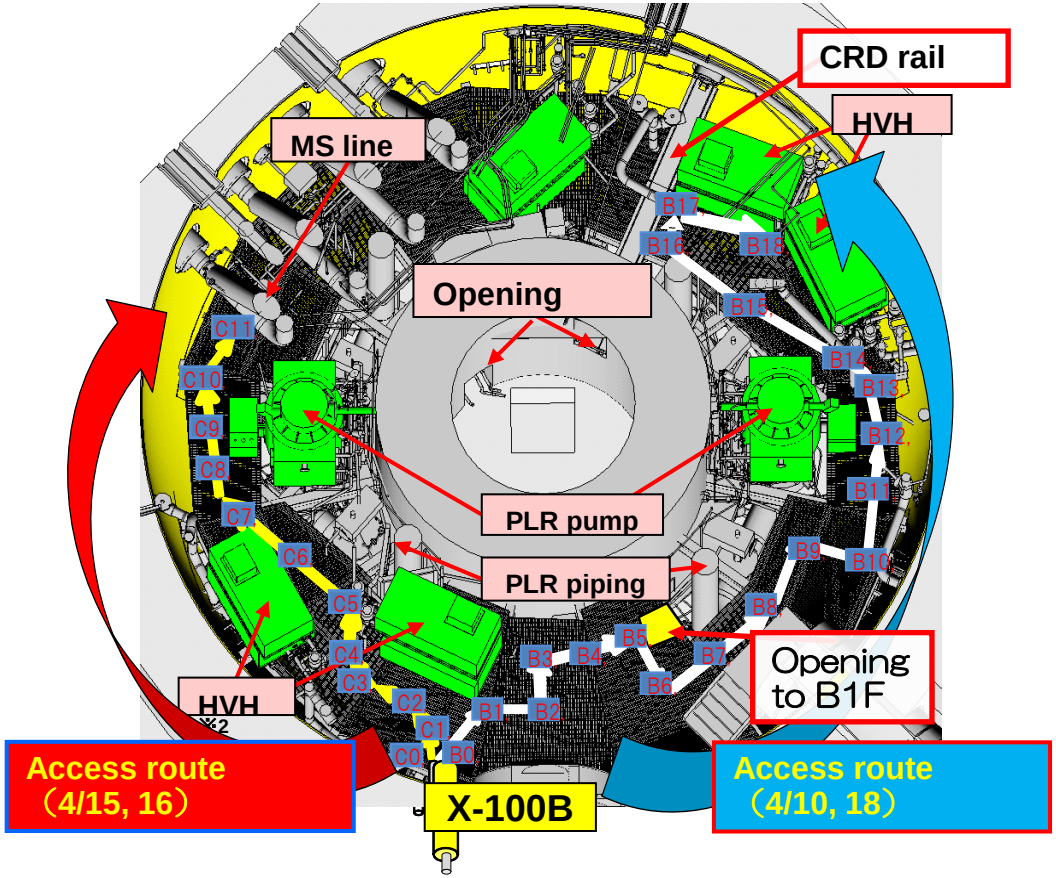
Investigation inside the pedestal is planned to be conducted after investigation of Unit No.2 finishes.

B1 Investigation Completed in April, 2015

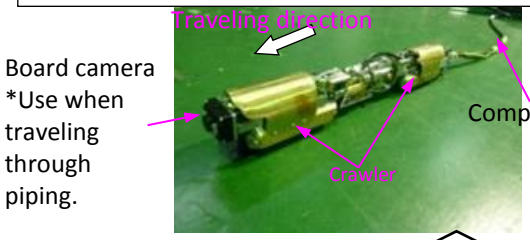
(1)Overview of equipment

- Shape-changing crawler equipment
- Inserted from the narrow access entrance (X-100B penetration: ϕ100 mm)
- Travel on the grating stably.

(2) Image of investigation routes

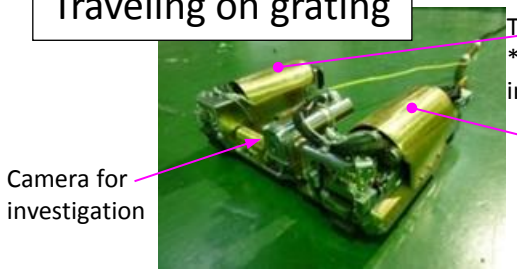


Traveling through penetration on PCV



transformation

Traveling on grating

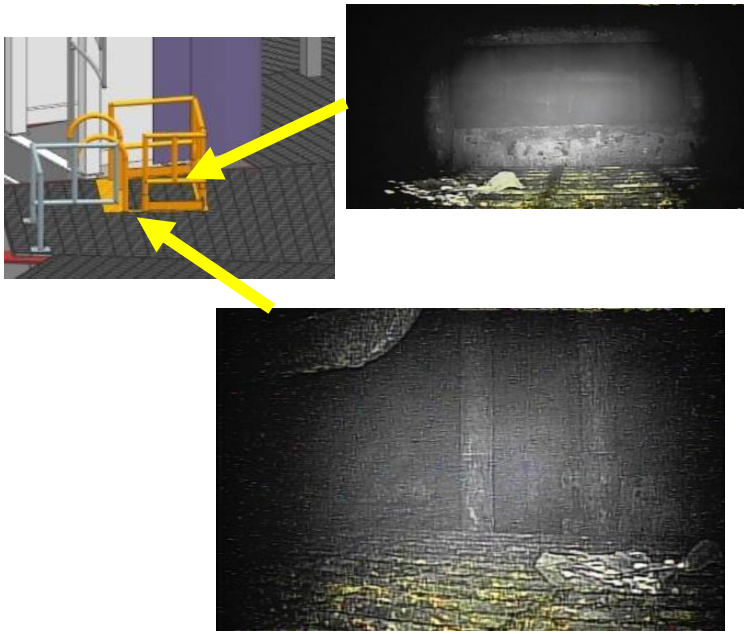


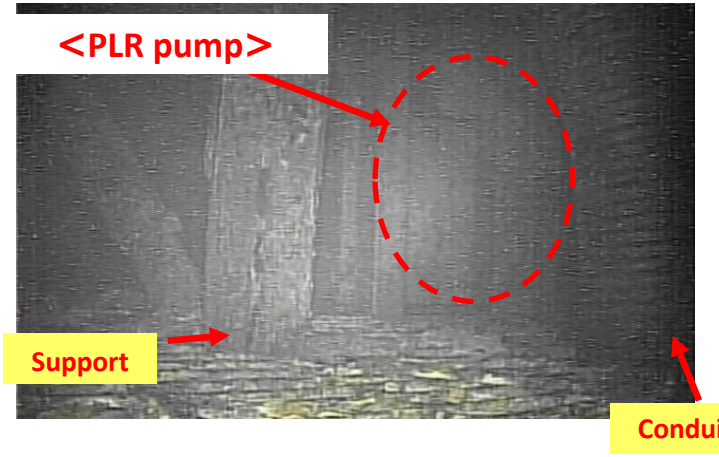
Features of equipment

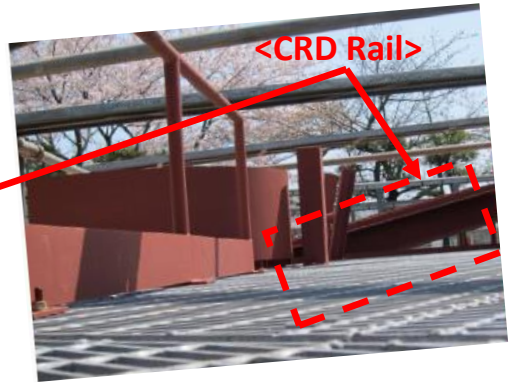
Results of B1 Investigation

Investigated area	Results
Access point to the basement	・For the next investigation (outside the pedestal on the basement), it is confirmed that **there is an access point to the basement** and **no obstacles around it**
CRD rail	・**Could not reach to the CRD rail** ・**Could not recognize the CRD rail by evaluation of image-processed pictures,** which were taken from the farthest reaching point by the investigation camera
En route of investigation	・**No major damage was found** inside the PCV equipment (HVH, PLR Line, pedestal wall, etc.) ・At every investigating point, **temperature and dose rate were recorded.**

<Access point to the basement>







(Image at mock-up facility)

Investigation inside the PCV (Unit 2)

[Investigated area] - On the platform inside the pedestal (Upper surface of platform and CRD housing)
- Basement floor

(1) Investigation from X-6 penetration (Φ115 mm) (FY2015): A2

(2) Investigation from X-6 (Enlarge hole) (FY2016- 2017): A3 and A4

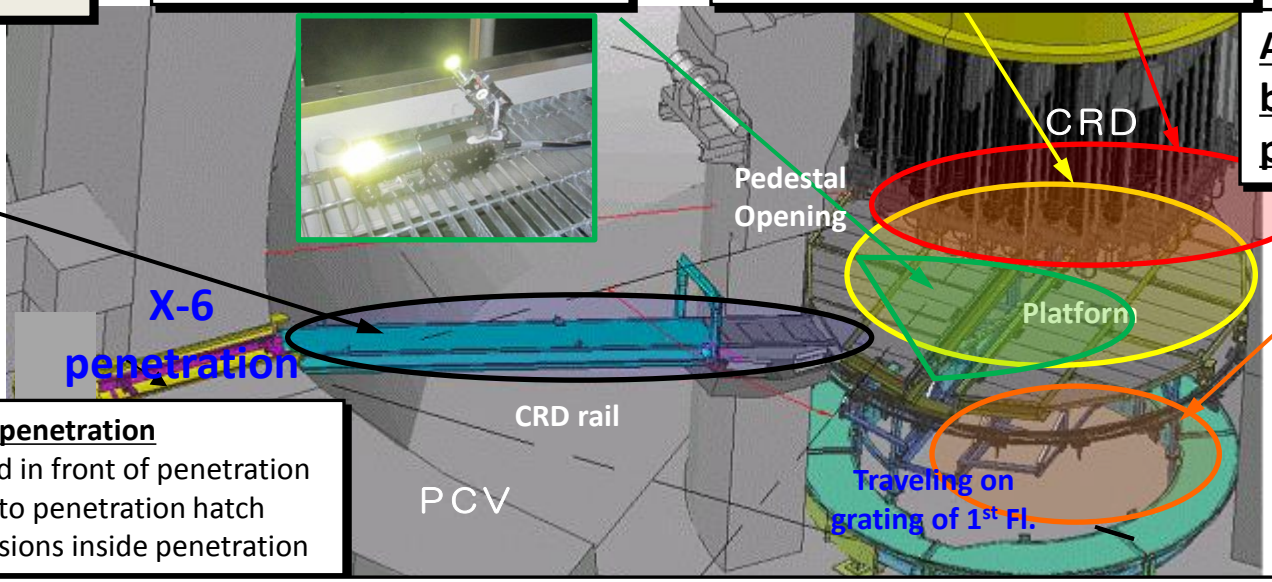
・Insert debris visualization system, investigate inside the pedestal.

A1. Investigation on CRD rail(Conducted in Aug.2013)

A2. Investigation on platform inside pedestal

A3. Investigation of CRD Hsg and on platform (detail)

A4. Investigation on basement inside pedestal



Step to use X-6 penetration
- Remove shield in front of penetration
- Pierce a hole to penetration hatch
- Remove inclusions inside penetration

Based on the results of internal investigation from A2 to A4, investigation outside pedestal may be conducted.

IRID's R&D projects in FY2015

Evaluation of Long Term Integrity of spent fuel (FY 2015-2016)

Decontamination/ Dose Reduction

- Remotely Operated Decontamination Equipment (FY 2015)

Repair and Water Leakage Stoppage of PCV

- Water Stoppage Technology of PCV (FY 2015)
- Full-Scale Test (FY 2015)

Debris Retrieval

- PCV/RPV Integrity Evaluation (FY 2015)
- **Fundamental Retrieval Technology for Fuel Debris & Reactor Internals (FY 2015-2016)**
- Criticality Control in Fuel Debris Retrieval (FY 2015)
- **Upgrading of Retrieval Method for Fuel Debris & Reactor Internals (FY 2015-2016)**
- Collecting, Transferring and Storing of Fuel Debris (FY 2015-2016)

Investigation/Analysis in the Reactor

Investigation

- Detection of Fuel Debris (FY 2015)
- Investigation Inside RPV (FY 2015)
- Investigation Inside PCV (FY 2015)

Characterization

- Accident Progression Analysis (FY 2015)
- Identifying Properties of Fuel Debris (FY 2015-2016)

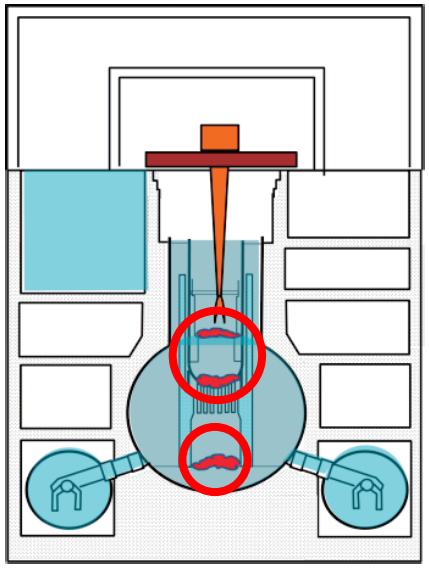
Radioactive Waste Treatment/Disposal

- Solid Waste Treatment and Disposal (FY 2015-2016)

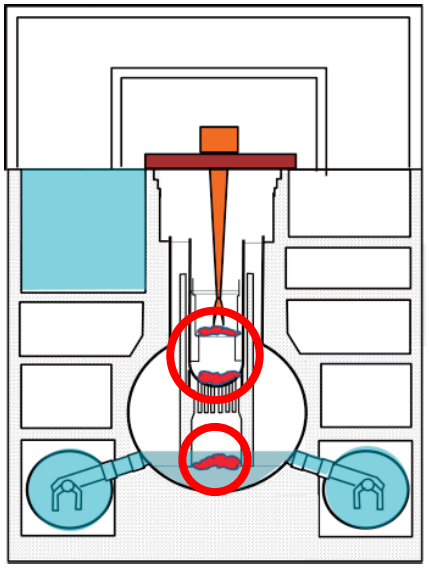
Outline: R&D for Fuel Debris Retrieval Methods

Selected options of fuel debris retrieval

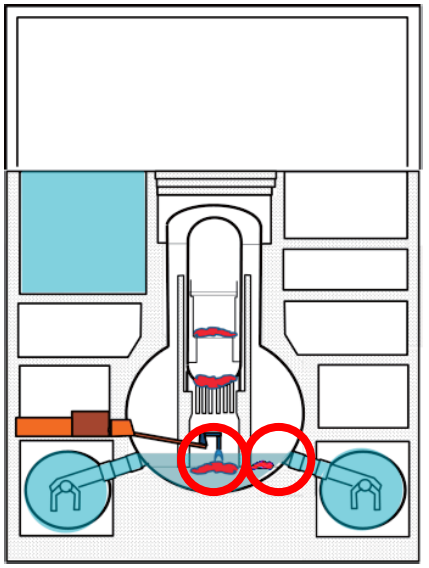
a. Submerged-top access method



b. Dry-top access method



c. Dry-side access method



- According to the Technical Strategic Plan*, the three methods above will be studied
- Major issues to be studied (regarding the three methods)
  1. Examine the feasibility of each method
  2. Conduct a conceptual study on a system to judge the feasibility of each method
  3. Design fuel debris retrieval equipment and draw up its development plan
  4. Based on 1.-3. above, draw up development plans of systems and equipment to retrieve fuel debris and reactor internals

*Technical Strategic Plan 2015 for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company (Nuclear Damage Compensation and Decommissioning Facilitation Corporation, April 3, 2017)

Outline: R&D for Technology of Retrieving Fuel Debris and Core Internals

◎ Contents

As for the three methods of fuel debris retrieval, develop and evaluate element technologies necessary to judge the feasibility of each method.

◎ Issues for developing technologies of fuel debris retrieval

Issues common to the methods of fuel debris retrieval are as follows:

1) Cutting of fuel debris
2) Remote operation
3) Prevention of expansion of contamination
4) Shielding
5) Criticality prevention

◎ Element test

Conduct following element tests

1) Technology for preventing contamination expansion
2) Technology for accessing fuel debris
3) Technology for remote operation
4) Technology for reducing exposure of workers
5) Cutting, dust collection, visualization and measurement technologies

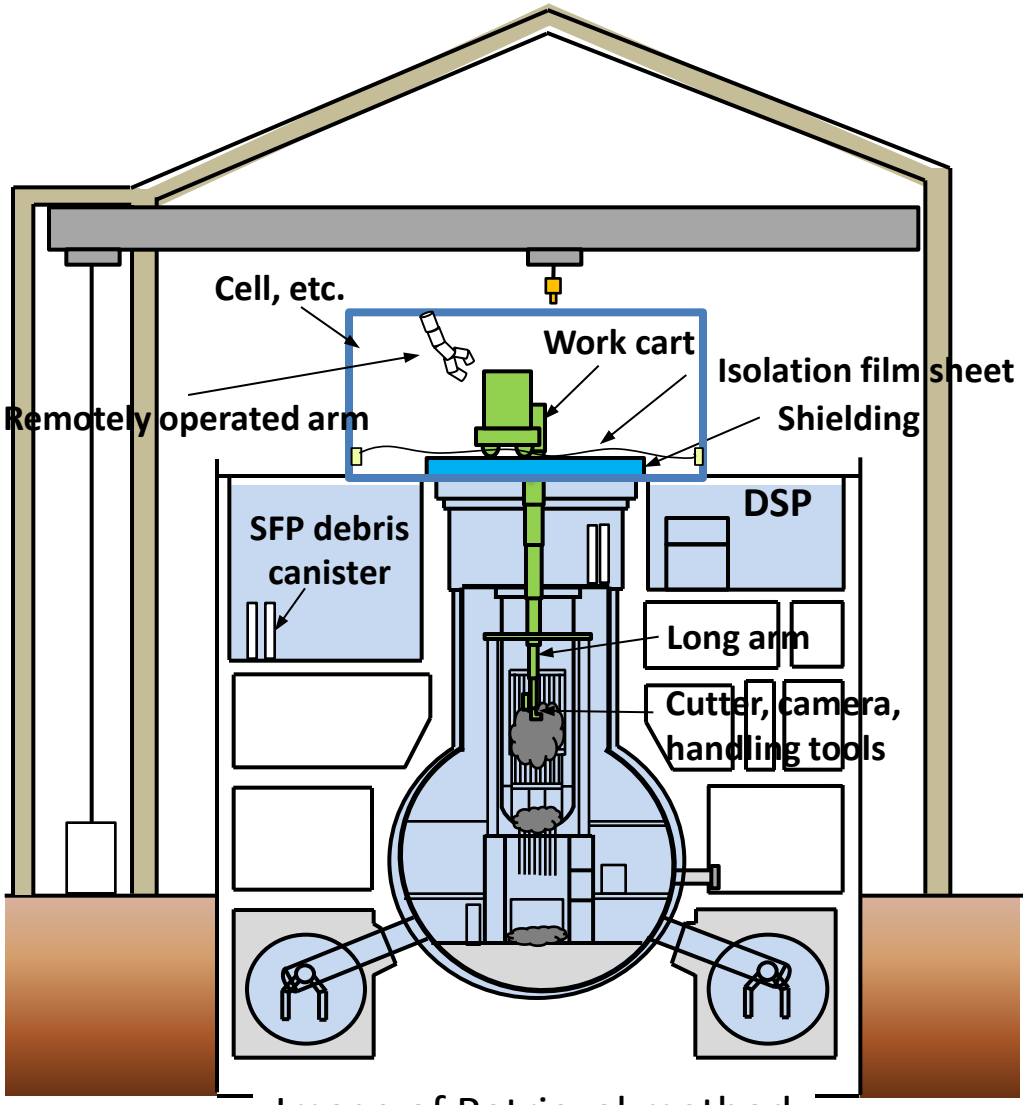


Image of Retrieval method

IRID's R&D projects in FY2015

Evaluation of Long Term Integrity of spent fuel (FY 2015-2016)

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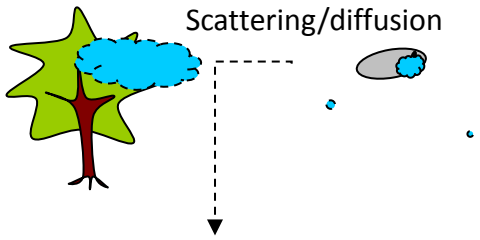
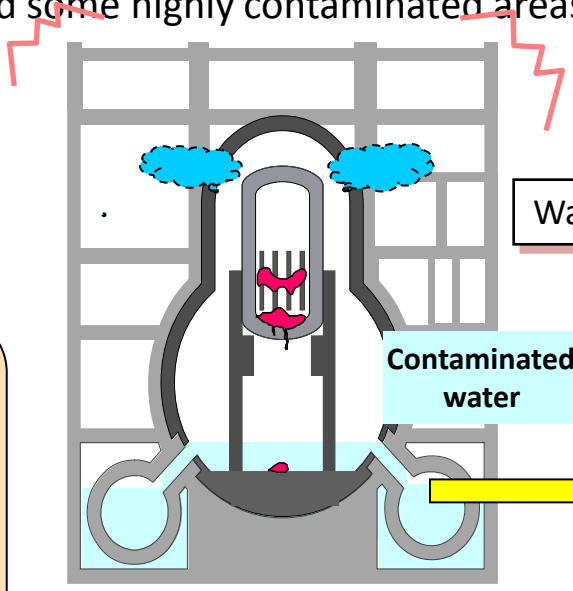
Radioactive Waste Treatment/Disposal

- **Solid Waste Treatment and Disposal (FY 2015-2016)**

Characteristics of Nuclear Waste Generated from Fukushima Daiichi NPS Accident

- The waste was created under the uncontrollable condition due to the accident
- The contamination originated from damaged fuel of Unit 1 to 3.*
- It is difficult to estimate the amount of the waste because decommissioning work changes according to the site condition
- Analytical data, (especially on the composition of long half-life nuclides), are extremely limited because the contaminated area is large and some highly contaminated areas exist.





Water treatment system

[Rubble/Felled and removed trees, etc.]

Rubble | Felled and removed trees | Soil

✓ Large quantity and widely distributed
✓ Poor experience with the treatment and disposal of felled and removed trees and soil
✓ Surface contamination by scattering/ diffusion is main contamination and some contamination is penetrating contamination caused by accumulated water.

[Fuel debris/Demolishing waste]

✓ Large amount and high dose rate
✓ Difficult to sample actual waste due to low accessibility at present

[Secondary waste by water treatment]

Secondary waste from contaminated water treatment | Replaced pipes, Storage tanks

✓ Poor experiences of treatment and disposal
✓ Difficult to collect the waste
✓ Partial estimation of quantity and kind of nuclide may be possible based on the characteristics of water treatment equipment

*** Activation products and waste from operation may be included**

Comparison between Wastes from Accident and Operation

Item of uncertainty	Waste from operation	Waste from accident
Generation of waste [quantity, type, period]	◎	△
Handling (collecting/classifying) [difficulty]	◎	△
Characterization [sufficiency of information, difficulty of sampling, representativeness of sample]	○	△
Technologies for processing and packaging waste	○	？～△
Burial and disposal methods and safety assessment	△～○	？
Regulations, technical standards, guidelines, siting	△～○	？

◎：Fully understood or good prospect, ○：Fair prospect, △：Limited ,
？：Cannot be discussed

- Waste generated from operation has its own problem but is **fairly under control**.
  - ・Information on basic properties of waste, including quantity at present, future change, activity and chemical substances contained in individual waste is identified.
  - ・Both unprocessed and processed wastes are appropriately stored and managed in accordance with the current regulations.
  - ・Regulations and standards, as well as disposal method and safety assessment method, have been in place.
- Many uncertainties poses important technical problems to disposal of the accident-generated waste at the Fukushima Daiichi. **Solving these uncertainties and bringing the waste under control are the major goals** of countermeasures and technology development.

Technologies and R&D for Waste Treatment and Disposal

Waste Stream Study

Waste stream: A series of handling accident-generated waste from its generation to storage, finally to treatment and disposal

Technology information on treatment and disposal (including precondition), information related to the policy and system

Integrated judgment and adjustment for each research result, presentation of required agenda towards implementation of safe and rational treatment and disposal

Individual R&D items（Basic R&D that will give knowledge necessary for establishing Waste Stream)

Inventory, property of harmful substance, etc.

Necessary waste information items, etc.

Identifying Properties

[Targets] The safety assessment of processing and disposal, and information accumulation required for waste management / Development of the method of analyzing nuclides difficult to be measured for the analysis facility

Inventory, property of mixed contaminant, etc.

Study on Treatment of Waste

[Targets] Preparing catalogue about Treatment / Technology, and narrowing down and introduction of applicable candidate technologies for waste conditioning

Study on Long-Term Storage Method

[Targets]Introduction of long-term storage /stabilization policy on secondary waste from water treatment

Important nuclide, needed data, etc.

Study on Disposal of Waste

[Targets] Introduction of applicable disposal concepts for each kind of waste and its evaluation method

Required condition of waste body, etc.

Properties of waste body etc.

Information about properties of waste

Database Development

[Targets] Database development of waste properties, processing and disposal methods etc. (Information sharing with third party organizations)

Technical information on treatment and waste conditioning

Information on disposal technology

Finally - Forward Fuel Debris Retrieval-

- Fuel debris retrieval at the Fukushima Daiichi Nuclear Power Station is expected to be more difficult compared to that of the accident at the Three Mile Island 2 (TMI-2). It is necessary to put domestic and international wisdom together to develop the whole strategy, method and equipment for fuel debris retrieval.

- In order to complete the fuel debris retrieval, it is necessary to clarify the purpose and goal of relating each project, and then, to develop technologies flexibly by planning with an aim to achieve not partial but overall optimization.

- In making strategy, it is important to consider end-state (what you wish to achieve at the end), study various feasible options and always prepare alternative options.

Thank you for you attention