WRFPM 2014
Sendai, Japan

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

September 15, 2014

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*The contents of this presentation include the results of "Establishment of basic technology for decommissioning and safety of nuclear reactors for power generation in 2013 (technological study and research concerning forming an idea for processing and disposing of radioactive waste resulting from the accident)", a project commissioned by the Ministry of Economy, Trade and Industry, and the 2013 subsidiary for decommissioning and contaminated water measures (development of technologies for processing and disposing of waste resulting from the accident).
*Plant information included in this document is taken from TEPCO's official website.

Outline of IRID

1. Name

Research & Development Consortium,
"International Research Institute for Nuclear Decommissioning"
(IRID)

2. Location of Main Office

6F, Parkplace, 5-27-1, Shimbashi, Minato-Ku, Tokyo, 105-0004, Japan
(http://www.IRID.or.jp)

3. Founding Members (18)

- Incorporated administrative agencies:

Japan Atomic Energy Agency,
National Institute of Advanced Industrial Science and Technology.

- Manufacturers:

Toshiba Corporation, Hitachi-GE Nuclear Energy, Ltd.,
Mitsubishi Heavy Industries, Ltd., ATOX (since May 29, 2014).

- Electric utilities etc. :

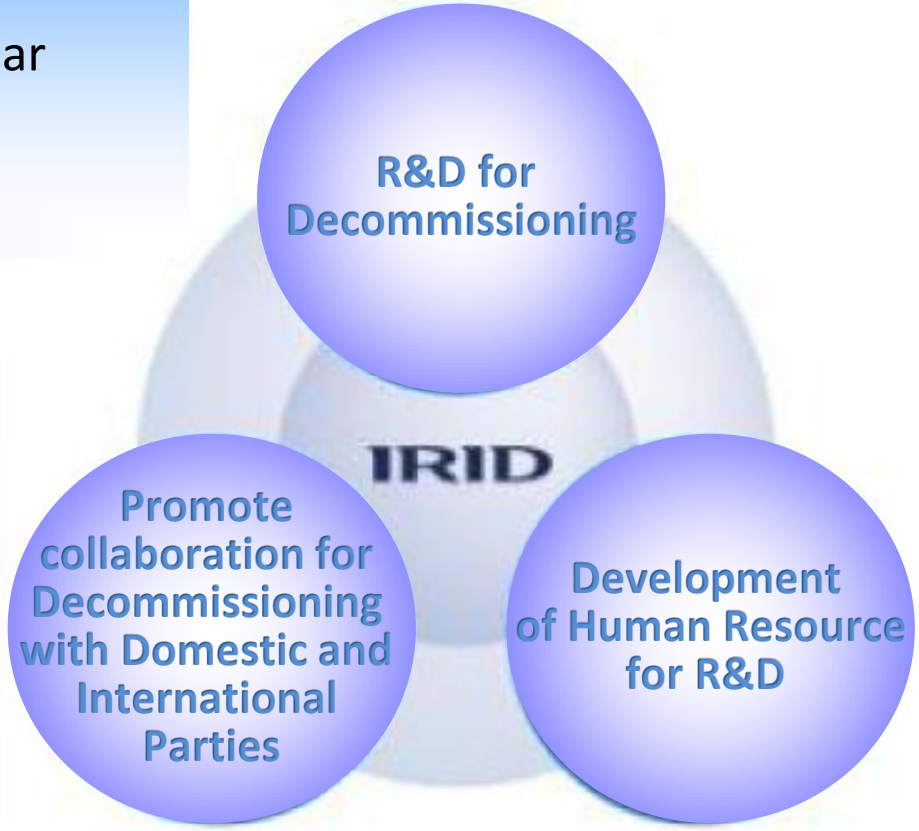
Hokkaido Electric Power Company (hereinafter called as EPC), Tohoku EPC,
Tokyo EPC, Chubu EPC, Hokuriku EPC, Kansai EPC, Chugoku EPC, Shikoku EPC,
Kyushu EPC, The Japan Atomic Power Company, J-POWER,
Japan Nuclear Fuel Limited.

Projects of IRID

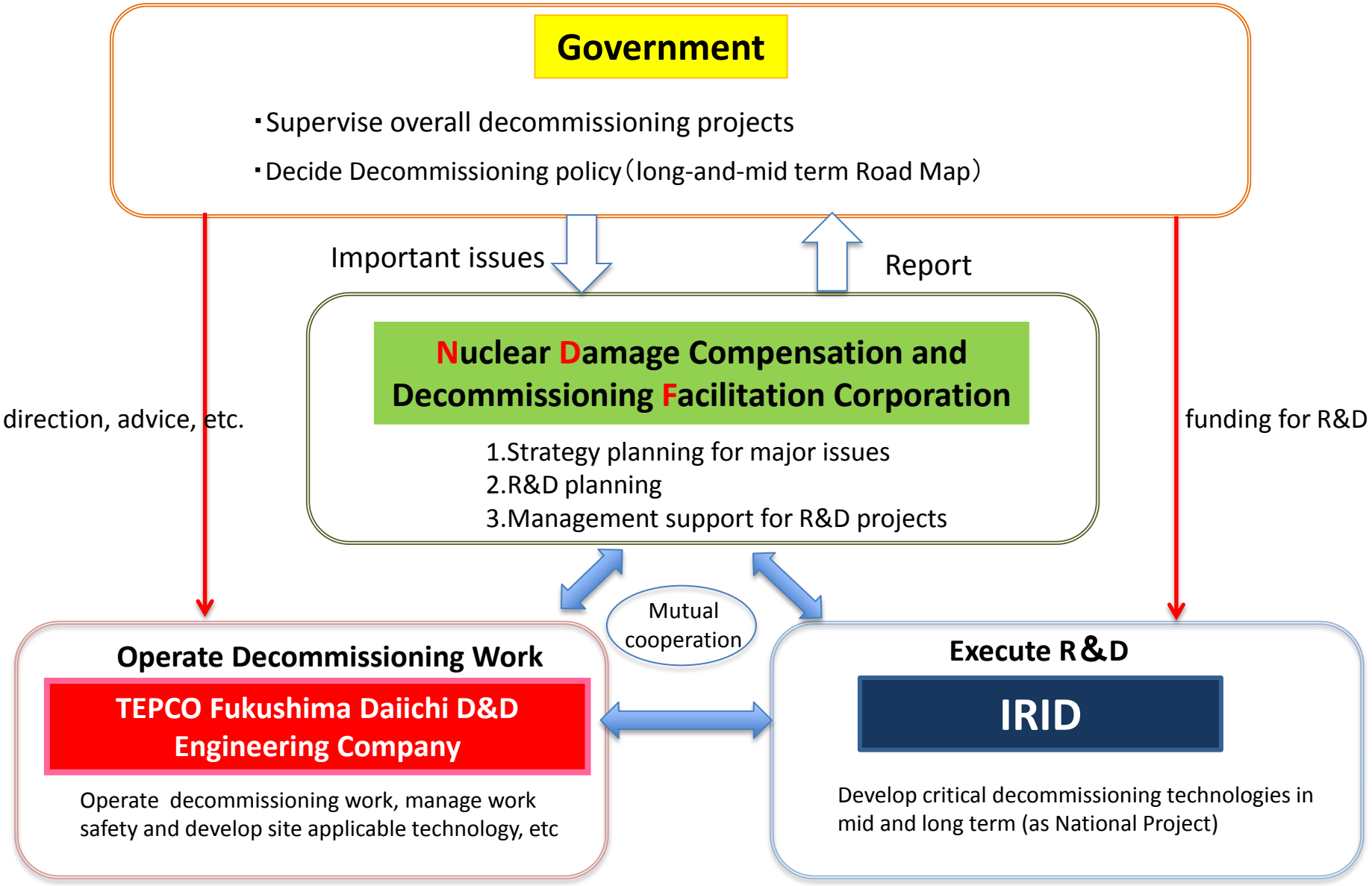
IRID gathers knowledge and ideas from around the world for the purpose of R&D in the area of nuclear decommissioning under the integrated management system.

R&D projects:

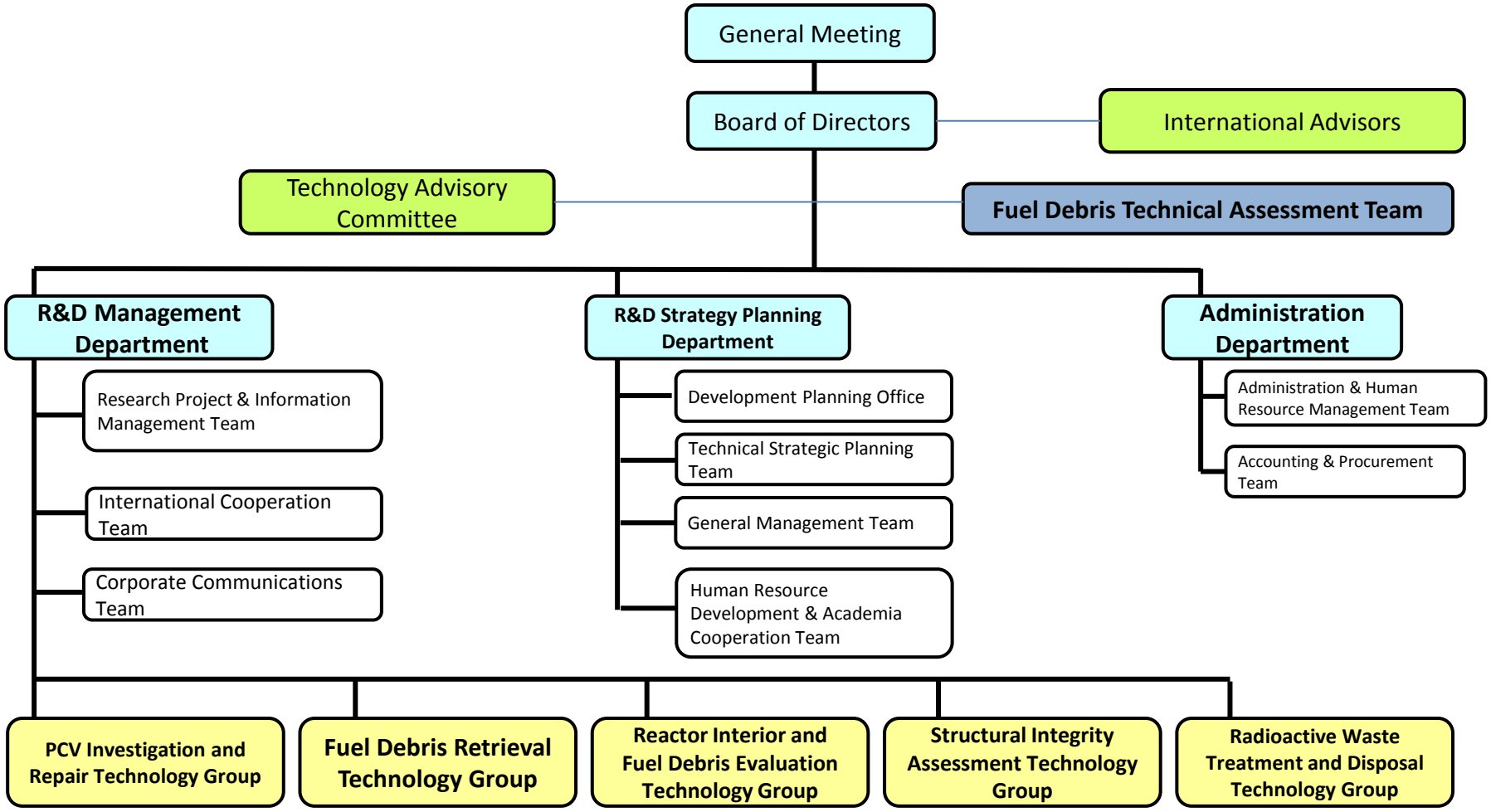
・Investigation of damaged PCV and preparation of repair tools
・Preparation for fuel debris retrieval
・Treatment and disposal of radioactive waste



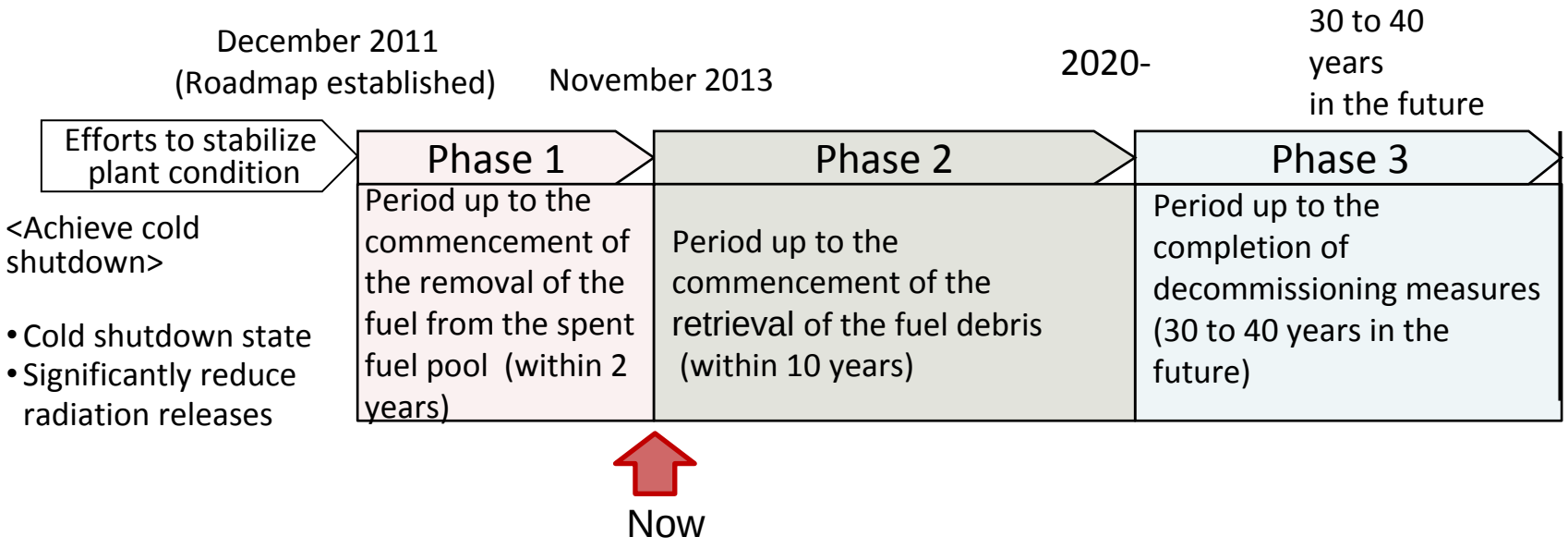
Decommissioning of Fukushima Daiichi NPS



Organizational Chart (2014. 8. 19～)



Mid-and-Long-Term Roadmap



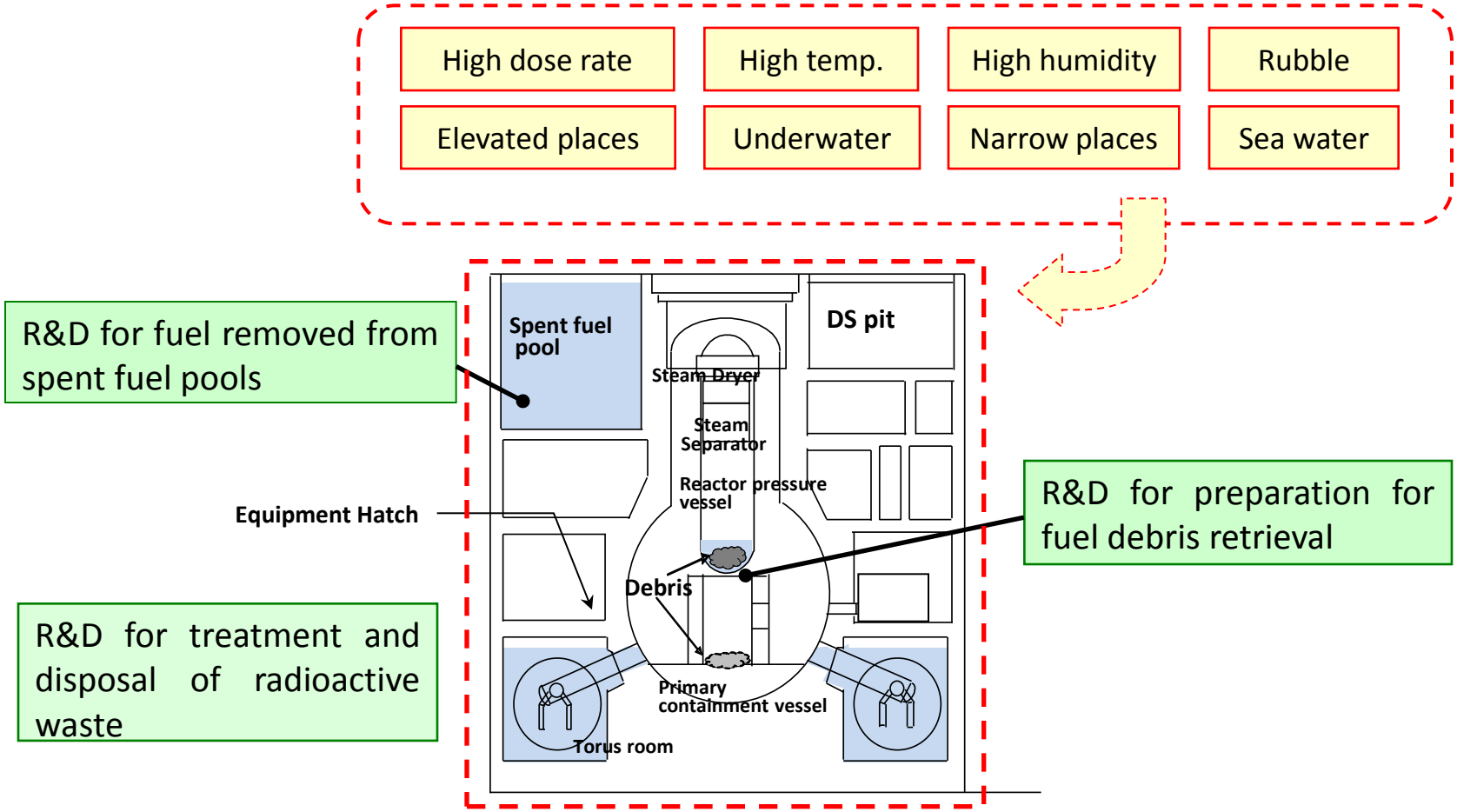
Having completed Phase 1 of Mid-and-Long-Term Roadmap, R&D will be addressed as follows from the Phase 2.

1. Promotion of long-term R&D in response to the start of fuel removal from spent fuel pool.
2. Development of multilateral, multilayered method and equipment for full scale preparation of fuel debris retrieval(1) - Submersion method- .
3. Development of multilateral, multilayered method and equipment for full scale preparation of fuel debris retrieval(2) - Alternative method- .
4. Stable promotion of R&D inconsideration of treatment and disposal of radioactive waste, and decommissioning.

R&D Activities of IRID

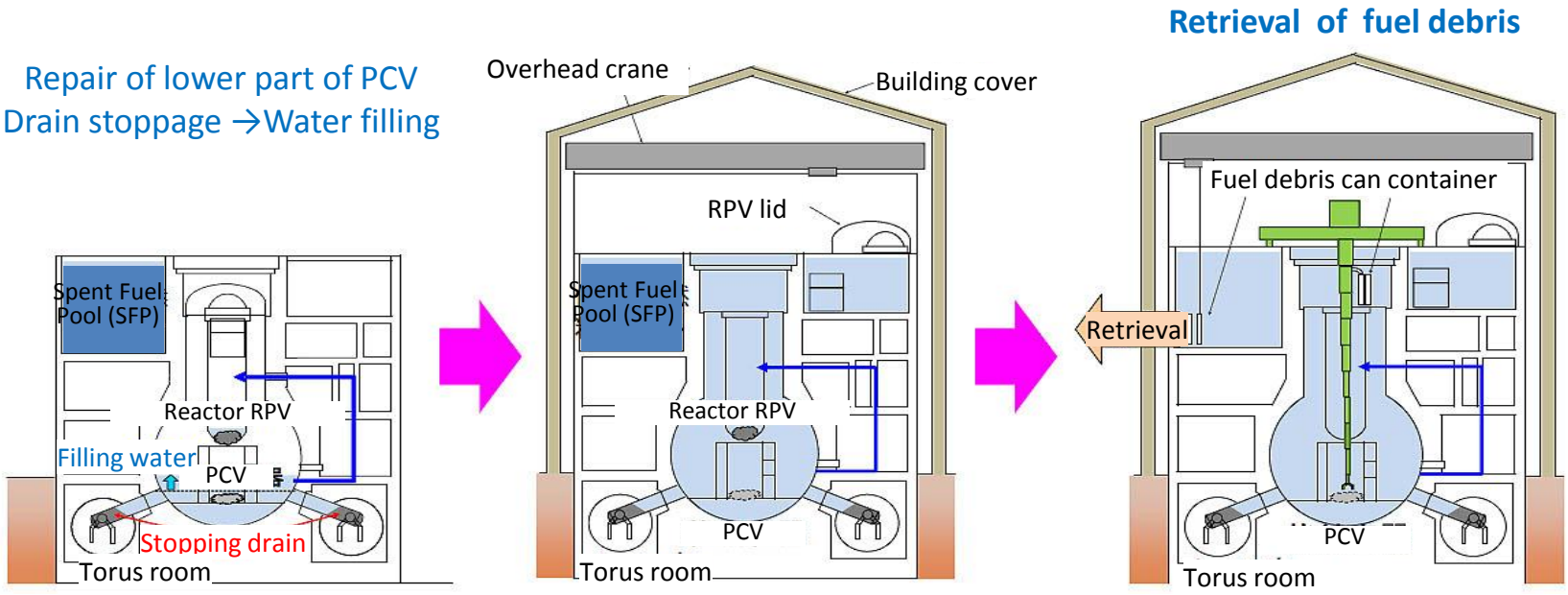
■ R&D activities should be carried out considering severe conditions of reactor buildings at Fukushima Daiichi.

High dose rate	High temp.	High humidity	Rubble
Elevated places	Underwater	Narrow places	Sea water



Concept of work steps for fuel debris retrieval

■The approach of retrieving the fuel debris submerged in water is the safest approach from the standpoint of minimizing exposure of workers.
■Technologies for investigation and repairing methods for filling the PCV with water are under development. Furthermore R&D for retrieval, packing and storage of fuel debris are implemented.
■Request for Information(RFI) on alternative methods for the fuel debris retrieval was conducted.



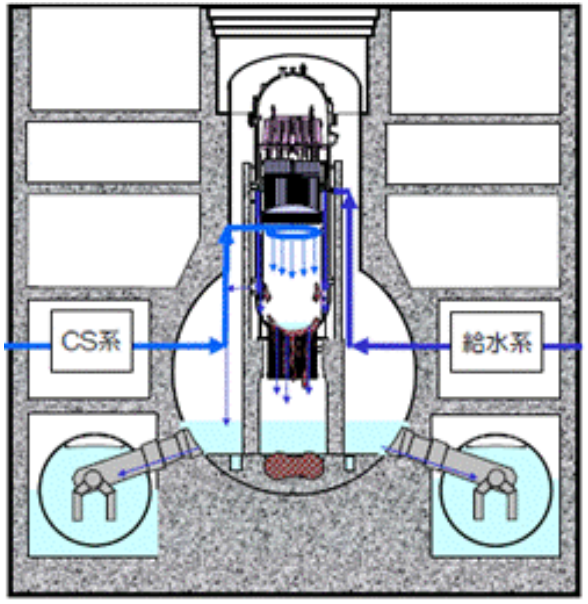
Major Challenges in the Existing Decommissioning Procedures

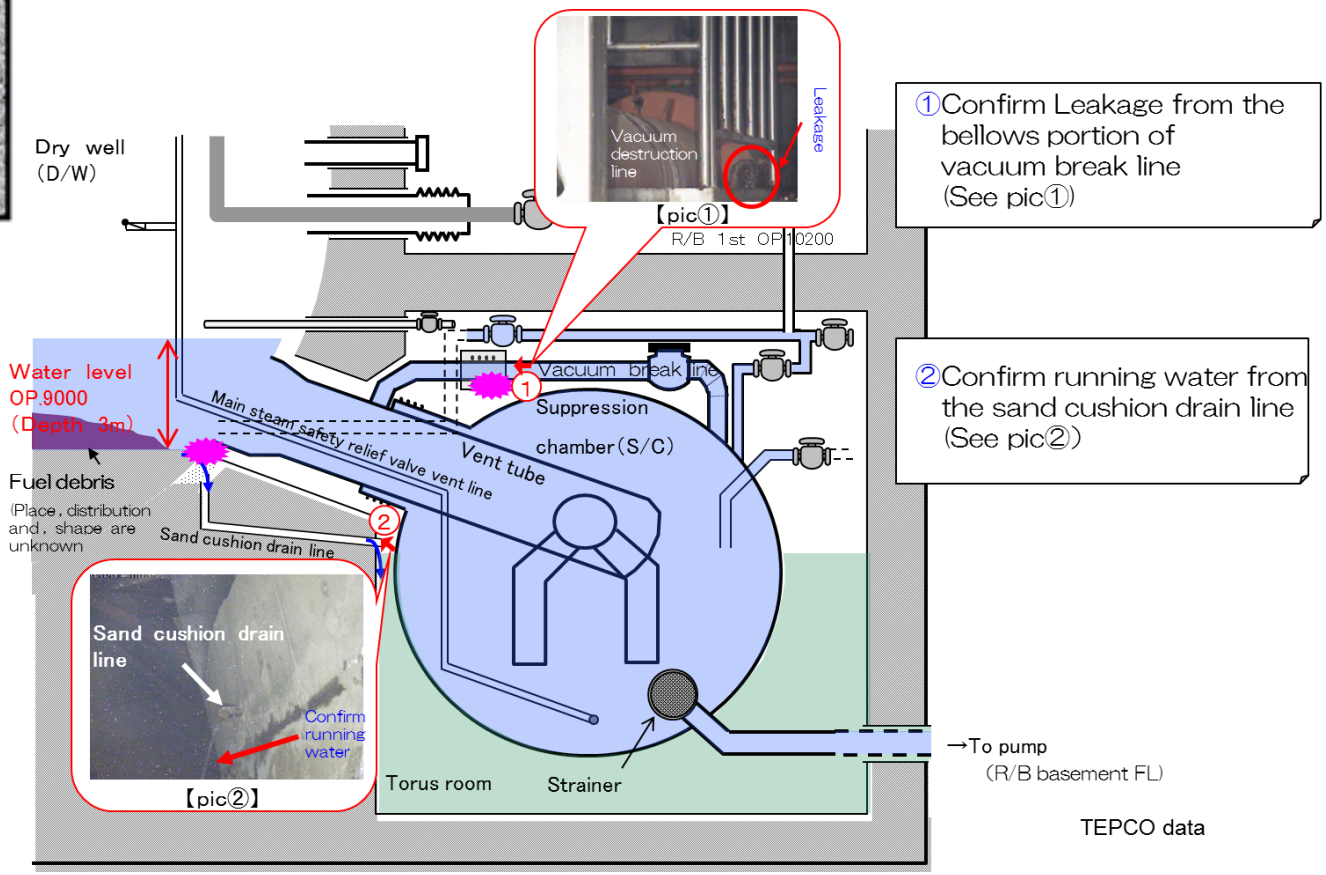
- **Final goal is to remove all fuels and fuel debris from Reactor Building (R/B).**
- **Removing procedure would be much more complicated than TMI-2 due to differences shown below:**

	TMI-2	Fukushima Daiichi
R/B Damage	Limited	Damaged by H_2 explosion (Units 1,3,4)
Water Boundary	RV remained intact	Both RPV/PCV are damaged (Units 1-3)
Fuel Debris Location	Remained in RV	Possibly fallen out of RPV
Bottom of the Vessel	No structural components	Complicated structure including Control Rod Drives

- Many of TMI-2 experiences can be utilized for fuel removal and decommissioning of Fukushima Daiichi.

Current status of lower part of PCV 【Unit 1】

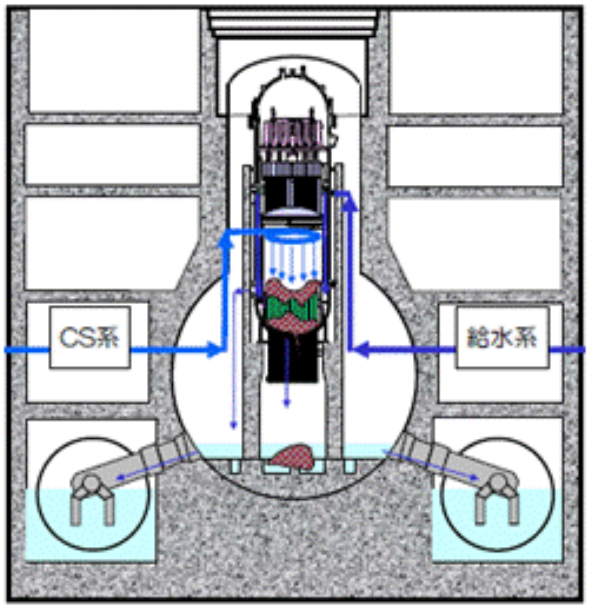


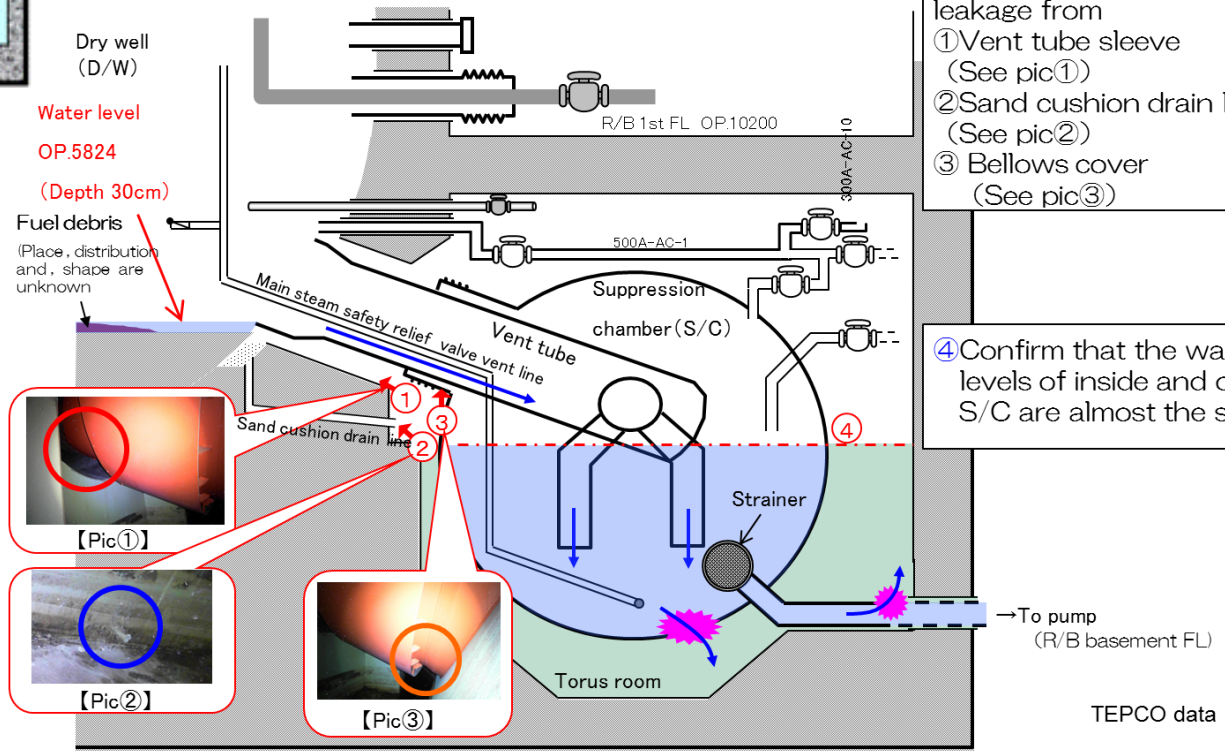


①Confirm Leakage from the bellows portion of vacuum break line (See pic①)

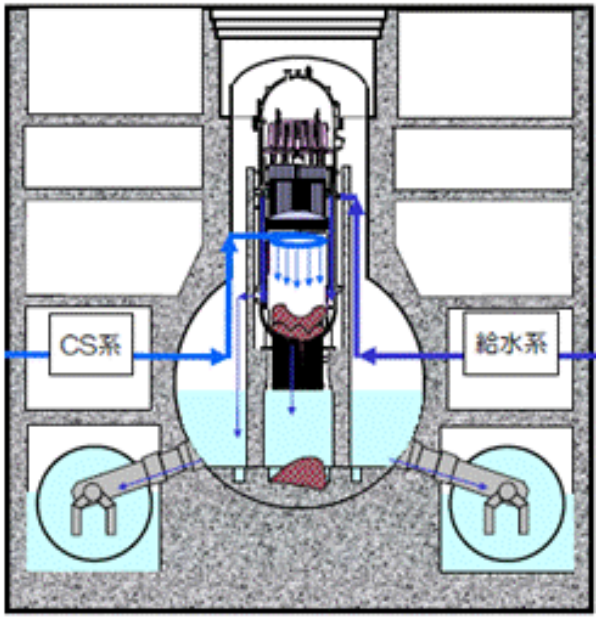
②Confirm running water from the sand cushion drain line (See pic②)

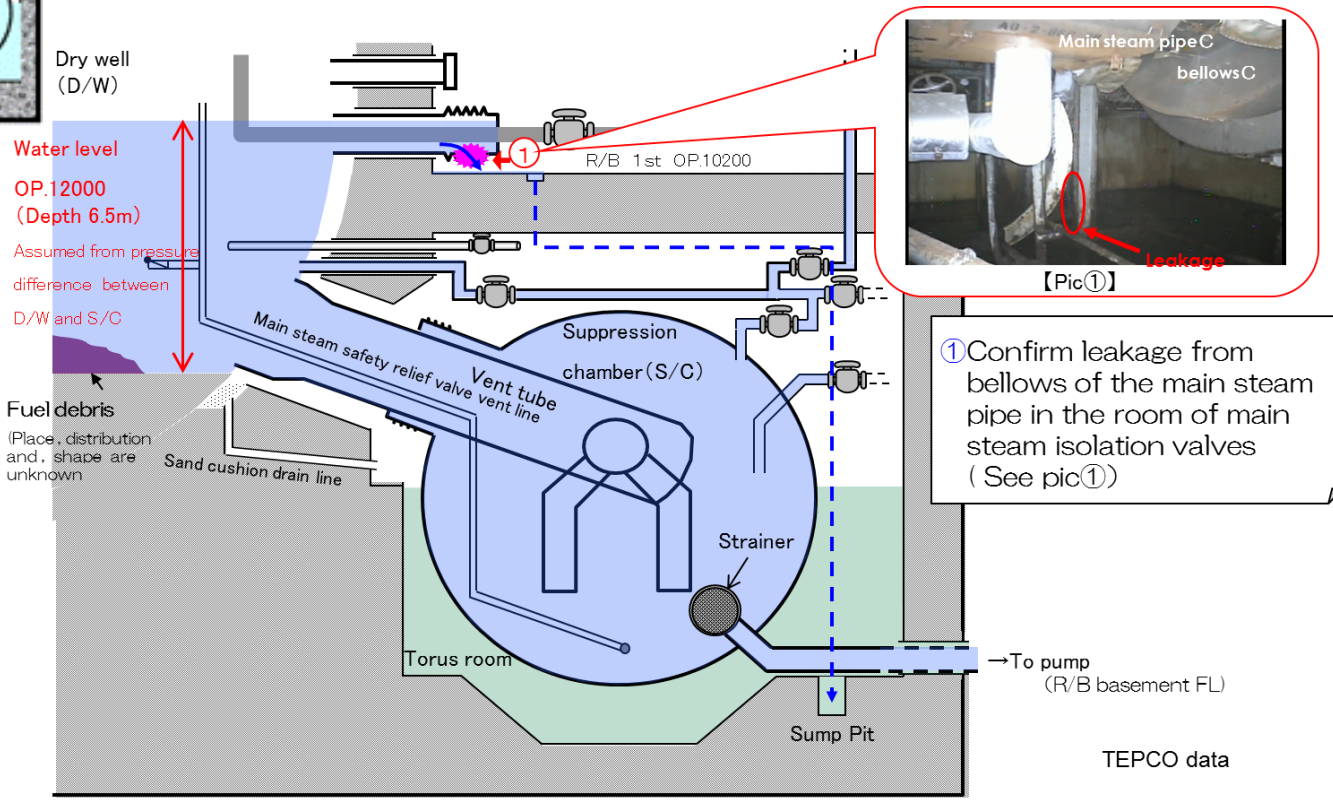
Current status of lower part of PCV 【Unit 2】





Current status of lower part of PCV 【Unit 3】





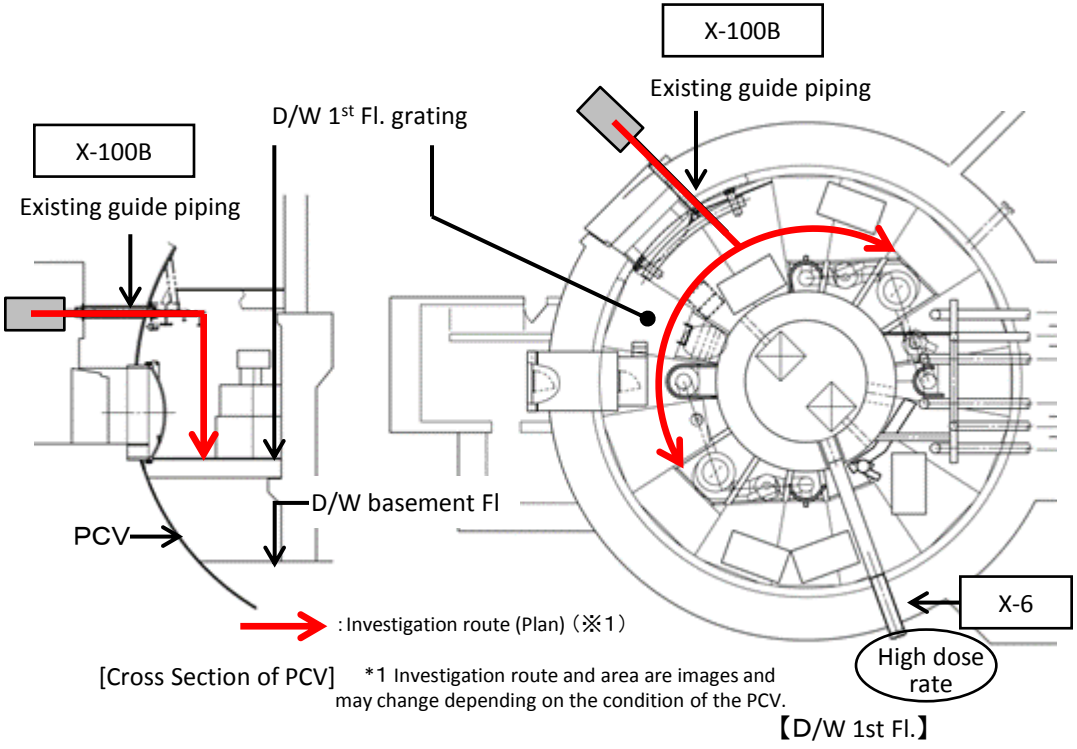
Investigation of status inside PCV

Investigation equipment of grating on the 1st floor outside pedestal

(1)Overview of equipment

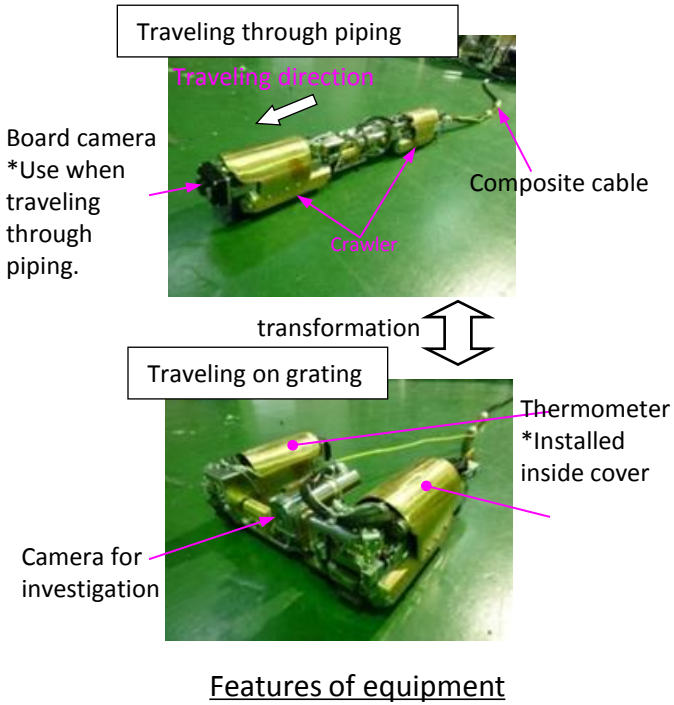
Shape-changing crawler equipment is inserted from the narrow access entrance (X-100B penetration opening : ϕ100mm) and safely travel on grating stably.

(2) Image of investigation route and equipment



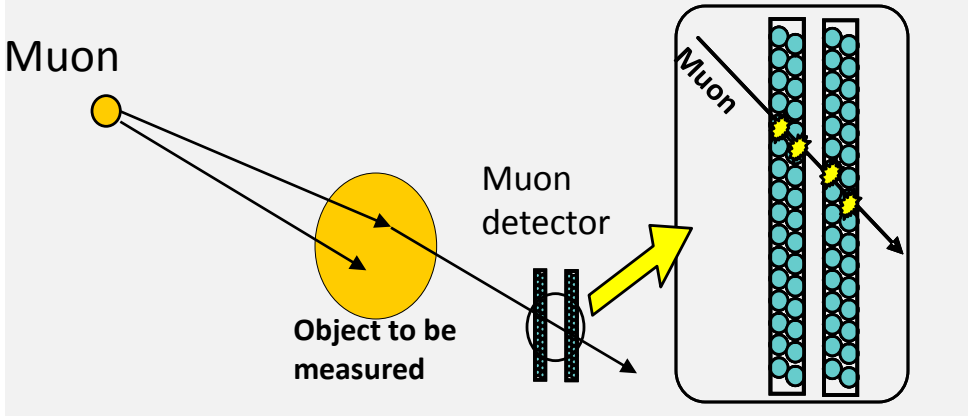
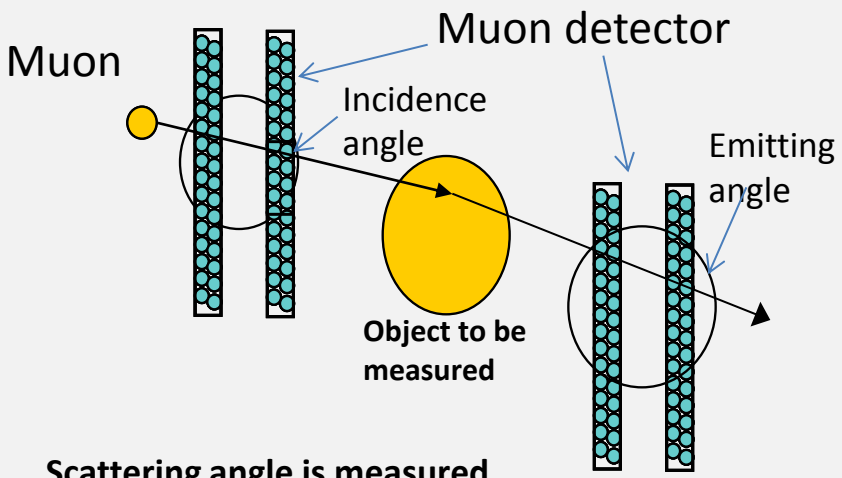
[Cross Section of PCV] *1 Investigation route and area are images and may change depending on the condition of the PCV.

Internal PCV investigation route (Plan)



Features of equipment

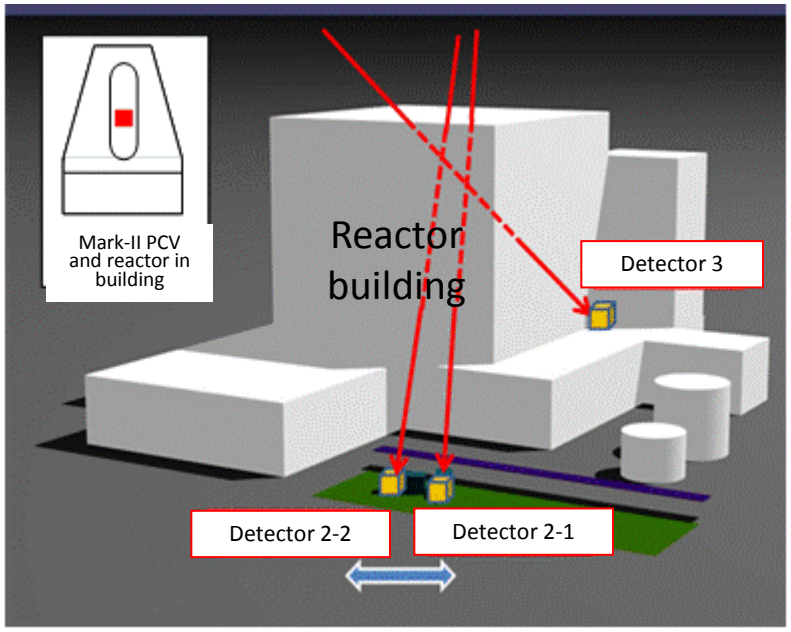
Fuel debris identification by muon observation technology

Permeation method	Scattering method
 **Permeation ratio is measured.**	 **Scattering angle is measured.**
Presence of matters in coming direction (two-dimensional)	**Presence of matters at scattering position (three-dimensional)**
Identifying ability (fuel debris): About 1 m	**Identifying ability (fuel debris) : About 30 cm**
One small-size muon detector (applicable early)	Two large-size muon detectors (need to be developed)
	Can identify heavy elements such as uranium.

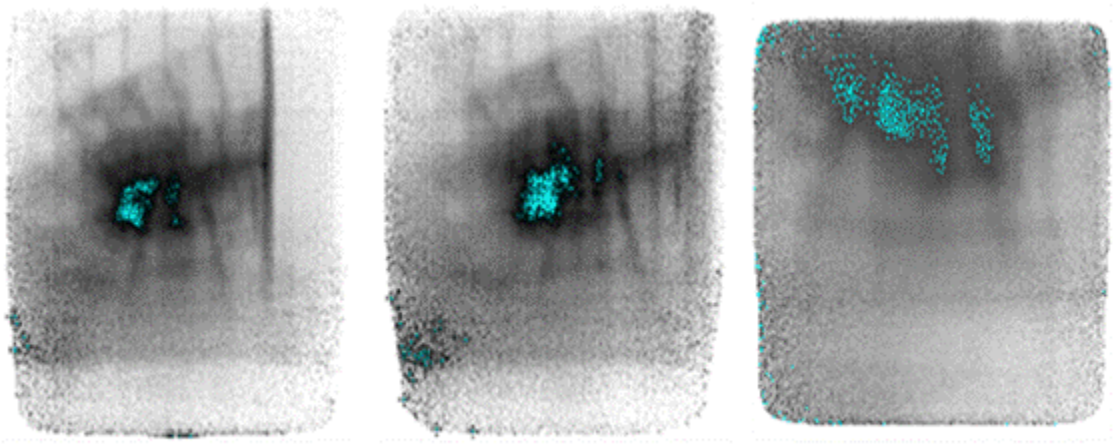
Test results (muon permeation method)

Results of measurement-at Tokai No. 2 nuclear power plant of the Japan Atomic Power Company:

- **No fuel in nuclear reactor**
- **Fuel existed in spent fuel pool**



Measurement positions at Tokai No. 2 nuclear power plant: (3 points)



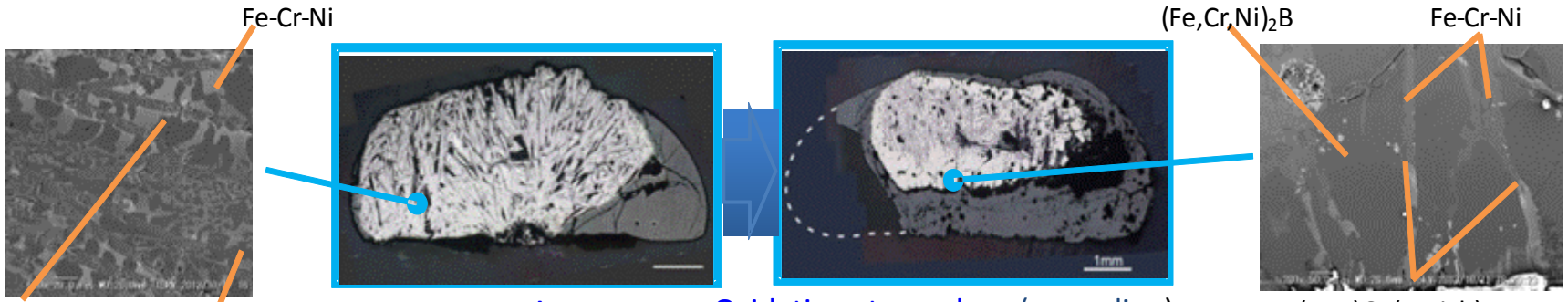
Detector 2-1 Detector 2-2 Detector 3

Measurement result at each point

High-density substance existed outside frustum-shaped PCV

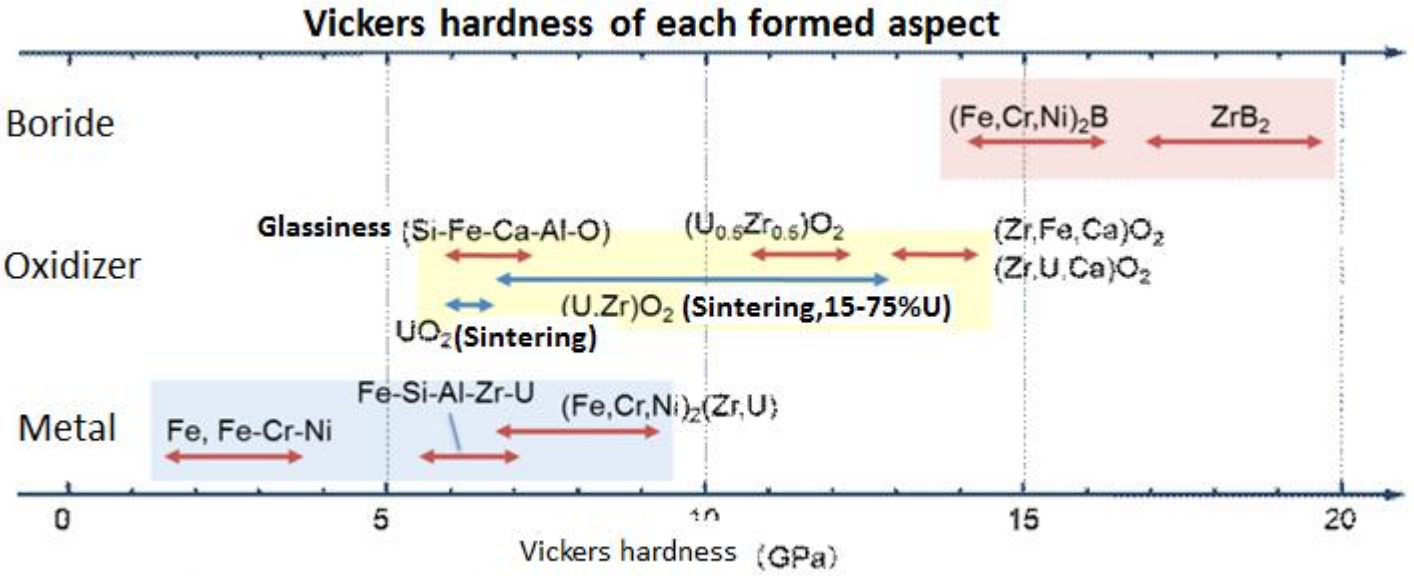
KEK(High Energy Acceleration Research Organization)data

Analysis of characteristics using mock debris



Reaction with control material（B_4C+SUS）（Example of the fusion solidification abstaining from side observation image

（ Obtained knowledge regarding the composition of solidified material generated when control rod and molten fuel ）



（Estimate hardness distribution for each chemical system of fuel debris (boride, oxide, metal)

Retrieval of Fuel Debris (Plan A)

◎ Technical method study

Retrieval scenario should be established considering information on the plant status, development of related technologies and investigation results.

→ Many information will be comprehensively evaluated and unclear points should be assumed.
→ Investigation of existing technologies is made in this project.

◎ Areas to be developed for retrieval of fuel debris

Areas common to retrieval of fuel debris, regardless of various "Plans", are as follows:

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

◎ Element tests

Element tests for cutting fuel debris, remote operation, and prevention of expansion of contamination are made.

(1) Cutting fuel debris
  1) Test to cut ceramic specimen
  2) Production of specimen
(2) Remote operation
  1) Long arm control technology
  2) Production of remote operated arm
(3) Prevention of expansion of contamination
  1) Selection of isolation film sheet

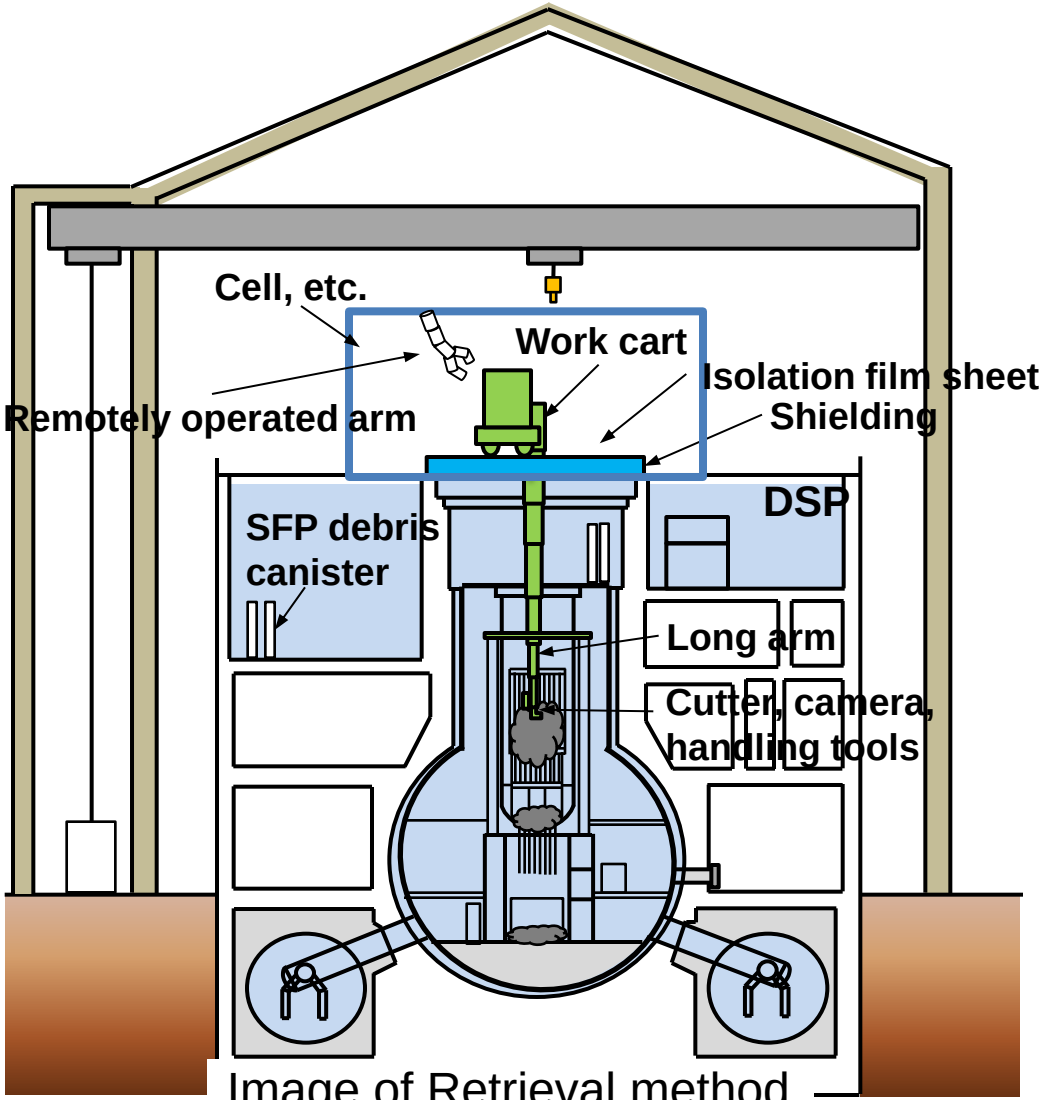
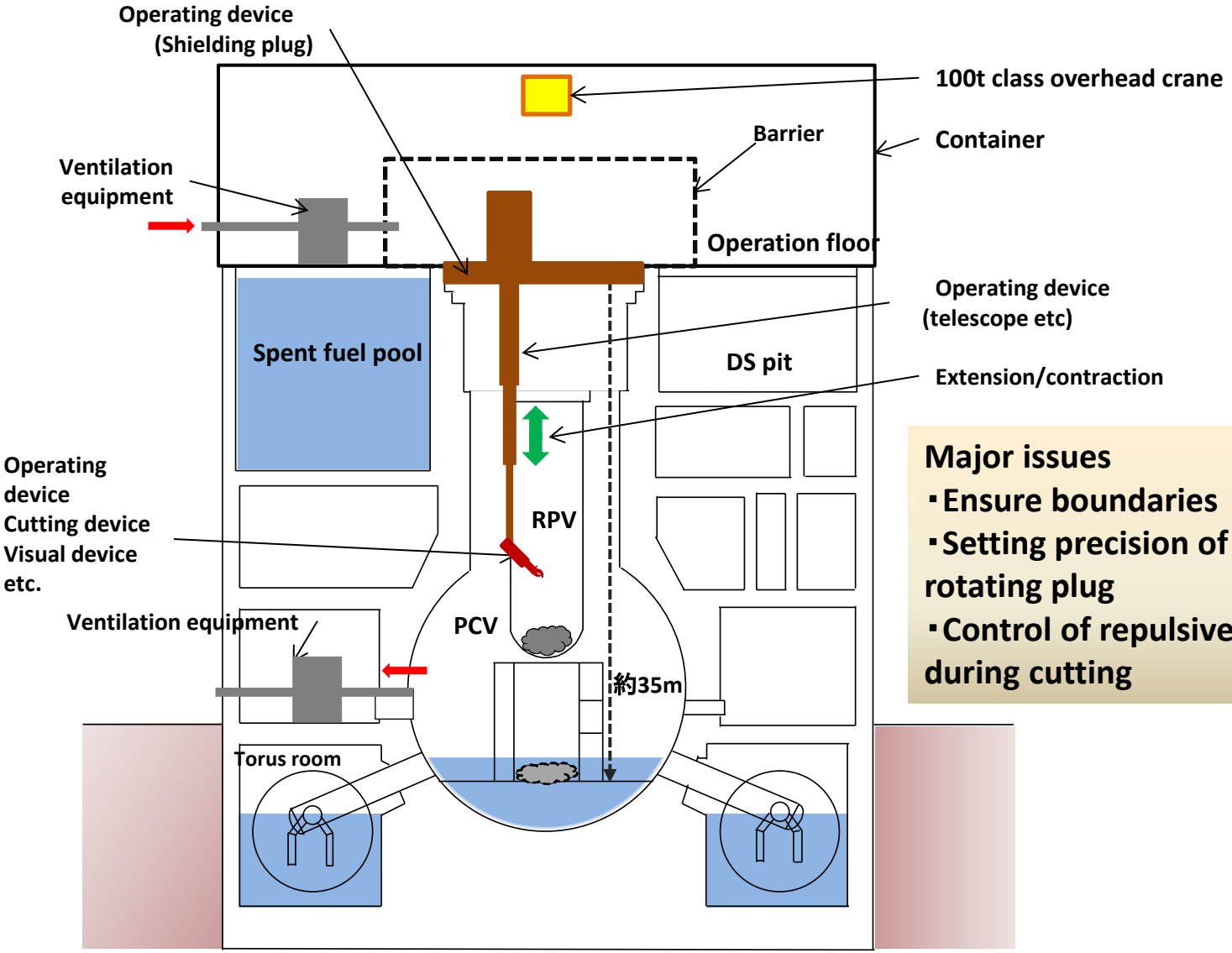


Image of Retrieval method

Plan B

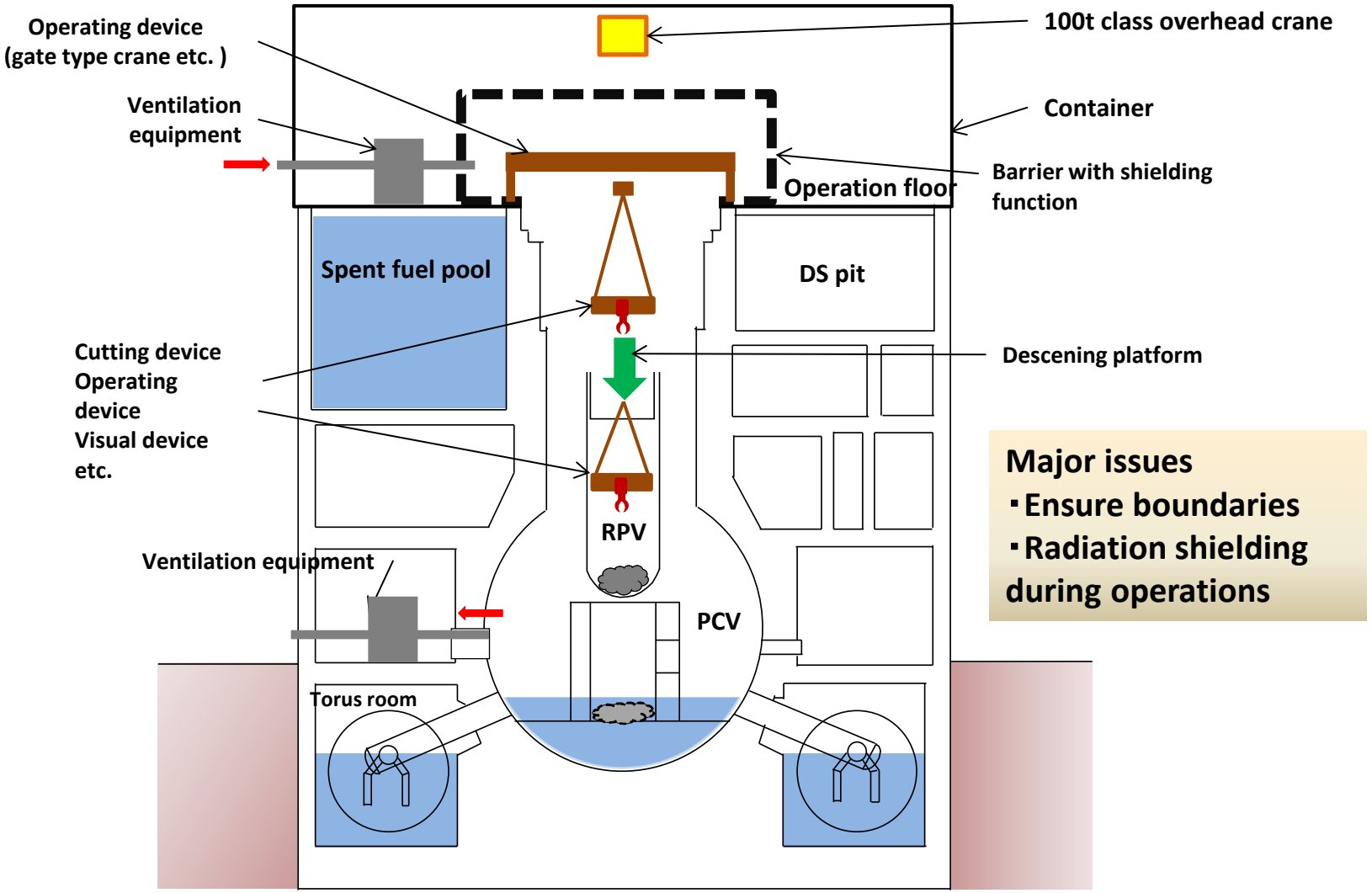


Major issues

- Ensure boundaries
- Setting precision of the rotating plug
- Control of repulsive force during cutting

Method to retrieve fuel debris in air by rotating plug

Plan C

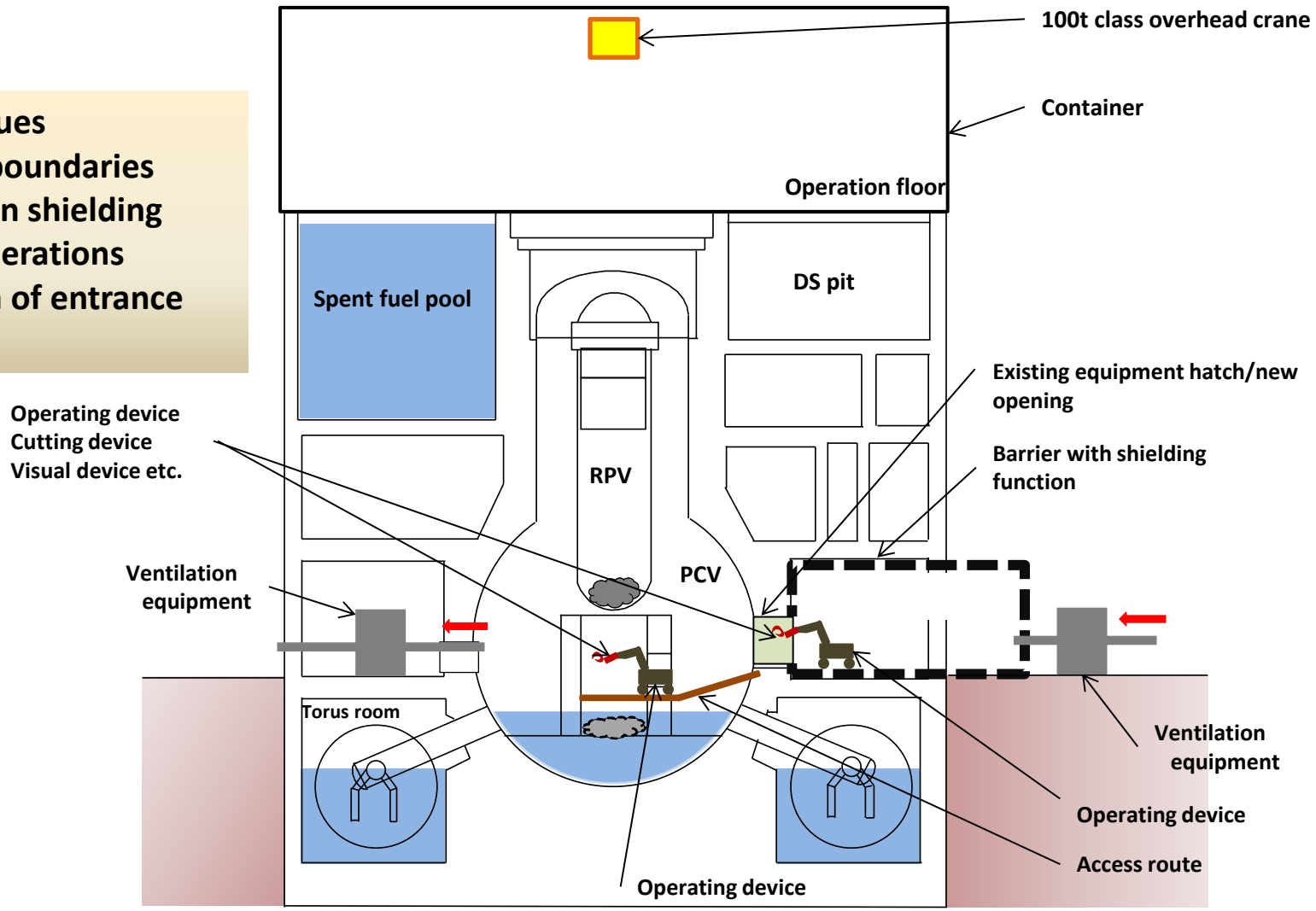


Major issues
- **Ensure boundaries**
- **Radiation shielding during operations**

Method to retrieve fuel debris in air by descending work platform

Plan D

Major issues
- **Ensure boundaries**
- **Radiation shielding during operations**
- **Location of entrance opening**



Method to retrieve fuel debris in air from the side

Conclusion

- In order to accomplish fuel debris retrieval, total optimization of the plan is essential. For that purpose methodology and technologies should be flexibly combined while purpose and objective of each Fukushima R&D program are clearly identified.

- Fuel debris retrieval of Fukushima Daiichi is much more difficult than that of TMI-2. In establishing overall strategy and developing retrieval tools, it is necessary to gather knowledge and information domestically and internationally.

- In establishing strategy, it is important to define the “End State”. Towards that End State alternatives should be prepared or made available in various stages.