Report of the Sub-Committee for the Evaluation of Fuel Debris Retrieval Methods (Outline)

March 7, 2024

Sub-Committee for the Evaluation of Fuel Debris Retrieval Methods

Nuclear Damage Compensation and Decommissioning Facilitation Corporation

Table of Contents

1. Background of the study

- **Although the fuel debris at the Fukushima Daiichi Nuclear Power Station is considered to be in a stable state** based on the investigation of the state inside the reactors and analysis from plant parameters, there is no guarantee that this state will continue for a long period of time, and there is a **concern that the risk will gradually increase resulting from age-related deterioration**. Therefore, it is desirable to **recover fuel debris as soon as possible to ensure safety in the medium to long term.**
- In preparation for the start of large-scale retrieval operations in the 2030s, **it is necessary to continue the work to make the retrieval method more reliable after narrowing down the direction of the design study and proceeding with more specific design studies than before**, by extracting technical issues and proceeding with elaborate studies.
- Fuel debris retrieval is not only an unprecedented technological challenge, but also **a social and policy issue**. In narrowing down the direction of the design study in the face of great uncertainties, **the government, TEPCO, and NDF should cooperate to advance it, and conduct specialized and intensive studies by gathering technical knowledge from inside and outside Japan.**
- For this purpose, the “Sub-Committee for the Evaluation of Fuel Debris Retrieval Methods" (hereinafter referred to as the "**Sub-Committee**") **was established under the NDF's Decommissioning Strategy Committee, to conduct a comprehensive study and evaluation of the retrieval methods based on the basic premise of safety.**
- The Sub-committee has reviewed and evaluated the followings;
  - ✓ **Organizing out issues and measures in retrieval methods to address them**
  - ✓ **Evaluation of each retrieval method (technological, etc.)**
  - ✓ **Recommendations for the selection of retrieval methods**
  - ✓ **Future Course of Action**

1. Background of the study

<List of Committee members for Sub-Committee for the Evaluation of Fuel Debris Retrieval Methods>

(Titles omitted/in Japanese alphabetical order)

Chairperson	Toyoshi Fuketa	Previous Chairman, Nuclear Regulation Authority
	Tatsuya Itoi	Associate Professor, School of Engineering The University of Tokyo
	Hiroto Uozumi	President & CEO, Atomic Energy Association
	Koji Okamoto	Professor, Graduate School of Engineering The University of Tokyo
	Akira Kirishima	Professor, Institute of Multidisciplinary Research for Advanced Materials, Tohoku University
	Takumi Saito	Professor, School of Engineering The University of Tokyo
	Nobuyuki Miura	Executive Director, Japan Atomic Energy Agency
	Yoshihito Miyaike	Previous President, Central Nippon Expressway Company Limited
	Akio Yamamoto	Professor, Graduate School of Engineering, Nagoya University
	Hans Wanner	Previous Director General Swiss Federal Nuclear Safety Inspectorate (ENSI)

1. Background of the study

<Date and agendas (1/2)>

Time	Date	Agenda
1	March 29 2023	• Procedures to study retrieval methods of fuel debris, etc.
2	April 18 2023	• Policy of securing safety (Partial submersion method) • Overview and issues of Partial submersion method (water injection into RPV), etc.
3	May 17 2023	• The groundwater structure and contaminated water management of Fukushima Daiichi Nuclear Power Station • Overview and issues of Submersion method, etc.
4	June 6 2023	• The necessity of fuel debris retrieval • Overview and issues of optional Partial submersion method, etc.
5	July 19 2023	• Clarifying issues on each retrieval method, etc.
6	September 22 2023	• Approach to securing safety [Containment and shielding (relating to seismic resistance)] • Issues and measures -Seismic resistance- (Containment/Shielding), etc.

1. Background of the study

<Date and agendas (1/2)>

Time	Date	Agenda
7	October 11 2023	• Approach to securing safety [Criticality control] • Issues and measures -Criticality control, etc.
8	November 16 2023	• Issues and measures -High radiation dose/insufficient site information, etc.
9	December 15 2023	• Approach to waste management • Evaluation of retrieval methods, etc.
10	January 17 2024	• Approach to securing safety, etc.
11	February 21 2024	• Technological feasibility and Business continuity of each retrieval method • Repot of the Sub-committee for the Evaluation of Fuel Debris Retrieval Methods （Preliminary draft), etc.
12	February 29 2024	• Repot of the Sub-committee for the Evaluation of Fuel Debris Retrieval Methods （Draft), etc.

2. Factors that make fuel debris retrieval difficult

① Extremely high radiation dose inside the PCV and people cannot enter.

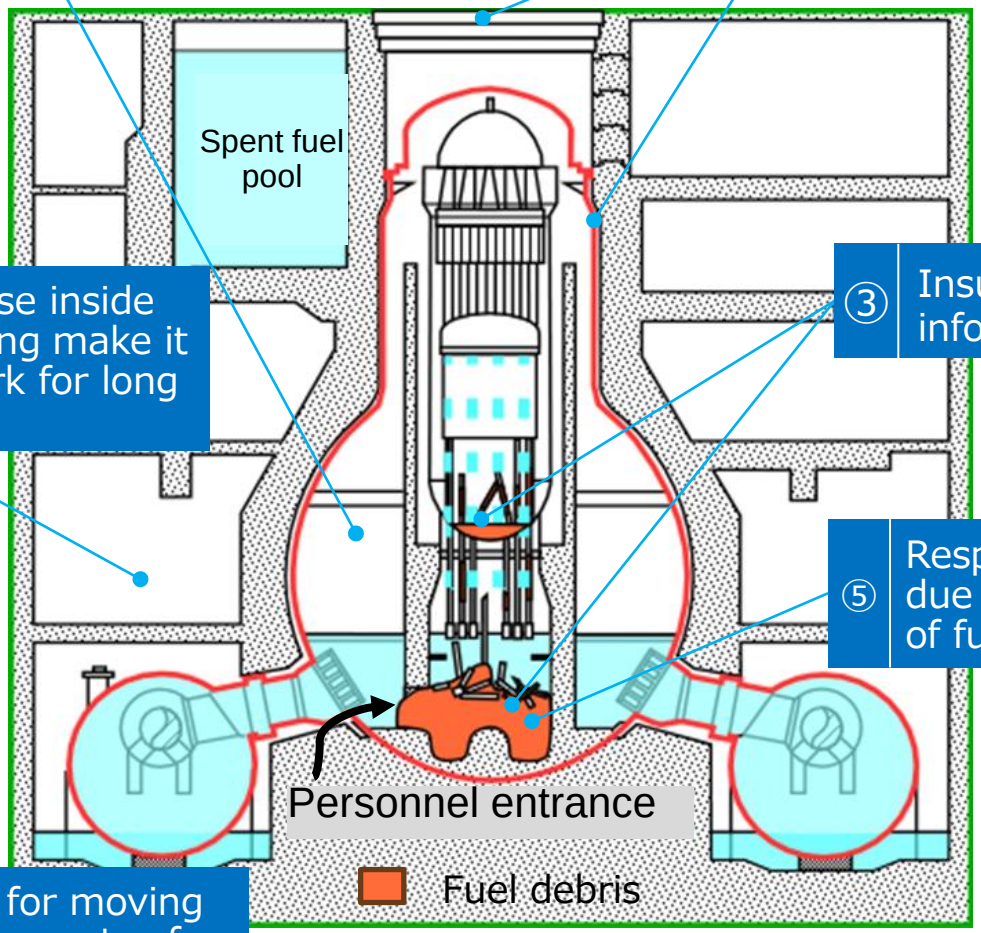
② High radiation dose inside the reactor building make it impossible to work for long periods of time

③ Insufficient on-site information due to ① and ②.

④ The containment vessel must be opened while controlling the diffusion of radioactivity

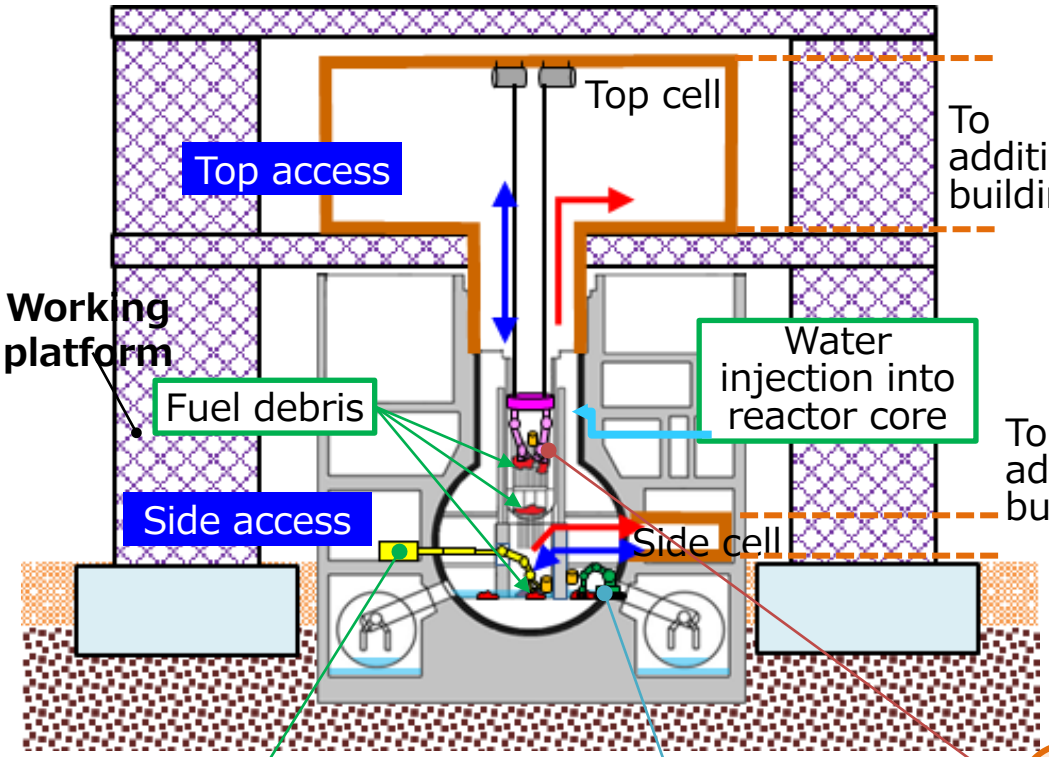
⑤ Responding to recriticality due to changes in the state of fuel debris

⑥ Developing a plan for moving and storing vast amounts of contaminated structures and waste



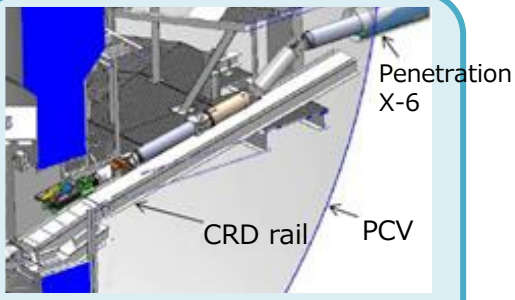
Estimated fuel debris distribution in Unit 3

3. Fuel debris retrieval methods
3.1 Partial submersion method



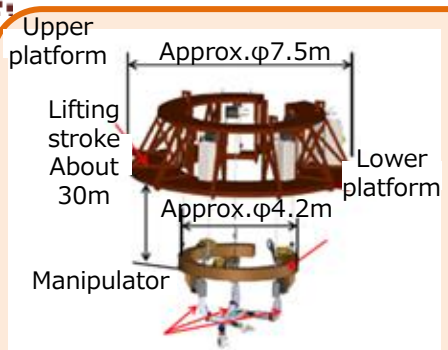
【Outline】
A method that is retrieved with fuel debris exposed in the air or submerged at low water level.

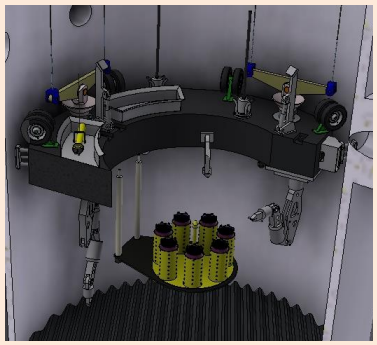
Examples of remote control equipment



An example of long-arm

An example of ROV





An example of platform-type access equipment

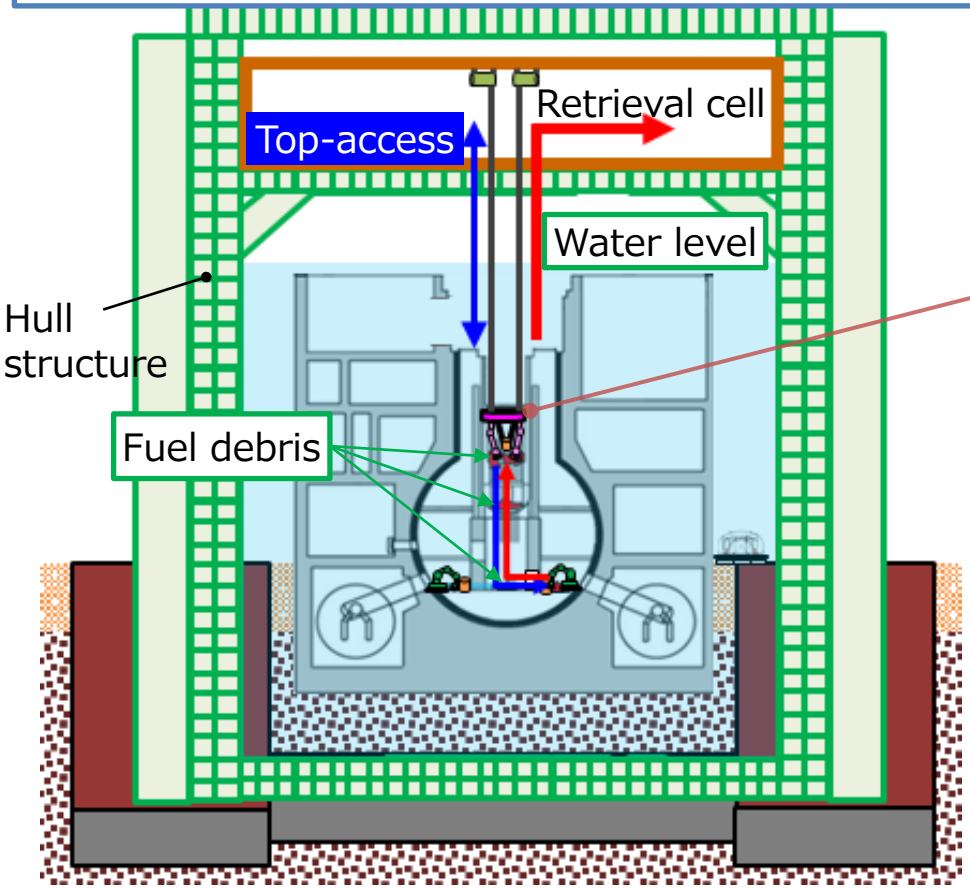
Diagram provided by TEPCO

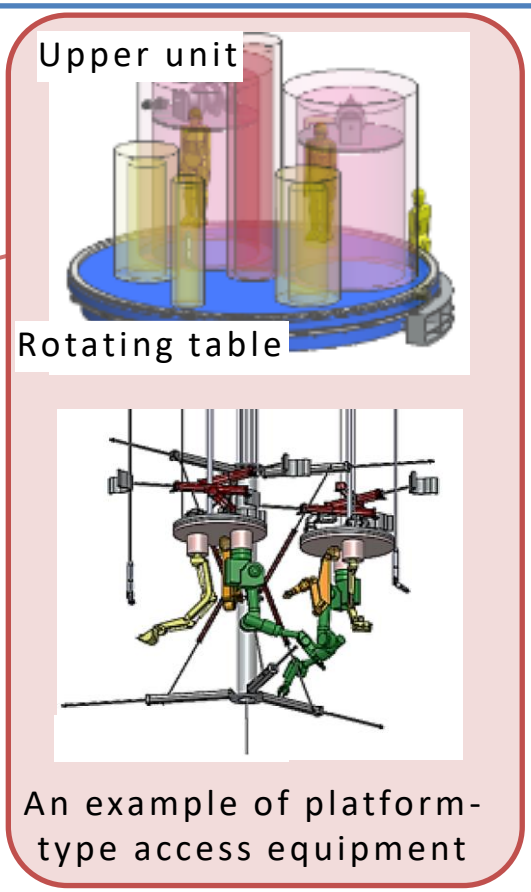
3. Fuel debris retrieval methods
3.1 Partial submersion method

Strengths	Issues
◆Since retrieving will be made in the situation that is currently being maintained without major change, there are few pending issues associated with the status change. ◆Fuel debris retrieval work can be started earlier than with submersion method ◆Fuel debris processing and recovery methods can be selected according to the internal conditions, such as selecting among multiple retrieval methods for top access, and a combination of top and side access.	◆Because of the high radiation dose at the site, a wide variety of remote control devices are required compared to other methods, and it takes a long time to develop, design, and verify the devices. ◆Based on the past experience, it takes a considerable period of time to respond to recovery from remote control device failures. ◆As high-level dose fuel debris and waste are removed from the top, which requires the installation of a heavy cell and removal equipment on the operating floor, the scale of the platform for supporting these components becomes enormous.

3. Fuel debris retrieval methods
3.2 Submersion method

【Outline】
A method for enclosing the entire reactor building with a new structure called hull structure as a containment barrier, submerging the building and retrieving fuel debris.





An example of platform-type access equipment

Diagram provided by TEPCO

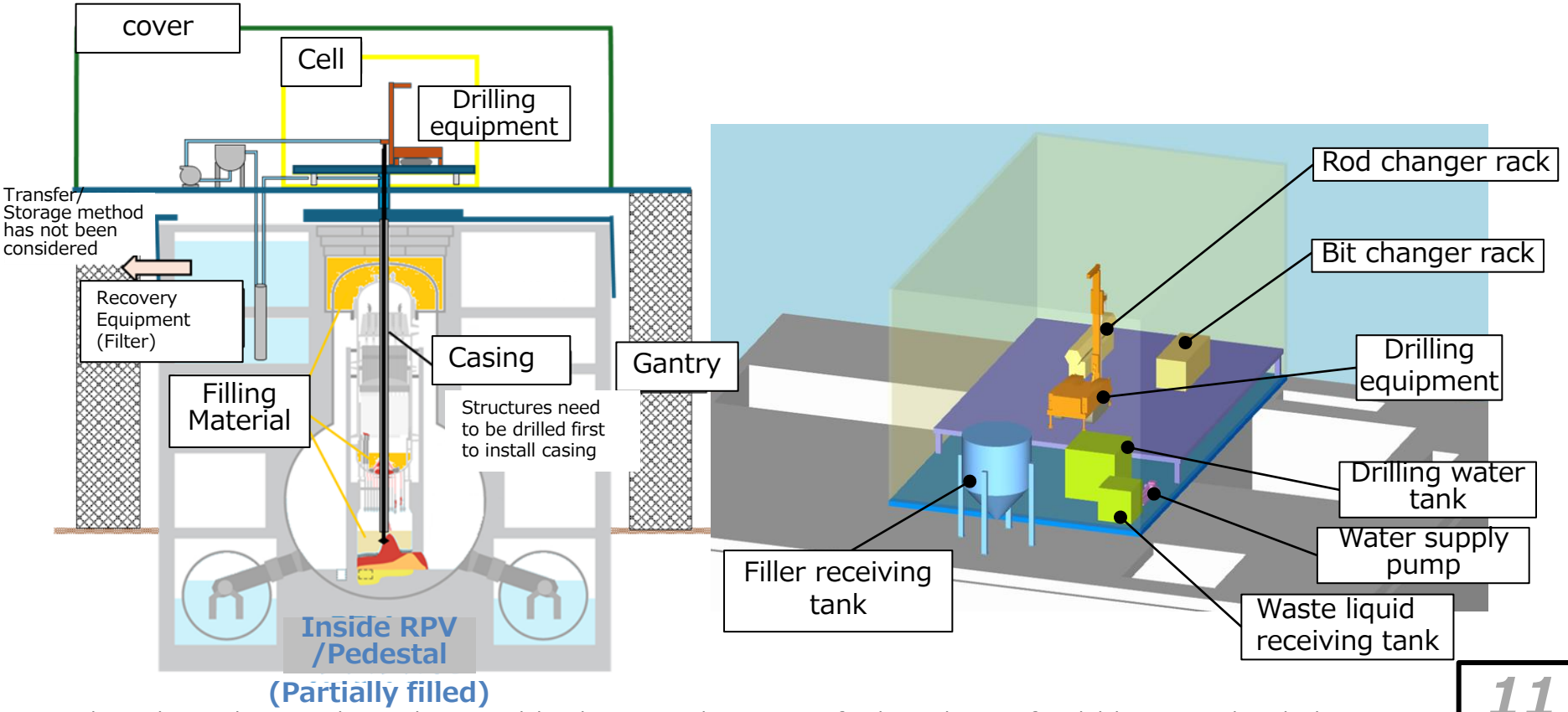
3. Fuel debris retrieval methods
3.2 Submersion method

Strengths	Issues
◆Water shielding is expected to reduce radiation dose and also suppress dust dispersion. ◆Strong containment barriers (hull structure) allow for complete isolation from the outside ◆Rescue at equipment failure can be manually operated from the operating floor.	◆It is necessary to verify the on-site workability in the construction of hull structure in the underground of the building (including ground stability at earthquake during construction). ◆ Criticality and water quality control need to be established for large volumes of retained water ◆ The scale of facility in the hull structure is enormous. ◆ Longest preparatory construction period and slowest start of fuel debris retrieval operations

3. Fuel debris retrieval methods
3.3 Partial submersion method option (Filling and solidification method)

【Outline】

A method to reduce the on-site dose while stabilizing fuel debris by filler materials and to recover fuel debris, structures inside reactor, by excavating through a relatively small opening provided in the operating floor.



3. Fuel debris retrieval methods
3.3 Partial submersion method option (Filling and solidification method)

Strengths	Issues
◆Once stabilized by solidifying with filler materials, solid form can be handled uniformly and simply during retrieval. ◆Dose reduction is expected due to shielding effect by filler material and access to fuel debris through small openings. ◆Manual operation is also expected in the rescue in case of equipment failure. ◆Drilling equipment is remotely operated, but the structure is simple, and the tip bit and other parts can be replaced depending on drilling targets. ◆Smaller facilities may be the earliest to start retrieval.	◆Selection of filler materials (flowability, adjustability of curing time, mechanical properties after solidification, thermal conductivity, chemical stability, degradability with radiation, etc.), filling method, and method to check filling condition must be established. ◆Selection and verification of tip bits, etc. depending on the drilling targets are necessary. ◆The amount of waste generated increases according to the filling range. ◆When collecting waste in the form of sludge, care must be taken in its handling.

4. Recommendations for the selection of retrieval methods

- 3 retrieval methods have issues, and **it is desirable to consider scenarios that take advantage of the strengths of each retrieval method**.

Method	Evaluation and direction of each retrieval method in terms of method selection
Partial submersion method	• Although it does not require significant changes on current status to retrieve fuel debris and it can avoid concerns on the changes in current conditions, there are significant performance concerns such as the feasibility of the construction sequence, remote operability, and overall availability, etc. Therefore, **it is necessary to conduct design studies that take into account the realistic constraints and conditions at the site.** • Since **merging the partial submersion method option with this method** may solve some of the issues of this method, it is appropriate **to explore to establish a complementary relationship with partial submersion method option** in future design studies.
Submersion method	• There are problems such as uncertainty in the on-site workability of hull structure and difficulty in handling a large amount of water, so **it is difficult to select retrieval method as the one to be started for full-scale construction at present**. • **The advantage of handling** high-level dose materials **in water is great**, and considering the possibility that it will be easier to retrieve from difficult parts in partial submersion method and the efficiency of the work, **it cannot be ruled out that it may be shifted from partial submersion method to submersion method, which can utilize water shielding functions in the future**. • The retrieval method, **which can utilize water shielding functions, should be studied in parallel**, for example, by investigating the nearby ground including the lower part of the reactor building.
Partial submersion method option	• It is too early to judge the feasibility of this method at this point, as insufficient technical study is undeniable. • **When the selection of filler material and the injection/recovery methods of filler material become clear, since it is expected that this method can develop partial submersion method, a scenario with partial submersion method by applying the features of partial submersion method option is assumed.**

4. Recommendations for the selection of retrieval methods

- **Enough understandings of the situation inside the reactor are a prerequisite for its design and for ensuring its** safety at any retrieval method.
- Accelerating progress of **internal** investigations is important in the future, however, it is **essential to make parallel progresses on the selection of a retrieval method and its engineering.**

- **Start design studies and research and development utilizing partial submersion method Option functions based on partial submersion method**
  - In parallel with this, **internal investigations on a small-scale through top-access will be conducted**.
  - **A retrieval method utilizing water shielding functions will also be studied**.

5. Future Course of Action

(1) TEPCO's engineering study for large-scale retrieval method

- ✓ TEPCO **will start more detailed engineering study based on the recommendation in this report.**
- ✓ **It is important to tackle the issues presented in this report such as internal investigations and research and development**, as well as engineering studies.

(2) Development of safety assurance concept

- ✓ **The concept of securing safety/judgment criteria and their basis should be clarified** at an early stage, then reflected in the basic design and detailed design **based on the views and suggestions from the regulatory side.**

(3) Follow-up by the Sub-committee

- ✓ It is recommended **to keep this Sub-committee in near future to follow up TEPCO's engineering, research and development activities.**

(4) Communications with local governments and residents

- ✓ The contents of this report and the implementation status of TEPCO's engineering study will be **fully shared through dialogue with local governments and residents in relevant regions.**