

**Technical Strategic Plan 2016
for Decommissioning of the Fukushima Daiichi
Nuclear Power Station of Tokyo
Electric Power Company Holdings, Inc.**

Overview

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Nuclear Damage Compensation and Decommissioning Facilitation Corporation

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1. Introduction

In response to the accident at the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company (hereinafter referred to as "Fukushima Daiichi NPS"), the measures have been taken for the most urgent issues such as the contaminated water management so far. However, for the damaged reactors of the Fukushima Daiichi NPS, development of a mid- and long-term decommissioning strategy is essential "to reduce the risks posed by radioactive materials and to carry out decommissioning over a long period of time." The NDF launched the "Technical Strategic Plan for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company Holdings, Inc. (hereinafter referred to as "the Strategic Plan")" as part of its statutory obligations "to provide advice, guidance and recommendations for ensuring an appropriate and steady conduct of the decommissioning of the Fukushima Daiichi NPS" and of "R&D for technologies required for decommissioning" based on the Nuclear Damage Compensation Facilitation Corporation Act.

The Strategic Plan 2016 was formulated based the status of the progress made in site conditions and technical development made in one year since the Strategic Plan 2015 was released on April 30, 2015.

2. The Strategic Plan

1) Progress in the decommissioning of the Fukushima Daiichi NPS over the last year

The progress has been made in the condition of the Fukushima Daiichi NPS as follows.

(1) Management of contaminated water

Measures based on the three fundamental policies (removing contaminated sources; isolating contaminated sources from the water; and preventing leakage of contaminated water) are being taken on the contaminated water generated from mixture of the groundwater flowing into buildings and cooling water for the fuel debris. As for "removing," water purification is performed continuously such as by Advanced Liquid Processing System and water leak from the sea water piping trenches was blocked. As for "isolating," in addition to the decrease in the water flowing into the building through the groundwater bypassing system and sub-drain operation, freezing operation of the land-side impermeable walls has been started. As for "preventing leakage," groundwater is pumped out through the underground drainage system with the sea-side impermeable walls closed.

(2) The removal of fuel assemblies from the spent fuel pool

Unit 1 Disassembled building cover and removing rubble. Unit 2 All the upper part of the R/B will be disassembled. Unit 3 Completed removal of large sized rubble in the spent fuel pool (SFP). Dose reduction on the operating floor is being performed.

(3) Conditions inside the reactor surveillance

Unit 1: Investigations using of the muon detection system and inspection inside the Primary Containment Vessel (PCV) using robot.

Unit 2: Arranging PCV internal survey using robot as well as the inspection using the muon detection system.

Unit 3: Sent inspection device inside the PCV and obtained information.

(4) Waste

The stored inventory was increased because of the secondary waste generated due to the progress of contaminated water treatment and radioactive solid waste caused by removal of rubble. Tokyo Electric Power Company Holdings, Inc. (hereinafter referred to as "TEPCO") is enhancing the structure of the waste management department, and working to control the generation of wastes. Also, they announced the waste storage plan for the solid wastes that will be generated for the next decade.

(5) Work environment

Reduction of dose rate on site (additional effective dose of less than 1mSv/year at site boundary) was achieved. Although it takes time to reduce dose rate in the high radiation area of the building, decontamination is currently being performed.

(6) R&D activities

The Decommissioning R&D Partnership Council was established by the Team for Countermeasures for Decommissioning and Contaminated Water Treatment in the NDF, enhancing research and development through the promotion of collaboration with the relevant institutions.

The Collaborative Laboratories for Advanced Decommissioning Science (CLADS) was established by Japan atomic Energy Agency (JAEA) as a global research and development organization.

JAEA also began operation of the Naraha Remote Technology Development Center where the development and the verification test of the remote operation equipment (e.g. robotics) will be carried out.

2) Positioning and purpose of the Strategic Plan

The NDF formulated the Strategic Plan to contribute to the revision and implementation of the "Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station" (hereinafter referred to as "the Roadmap") and provides a firm technical basis. In specific, the Strategic Plan describes strategies, policies and implementation plans related to the retrieval of fuel debris¹ and waste management, which are the key issues in the decommissioning from mid- and long-term perspectives.

It provides a path to decision making on the policy of the fuel debris retrieval methods considering the results of the study on the technical requirements for ensuring safety and the Five Guiding Principles. It is also based on information obtained by the investigation and evaluation for each unit performed so far. Issues relating to radioactive waste management to be addressed will be determined through the evaluation of the current status, as well as by examining its basic concept. Furthermore, tasks including R&D and technical investigations--which are required to be taken based on the above studies--are explained as well. Therefore, the Strategic Plan has to be subject to the continuous assessment and review based on the changes in the site situation and the results obtained by the research institutes.

The Strategic Plan 2016 develops the concept and method according to the concept and approaches of the Strategic Plan 2015 in order to serve as an aid for smooth and steady implementation of the Roadmap revised in June 2015.

¹Nuclear fuels molten and mixed with parts of reactor internals due to loss of reactor coolant and resulted in a re-solidified state.

3) Fundamental policy of the Strategic Plan

As the Specified Nuclear Facility that caused the accident, the Fukushima Daiichi NPS has been taking necessary safety measures as obligated by the NRA and a certain level of stable condition has been maintained. If no actions are taken, the risks from the radioactive materials continue to exist. Even though the risks may gradually be reduced by radioactive decay, there may still be increase of risks resulting from degradation of the containment function over mid- and long-term. Therefore it cannot be necessarily stated that the risks simply decrease over time.

For this reason, as described in the Strategic Plan 2015, "to continuously and promptly reduce the risks associated with the radioactive materials generated by the accidents" is the fundamental policy of decommissioning of the Fukushima Daiichi NPS. Therefore, the Strategic Plan can be called as "the design of risk reduction strategy" on a mid- and long- term basis.

4) Five Guiding Principles

Five Guiding Principles important to achieve the fundamental policies above are described below.

- Principle 1: Safe- Reduction of risks posed by radioactive materials* and ensuring work safety
*Environmental impacts and exposure to the workers
- Principle 2: Proven- Highly reliable and flexible technologies
- Principle 3: Efficient- Effective utilization of resources (e.g. human, physical, financial and space)
- Principle 4: Timely- Awareness of time axis
- Principle 5: Field-oriented- Thorough application of Three Actuals (actual field, actual things and actual situation)

5) Approach to the international cooperation

(1) Gathering and using wisdom and intelligence

Making an effort to gather and use the wisdom and experience from Japan and abroad, including adequately utilizing knowledge and experiences of decommissioning projects in other countries, are important as ever to conduct the decommissioning project at the Fukushima Daiichi NPS efficiently and effectively.

(2) Active information dissemination

Taking into account of Japan's responsibility to international society, as a country where the Fukushima Daiichi NPS accident occurred, it is important to carry out the decommissioning project in a manner open to the international society. Activities through bilateral and multilateral frameworks, such as disseminating information proactively on the current status of decommissioning, contaminated water management and the results of R&D that are performed by the research institutions and companies that are involved in the decommissioning. Also it is continuously important to receive advice/evaluation from specialists while considering the physical protection and safeguards.

(3) Close cooperation among the domestic organizations

In leading international efforts, it is important for the Japanese Government, the NDF, TEPCO and relevant research institutions to work together closely to carry out these cooperation with the international society.

3. Risk reduction strategy

In the Strategic Plan, the strategy for the reduction of the risks caused by the radioactive materials is designed to achieve the fundamental policy of the decommissioning of the Fukushima Daiichi NPS. For this purpose, this section identifies various radioactive materials and describes their features. The measures to reduce risk will be determined based on the priority determined by the analysis and evaluation.

Furthermore, it is important to identify the project risks that cause a significant impact on the progress in the decommissioning project and to control them appropriately in order to steadily carry out the risk reduction strategy. It is also important to acknowledge that the decommissioning is to be promoted with society by gaining the understanding from various stakeholders including local residents.

1) Strategy for reducing risks posed by radioactive materials

i. Major risk source

The major risk sources at the Fukushima Daiichi NPS include as follows.

- Fuel debris in the PCV of Units 1-3
- Fuel assemblies stored in Units 1-3 SFP (Pooled fuels), and fuels in the common pool and fuels in the dry cask
- The contaminated water in the buildings of Units 1-4 and in the Concentrated Radioactive Waste Treatment Facility (Contaminated water in buildings) and concentrated liquid waste stored in the tanks (concentrated liquid waste).
- Secondary waste generated from the water treatment system (waste adsorption column, waste sludge and HIC slurry stored in the high integrity container)
- Solid radioactive waste (solid waste stored in the storage facility and solid waste stored outside)
- Internal structures of the PCV including equipment, piping and pieces of the building contaminated by the dispersed fission products caused by the accident and contaminated and activated reactor internals (both are referred to as PCV internal structures etc.).

ii. Risk analysis

Risk level is a magnitude of impact caused when the radioactive materials contained in the risk sources above are released. It is shown in the combination of a "consequence" and its "likelihood." In this section, the risk analysis is performed by referencing the SED score (Safety and Environmental Detriment Score) developed by NDA, U.K. Nuclear Decommissioning Authority.

The "Hazard Potential" of the SED score is directly used as an index that expresses the "consequence." Hazard Potential is defined as the total amount of radioactive materials which is contained in the risk source, taking into account the properties such as gas, liquid and solid from the perspective of likelihood of leakage or migration and the available time for recovery when the safety function is lost.

The index that expresses "likelihood" is based on the "Safety Management." It consists of factors that determine the grade of the risk source by the combinations of the elements, such as the integrity of the facilities and containment functions and the factor determined by the combination of the elements of the changes in the conditions of risk source and packaging/monitoring. All factors are classified into ten categories and each category has a score. In the Strategic Plan, in order to flexibly correspond to the

situation of the Fukushima Daiichi NPS, the risk sources are graded through a relative comparison from the perspective of the combining elements of each factor without using the categories fixed for the SED measures.

Fig.-1 shows the sample of analysis of the major risk sources based on information as of March 2016.

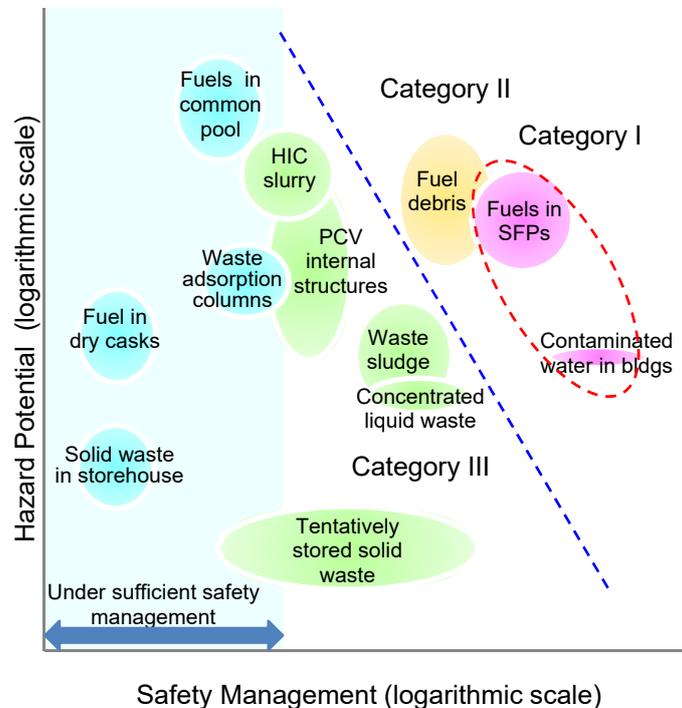


Fig.-1 Risk analysis example of the Fukushima Daiichi NPS

The extent of the impact caused by the uncertainties is shown in the figure above. The uncertainties anticipated in the concentrations, amount and properties of radioactive materials and time margin are considered in the Hazard Potential. The higher degree of uncertainty is considered for the PCV internal structures and fuel debris. The range of the score of each category is considered as uncertainties in the Safety Management based on those two factors are quantitated information which was originally qualitative. Various types of forms are considered for the temporary stored solid wastes. The categories of risk sources and analysis methods will be improved so as to correspond with the on-site work and be reflected to the decommissioning work.

iii. Risk source category and action policy

As a result of analyzing the risk level, it was found that the major risk sources should be addressed in the following three categories.

<Category I> Risk sources to be addressed as soon as practicable

The pooled fuels contain a large amount of radioactive material. The building ceilings of some Units have been damaged and rubble and heavy-weight objects were dropped. Contaminated water in the buildings has high mobility and remains being confined by the control of water level. As for these risk sources, the treatment policy for the risk reduction is clear and is difficult to be implemented. The specific measures are,

however, currently taking place since there is no mid-and long-term R&D issue. Preparations such as the removal of rubble to transport the pooled fuels to the common pool which has a sufficiently small Safety Management are underway. The transfer from Unit 4 has been finished in 2014. As measures against the contaminated water in the buildings, the inventory is aimed to be reduced by controlling the inflow of groundwater by the land-side impermeable walls and by lowering the water level. Since the radioactive materials contained in contaminated water are converted into secondary waste and Safety Management is significantly improved.

While the NDF provides support for the various types of issues for the risk treatment, Category I is out of scope of the Strategic Plan.

<Category II> Risk sources to be addressed safely, effectively and carefully with thorough preparation and technologies to realize a more stable state

Although the fuel debris is in a certain stable condition, it needs to be handled by thorough preparations and proven technologies in a safe, steady and careful manner due to a large amount of radioactive materials and high degree of uncertainties in the locations and properties. The retrieved fuel debris will be collected in the storage canister designed from the safety perspective of criticality, shielding and heat removal and stored in a manner where Safety Management is sufficiently small.

<Category III> Risk source that requires actions to be taken for a more stable condition

Contaminated water containing highly concentrated radioactive materials that stored in the tank includes concentrated salt water and concentrated liquid waste. Former one has been processed in 2015 and it made a great contribution to the risk reduction. Although concentrated liquid waste will not be increased, highly concentrated liquid waste is being stored for a long period of time. Agglomeration pits that store the waste sludge were not designed for long-term storage. Solid wastes stored outside are not intended to be stored permanently. For PCV internal structures, activation products are fixed inside, whereas some fission products that are attached to the surface are not stabilized. HIC was designed so as to store the wastes for a long period of time after the accident; however, since distillation of water occurred, drainage has been conducted while limiting the storage quantity and monitoring impacts caused by hydrogen generation. These risk sources are to be addressed systematically to achieve more stable condition. Also, the PCV internal structures etc. will be reflected to the risk analysis as the internal PCV condition analysis progresses.

The risk sources other than those mentioned above are sufficiently in a stable and safe condition. The common pool, dry casks, and solid waste in the storehouse have been safely designed and used, and no impacts caused by the accident are observed on them. The waste adsorption column was designed for long-term storage after the accident. For these items, sufficiently low levels of risks can be maintained by ensuring continuous management in the future. Also, removal of contaminated water in the trenches has been finished for Units 2-4 with high radioactive material concentration in 2015. It made a great contribution to the risk reduction. It is important to implement the measures to reduce risk considering the

time axis. Even if the risk source is currently in a certain stable condition, it will not be continued. In addition, the level of the risk may rise due to degradation of facilities and changes made in the conditions of risk source. Although the measures should take place before the level of risk cannot be allowed as a matter of course, additional radiation exposure will be caused to workers without any preparation. Such changes in the risk level to be made over time are different each risk sources. It is therefore important to set the timing suitable for the features of the risk sources and thorough preparation should be given to it.

Furthermore, the level of the risk may rise temporarily due to the changes made in the conditions of facilities and process itself during the risk reduction work.

In addition to minimizing the risk level increase, comparison with the benefit obtained by the reduction of the existing risks achieved by the work should be considered to achieve reasonable operation. Also, even if it is currently in a certain stable condition, it will not be tolerated indefinitely. In addition, the level of the risk may rise due to degradation of facilities and risk source. Since the operations will have to be performed under the various kinds of uncertainties, the plan should be reviewed flexibly as they are clarified.

2) Steady progress in decommissioning project

To make steady progress in the designed risk reduction strategy, and to accomplish the fundamental policy and promptly reducing the risks posed by radioactive materials, risks affecting the progress of decommissioning should be identified. Analyzing their severity, measures against significant risks should be prepared. Namely, it is important to review comprehensively the project risks, such as failure of technological development, insufficient personnel and space, cost increase, and reworks caused by uncertain safety considerations.

Making progress in decommissioning the Fukushima Daiichi NPS is deeply connected with the return of the evacuees to their homes. Even minor troubles or environmental impacts may affect the residents of the surrounding areas seriously because of reputational damage.

Therefore, it is essential to make a clear explanation to society about the prospect of decommissioning work and to share various risks and measures with the local residents.

i. Project risk management

Project risk management is to identify the risks associated with the progress in the decommissioning project and to take actions against significant risks in advance, and this is nothing but deploying specific efforts through the Strategic Plan. To strengthen risk management more systematically, the method generally used can be applied. "General risk management methodology is as follows:

- listing the potential failures for each process or function
- assessing the effects and severity of those failures
- identifying the cause of the failure and its likelihood
- evaluating the control or detection methods and their feasibility"

Then, the measures against the risk with a high severity are planned and performed after confirmation of the effectiveness. Also, there is a method that sees the risks as the impacts (both threats and opportunities) caused by uncertainties that affect the purpose of the decommissioning and that regards risk management

as maximizing the opportunities and minimizing the threats. These methods will be useful for the project risk management in the decommissioning of the Fukushima Daiichi NPS.

In the project risk management, not only direct impact of radioactive materials but also various factors should be considered including the safety to the workers, cost and return on investment, impacts on the local economy etc.

ii. Basic concept for ensuring the safety

The plan needs to be carefully laid out in order to secure the safety when executing the fuel debris retrieval or other work which has never been experienced and causes a significant change in the current condition. To prevent the rework, the basic concept for ensuring the safety is to be established in advance based on the "The matters for which measures should be taken" issued by Nuclear Regulation Authority and to be shared with the relevant parties.

iii. Relationship with the society

In steadily proceeding with the decommissioning, importance of communication with local residents has been pointed out from the experts in Japan and abroad who have experience of decommissioning and also from the international organizations. As a first step, accurate and timely information should be sent out; the fact that great efforts made by the workers are contributing to the progress in decommissioning should be conveyed, as well, of course, as the troubles that actually happened.

In addition, it is expected to explain the risk status, as well as its control method for the local residents, at every milestones of the decommissioning process. It is also expected to establish common understandings on the target level of risks to be achieved.

Also the risk reduction strategy involves trade-off between promptness and carefulness. It is therefore important to develop common understanding with local residents regarding that the risks are required be divided into those to be addressed as soon as practicable and those to be addressed carefully. Information sharing between disclosing and receiving parties is not enough for this type of communication. It is important to make mutual effort to close a gap between them and make decisions through such process.

A representative reputational damage is "an economical damage caused through suspension of spending and sightseeing by the people who regard the inherently safe food or products as dangerous when a particular event, accident, environmental contamination or disaster is sensationally reported." Reputational damage, however, may be caused by the existence of the risk even it does not occur yet. Also, likelihood is not taken into account and only the magnitude of the consequence is generally considered as a risk.

In response to the reputational damage that already occurred or in execution of the reduction of the existing risks caused by radioactive materials, additional measures to prevent further reputational damage may be required or the implementation of the measures may not be accepted. As a result, delay in response, increase in workers' exposure, increase in the cost and other impacts could occur. These may be detrimental to the public perception for the efforts to the decommissioning and may result in further delay in taking the measures to form a vicious circle.

To prevent further occurrence of such reputational damage, it is most important to properly manage the radioactive materials so as not to lead to leakage, and to promptly reduce the existing risks. Further, it is

important to continuously provide accurate information to the consumers including those of overseas, in addition to the local residents, the people in the press and the market participants and distributors.

4. Strategic plan for fuel debris retrieval

1) Study plan for fuel debris retrieval (risk reduction)

Fuel debris is characterized by "being in a state that contains nuclear fuel materials without being contained in the cladding, and combined with other materials"; therefore they have factors of risks related to criticality, decay heat, containment, risk of high radiation, hydrogen generation, and degradation of the integrity of supporting structures. Followings are difficulties in managing such risks. -"Uncertainties" of the reactor condition,

-"Instability" of molten fuels and damaged facilities caused by the accident and

-"Insufficient management" due to severe access condition under a high radiation environment.

The amount of radioactivity (Bq) of fuel debris has been greatly decreased to about one several-hundredth of the amount immediately after the accident. Also plant parameters for criticality, cooling and containment are stabilized by the management performed according to the "Fukushima Daiichi NPS, Implementation plan on a Specified Nuclear Facility" issued by TEPCO. However, to continuously and promptly reduce the risks associated with fuel debris, which is the fundamental policy, the strategy to reduce risks from two points of view from mid-and long-term will be required.

Mid-term risk is a risk of a deviation from "a certain stable state" which is currently maintained for the fuel debris. Although it is unlikely to be occurred, the understanding of the conditions and planning of the measures against risk sources are desired to be established in the early stage since the methods which can directly control the conditions inside the reactor have yet to be established.

Long-term risk is a risk of environmental contamination caused by the leakage of highly toxic nuclear fuel materials due to the deterioration of the buildings. To secure the ultralong-term safety by isolating spent fuels from human environment, in Japan, high level waste is isolated and stabilized after being reprocessed (geological disposal) as a fundamental policy. The fuel debris are, therefore, to be collected within a time frame (about several decades) where the containment can be maintained by the R/B and be brought into a stable state under sufficient control.

Having considered the above discussion, and seen the consequences of the initial measures to reinforce the R/B taken at the accident of Chernobyl nuclear plant Unit 4, leaving the nuclear materials for a long time without establishing the proper collection policy - just thinking about short-term containment without long-term safety considerations - must be labelled as an irresponsible postponement of the issue to the next generations, as long-term safety can never be envisaged in such a situation. In the decommissioning of the 1F NPPs, therefore, the measures taken at the Chernobyl nuclear plant Unit 4 can never be an option, and, fuel debris retrieval as explained below has an absolute priority.

As a mid-term risk reduction strategy for the fuel debris, the following items are to be studied based on the current stable state to solve the difficulties in the risk management described above, and "the stably controlled condition based on the more accurate information" is aimed to be achieved.

Such risk reduction of fuel debris, especially for the approaches to the study on the fuel debris retrieval is shown in the Fig.-2 "Logic tree of risk reduction for fuel debris."

- (1) Understanding of the conditions and properties of fuel debris (decrease in uncertainties)
- (2) Improving the reactor condition during the fuel debris retrieval (resolution of instability)
- (3) Maintain the fuel debris in a stable storing state (improvement of management level)

Both mid-term and long-term risk reduction are important for the fuel debris retrieval. The former one requires to be performed in early stage and effectiveness of stabilization inside the reactor and latter one is expected to achieve high collection rate for the fuel debris even if it takes time. For this reason, in the initial operation of fuel debris retrieval, mid-term risk reduction is to be focused on, and at the same time, the method which can achieve more efficient collection of fuel debris is required to be selected. If a certain amount of fuel debris is retrieved by this method and mid-term risk will be reduced and safety of the R/B is maintained by a passive method*, "low level of risk widely accepted by society" can be achieved. On that basis, the risk elimination (removal and isolation of nuclear fuel materials) is to be aimed from a longer term perspective through the subsequent works such as further fuel debris retrieval and facility disassembling. Consequently, the fuel debris retrieval to reduce mid-term risk is required to be aimed for the time being.

*A state where cooling of the fuel debris and prevention of re-criticality, leakage such of radionuclide and hydrogen explosion are ensured by a passive method.

In the studies of the fuel debris retrieval strategy described above, note that the retrieval work itself will not be justified if the level of the risk that caused by the fuel debris retrieval work is higher than the permissible level. Also, the human resources and time assigned for decommissioning are not unlimited. It is important to reduce risks by searching a realistic technical strategy for fuel debris retrieval with ensuring safety. The basic approach needs to be recognized as a "risk-aversion-oriented approach instead of focusing on the outputs" described in the Roadmap (Revised on June 2015). The process of fuel debris retrieval is to be set flexibly while assessing the risks.

That is, the strategy of fuel debris retrieval is to search the optimal point between "resolution of mid- and long-term risk of damaged reactors" and the "risk induced by the retrieval work," those are in the trade-off relationship, by balancing the issues from the viewpoints of technical specifications, time period, ensuring work safety, and actual work site conditions.

The Roadmap declares that "Start of fuel debris retrieval at the first implementing unit" is to start by December 2021, and, as major milestones for that, "Determination of fuel debris retrieval methods for the first implementing unit" is to be made in the first half of FY2018 and "Determination of fuel debris retrieval policies for each unit" in summer of FY 2017. In response to this, the conditions/properties of fuel debris are identified/estimated and feasibility of technical requirements for fuel debris retrieval method is studied/evaluated. The fuel debris retrieval method whose design/technical development is preferentially promoted is required to be studied for each unit.

The fuel debris retrieval method and application technology are evaluated and determined based on the perspective of Five Guiding Principles as shown in the Strategic Plan 2015.

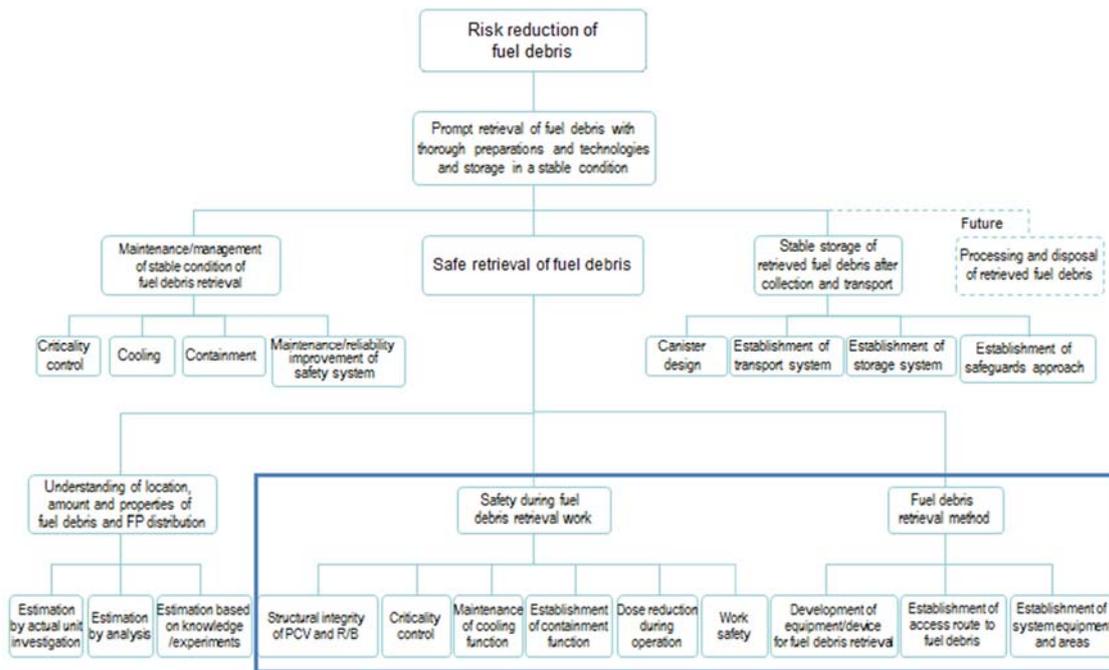


Fig.-2 Logic tree of risk reduction for fuel debris

2) Strategy and latest information for the internal PCV condition analysis

i. Basic concept of the internal PCV condition analysis

To understand the internal PCV conditions including plant conditions and fuel debris, it is extremely important to carry out the studies on the fuel debris retrieval method. However, considering the severe environmental conditions due to high radiation, to conduct inspection for all kinds of required information using with remote devices will be difficult from technical and temporal perspective.

For this reason, in order to obtain highly accurate results, making maximal use of not only plant investigation but also the results of the severe accident progression analysis and the evaluation based on plant parameter, required information should be analyzed and evaluated comprehensively based on the priorities set by the required timing, accuracy level, and significance.

Also it is important to obtain valuable information in consideration of the balance of the "workload (exposure), time and cost" for obtaining information and "safety measures, retrieval equipment and equipment design/cost" for the retrieval method.

If it is difficult to obtain information in advance, assessment is to be performed based on the maximum likelihood method. A conservative process plan is to be established including contingency plan, and conditions of actual unit are confirmed while carrying out the work. The approach where process plan is narrowed down, materialized, and reviewed following the improvement of the accuracy of internal PCV condition analysis is also to be studied. This concept is based on the experiences of TMI-2 which was a similar accident plant. Fig.-3 shows the image of the procedures.

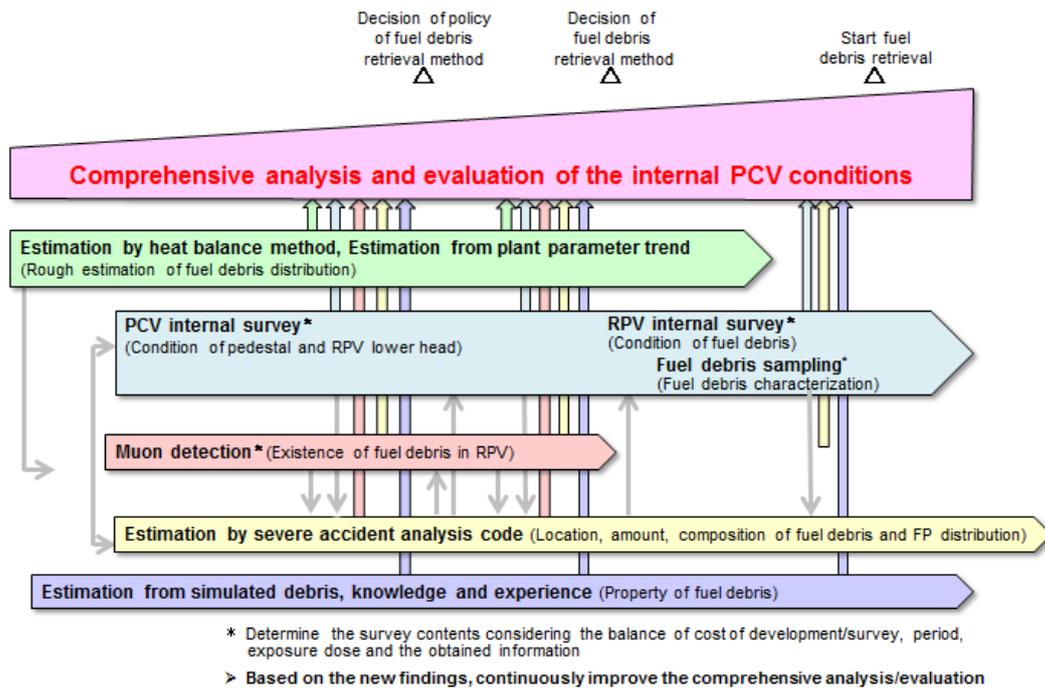


Fig.-3 Strategy for internal PCV condition analysis (Comprehensive analysis and evaluation)

Purpose and timing of necessary information relating to the retrieval work are categorized as follows.

Purpose	Required information	Required timing
(1) Determination of fuel debris retrieval policies	Fuel debris distribution	In summer of FY 2017
(2) Advancement of ensuring safety	Fuel debris distribution and properties	In summer of FY 2017
(3) Optimization of retrieval equipment and equipment design	Improvement of accuracy of information above, and FP distribution.	After FY2018 on a timely basis
(4) Further optimization for retrieval method and improvement of applicability	Detailed internal PCV conditions and fuel debris properties by sampling	To be continued including the period after the commencement of fuel debris retrieval

The purposes of the information above are as follows:

- (1) To study the access direction and flow lines of fuel debris retrieval and concept of the systems.
- (2) To ensure safety, such as the evaluation of re-criticality and cooling conditions. Allowance of the method can be reviewed reasonably according to the information.
- (3) To rationalize the application to the actual plant depending on the quantity of information.
- (4) To perform retrieval work according to on-site situation before and after the commencement of the retrieval work.

Current status and future issues of the investigation of conditions inside the actual reactor and comprehensive analysis/evaluation of the internal PCV conditions are described as follows.

ii. Investigation of conditions inside the Actual reactor

It has been shown to progress of the investigation and future issues after the release of the Strategic Plan 2015, as follows.

- Muon detection (transmission method) was performed for Unit 1 and it was evaluated that there is not a large amount of fuel debris in the core region. Also, the internal survey in the outside of the pedestal in the PCV (B1 inspection) was performed and it was found that the dose rate is about 10Sv/h and no

damage was observed within the area subject to the inspection. It was, however, newly found the deposits are widely distributed at the bottom of the D/W. In future inspections and fuel debris removal operation, it is necessary to take measures for the deposition. Therefore, the internal survey of the outside of the pedestal in the PCV (B2 inspection) was postponed to FY2016.

- In unit 2, the muon detection (transmission method) has started at the end of FY 2015 and now the measurement is carried out for the core region and the RPV lower plenum. Also, the inspection in the inside of the pedestal in the PCV (A2 inspection) was planned, but eluted materials from the inside of the penetration were found in the peripheral of CDR hatch (X-6 penetration), and the inspection was postponed to FY 2016 to reduce the dose rate.
- First entry into the PCV was performed for Unit 3, and it was found that the dose rate was approx. 1 Sv/h, which is lower than those of Units 1 and 2(*). Water clarity inside the PCV was excellent but the deposits were confirmed as with Unit 1. The internal survey in the inside of the pedestal in the PCV using such as the swimming devices is planned in the first quarter of FY2017.

(*) Unit 2 dose rate about maximum 73Sv/h; Measured on Mar. 2012

iii. Comprehensive analysis/evaluation of the internal PCV conditions

The internal PCV conditions were confirmed by the images from the muon detection and the PCV internal survey using robots, temperature, radiation dose and the other information from the investigation of conditions inside the actual reactor. Also whole image was estimated by the accident progression analysis code which was improved to estimate close to the actual behavior of fuel debris. Fuel debris locations and quantity were estimated from heat balance and its trend using the actual plant parameter.

Based on the above, the results of the comprehensive analysis/evaluation for the internal PCV conditions and its considerations are described below

- As shown in the Table-1, although there is a variation among Units 1-3, the fuel debris are located on the RPV lower head and the bottom of the D/W (in and outside of the RPV pedestal), and those are distributed especially for the bottom of the D/W. Since very little fuel remaining in the core region, criticality risk caused by stub-shape fuel will be small.
- However, in the evaluation of Unit 2, since the amount of fuel debris on the RPV lower plenum has been greatly changed according to the amount of injected water during the accident (with high degree of uncertainties), it is desirable to verify the actual fuel debris distribution by the internal survey.
- Also, due to high degree of uncertainties, further analysis/evaluation for concrete erosion at the bottom of the D/W caused by MCCI and the properties of the products, rate of the fuel debris in and outside of the RPV pedestal will be required including internal survey.
- Since there is a possibility that the internal structures may be deformed as the results of experience of the high-temperature state during the accident, it is necessary to take into account when studying the fuel debris retrieval method.
- For the analysis results of FP distribution is large difference between the analysis codes, it is necessary to further study.
- According to the PCV internal survey for Units 1 and 3, there were some deposits on the structures in

the accumulated water in the PCV, and those should be considered in the future internal survey and the studies of fuel debris retrieval methods.

In addition to the results obtained from various plant data and investigation of conditions inside the actual reactor, estimating the physical phenomenon caused in the plant at the time of the accident, such as generation of the fuel debris and FPs and relocation behavior, the comprehensive analysis and evaluation of the internal PCV conditions are required to be continued. Also, it is important to improve the accuracy of comprehensive analysis/evaluation by identifying the factors of uncertainties in the fuel debris locations/distribution and performing the sensitivity analysis using analysis codes to reduce such uncertainties.

Table-1 Plant status of Units 1-3 (including estimation of fuel debris distributions)

Location	Unit 1			Unit 2			Unit 3		
	Range of Estimation*1	Typical Value**	Range of Estimation*1	Typical Value**	Range of Estimation*1	Typical Value**			
Core	0-3	0	0-51	0	0-31	0			
RPV Lower Head	7-20	15	25-85	42	21-79	21			
Inside RPV Pedestal	120-209	157	102-223	145	92-227	213			
Outside RPV Pedestal	70-153	107	3-142	49	0-146	130			
Total	232-357	279	189-390	237	189-394	364			
Dose Rate measured in PCV	Approx. 5-10 Sv/h (measured on Apr. 10-16, 2015, in gas phase of 0.7 m from the water level, on the grating)			Approx. 31-73 Sv/h (measured on Mar. 27, 2012, in gas phase of 3.7 to 6.7 m from the water level, around X-53 penetration)			Approx. 0.75-1 Sv/h (measured on Oct. 20, 2015, in gas phase of 0.55 m from the water level, around X-53 penetration)		
Observed water leakage points	Water flows were detected from one sand cushion drain pipe (Ⓔ) and one expansion joint cover (Ⓓ) of the S/C vacuum break line.			It is expected water flow from somewhere below water level inside the torus room, since there is no trace of water leakage in gas phase.			Water flow was detected from the expansion joint (Ⓔ) of the MS Line D in the MSIV room.		
PCV internal survey	-No large scale damage on the existing facilities (e.g. PLR pump, wall inside the PCV and HVH). -Deposits are scattered over a wide range. -PLR piping shielding units fallen.			-The structures of the RPV bottom was confirmed by the photographs taken from RPV pedestal opening. Breackage of the RPV bottom is unlikely to be a large.			-PCV internal survey using inspection device inserted from PCV penetration indicated that no damage of the walls and PCV was found within the scope of the survey.		

*1: Range of results based on Severe Accident codes

*2: The most reliable value by a plurality of analysis results in the current

*3: Weight of fuel debris, indicating the weight of the fuel + melted and solidified structural material (including a concrete component).

Fuel debris distribution: Based on the document provided by IRID

Plant investigation status: Based on the document released by TEPCO

3) Feasibility study of fuel debris retrieval method

i. Fuel debris retrieval method

There are some options for PCV water level during retrieving the fuel debris. -full submersion (water is filled up to the top of PCV, -submersion (water level is middle of the PCV, and - dry (completely no water and air cooling). Fuel debris retrieval method has different features depending on the water level. Fig.-4 shows the method for each PCV water level.

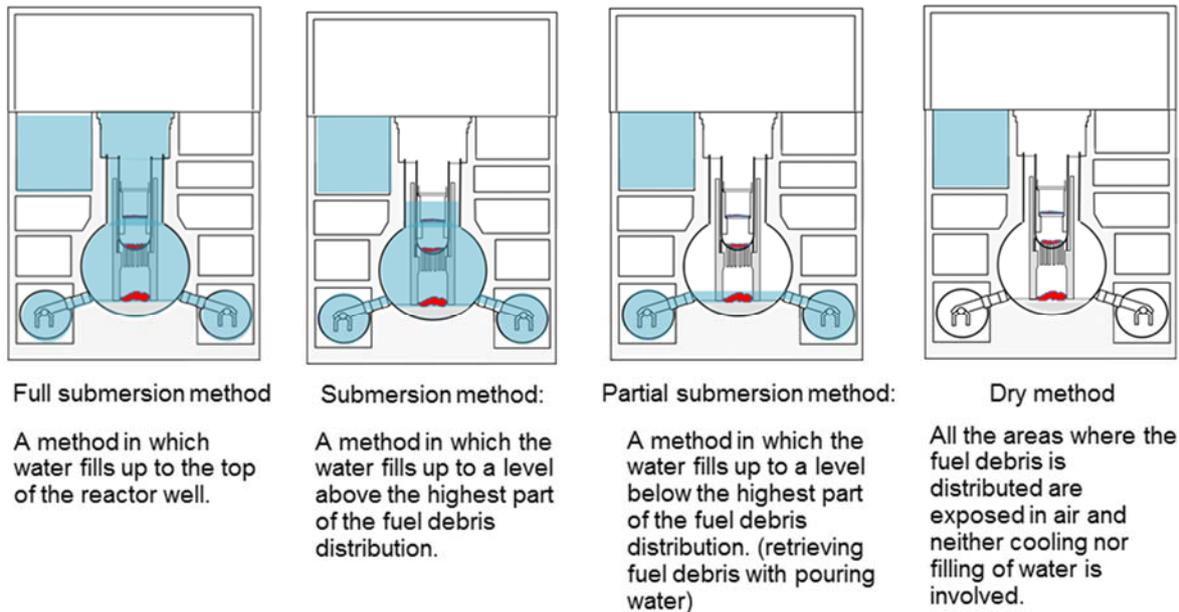


Fig.-4 Types of the method for each PCV water level

In addition to the classification of water levels, there are three types of access direction to the fuel debris, - from the top, -from the side and -from the bottom. Each access direction has different features depending on the locations of fuel debris. Multiple methods can be created by combining the water levels and access directions.

The access method from the bottom is judged not to be subject to the intensive study since it has high degree of technical difficulties such as

- maintaining contaminated water within the reactor building (R/B) by long term water tightness at the connection of drilling device and building and/or drilling device itself,
- transfer of the retrieved fuel debris through the access tunnel in the basement of the building, and development of small-size of device capable of retrieval of broadly expanded fuel debris and so on, even though an access route may be provided.

In the case that the PCV water level is higher than the access port of the side access method, this method will not be studied (or investigated) intensively. Its reasons are; -a large water tight hatch shall be implemented for water leakage prevention, long-term maintenance is required, and these are accompanied with very high difficulties.

The Dry method that has completely no water will not be studied in depth since it is difficult to cool the

fuel debris by air at a time of fuel debris retrieval and to prevent the scattering of the radioactive materials (gas and particle) generated by the fuel debris cutting.

Feasibilities of Full submersion method and Submersion method are determined mainly depending on the feasibility of PCV repair that governs the PCV water level. Extensive study is being performed to assess the feasibility of PCV repair for each unit.

The combinations of the directions of accessing the fuel debris and PCV water levels to be focused on are narrowed down from the feasibility perspective as shown in the Fig.5. This study was performed in the Strategic Plan 2015.

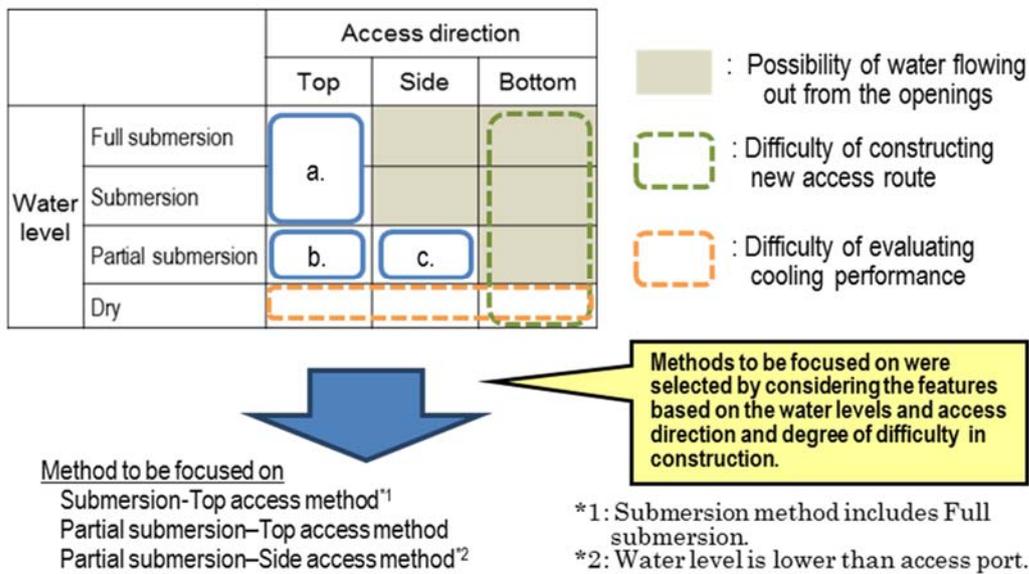


Fig.-5 Narrow down of fuel debris retrieval method

Fig.-6 shows the specific image of three methods to be focused on.

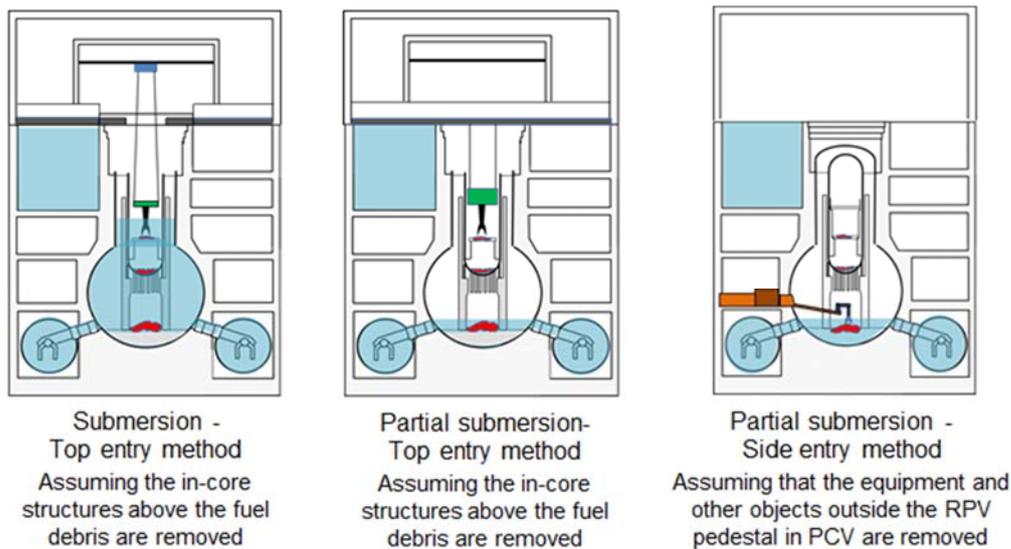


Fig.-6 Three methods to be focused on (image)

(Reference) Top access method is suitable for retrieving the fuel debris in the RPV. The fuel debris at the inside of RPV pedestal is considered to be retrievable by the top access method after retrieval of it inside of the RPV. The Top access method is, however, difficult to reach the fuel debris spread outside of RPV pedestal. Although the Side access method is suitable for the retrieval of the fuel debris at the bottom of the D/W (or inside and outside of the RPV pedestal), it is very difficult to access the fuel debris inside of the RPV.

Consequently, depending on the distribution condition of fuel debris, three methods (Submersion-Top access method, Partial submersion-Top access method, and Partial submersion-Side access method) will be implemented independently or in combination of two methods.

The major technical issues for the implementation of the fuel debris retrieval method are identified in the light of the logic tree shown in the Fig.-2 and summarized below.

- Ensuring the structural integrity of the PCV and R/B
- Criticality control
- Maintaining the cooling function
- Establishing the containment function
- Reduction of radiation dose to workers during operation
- Ensuring industrial safety
- Establishing access routes to the fuel debris
- Developing fuel debris retrieval equipment and device,
- Establishing system equipment and working areas
- Establishing the system to collect, transfer and store fuel debris in a safe manner.

Achievement and approach for above mentioned technical issues are described below.

ii. Ensuring the safety during the fuel debris retrieval work

- Basic concept for ensuring the safety

The purpose of ensuring safety is to protect (1) local residents, and (2) environment and workers from the exposure by radioactive materials, and to reduce current level of risk caused by the severe accident through fuel debris retrieval work. Although volatile fission product release and decay heat are deteriorated in each unit, facilities such of R/B, PCV etc. are left in damaged by the accident with high radiation environment.

The risk increment from the current state during fuel debris retrieval work (at the normal and expected abnormal operation) shall be minimized to the extent possible and be kept under a certain level of limit. This level of limit will be set based on the assessment of impacts by increment of risk on the local residents and environment. The risk that attributable to external events (e.g. seismic, tsunami, tornado) is to be studied. In response to the study, the concept assuming the plant that experienced severe accident is to be studied.

- Achievement and approaches to the important technical issues to the ensuring safety during the fuel debris retrieval work.

Most of important technical issues for ensuring safety during the fuel debris retrieval work are common for three methods to be focused on. However, since the conditions between the plants are different when

retrieving the fuel debris by Submersion method or Partial submersion method, there are important technical issues particular to each method. Important technical issues for Full Submersion/Submersion - Top access method are the establishing the barrier for leakage (PCV repair (water tightness)), criticality control, and the structural integrity of the PCV and the R/B, those for Partial Submersion/Full Dry-Side Access method are the establishment of the barrier for leakage (prevention of radioactive dust scattering) and reduction of radiation exposure of workers during fuel debris retrieval work. Achievement, approach and future actions of these issues are described as follows.

(1) Ensuring the structural integrity of the PCV and R/B

Assessment of the impact caused on the important functions of RPV/PCV during a severe earthquake should be performed in consideration of the additional weight such of the required installations/equipment and cooling water required for the fuel debris retrieval, and the degradation due to corrosion of the structures.

- ✓ The evaluation of design basis seismic ground motion S_s is currently being conducted for seismic safety of the RPV/PCV and the peripheral equipment and facilities. The SC supports which are considered to have comparatively small margin will be evaluated through the detailed analysis.
- ✓ Also molten fuels are estimated to have fallen at the bottom of the D/W. Through the analysis of the spread of fuel debris distribution and the internal survey inside the PCV and RPV pedestal, the impact caused by erosion to the RPV pedestal is to be evaluated, as needed.

(2) Criticality control

Subcritical state shall be maintained even when the water levels were varied and shapes of the fuel debris are changed during the fuel debris retrieval operation. Also workers' exposure and adverse influences on environment shall be suppressed through shifting the state to subcritical state, in case of re-criticality accident.

Sub-criticality state is desired to be maintained by diluting neutron absorber such as boron with coolant. Studies are carried out for the feasibility of water quality management system including nuclide removal and environmental impact caused by the sodium pentaborate leakage.

Current study indicated that water level up to RPV lower plenum may not cause re-critical state because of understanding on the chemical composition of fuel debris and that water level up to RPV core region also may not cause re-criticality if remaining fuel assemblies of Unit 2 is smaller than 5x5 (fuel assemblies). In parallel, mitigation measure of impact by re-criticality has been investigated just in case of criticality accident because conditions of fuel debris inside of the PCV/RPV are still unknown.

- ✓ Method to maintain sub-criticality state of fuel debris has been studied for each fuel debris retrieval operation step and for the water level rising.
- ✓ Detail specification of sub-critical control method will be studied from the view point of actual applicability based on the results of evaluation of critical accident.

(3) Establishing the containment function (the PCV repairs (water seal))

Conducting the development and study of the method to repair the leakage of the PCV, PCV circulation cooling loops, and leakage water collection/ water level control systems, a system to control the PCV water level in a safe manner is required to be established.

- ✓ The development has been performed to date focusing on the feasibility of the water sealing technology and method for the vent pipe and downcomer at the PCV bottom (under the torus room ceiling).
- ✓ The solutions of the issues which became apparent to date and tests regarding the construction quality and long term reliability is required to be focused on.
- ✓ Since complete water sealing for vent pipes and downcomers by pouring grout materials with remote devices may face great difficulties, some degree of leakage to the torus rooms needs to be taken into account. Not only the control of the differences in the water levels between the inside and outside that maintains torus room water level lower than groundwater level but also the studies will be required such as for the prevention of the leakage from the R/B in the case of a large amount of leakage during the fuel debris retrieval.
- ✓ The development for the repair technology is to be carried out for the upper part of the PCV based on the on-site radiation dose situation.

(4) Establishment of containment function (radioactive dusts prevention)

The fuel debris retrieval methods and the dust scattering prevention method have to be established so as to prevent radioactive dust scattering to the outside of the building.

- ✓ Dust scattering during fuel debris cutting operation is to be prevented by providing the isolation wall consists of operation cells, PCV and R/B, and by maintaining internal of them under negative pressure. The adverse impact on the facilities caused by negative pressure control system stops and its countermeasure will be studied as well as the specifications of negative pressure control system are to be established.
- ✓ A repair method of gas leak blockage is also studied for expected damaged portions of the upper part of the PCV, as necessary.

(5) Reducing workers' exposure during operation

The shielding needs to be developed considering the impact to the workers and public caused by radiation from the fuel debris, FP, and activated materials. Also, impact on the R/B by the weight of shielding materials has to be considered.

- ✓ Decontamination of the inside of the R/B

Decontamination work around the X-6 penetration as a preparation of internal survey on for Unit 2 PCV requires significantly longer time than expected. For the decontamination/dose reduction which will be performed in the area, more close to the PCV will shifting the state to subcritical state, in case of re-criticality accident.

If the decontamination work will be delayed, it may lead to a delay in the on-site process such as PCV internal survey and PCV repair work. Under a high dose rate, the characterization will be forced to be performed by remote-controlled robot and it is considered to be difficult to acquire accurate data. Multiple possible decontamination work plans which are considered effective will need to be developed and prepared. Also, flexible measures in responding to the situation should be developed so as to prevent a delay in on-site process schedule for the decontamination.

- ✓ Radiation shielding during the fuel debris retrieval

It was confirmed that the prospect that the shielding can achieve 1mSv/h of dose rate on the operating floor

even if all fuel debris are located in the core region. The reasonable shielding specifications are to be studied based on the fuel debris distribution estimated by the PCVRPV lower plenum conditions and the dose rate data obtained through the PCV/RPV internal survey. The same studies are to be conducted for the specifications of the shielding for the cells used for the Side access.

(6) Ensuring work safety

To ensure industrial safety during the fuel debris retrieval work, the conditions of work place are required to be improved with the strong awareness of the safety shared among the concerned people and the assessment of the safety performed in advance.

iii. Study toward the realization of the method to retrieve the fuel debris

- Important technical issue to realize the fuel debris retrieval method

The technical subjects that directly relate to the fuel debris retrieval include the establishment of access routes to the fuel debris, development of fuel debris retrieval equipment and device, and development of system concept & equipment and planning of working areas. Current status, issues and future actions of these subjects are described as follows.

(1) Establishment of access route to the fuel debris

The access routes inside the building and ones on the operating floor or ones from the side of the building to reach the fuel debris located inside are required to be developed for fuel debris retrieval work. In the Top access method, to access to the fuel debris inside of the vessel, structures such as reactor well shield plug, PCV head, RPV head, and reactor internals needs to be removed. In the Side access method, before accessing the PCV internals a route to the PCV on the first floor of the R/B is necessary to be established through the work of removing the obstacles such as existing piping and equipment. In establishing the access route, it is important to prevent the release of radioactive materials from the inside.

- ✓ In the study for establishment of the access routes to the fuel debris in the development work for three methods focused on, fundamental tests are being performed for the key portion to prevent the radioactive materials' release to the outside so as to obtain the prospect and determine the feasibility by the time of making decisions on the fuel debris retrieval policy.
- ✓ The detailed studies based on the site conditions are to be carried out not to affect the schedule. The plans are also required to be studied for decontamination/shielding work in the access range including the preparation works and for cleaning up of the obstacles such as the equipment installed and piping that interfere with access in the reactor building and PCV.

(2) Development of the fuel debris retrieval equipment and devices

Development of fuel debris retrieval equipment and device required for fuel debris retrieval work is required to be developed. The retrieval equipment and devices will be exposed to the fuel debris with high radiation, and they are required to have radiation resistance that will encourage the smooth progress of retrieval work. Also, the design is required to be capable of maintenance work such as replacement and inspection of the components and repair in case of trouble. Furthermore, development in timely manner may be required according to the situation to be clarified as the work progresses.

- ✓ As for the retrieval equipment/device which is planned to be used in the plans of three retrieval

methods to be focused on, fundamental tests are being performed so as to obtain the prospect and determine the feasibility by the time of making a decision on the fuel debris retrieval policy.

(3) Establishment of the system equipment and working areas

It is essential to conduct conceptual studies for the additional container to be installed in the building, cell with prevention function for dust scattering during the fuel debris retrieval work, and various systems to be used for the fuel debris retrieval. Also preparation for the installation and operation of facilities and systems and securing and operating of the necessary working area are necessary.

- ✓ Conceptual studies need to be conducted on the devices and equipment that constitute the system, establishment of a layout and development of a plot plan of the Fukushima Daiichi NPS taking into account a temporary placement area for retrieval equipment and storage area for fuel debris. These activities will be carried out from FY2015 starting with those required for FS on the retrieval method. The needs of building expansion are required to be studied in the early stage so as to make a plan in an appropriate timing.
- ✓ Coordination with the situation outside the building (other construction, dose reduction project, ground improvement etc.) that interface with the process preparation is also required to be confirmed.
- ✓ To determine the feasibility of three methods focused on, conceptual studies are being performed for the safety concepts for the entire system and important system such as cooling water injection system, negative pressure control system, radioactive dust processing system and criticality control system. According to these development plans the prospect of feasibility of major systems will be obtained by the time of making decisions on the fuel debris retrieval policy, and feasibility of the method is determined.

In the studies of the important technical issues for toward the realization of the fuel debris retrieval method, international tender was carried out as a part of the subsidized project of decommissioning and contaminated water management implemented by the Agency for Natural Resources and Energy in June 2014. Those include "Conceptual Study of Innovative Approach to Retrieve Fuel Debris in the Air Safely and Reliably" "Feasibility Study of Visual and Measurement Technology for Innovative Approach," and "Feasibility Study of Fuel Debris Cutting and Dust Collection for Innovative Approaches" and the effective results from each project are now being utilized.

- Important subjects on the storage of the retrieved fuel debris in a stable condition after being collected and transported

The fuel debris that retrieved requires to be collected in the storage canister, transferred to the storage facility and stored in a stable condition. Action status and future actions of related issues are described as follows.

(1) Establishment of the system for collection, transport and storage of fuel debris

The system that performs for the design and manufacturing of the storage canister that accommodates retrieved fuel debris, followed by transfer and storage at the site is required to be developed. The study on the collection, transfer, and storage system is carried out based on requirements assuming various types of

fuel debris.

- ✓ Detailed study for the storage canister is being performed based on the design conditions, basic function and general shape that have been specified.
- ✓ The transfer and storage methods are to be realized and the basic design of the storage facility is to be performed.
- ✓ Since the pieces of fuel debris are expected to be retrieved when collection of the sludge accumulated in the PCV and purification of stagnant water, measures to response these are required to be studied.
- ✓ In the establishment of the systems above, a close cooperation with relevant parties is required so that the safeguards are applied in a proper manner.

4) Fuel debris retrieval policy

As described above, inspection and evaluation for internal PCV condition analysis of each Unit and feasibility for three methods of fuel debris retrieval to be focused on are being studied. The results are aimed to be summarized in FY2016 to contribute to the "Determination of fuel debris retrieval policies for each unit" in summer of 2017.

According to the current estimation of the internal PCV conditions, fuel debris of all Units are scattered in the RPV lower plenum and at the bottom of the D/W (in and outside of the RPV pedestal). All the fuel debris scattered in each Unit are not always retrieved by one method and the policy may be made by combining multiple methods according to the fuel debris locations. In such case, in parallel with the retrieval work for initial location of retrieval, inspections and studies are considered to be performed for the fuel debris in different locations. The work in the next stage may be continued with revising the plan for the fuel debris retrieval method.

In the "Determination of fuel debris retrieval policies for each unit," the results of the studies and findings obtained to date, fuel debris location to be addressed first and the likely method is to be selected for each Unit from the perspective of ensuring safety.

In particular, the following studies will be conducted to evaluate, such as the risks that affect the fuel debris retrieval work.

- (1) Evaluate the effect of risk reduction through the resolution of the instability of the inside of the PCV/RPV for each unit and fuel debris location based on the estimation results of fuel debris properties and amount,
- (2) Evaluate access route and retrieval method for each Unit and fuel debris location, including PCV water level are nominated and risk regarding ensuring safety, such as criticality that might be caused by the retrieval work and the leakage of radioactive materials based on the features of three methods to be focused on and the results of the studies.
- (3) Including the evaluation of (1) and (2), select the first fuel debris to be retrieved and its method in a comprehensive consideration of evaluation for the estimative index based on the Five Guiding Principles described in the Table-2. In specific, the degree of difficulties of technical development, site constrain including the radiation dose imposed by the work and required areas, and period of time for preparation are important.

Also, regarding the Unit where first retrieval work is expected, without any experience of construction

before, the smaller degree of difficulties of fuel debris retrieval work should be made.

- (4) With regard to the fuel debris other than those retrieved at first, the access route and retrieval method depending on the PCV water level are to be studied to make sure that initial retrieval work will not affect the subsequent work.

Since fuel debris retrieval work consists of the retrieval of fuel debris from three Units and stable storage, not only the selection of the individual retrieval method for each unit but also the optimization for three Units is important. If construction periods of multiple units are overlapped depending on the order and timing of the commencement of fuel debris retrieval for three units, construction risks will be and required human resources will be increasing. On the other hand, if constructions are conducted in series, there is an advantage to reflect the results of the preceding construction to the next construction but overall construction period will be prolonged. Based on the above, the study on the comprehensive optimization will proceed based on the examinations of a whole image of fuel debris retrieval in three Units.

Table-2 Estimative index based on the Five Guiding Principles

Five Guiding Principles		Estimative index
Safe	Reduction of risks posed by radioactive materials and ensuring work safety	Containment of radioactive materials (environmental impact)
		Radiation workers' exposure (operation time, environment)
		Ensuring work safety
		Effect of risk reduction
Proven	Highly reliable and flexible technology	Level of difficulty of technical development and TRL
		Conformity to requirements
		Flexibility of uncertainties and robustness*
		Alternative plans
Efficient	Effective utilization of resources (e.g. human, physical, financial, space)	Securing human resources (researchers, engineers and workers)
		Reduction of generated waste
		Cost (technical development, design and field work)
		Securing working and storage areas
		Impact on the subsequent processes of decommissioning
Timely	Awareness of time axis	Early commencement of fuel debris retrieval
		Time required for fuel debris retrieval
Field-oriented	Emphasize the Three Actuals (actual field, actual things and actual situation)	Workability (environment, accessibility, and operability)
		Conservativeness (maintenance and actions against troubles)
		Applicability to each unit

*The capability to maintain the robust function even when the condition is changed to a certain extent from what is expected.

After making a decision on approaches to the retrieval method, the preparation should be made, focused on the fuel debris to be retrieved first for each unit, for the basic designs of system equipment and retrieval equipment for the fuel debris and specific installation area plan while performing the inspections for internal PCV condition analysis. Detailed studies and technical developments need to be accelerated to determine the method to retrieve the fuel debris from the initial unit.

5. Strategic plan for radioactive waste management

1) Policy of study on radioactive waste management

Toward the decommissioning of the Fukushima Daiichi NPS, the necessary measures for risk reduction and optimization of overall facilities have to be carried out promptly and effectively. Compared with radioactive solid wastes generated from the normal NPSs, those generated mainly due to the accident *2 have different characteristics, for example, contamination with radionuclides deriving from damaged fuel, presence of salt, etc. Therefore, as for their management, the studies are important on their technology for processing and disposal concept as well as their safe and stable storage from the view point of mid- and long-term perspective.

In the current Roadmap, some important HPs for decisions on transition to next steps are set, such as that the basic concept of processing and disposal for radioactive solid wastes is to be compiled in FY 2017 and the prospects of a processing/disposal method and a technology related to its safety is to be made clear by around FY 2021 as a target. Studies on the strategic plan are also aiming at the HPs set in the Roadmap. Therefore, as the strategic plan for waste management, studies have been done in the following steps.

- (1) Review the general principles compiled internationally for ensuring the safety of radioactive waste disposal and develop an appropriate approach for waste management that emerges from these principles, giving shape to the measures for the disposal of radioactive solid wastes.
- (2) Evaluate the status of the solid waste management activities described in the current roadmap, and identify issues that may affect future waste management activities or the plan of waste management.
- (3) Describe issues should be addressed or noted from the present on the mid- and long-term solid waste management strategy by taking into account the principles in (1) and the issues identified in (2) above.
- (4) Describe future actions on the radioactive solid wastes management based on the (2) and (3) above including the R&D.

This strategic plan is to be reviewed and elaborated in accordance with the future development.

2) International safety principles on radioactive waste management

Summarized below are the principles for ensuring safety in implementing general radioactive waste management developed by international organizations such as the International Atomic Energy Agency (IAEA) and the International Commission on Radiological Protection (ICPR).

i. Safety principles on radioactive waste disposal

For the specific radioactive waste disposal, measures are taken based on one or combinations of these safety principles in order to prevent significant health effects.

*2 The "radioactive solid wastes" in the Roadmap refers to "some rubble, etc. generated after the accident may not be wastes or radioactive wastes due to on-site reuse or other measures. However, these wastes and the radioactive solid wastes that were generated before the accident and have been stored at the Fukushima Daiichi Nuclear Power Station are included in the 'radioactive solid wastes'.

- (1) To contain the waste;
- (2) To isolate wastes from the accessible biosphere and reduce substantially the likelihood of, and all possible consequences of, inadvertent human access to the waste;
- (3) To inhibit, reduce and delay the migration of radionuclides from the waste to the accessible biosphere at any time;
- (4) To ensure that the amounts of radionuclides reaching the accessible biosphere due to any migration from the disposal facility are such that possible radiological consequences are acceptably low at all times;
- (5) To control the release of radioactive materials to ensure that their concentrations are at the level that will not cause significant effects on health.

ii. Appropriate radioactive waste management

- (1) The radioactive waste needs to be characterized and separated into categories in all stages of radioactive waste management, from waste generation, processing (pretreatment, treatment and conditioning), storage and transport to disposal.
- (2) The main purpose of processing radioactive waste is to produce waste in a form that meets the criteria for the safe processing, transport, storage and disposal of waste and thus to increase the safety of radioactive waste management and ensure the safe disposal of waste.
- (3) The processing shall be based on appropriate consideration of the characteristics of the waste and of the demands imposed by the different stages in its management (pretreatment, treatment, conditioning, transport, storage, and disposal). The anticipated needs for any future stages in radioactive waste management have to be taken in to account as far as possible in making decisions on the processing of the waste. Various factors are to be considered not only effects on health of radiation, but also other factors such as environmental impact that may result from the content of non-radioactive materials, and social and economic impacts.
- (4) Quantities, activity and physical and chemical nature of the radioactive waste to be treated, the technologies available, the storage capacity and the availability of a disposal facilities are taken into account in determining the level of waste processing.
- (5) If waste processing is performed before the waste disposal requirements are set, it must be remaining possible to process the waste in a way which meets those requirements once they have been set.
- (6) Storage is an option that should be considered in the waste management strategy. Proper storage should be provided at all stages in waste processing prior to disposal to ensure waste isolation and environmental protection. Storage is used to facilitate the subsequent stages in radioactive waste management; to act as a buffer between and within waste management stages; to allow time for the decay of radionuclides prior to clearance and other activities or is used to store waste in cases where the management has yet to be determined.
- (7) Waste shall be stored in such a manner that it can be inspected, monitored, retrieved and preserved in a condition suitable for its subsequent management and under passive condition to the extent possible. Due account shall be taken of the expected period of storage, and, to the extent possible, passive

safety features shall be applied. For long term storage in particular, measures shall be taken to prevent the degradation of the waste containment.

Since the ultimate goal of radioactive waste management is the safe disposal, processing is required to be flexible to comply with the management of disposal, even in taking measures to reduce risks of leakage or scattering of water-containing materials during storage for the purpose of enhancing safety. Also, processing with volume reduction needs to be studied actively from viewpoints of restrictions on storage capacity and economic reasonability while consistency with the management of disposal is maintained.

3) Evaluation and issues on the action status based on the current Roadmap

Action status and issues based on the current Roadmap are described as follows.

(1) Reduction of waste generation

The structure of the waste management department of has been improved, and waste management has been driven forward by the involvement of the department from the stage of developing construction project for decommissioning work. Measures have been taken and driven forward to reduce amount of radioactive solid wastes generation by control of bringing packing, materials and equipment into the site, reuse and recycling.

(2) Storage

As the measures for storage of radioactive solid wastes generated, they are stored separately in the storage facilities or the interim storage facilities, depending on their dose rate.

Now, the building No. 9 for radioactive solid waste storage is under construction. In the near future, additional buildings such as No. 10-13 are planned to be constructed in series to expand the storage capacity. Then it is planned to dissolve the temporary storage situation, such as radioactive solid wastes piled outside, soil-covered interim storage, etc. As for measures for increasing radioactive solid wastes, they are stored in the buildings after incineration of the combustibles and volume reduction of the metals and concretes in the rubble are done as many as possible. This system can reduce the waste temporarily stored outside the solid waste storage facilities, which is projected to increase to about 750,000 m³ by around FY 2027 under the current storage conditions, to about 200,000 m³ (mainly waste with a dose rate of less than 0.005 mSv/h).

The need for countermeasures for further risk reduction has to be studied continuously for the secondary waste generated from the water treatment system.

(3) Waste characterization

On the solid waste, radiological analysis on rubble and others, characterization on secondary waste from water treatment and development of radiological analysis technique for difficult-to-measure nuclides have been implemented. Though sampling was performed within limited locations due to their high dose rate (i.e. rubble in a high radiation area inside the R/B and secondary wastes generated from water treatment system), the study of sampling materials with high dose rate has been started. Also, it is important to analyze radioactive solid wastes generated in retrieving the fuel debris, secondary wastes in decontamination, etc.

The analytical capability was increased from about 50 pieces to about 70 pieces per year through a new

collaboration with external organizations since FY2015.

It is appropriate to reflect flexibly the progresses of decommissioning and research to the analysis, with utilizing the results of analysis to the decommissioning process as well.

(4) Studies on the processing and disposal management

The research of the existing treatment technologies, including conditioning, fundamental test on technologies for conditioning, research and study of existing disposal concept, safety assessment method, and so on, are being performed on radioactive solid waste. Safety and reasonability of radioactive waste management is being ensured, from its generation to disposal via storage and treatment. Also waste streams have been studied for efficient R&D advance from a point of view of overlook. Basic concept of processing and disposal of radioactive solid wastes is being summarized by taking the above actions steadily, based on mainly their characterization study.

4) Mid- and long-term action policy and future actions for radioactive waste management

The matters to be taken measures to and be addressed in the mid- and long-term radioactive solid waste management at the Fukushima Daiichi NPS are described based on the issues identified from approaches according to the basic concept of ensuring safety for radioactive waste measure and current Roadmap.

(1) Reduction of generated waste

Measures on minimizing the amount of radioactive solid wastes generation such as control of bringing things into the site and on-site recycling have been taken by involvement of waste management department from the stage of developing construction project for decommissioning work, and achieving certain results. It is important to study and perform the measures continuously for further reduction of generated waste. The U.K. also succeeded in reducing the amount of radioactive wastes to be disposed of by performing radioactive waste management based on the concept of the waste hierarchy from the perspective of minimizing the amount of wastes to be generated and to be disposed of. When the decontamination technology for radioactive solid waste is selected, considering generation of secondary wastes, it is important to select an appropriate one by evaluating properties of the secondary wastes and impact to the disposal as well as to control the secondary contamination. Therefore, overall volume reduction including the secondary wastes and processing of the secondary wastes are required to be considered when introducing the volume reduction facilities.

(2) Storage

The storage plan was formulated based on the estimation of the volume of radioactive solid wastes generated by the construction plans following the Roadmap. The radioactive solid wastes in the temporary storage area are planned to be transferred into the storage buildings after being greatly reduced by the introduction of the volume reduction facilities introduced according to the progress in the decommissioning process. This plan is appropriate to aim to reduce the risk of scattering/leakage of radioactive solid wastes. It is important to implement the storage plan and reduce the risk attributable to the radioactive solid wastes. The R&D of dehydration method applied to the HIC slurry, which has been generated from pretreatment facilities of Advanced Liquid Processing System, has been prospective in the

basic stage from the point of view of stabilization. The study on the waste sludge and concentrated liquid waste should be accelerated to achieve more stable storage from the perspective of risk reduction for the radioactive solid waste perspective. It is required to examine the appropriate area and method for storage of radioactive solid waste generated during the fuel debris retrieval work, in parallel with examination of fuel debris retrieval method.

(3) Waste characterization

To develop specific measures for the storage, processing and disposal of radioactive solid waste, it is extremely important to characterize the waste by performing radiological analysis based on the characterization analysis plan. In order to obtain data effectively, higher priority should be put on the data which can contribute to progress in the decommissioning process and studies on treatment and disposal management. It is important to reinforce the analytical capability for characterization by utilizing the existing facilities for analysis, developing new facilities for analysis/research of radioactive materials and reinforcing and establishing the operational structure.

(4) Studies on processing and disposal management

It is very important to materialize processing and disposal management of radioactive solid wastes with comprehensive study, including understanding of their features, appropriate disposal management for the understanding, processing based on the disposal management and so on, in order to enhance the processing and disposal management to be safe and reasonable.

Following their classification, management of radioactive solid wastes must be done, based on their information of origin and contamination history, concentration in them, and so on.

For smooth establishment of regulatory system for solid radioactive solid wastes, required information concerned is required to be shared with the regulatory authority when needed.

6. R&D Initiatives

1) Basic principles and overview of R&D projects

- (1) The Strategic Plan 2015 described overall R&D plan to be addressed based on the issues specified in the R&D of Fuel debris retrieval and Waste management. The NDF also has been working on strengthening management to improve R&D and its effectiveness and partnerships between universities and research institutes that are conducting human resources development and basic/generic researches, IRID (which deals with practical development), and TEPCO (which is engaged in decommissioning work at the site). In the decommissioning of the Fukushima Daiichi NPS, there are some successes appeared in measures to deal with contaminated water and the focal point is now gradually moving towards mid-and-long-term efforts such as fuel debris retrieval. In order to deal with the challenges in uncharted territory, it is required to further promote effectiveness of R&D activities, collaboration between relevant institutions, cooperation with organizations overseas, utilization of R&D facilities, and human resources development.
- (2) To deal with the decommissioning of the Fukushima Daiichi NPS that involves many technically

challenges, R&D activities on a variety of fronts is being conducted by a number of organizations. The NDF comprehensively reviews such R&D activities in order to promote effective and efficient R&D approaches, and seeks the overall optimization of these activities through the promotion of further clarification and adjustment of roles allocation based on their special characteristics and the expected results of the R&D they are engaged and also through close cooperation with related organizations. (Fig.-7 Reference)

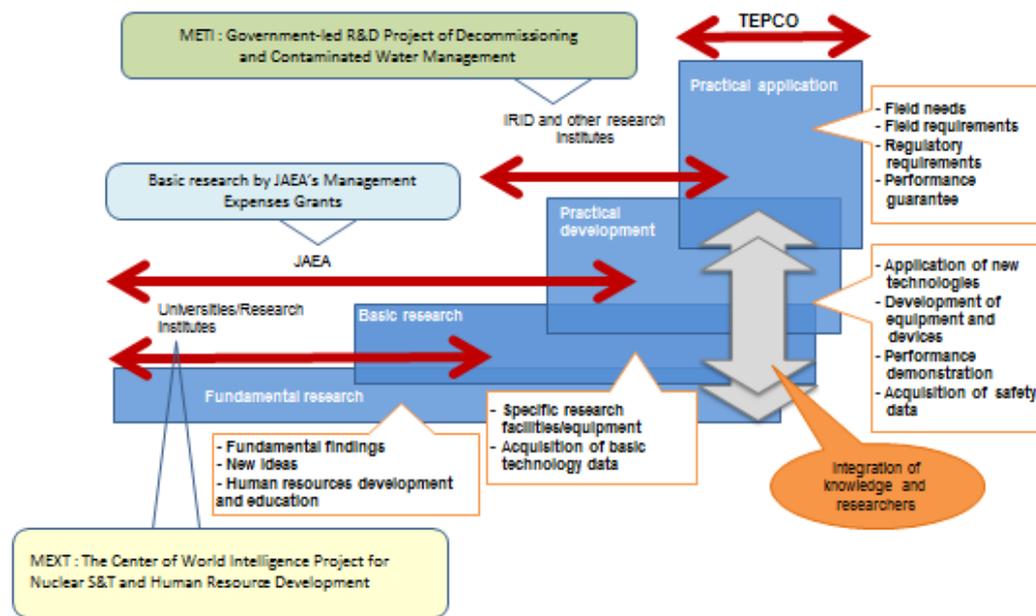


Fig.-7 Overview of R&D activities related to the Fukushima Daiichi NPS

2) R&D management for application to decommissioning work

- (1) Considering that the focus in the effort to decommission the Fukushima Daiichi NPS is shifting towards mid-and-long-term efforts such as the removal of fuel debris, TEPCO, IRID, and NDF should develop closer cooperative relationships, and review and strengthen R&D efforts being promoted such as by IRID, that are in line with the current status of decommissioning work and have direct application at the site in mind to enhance effectiveness. It is important for related organizations including research institutes and universities to make a shift towards developing closer ties based on decommissioning work requirements as well.
- (2) It is also important to set appropriate objectives that are directly related to an achievement of the objectives of each R&D effort in order to ensure a steady advanced. On this occasion, an R&D management mechanism that takes an overall view of these efforts including on-site construction work and technical considerations is needed. Furthermore, even after the R&D projects initiated, R&D management system that periodically monitors achievement and challenges of each R&D project, site conditions, needs at every milestone, and conducts expert review on transition to the next stage is important.
- (3) For "Determination of fuel debris retrieval policies for each unit " (summer of FY2017) and " Determination of fuel debris retrieval methods for the first implementing unit" (FY2018), it is

important to continuously monitor progress and achievements of the "Project of Upgrading Approach and System for Retrieval of Fuel Debris and Internal Structures" carried out in the "Project of Decommissioning and Contaminated Water Management." As a part of this, it is important to determine further R&D needs and respond in an agile manner to critical issues regarding access to fuel debris, containment of radioactive material, and minimization of exposure, or have requirements reflected in new R&D initiatives.

- (4) Through the experience in decommissioning and environmental restoration of nuclear facilities including nuclear power plants, various types of knowledge/experiences have been accumulated in the U.K., U.S., France and so on. It is considered that expertise and experience from such countries either directly or indirectly should be useful for the decommissioning of the Fukushima Daiichi NPS. Therefore, relevant domestic institutions are proactively promoting cooperation between overseas bodies. It is important to continue to actively incorporate knowledge gained from overseas according to the needs derived from the decommissioning work.

3) R&D reinforcement of the cooperation

- (1) In the decommissioning and contaminated water management team meeting held on May 21, 2015, Decommissioning R&D Partnership Council was decided to be established in the NDF to enhance the utilization of the results and findings obtained from the basic and fundamental technology research for the decommissioning technology in the practical application development. The communication is to be activated by integrating and sharing information for the details of the activities conducted by the nuclear industry, universities and academic societies. A wide range of R&D results is required to be applied to the actual site through these activities. (Fig.-8 Reference)

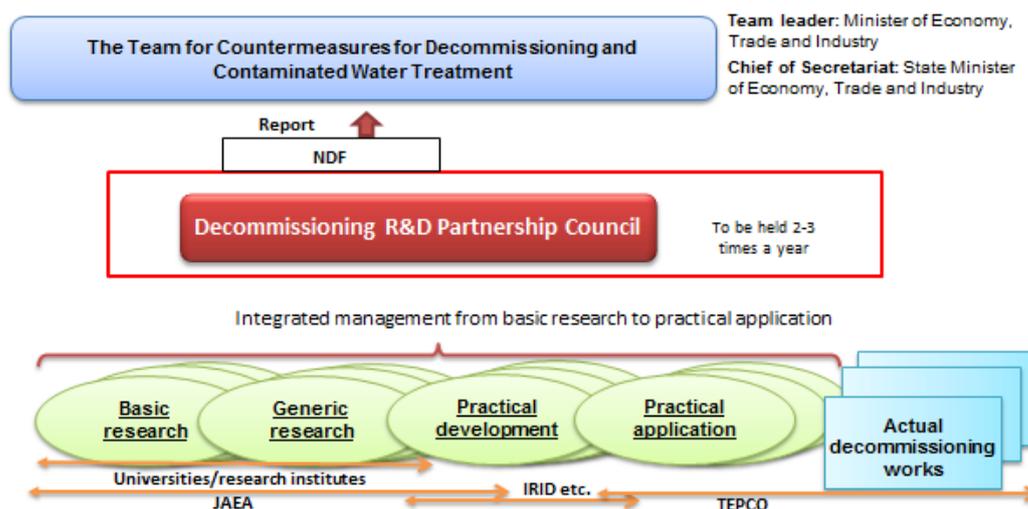


Fig.-8 Function of Decommissioning R&D Partnership Council

- (2) For the purpose of reinforcement of the cooperation for R&D projects, information regarding the seeds and needs of R&D and decommissioning that the relevant parties have should be disseminated and shared. With regards to the information sharing in basic and generic research areas, JAEA established the Collaborative Laboratories for Advanced Decommissioning Science (CLADS) in April

2015. It aims to promote exchanges such as between personnel of domestic and international universities, research institutes, and industry, and to promote R&D and human resource development in an integrated manner by industry, academia, and government. Also, Atomic Energy Society of Japan launched "Association for revitalization of Fukushima and promotion of decommissioning (consists of 33 organizations)" in December 2015 for the purpose of enhancement of the extensive cooperation with the various kinds of academic societies. It is important that the relevant institutions make full use of such opportunity to offer and share information.

- (3) Many of the needs of decommissioning work are not R&D needs itself, and it does not match simply with R&D seeds that the researchers have. Also, since the needs of decommissioning work will be originated from the site conditions and R&D performed at the time, "appropriate R&D needs" are required to be identified from the needs of decommissioning work, in advance of searching the R&D seeds. In addition, in order to search for and to pick out basic and generic technologies that would be required in the future from a wide area, it is needed to have efforts to grasp an overall image of the challenges associated with the decommissioning of the Fukushima Daiichi NPS.
- (4) In addition to providing opportunities to make actual matching, it is needed to provide information to researchers who have potential and have interests in the technology for which there is a clear need through the "Information Portal for the R&D for the Fukushima Daiichi Decommissioning" and the Platform of Basic Research for Decommissioning set up by JAEA as a consultative body to promote basic and generic research for decommissioning, and to encourage their participation in R&D related to the decommissioning of the Fukushima Daiichi NPS as well.
- (5) Taking these efforts into account, a task force has been established to identify additional R&D needs for the decommissioning of the Fukushima Daiichi NPS that should be addressed strategically and in a prioritized manner, to prioritize issues with matching R&D needs and seeds, and also to accurately deploy R&D at relevant institutions based on TRLs and so on. The NDF and JAEA will lead efforts that continue to actively promote activities of the taskforce and the Platform with cooperation with TEPCO and other related institutions.

4) Development of R&D center

- (1) It is important to construct a framework that brings together human resources from varied fields with different roles and levels of expertise referencing the types of functions required of an open innovation hub to accomplish research efficiently and effectively in the course of developing and operating R&D centers. Furthermore, basic and generic research, and the development of human resources should also be undertaken in an integrated manner, working closely such as with universities.
- (2) In addition to cooperating with efforts concerning the revitalization of Fukushima and surrounding areas and R&D center projects (e.g. environmental recovery, health management, regional economic development), it is important to consider activities being undertaken at existing facilities (e.g. academic research on debris from Three Mile Island (TMI) at JAEA Tokai and the Oarai Research and Development Center, sharing workload or providing a backup system related to the decommissioning of the Fukushima Daiichi NPS). The functions of mockup test facility of JAEA, Radioactive Material

Analysis and Research Facility and Collaborative Laboratories for Advanced Decommissioning Science are as follows.

<p>Mockup test facilities (“Naraha Remote Technology Development Center”) -Research management building -Test building</p>	<ul style="list-style-type: none"> ▪ A facility to conduct development/demonstration of remote control equipment/devices ▪ Simulating the work environment in the building of the Fukushima Daiichi NPS by using mockup facility, virtual reality and robotics simulator. ▪ Demonstration test of equipment required for decommissioning work by using the mockup and training for workers using virtual reality system and so on.
<p>Radioactive Material Analysis and Research Facility (“Okuma Analysis and Research Center”) -Facilities administration building -Building No. 1 -Building No. 2</p>	<ul style="list-style-type: none"> ▪ Analysis facility for radioactive wastes, fuel debris, etc. ▪ Installed analysis devices to obtain data that can contribute to the appropriate processing of radioactive waste. ▪ Installed equipment that can obtain basic data of fuel debris, which are high level radioactive waste.
<p>Collaborative Laboratories for Advanced Decommissioning Science (CLADS) -International Collaborative Research Building</p>	<ul style="list-style-type: none"> ▪ Promotes R&D and human resource development in comprehensive manner while establishing a network that facilitates the communication among universities, research institutes, and industry of multiple fields in Japan and abroad and the nuclear industry. ▪ R&D for characterization, storage, processing and disposal of radioactive wastes. ▪ R&D for characterization, handling, analysis, etc. of fuel debris ▪ R&D for clarification of chemical and migration behavior of substances inside the reactor ▪ Inspections of fuel debris and R&D for the visualization of the radiation

5) Development and securing of human resources

In regard to development and recruitment of human resources required to continue the decommissioning of the Fukushima Daiichi NPS over the long term, it is important to specify models of human resources required and priority technical fields in which training should be focused, taking an overall view of the entire decommissioning process in the date ahead and human resources involved in it into account. Meanwhile, efforts of the nuclear power industry as a whole are also required in order to recruit necessary human resources continuously. In addition to industry and educational institutions cooperatively promoting activities that makes students deepen their understandings on nuclear industry and conveying attractiveness of nuclear energy industry to students continuously, it is important to show paths of researchers and technicians to success in the process of decommissioning of the Fukushima Daiichi NPS, such as conveying the "attractiveness" of the decommissioning of the Fukushima Daiichi NPS that is extremely high-level technical challenges never seen or presenting diverse clear career paths that researchers and engineers can play an active part in.

7. Future Actions

The risk reduction strategy is to be reviewed considering the changes of the situation due to the progress of the decommissioning work and internal PCV condition analysis. Also, the countermeasures against various risks including the project risk are studied to steadily advance the decommissioning.

The milestones indicated in the Roadmap, such as "Determination of fuel debris retrieval policies for each unit" and "Establishment of basic concept of processing/disposal for radioactive solid wastes solid radioactive wastes" will be reached respectively in FY2017. Therefore, the next one year will be an important period for the fuel debris retrieval and waste management.

Based on the investigation and study results obtained from all the activities performed so far, the results of the R&D for the important technical issues to be obtained in the future are to be reflected while collaborating with related institutions. Also, the "spiral-up" of the strategy is aimed to be achieved by repeating the evaluations and reviews in order to contribute to the determination of fuel debris retrieval policies to be made in summer of 2017.

The studies on the strategy are also to be carried out towards the subsequent determination of the methodology for fuel debris retrieval and the steady progress of the decommissioning work including actual fuel debris retrieval.

With regard to the radioactive waste management, the overview of the basic concept of the processing and disposal that specifies the direction of the resolution of the issues attributable to the features of the wastes at the Fukushima Daiichi NPS is aimed to be incorporated in the Strategic Plan 2017.

In the light of the fact that the decommissioning of the Fukushima Daiichi NPS is a challenge which has never been experienced before, the approaches to the practical application of the R&D results are to be carried out through the improvement of the R&D effectiveness, enhancement of cooperation with relevant organizations, cooperation with the organizations overseas and further utilization of the R&D facilities.

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