Mid-to-Long-Term Roadmap for Decommissioning of Fukushima Daiichi NPP and International Cooperation

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Outline

1. Mid-to-Long-Term Roadmap for Decommissioning of Fukushima Daiichi NPP

2. R&D Roadmap

3. International Cooperation

1. Mid-to-Long-Term Roadmap for Decommissioning of Fukushima Daiichi NPP

Mid-to-Long-Term Roadmap and Primary Targets

“Government and TEPCO Council on Mid-to-Long Term Response for Decommissioning”, which was established last December, adopted the “Mid-to-Long-Term Roadmap for TEPCO’s Fukushima Daiichi Units 1 to 4.” This Roadmap defines the term of decommissioning into three phases, and outlines major milestones of on-site work and R&D projects

Phase 1: From the completion of Step 2 (last December) to the commencement of fuel removal from spent fuel pools
（Target: Accomplish in 2 years）

Phase 2: From the end of Phase 1 to the commencement of fuel debris removal from RPVs
(Target: Accomplish in 10 years)

Phase 3: From the end of Phase 2 to the end of the decommissioning process
（Target: Accomplish within 30 to 40 years）

Roles of the Government and TEPCO on the Mid-to-Long-Term Roadmap

- Role of the Government
  - METI/ANRE
    - Oversee the progress of the Roadmap and TEPCO's on-site work
    - PDCA Management of the R&D program
  - NISA (Regulatory Authority)
    - Prepare necessary regulatory systems
    - Ensure safety
- Role of TEPCO
    - On-site work, consistently ensuring human resources and project management, as the responsible site operator

Organizational Structure

Government and TEPCO Council on Mid-to-Long Term Response for Decommissioning

Co-Chair ：Mr. Hosono, Minister for the Restoration from and Prevention of Nuclear Accident, Cabinet Office
Mr. Edano, Minister of Economy, Trade and Industry (METI)
Vice-Chair ： Parliamentary Secretary of Cabinet Office, Vice Minister of METI, and President of TEPCO
Members ： Agency of Natural Resources and Energy(ANRE), The Nuclear and Industrial Safety Agency (NISA)

Management Board

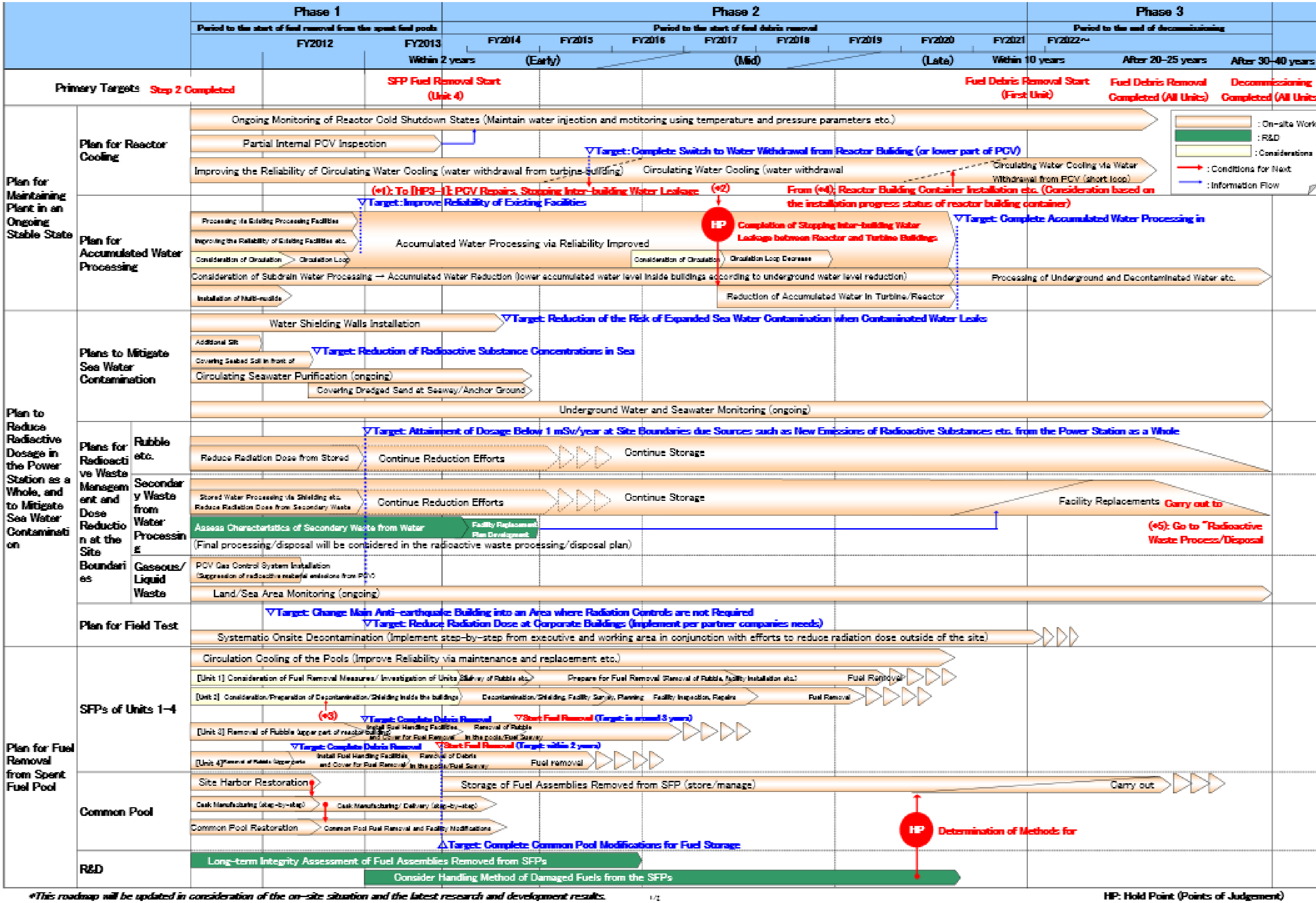
Co-Chair: Mr. Sonoda, Parliamentary Secretary of Cabinet Office
Mr. Kitagami, Vice Minister of METI
Mr. Aizawa, Executive Vice-President of TEPCO
Adviser : Ms. Kamimoto, Vice Minister of MEXT
Members: METI/ANRE
TEPCO
NISA (Nuclear and Industrial Safety Agency)
MEXT (Ministry of Education, Culture, Sports, Science and Technology)
JAEA (Japan Atomic Energy Agency)
Toshiba
Hitachi-GE

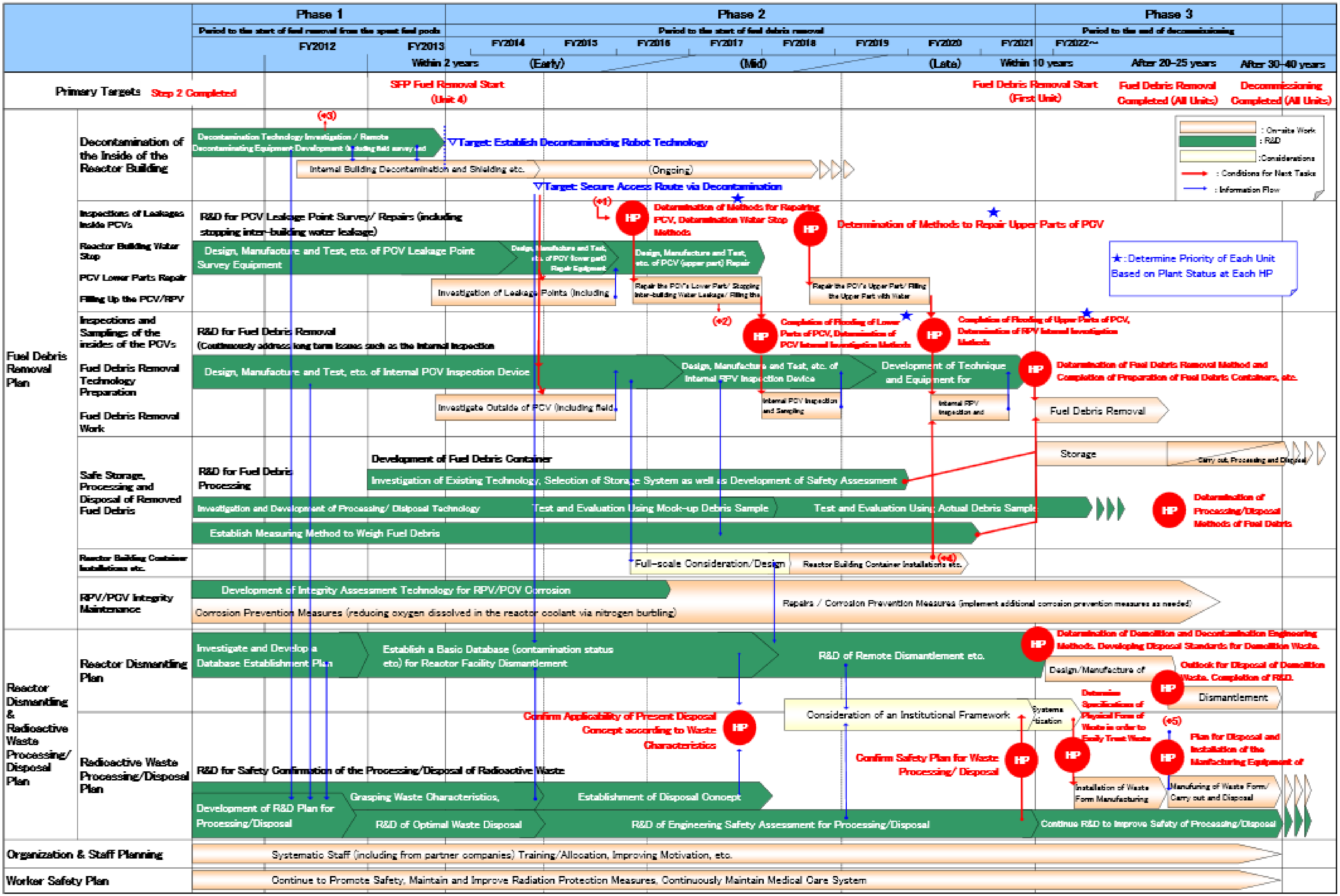
R&D Management Headquarter

Chair : Mr. Kitagami, Vice Minister of METI
Vice-Chair: Mr. Sonoda, Parliamentary Secretary of Cabinet Office
Ms. Kamimoto, Vice Minister of MEXT
Members : METI/ANRE
TEPCO
MEXT
AEC (Atomic Energy Commission)
JAEA
AIST
CRIEPI
Toshiba
Hitachi-GE
and a couple of academic advisors

Major Schedule of the Roadmap

- TEPCO's on-site work and government-led R&D program are clearly differentiated.
- Some of the on-site work will proceed in a phased process, based on R&D results.
- At the key points for judgment on the progression to subsequent processes, there will be further deliberation and judgment, including additional R&D and revision of process and task content. These are set as Holding Points (HPs).


Phase 1
Period to the start of fuel removal from the spent fuel pools
FY2012
FY2013
Within 2 years
Phase 2
Period to the start of fuel debris removal
FY2014
FY2015
FY2016
FY2017
FY2018
FY2019
FY2020
FY2021
(Early)
(Mid)
(Late)
Within 10 years
Phase 3
Period to the end of decommissioning
FY2022~
After 20–25 years
After 30–40 years
Primary Targets
Step 2 Completed
SFP Fuel Removal Start (Unit 4)
Fuel Debris Removal Start (First Unit)
Fuel Debris Removal Completed (All Units)
Decommissioning Completed (All Units)
: On-site Work
: R&D
: Considerations
: Conditions for Next
: Information Flow
Plan for Maintaining Plant in an Ongoing Stable State
Plan for Reactor Cooling
Ongoing Monitoring of Reactor Cold Shutdown States (Maintain water injection and monitoring using temperature and pressure parameters etc.)
Partial Internal PCV Inspection
▽Target: Complete Switch to Water Withdrawal from Reactor Building (or lower part of PCV)
Improving the Reliability of Circulating Water Cooling (water withdrawal from turbine building)
Circulating Water Cooling (water withdrawal
Circulating Water Cooling via Water Withdrawal from PCV (short loop)
(*1): To [HP3-1]: PCV Repairs, Stopping Inter-building Water Leakage
(*2)
From (*4): Reactor Building Container Installation etc. (Consideration based on the installation progress status of reactor building container)
Plan for Accumulated Water Processing
▽Target: Improve Reliability of Existing Facilities
Processing via Existing Processing Facilities
Improving the Reliability of Existing Facilities etc.
Consideration of Circulation
Circulation Loop
Accumulated Water Processing via Reliability Improved
HP
Completion of Stopping Inter-building Water Leakage between Reactor and Turbine Buildings
▽Target: Complete Accumulated Water Processing in
Consideration of Circulation
Circulation Loop Decrease
Consideration of Subdrain Water Processing → Accumulated Water Reduction (lower accumulated water level inside buildings according to underground water level reduction)
Processing of Underground and Decontaminated Water etc.
Installation of Multi-nuclide
Reduction of Accumulated Water in Turbine/Reactor
Plan to Reduce Radiative Dosage in the Power Station as a Whole, and to Mitigate Sea Water Contamination
Plans to Mitigate Sea Water Contamination
Water Shielding Walls Installation
▽Target: Reduction of the Risk of Expanded Sea Water Contamination when Contaminated Water Leaks
Additional Silt
Covering Seabed Soil in front of
▽Target: Reduction of Radioactive Substance Concentrations in Sea
Circulating Seawater Purification (ongoing)
Covering Dredged Sand at Seaway/Anchor Ground
Underground Water and Seawater Monitoring (ongoing)
Plans for Radioactive Waste Management and Dose Reduction at the Site Boundaries
▽Target: Attainment of Dosage Below 1 mSv/year at Site Boundaries due Sources such as New Emissions of Radioactive Substances etc. from the Power Station as a Whole
Rubble etc.
Reduce Radiation Dose from Stored
Continue Reduction Efforts
Continue Storage
Secondary Waste from Water Processing
Stored Water Processing via Shielding etc.
Reduce Radiation Dose from Secondary Waste
Continue Reduction Efforts
Continue Storage
Facility Replacements
Carry out to
Assess Characteristics of Secondary Waste from Water
Facility Replacement Plan Development
(*5): Go to "Radioactive Waste Process/Disposal
(Final processing/disposal will be considered in the radioactive waste processing/disposal plan)
Gaseous/Liquid Waste
PCV Gas Control System Installation
(Suppression of radioactive material emissions from PCV)
Land/Sea Area Monitoring (ongoing)
Plan for Field Test
▽Target: Change Main Anti-earthquake Building into an Area where Radiation Controls are not Required
▽Target: Reduce Radiation Dose at Corporate Buildings (Implement per partner companies needs)
Systematic Onsite Decontamination (Implement step-by-step from executive and working area in conjunction with efforts to reduce radiation dose outside of the site)
Plan for Fuel Removal from Spent Fuel Pool
SFPs of Units 1–4
Circulation Cooling of the Pools (Improve Reliability via maintenance and replacement etc.)
[Unit 1] Consideration of Fuel Removal Measures/ Investigation of Units
Prepare for Fuel Removal
Fuel Removal
[Unit 2] Consideration/Preparation of Decontamination/Shielding inside the buildings
Decontamination/Shielding Facility Survey, Planning
Facility Inspection, Repairs
Fuel Removal
(*3)
▽Target: Complete Debris Removal
▽Start Fuel Removal (Target: in around 3 years)
[Unit 3] Removal of Rubble (upper part of reactor building)
Install Fuel Handling Facilities and Cover for Fuel Removal
Removal of Rubble in the pools/Fuel Survey
▽Target: Complete Debris Removal
▽Start Fuel Removal (Target: within 2 years)
[Unit 4]
Install Fuel Handling Facilities and Cover for Fuel Removal
Removal of Debris in the pools/Fuel Survey
Fuel removal
Common Pool
Site Harbor Restoration
Storage of Fuel Assemblies Removed from SFP (store/manage)
Carry out
Cask Manufacturing (step-by-step)
Cask Manufacturing/ Delivery (step-by-step)
Common Pool Restoration
Common Pool Fuel Removal and Facility Modifications
HP
Determination of Methods for
△Target: Complete Common Pool Modifications for Fuel Storage
R&D
Long-term Integrity Assessment of Fuel Assemblies Removed from SFPs
Consider Handling Method of Damaged Fuels from the SFPs
*This roadmap will be updated in consideration of the on-site situation and the latest research and development results.
HP: Hold Point (Points of Judgement)



*This roadmap will be updated in consideration of the on-site situation and the latest research and development results.

HP: Hold Point (Points of Judgement)

Major Areas in the Roadmap

The Management Board supervises the progress of the Roadmap. The major areas the following:

- Circulating Water Injection Cooling
- Accumulated Water Treatment
- Reducing of Environmental Radiation Dose
- Improvement of Work Environment
- Fuel Retrieval from Spent Fuel Pool
- Preparation for Fuel Debris Removal
- Radioactive Waste Treatment and Disposal

The Roadmap Updated in July

The “Government and TEPCO Council on Mid-to-Long Response for Decommissioning” held its second meeting on July 30, 2012, and adopted the updated roadmap, which:

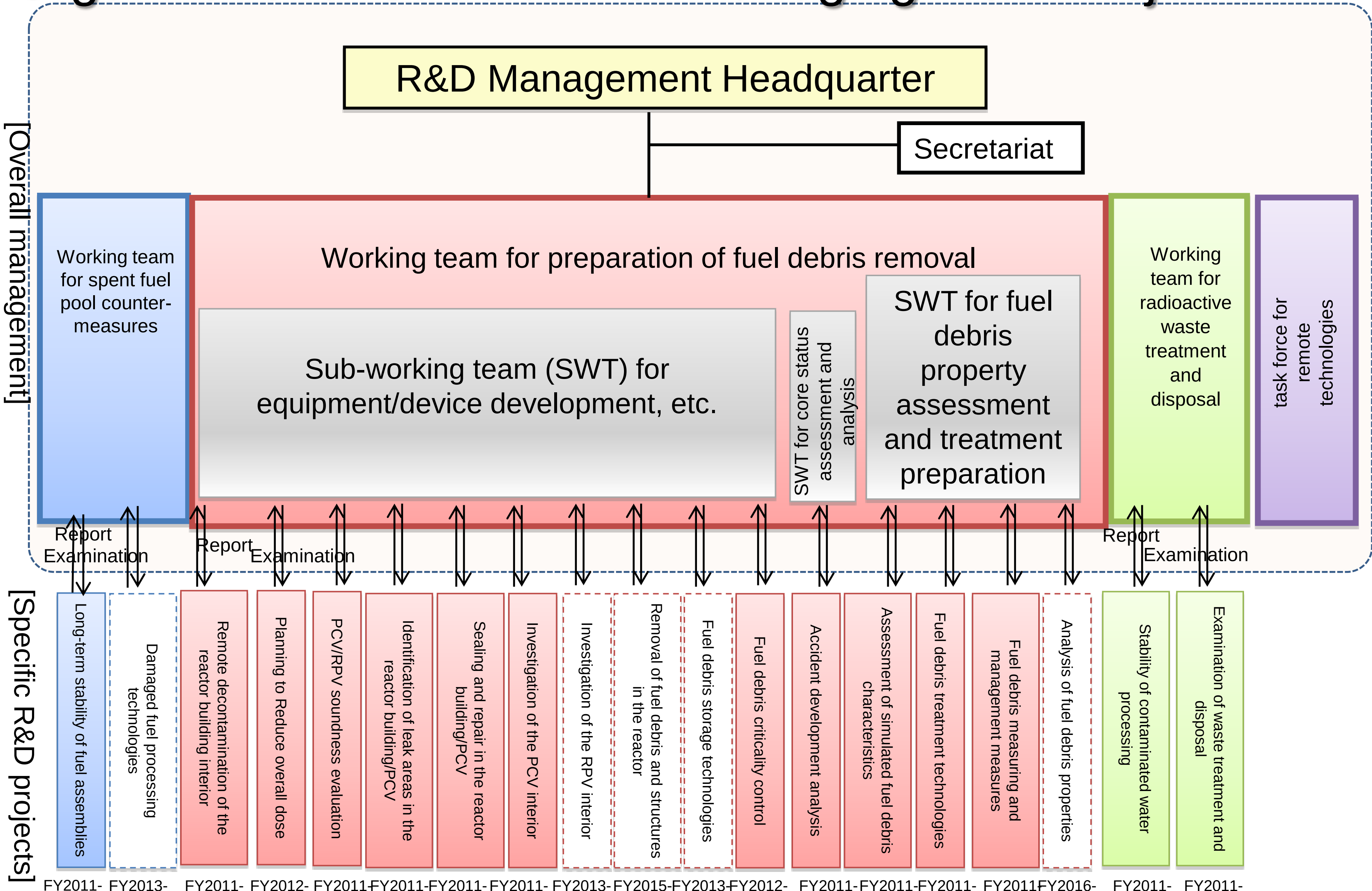
- reflects the latest version of TEPCO’s “Facility Operation Plan” for increasing reliability of equipment and site facilities
- highlights major outcomes to date
- clarifies short-term targets and milestones in response to the progress of the roadmap

2. R&D Roadmap

Major Areas in the R&D Roadmap

- Long-term management of retrieved fuel from SFP
- Preparation of fuel debris removal
  - Equipment/device development
  - Core status assessment and analysis
  - Fuel debris characterization and management
- Radioactive waste treatment and disposal
- Remote-controlled technologies as a common base

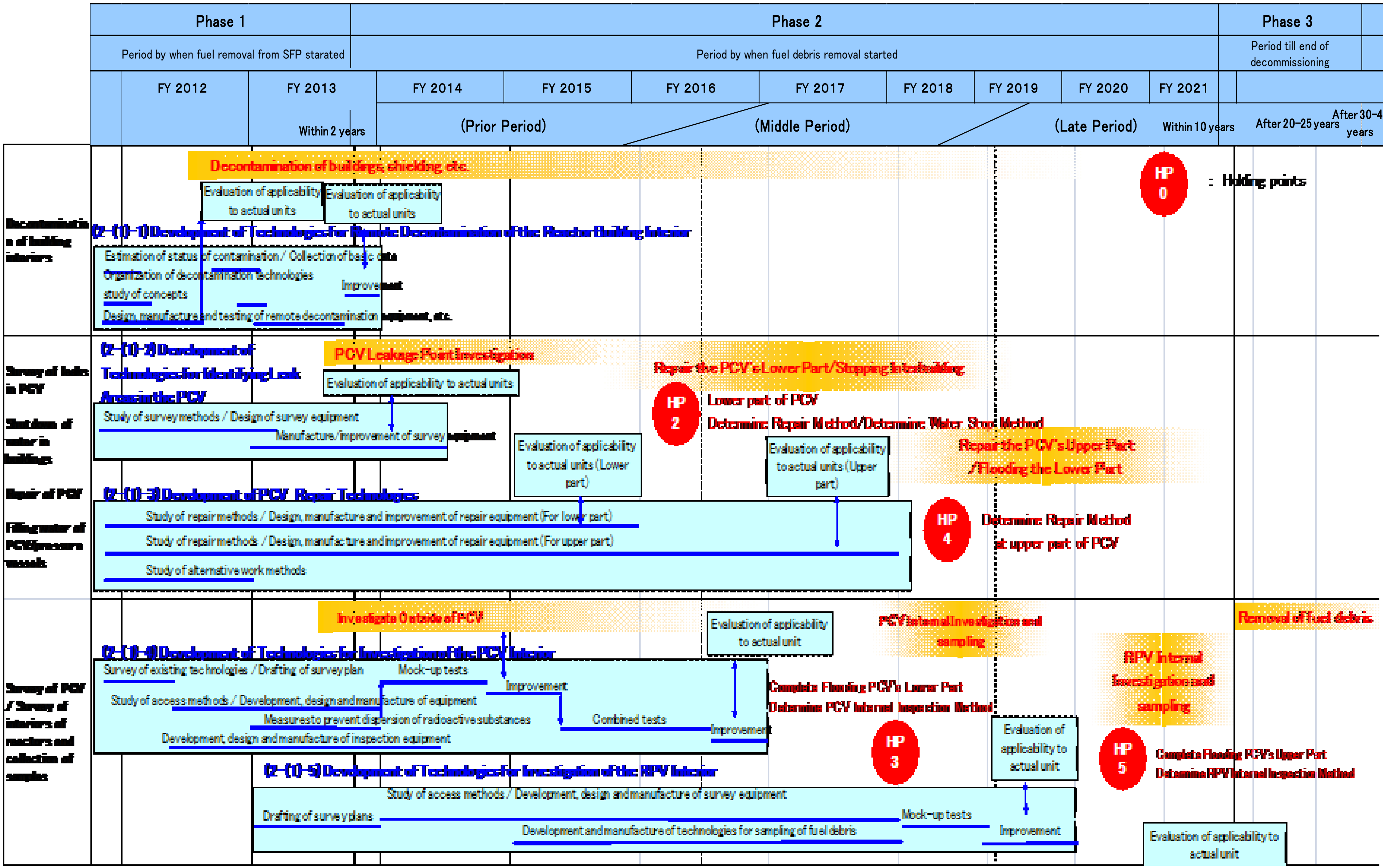
Organizational Structure for Managing R&D Projects



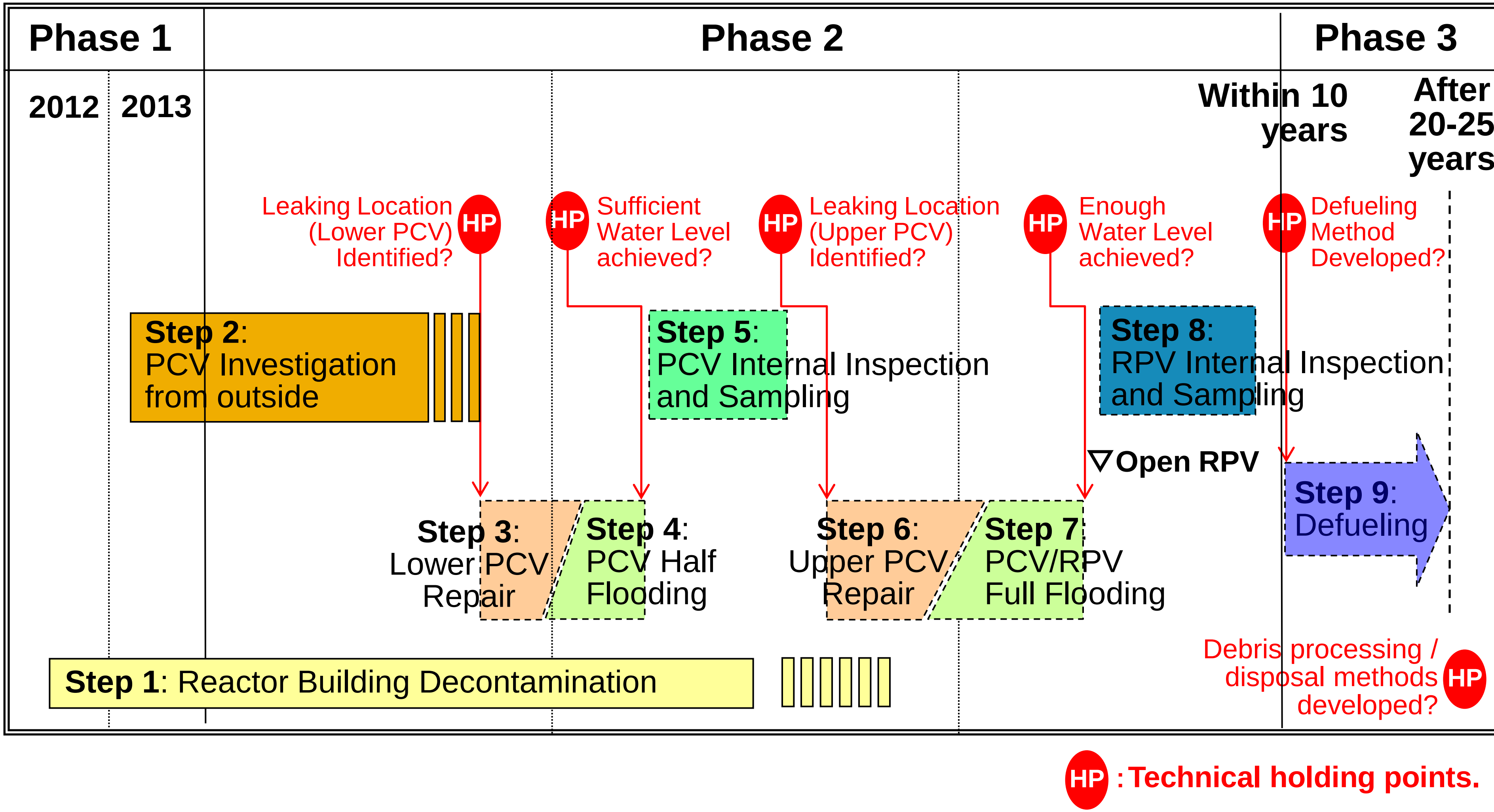
Three Principles for Implementing the R&D Program

- Address on-site technological needs
- Government involvement and support
- Open and flexible framework for implementation with support from international engineering and science communities

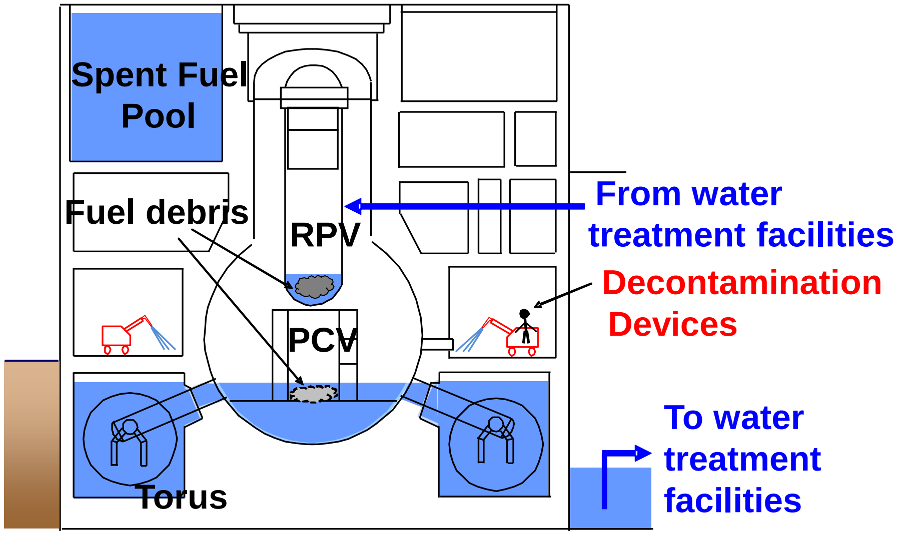
R&D Roadmap (Example)



Milestones for Fuel Debris Removal (Defueling)



Step 1: Reactor Building Decontamination



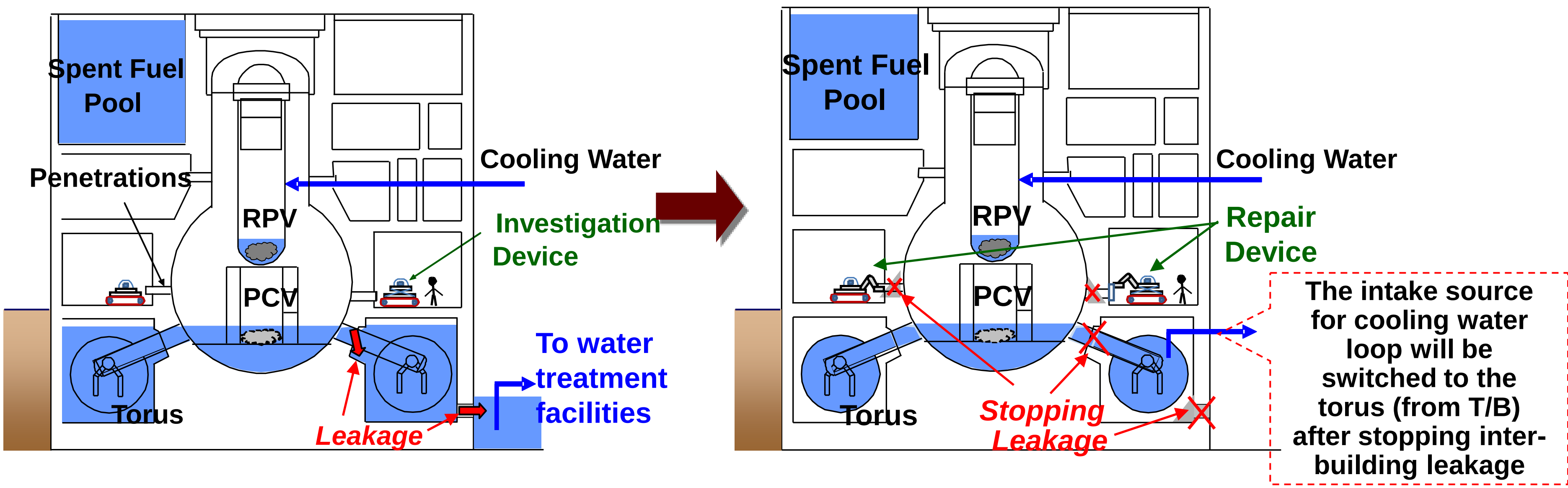
Decontamination of the area is essential to following procedures.

- Research and technology development of high-pressure washing, coating, scraping, etc.
- Combined usage of shielding

Major Challenges and Difficulties:

- High dosages (~ 5 Sv/h).
- Obstacles such as rubble scattered in R/B.
- Smaller space due to the compact design of BWR4

Steps 2&3: Identification and Repair of the PCV Leakage Points

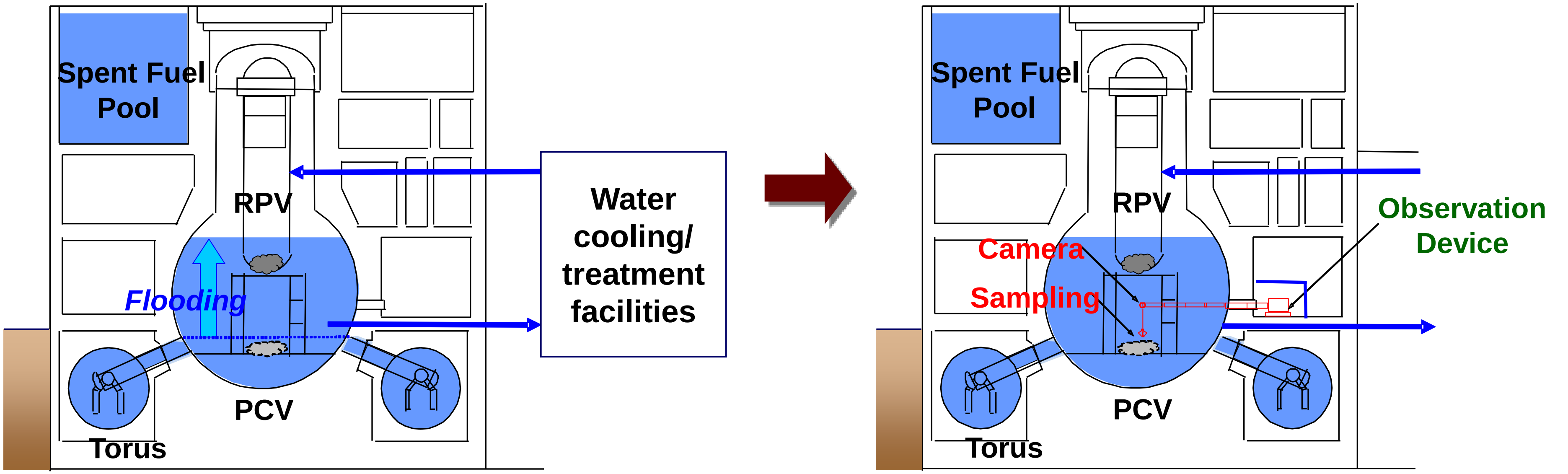


Leaking locations will be investigated from outside the PCV and will be repaired

Major Challenges and Difficulties:

- High dose rate and humidity of PCV inside.
- Most "suspicious locations" are underwater with poor visibility.
- Repair work has to be conducted while highly radioactive cooling water is running for continuous fuel cooling

Steps 4&5: Flooding of the Lower PCV, and Inspection & Sampling

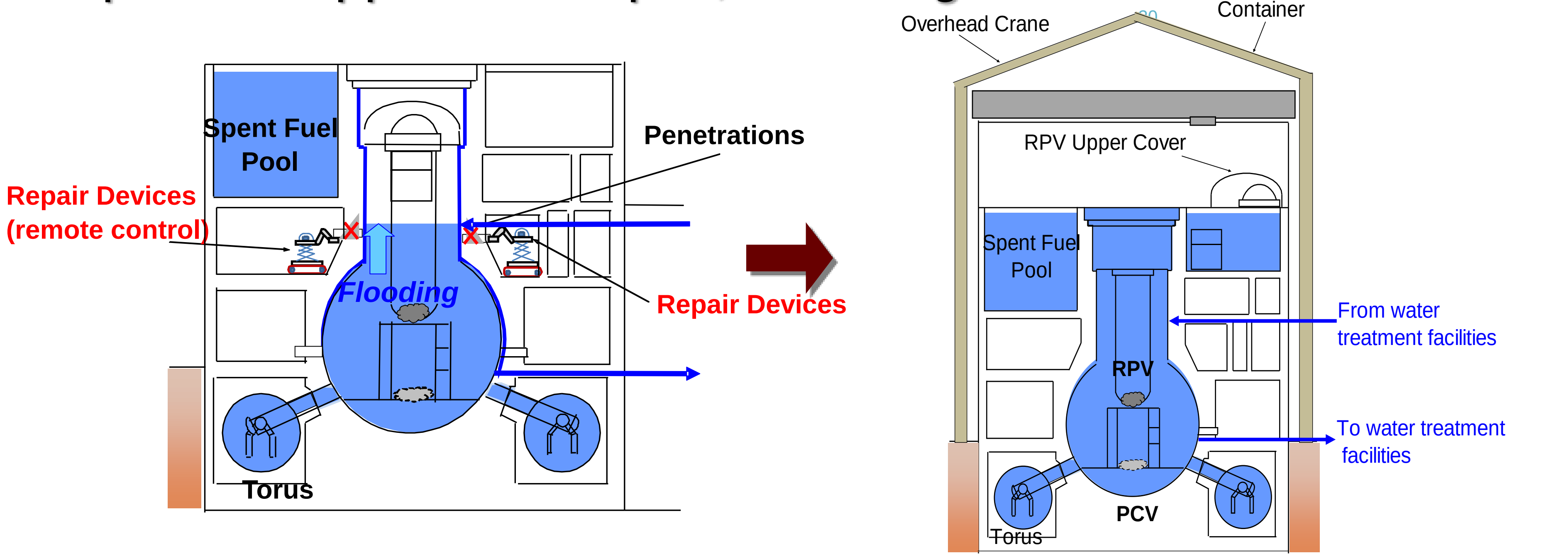


- Once the PCV gains its boundary, water will be filled (flooding)
- The distribution and characteristics of the fuel debris will be investigated

Major Challenges and Difficulties:

- High dose rate, limited accessibility and poor visibility.
- Leak-tight penetration is required for the investigation device once PCV flooding is achieved.
- Subcritical assessment

Steps 6&7: Upper PCV repair, Flooding of Entire Reactor Well

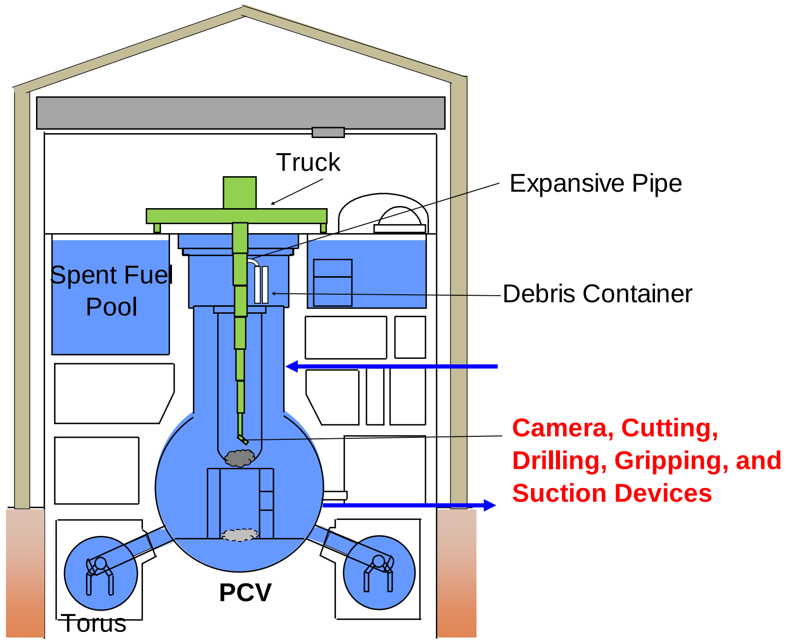


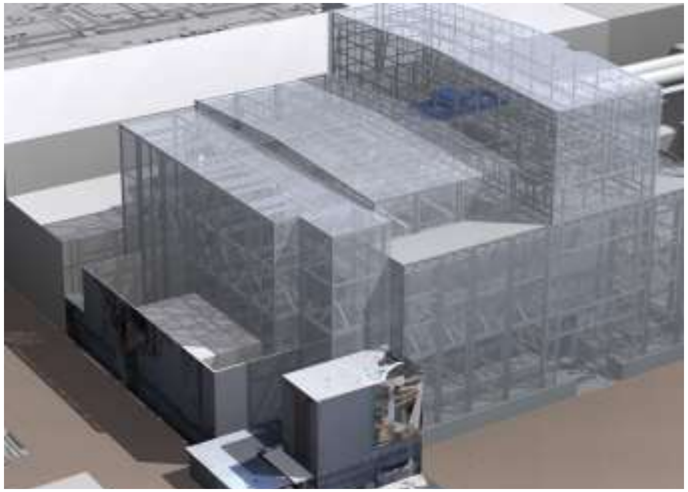
1) **Filling entire PCV/RPV with water after repairing upper PCV**
2) **R/B container and overhead crane will be installed for defueling.**
3) **RPV/PCV top heads will be removed after sufficient water is attained**

Major Challenges and Difficulties:

- High dose rate, limited accessibility.
- Seismic stability after flooding has to be maintained considering water mass.
- Prevent radioactive substances release from PCVs
- Subcritical assessment

Step 8: Internal RPV Inspection& Sampling



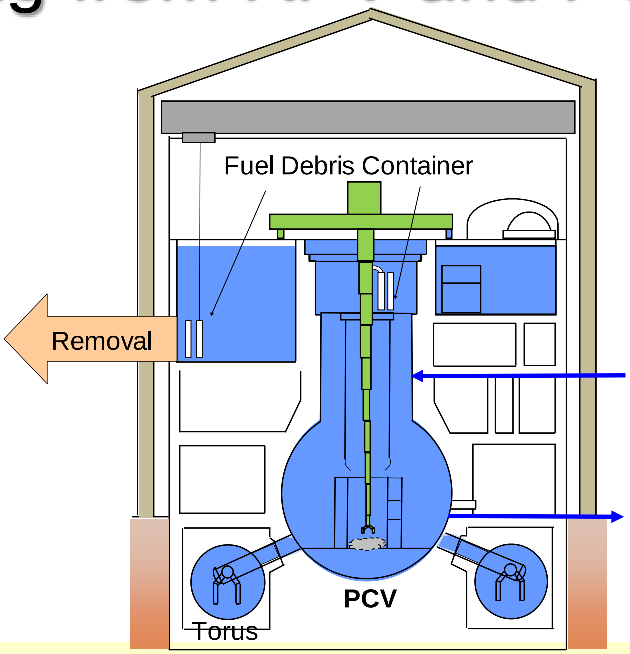


Condition of RPV internal and Fuel debris will be investigated

Major Challenges and Difficulties:

- High dose rate, limited accessibility and poor visibility.
- Development of necessary devices
- Subcritical assessment
- Store the removed debris

Step 9: Defueling from RPV and PCV



Fuel debris and RPV internal structure will be removed

Major Challenges and Difficulties:

- Fuel debris is assumed to have fallen onto the complicated RPV bottom structure (BWR structures are much more complicated than those of PWRs)
- Debris may have fallen even out of the RPV (debris remained in PRV in TMI-2)
- Diversity of neutronic, mechanical and chemical properties of debris as a mixture with different types of metals and concrete
- Subcritical assessment
- Store the removed debris

R&D Issues for Radioactive Waste Processing and Disposal

1. Properties Investigation and Characterization

- Properties differ from conventional waste, such as rubble, sludge, and decontaminated waste liquid (nuclide composition, chloride content, etc.)
- Basic information needs to be assessed for the development of each technologies

<u>Examples of differences with conventional waste</u>

- Main nuclides: Co-60, C-14, etc.
  →Fukushima Daiichi: Cs-137, Sr-90, etc.
- Sodium concentration is 5 times that of the TMI case due to 50-90% contamination by seawater
  →Lower Cesium absorption performance, increased waste generation
- Presence of sludge and other materials of unknown chemical composition
  →Need to identify these materials through analysis

Sludge sample (made by JAEA)

Zeolite sample

Outputs
- Radioactive concentration of each type of nuclide
- Component content
- Physicochemical characteristics, etc.

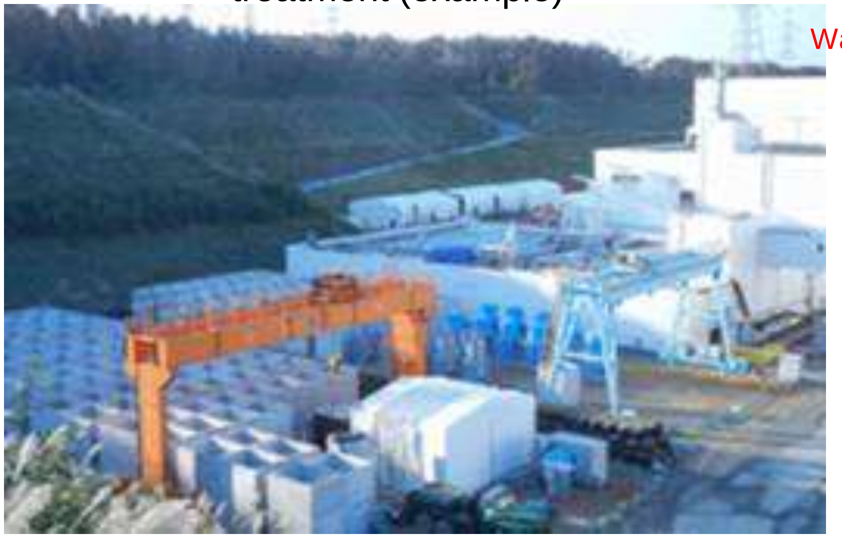
The installation of a hot lab near 1F must also be considered, as large volumes of high-dose, untransportable samples are expected to be generated accompanying decontamination and fuel debris removal.

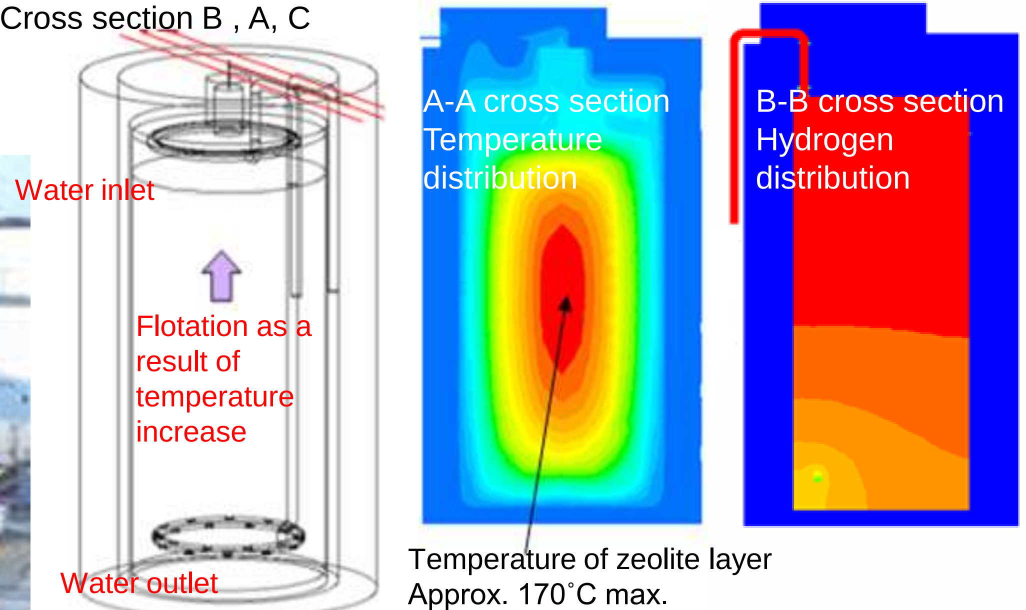
R&D Issues for Radioactive Waste Processing and Disposal

2. Long-term storage technologies

- Impact of chloride (corrosion) and high radioactivity (heat, hydrogen, surface radiation)
- Duration of storage: how long should it be?
- Is treatment necessary before storage?

Facility for secondary waste storage after water treatment (example)





Evaluation of temperature and hydrogen distribution in a KURION absorption vessel (by JAEA)

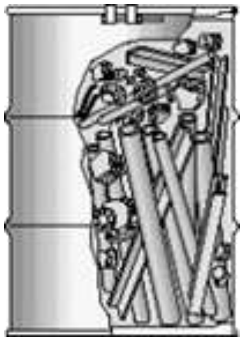
Output: Long-term storage method for each type of waste

R&D Issues for Radioactive Waste Processing and Disposal

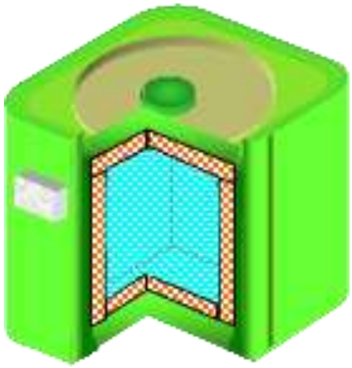
3. Processing technologies

- Can technologies used for existing processing technologies be applied?

Examples of waste package

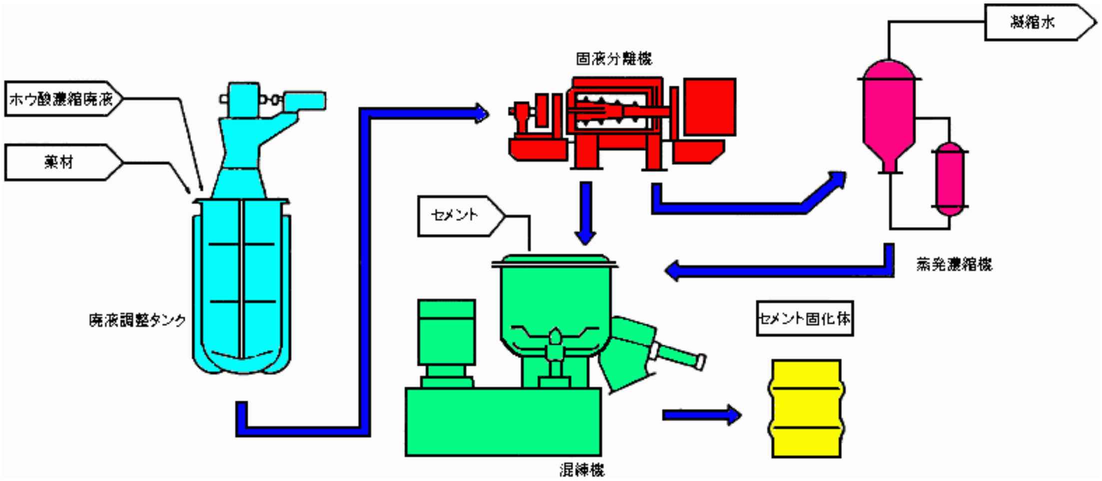


Drums



Square vessels

Examples of solidification



Basic flow in a cementing facility

Outputs
- Treatment methods for storage
- Methods for production of waste packages
- Performance of waste packages

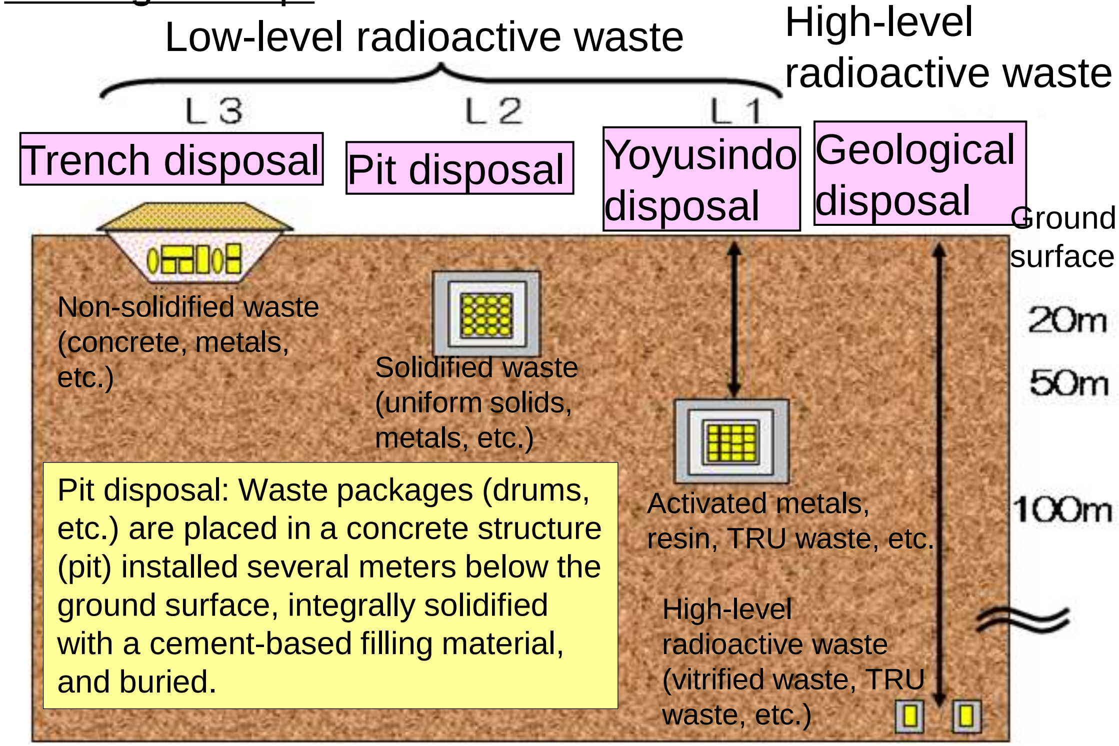
Source: Japan Atomic Industrial Forum Inc. (ed.), *Radioactive Waste Management: Technical Development and Plans in Japan*, July 1997, p.81.

R&D Issues for Radioactive Waste Processing and Disposal

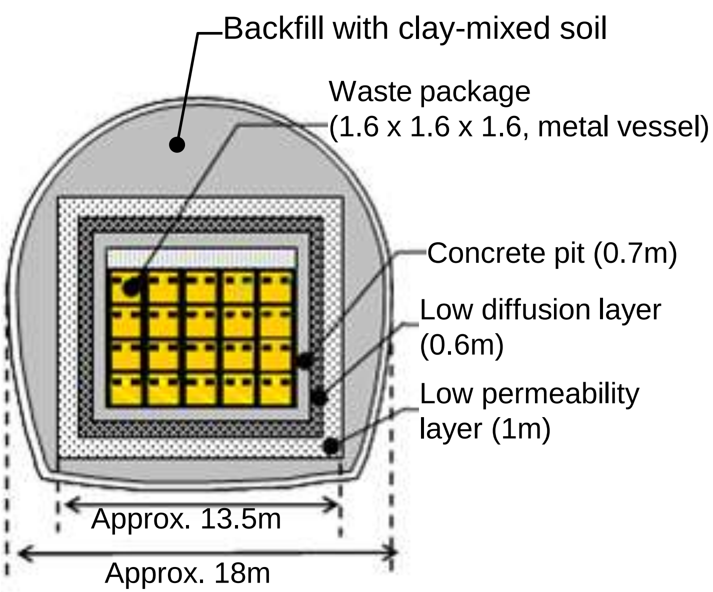
4. Disposal technologies

- Fundamental new technologies on the existing disposal concept
- Extract and address issues related to safety evaluation and find a solution

Existing concept



Example of an engineered barrier (Yoyusindo disposal)



Output: Waste disposal methods (required burial depth, construction of an engineered barrier, etc.)

3. International Cooperation

- Technological challenges in conducting a wide array of government-led R&D projects require wisdom and expertise from international communities, which indicate potential areas for international cooperation.

- The knowledge and technologies gained from these R&D projects will be valuable common assets for the improvement of decommissioning processes and become a knowledge base for further enhancing safety at nuclear facilities all over the world.

  - Government and TEPCO Council on Mid-to-Long-Term Response for Decommissioning held an International Symposium on March 14, 2012 in Tokyo. This event was organized in cooperation with the IAEA and OECD/NEA.

1． Challenges for Defueling:
1) Development of Remote Equipment and Devices

■ Short-term

✓Monitoring devices for the R/B under high dose enviroment

- remote-controlled UAVs, etc.

✓Sensing devices for water surface in the S/C and PCV to identify location of leaks

✓Remote-controlled robots running in the water to repair leaks

- Identify self location in the water
- Automatic treatment of long-length communication cable
- Sensor for the shape and water-flow

■ Mid-term

✓PCV repair devices and defueling equipment

1． Challenges for Defueling:
2) Accident analysis for evaluating the core status

■ Short-term

- ✓Accident progression analysis and benchmark study, by using existing and improved integral severe accident codes (cf. TMI-2 experience of OECD/NEA joint research)
- ✓Database/information portal to make accident data readily available to the international community.
- ✓Assessment on the validity of severe accident codes and leading greater confidence in the code predictive capabilities

■ Mid-term

- ✓Further analysis applying various models and methodologies
- ✓Collection of physical data during sampling and defueling

１． Challenges for Defueling:
3) Characterization and Sampling of Fuel Debris

■ Short-term

✓Simulated fuel debris for evaluating its characterization

✓Creating and updating database by making use of the experience of the TMI-2 debris study

✓Management and storage of fuel debris, and development of a new accountancy method

■ Mid-term

✓Sampling and analyzing actual fuel debris

✓Deployment of defueling equipment, devices, and storage.

2. Challenges for Radioactive Waste Treatment

■ Short-term

✓Development of analysis techniques and methods for the characterization of accident-origin solid waste

- Pre-treatment of solid radioactive waste
- Simplified and standard methodologies
- Regulatory and institutional framework

✓Management and processing secondary waste storage after water treatment

■ Mid-term

✓Exploring possibility for building a research center for international collaborative research program

✓Researchers/experts exchanges with international community

3. Challenges for Improving the Work Environment

■ Short-term

✓Technologies and systems to reduce the doses of workers

- Dose reduction management, including shielding
- Improving materials for workers' suits

✓Studying methodologies for increasing human performance

- Advancing human health and performance innovations for severely challenging environments
- Designing a better work environment

■ Mid-term

✓Address human resource needs for the mid-to-long term

Conclusion

In addressing the challenges we are facing, we are committed to the international community to make available information and data from the accident and decommissioning processes, through international collaboration projects.

With lessons learned from the Fukushima Daiichi accident, It is our responsibility to work together with international community for further improving decommissioning processes and knowledge-base for the safety at nuclear facilities.

Thank you very much.

Please visit our website:
www.meti.go.jp/english/earthquake/nuclear/decommissioning