The Mid-to-Long Term Strategy for the Decommissioning of Fukushima Daiichi NPP

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Outline

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

2. Technological Challenges and R&D Program

3. International Cooperation

4. Next Step Forward

1. MID-TO-LONG-TERM ROADMAP FOR DECOMMISSIONING

Mid-to-Long-Term Roadmap and Primary Targets

⇒See P.19-23

“Mid-to-Long-Term Roadmap for Decommissioning of TEPCO’s Fukushima Daiichi ” was decided in December, 2011.

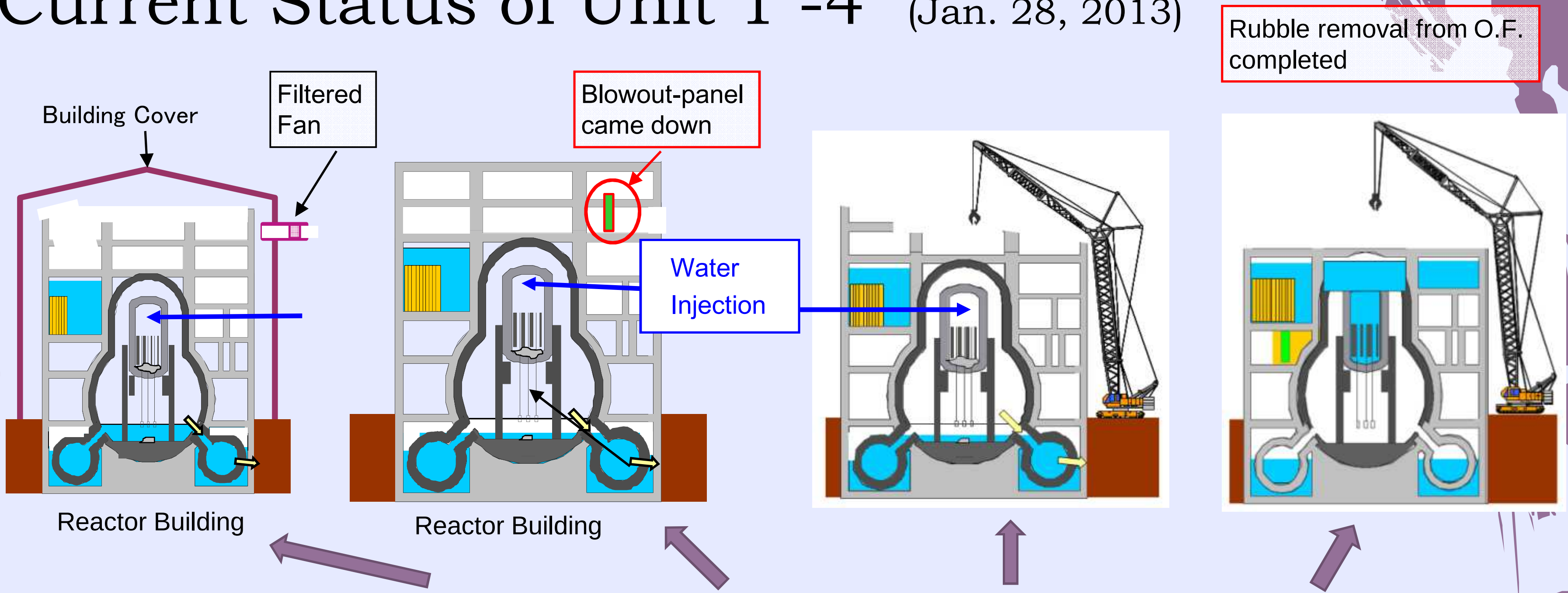
It defines the decommissioning work into three phases, and sets major milestones of on-site work and R&D projects.

Phase 1（with in 2 years）:
Commence fuel removal from spent fuel pools

Phase 2(with in 10 years):
Commence fuel debris removal from RPVs

Phase 3（within 30 to 40 years）:
Terminate the decommissioning process

Current Status of Unit 1 -4 (Jan. 28, 2013)



	Unit #1	Unit #2	Unit #3	Unit #4
Core Melt	Y	Y	Y	N
Hydrogen Explosion	Y	N	Y	Y
RPV Temp. (℃)	18	31	31	NA
PCV Temp. (℃)	20	32	31	NA
PCV Water level (m)	+2.8	+0.6	Unknown	NA
Dose rate O.F.(mSv/h)	53.6	880	500	1.3
# of SPF	392	615	568	1,533
SFP Temp. (℃)	10	12	9	20

Four short-term challenges

⇒See P.23-25

Although reactor cores are maintained low temperature, we are now facing at four major challenges;

- Management of accumulated contaminated water
- Reduction of environmental radiation dose
- Improvement of work environment
- Retrieval of spent fuel from spent fuel pool

Three long-term challenges

⇒See P.21,22

Ten years (End of Phase 2) seems far future, but many issues and problems exist to be tackled and solved well before hand.

- Preparation for Fuel debris removal
- Treatment and disposal of radioactive waste
- Development of remote control devices

2. TECHNOLOGICAL CHALLENGES AND R&D PROGRAM

Principles for implementing R&D

- Address on-site technological needs
- Government involvement and support
- Open and flexible framework in collaboration with international science and engineering communities

Key Areas of R&D Projects

■Preparation of fuel debris removal ⇒See P.27-31

- ➢ Equipment/device development
- ➢ Core status assessment and analysis
- ➢ Fuel debris characterization and management

■ Radioactive waste treatment and disposal ⇒See P.33-39

- ➢ Processing and Disposal of Secondary Waste
- ➢ Processing and Disposal of Radioactive Waste

■ Remote-controlled technologies as a common tool

3. INTERNATIONAL COOPERATION

Working with the International Community

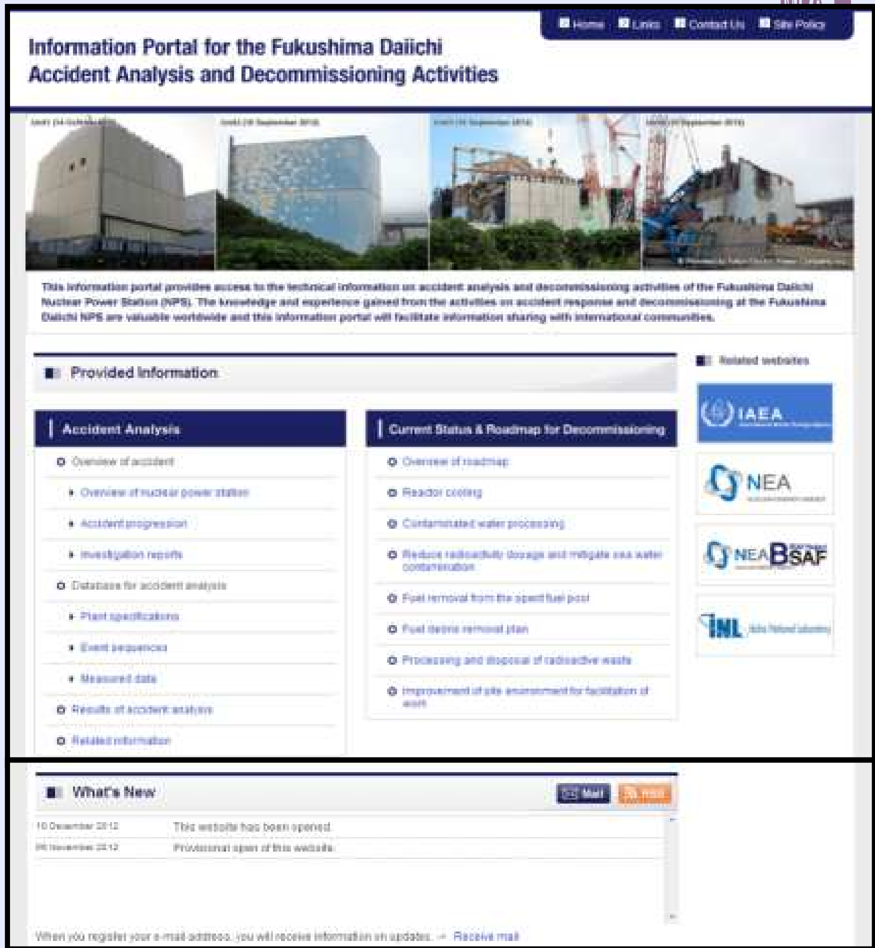
1) Bilateral dialogue framework with;

- France, Russia, Ukraine, UK,US

2) Information Portal for Accident Analysis & Decommissioning

- Opened Dec. 2012.
- This information portal provides an easy access to the technical information.

https://fdada.info/



Working with the International Community

3) Cooperation with IAEA

Japan proposed the followings at the Fukushima Ministerial Conference on Nuclear Safety in Dec. 2012.

- **Hosting IAEA peer review missions**
  - Expert's review for decommissioning program and activities of Fukushima Daiichi NPP.

- **Setting up an international advisory group**
  - Sharing information and data from the accident and decommissioning process.
  - Provide advice and guidance on safety approaches and policies regarding decommission to the international community.

Working with the International Community

4) International Collaborative Research

- Severe Accident Analysis Benchmark Project
  (NEA / BSAF Project: Phase Ⅰ −2014, Phase Ⅱ Planned)
  - Started initial analysis in November 2012 with the participation of 12 institutions from 8 countries
  - Detailed data and boundary conditions are also made available to non-participating organizations through portal site.

- Exploring possibility of international joint research projects such as;
  - Fuel debris sampling and removal,
    - Processing and disposal of radioactive wastes generated from the nuclear accident.

Working with the International Community

5) Enhancing international business and research partnership

- Government-led R&D projects are seeking expertise from the international community, ensuring openness and transparency.

(Example)

- ATOX Co., Ltd., opened a request for proposal on "Integrated Dose Reduction Planning" from Nov 16th to Dec 15th 2012.
- Six out of thirteen companies were selected as advisors.
  - Areva (France)
  - Babcock International Group (UK)
  - CH2M HILL (US)
  - Onet Technologies (France)
  - Perma-Fix Environmental Services (US)
  - Plejades (Germany)

4. NEXT STEPS FORWARD

Next Steps forward

Visit of Prime Minister Abe (Dec. 2012)

Visit of METI's Minister Motegi (Jan.2013)

- **Commitment of Government**
  - Support for establishing R&D institution
  - Strengthen of JAEA's ability
- **Accelerate and revise the Road Map**
  - Revise Road Map
- **Work and walk with international communities**
  - Shear information, elaborate plans and collaborate
  - Contribute to enhance the world nuclear safety

THANK YOU VERY MUCH FOR YOUR ATTENTION

Please visit our website:

www.meti.go.jp/english/earthquake/nuclear/decommissioning

APPENDIX

Mid -to-Long Term Road Map Dec.2012 (Reference)

Present（Completion of Step 2）	Within 2 Years	Within 10 Years	After 30-40 Years
Step 1, 2	Phase 1	Phase 2	Phase 3
<Achieved Stable Conditions>	Period to start of fuel removal from the spent fuel pool (in 2 years)	Period to start of fuel debris removal(in 10 years)	Period to the end of decommissioning (After 30-40 years)
-Condition equivalent to cold shutdown -Significant Suppression of Emissions	-Commence the removal of fuels from the spent fuel pools (Unit 4 in 2 years) - Maintain the effective radiation dose to be less than 1 mSv / year at the site boundary caused by additional emission and stored debris. -Maintain reactor cooling and accumulated water processing and improve their reliability. -Start R&D and decontamination towards removal of fuel debris -Commence R&D of radioactive waste processing and disposal	-Complete the fuel removal from the spent fuel pools at all Units -Complete preparations for the removal of fuel debris such as decontamination of insides of buildings, restoring PCVs and filling PCVs with water. Then commence the removal of fuel debris (Target: within 10 years) -Continue stable reactor cooling -Complete the processing of accumulated water -R&D on radioactive waste processing and disposal and on reactor facilities decommission	-Complete the fuel debris removal (in 20-25 years) -Completed decommission (in 30-40 years) -Implement radioactive waste processing and disposal

Actions towards systematic staff training and allocation, motivation improvement, and securing of workers' safety will be continuously implemented.

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

Government and TEPCO Council on Mid-to-Long Term Response for Decommissioning(Dec. 2012)

Co-Chair : Minister for the Restoration from and Prevention of Nuclear Accident, Cabinet Office
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), TEPCO
Observer : Nuclear Regulatory Agency (NRA)

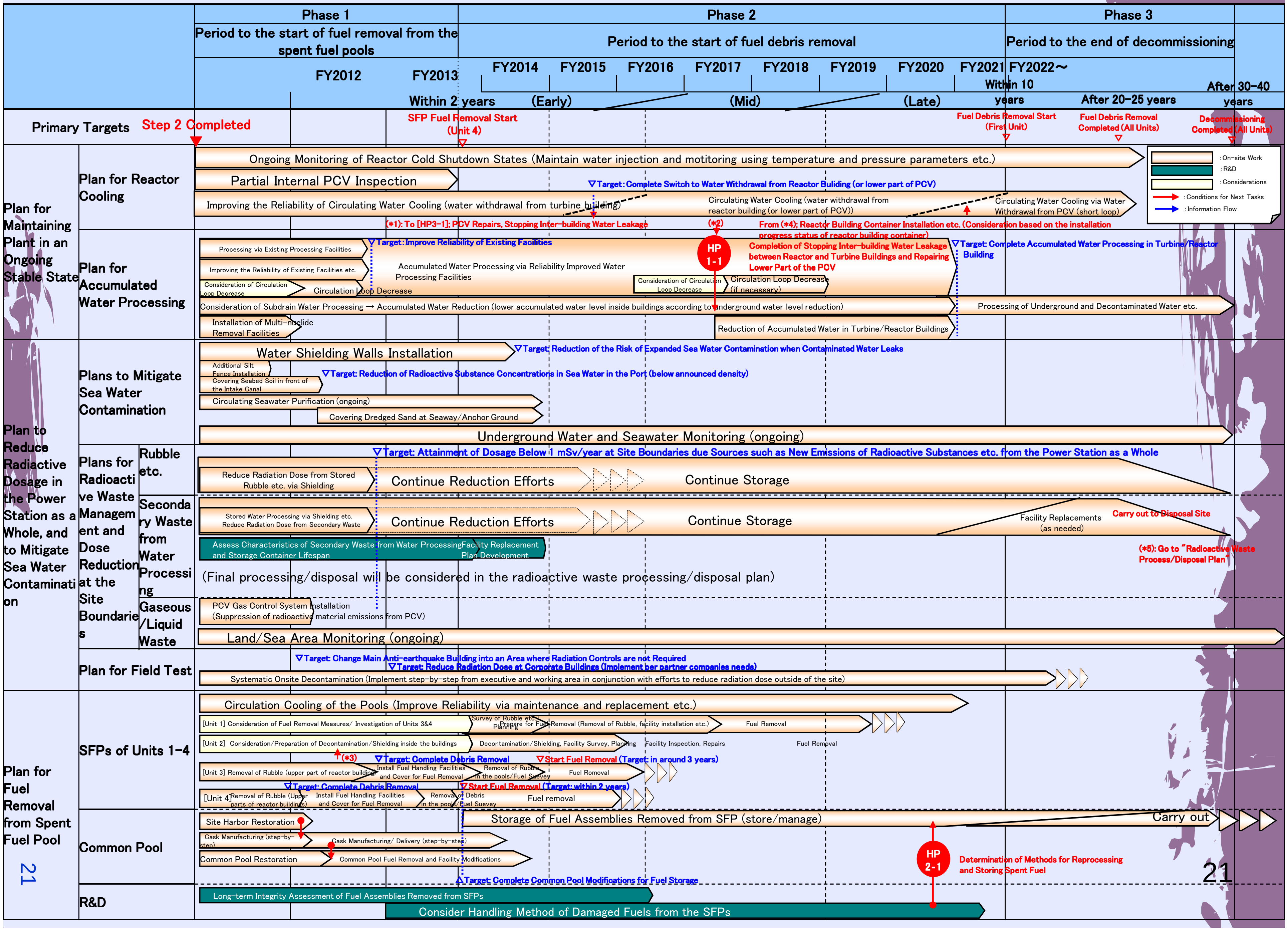
Management Board

Co-Chair: Parliamentary Secretary of Cabinet Office
Vice Minister of METI
Executive Vice-President of TEPCO
Adviser : Vice Minister of MEXT
Members: METI/ANRE
TEPCO
MEXT
JAEA (Japan Atomic Energy Agency)
Toshiba
Hitachi-GE
Observer NRA

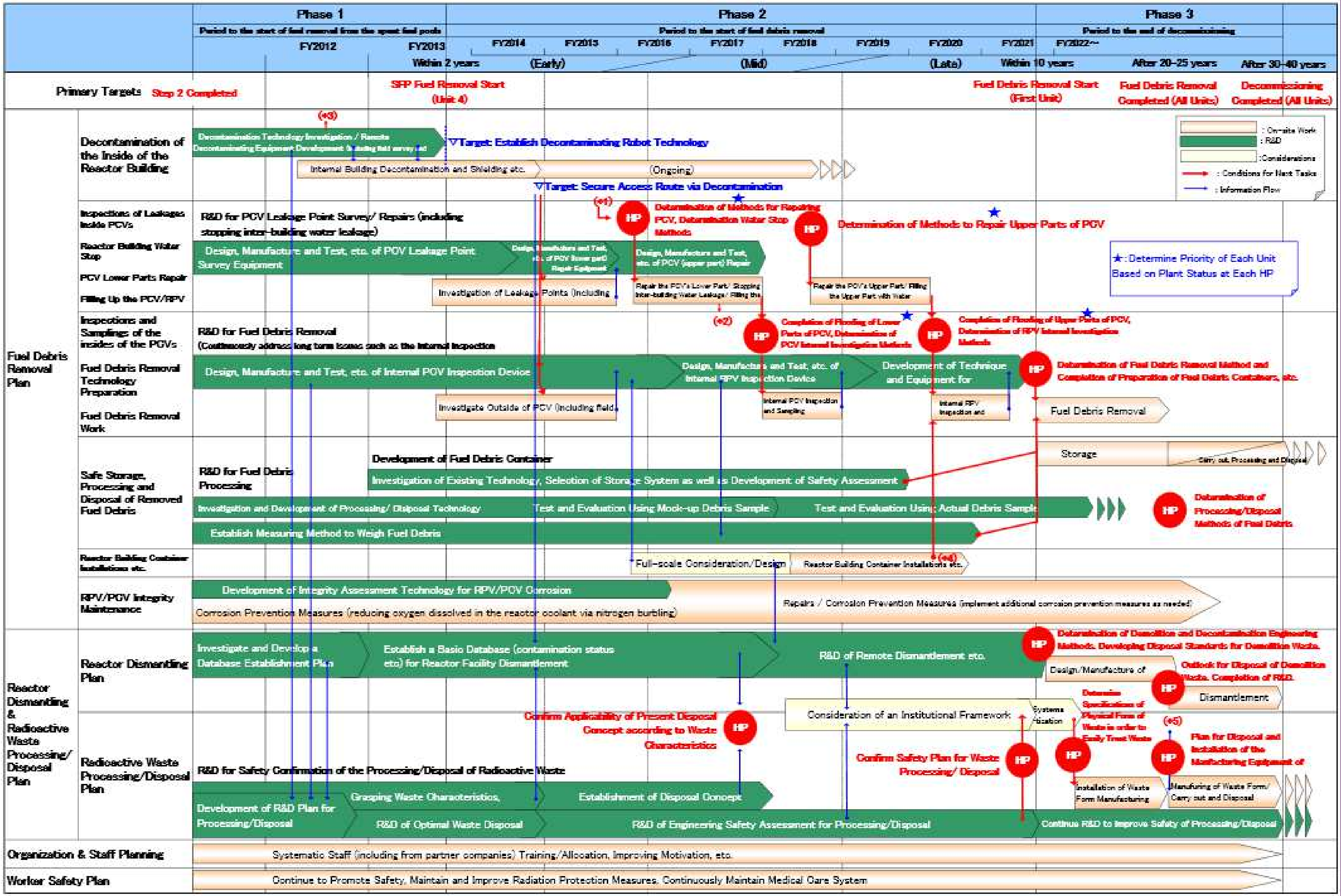
R&D Management Headquarter

Chair : Vice Minister of METI
Vice-Chair: Parliamentary Secretary of Cabinet Office
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

Main Schedule of Mid-and-long Term Roadmap towards the Decommissioning of Fukushima Daiichi Nuclear Power



Main Schedule of Mid-and-long Term Roadmap



*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)

Accumulated water increased by groundwater intrusion

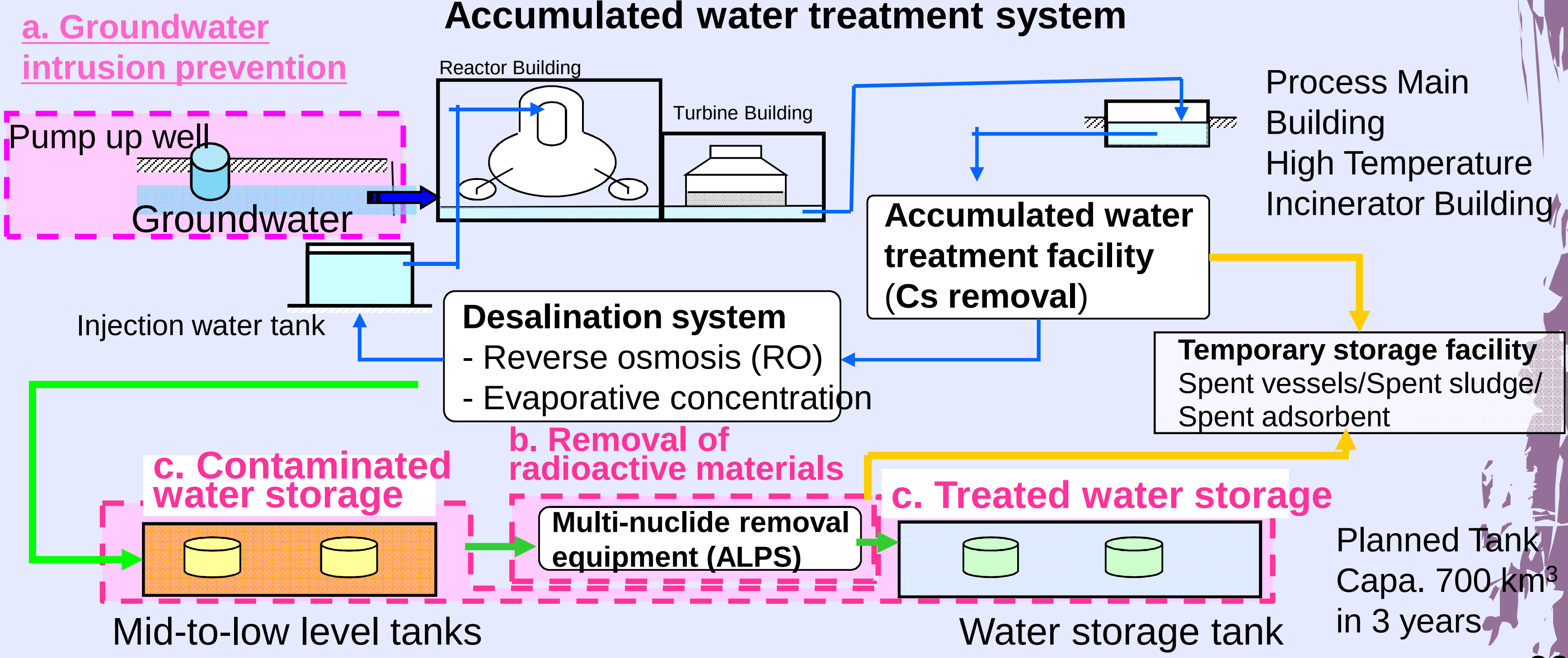
The highly contaminated water accumulated in the building basement is treated to be used for reactor cooling again. And there exists grand water intrusion (400t/day) to basement as well. The contaminated water generated in this process treated and stored in tank.

a. Prevent groundwater flow into the building → **Develop groundwater bypass**

b. Remove the radioactive materials in the contaminated water → **Install multi-nuclide removal equipment** (Tritium cannot be removed)

c. Storage of contaminated water → **Build additional storage tanks in the site**

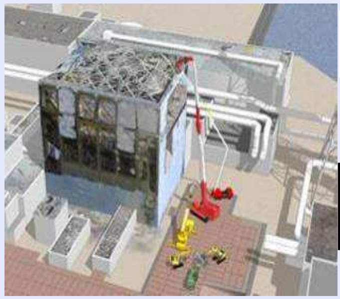
Accumulated water treatment system



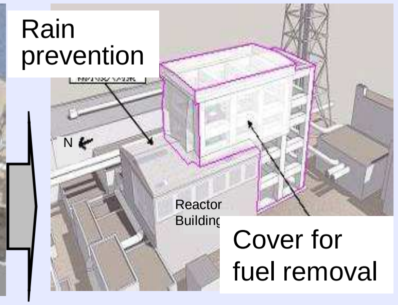
Plan and progress of fuel removal from the spent fuel pool

- The Circulating Cooling System had started operation. And desalination of the water in Spent Fuel Pool were in operation.
- Confirmed conditions inside the spent fuel pool via an underwater camera, corrosion investigation of removal unused fuel removal.
- Debris removal from the upper part of Units 3-4 Reactor Building is in progress. (to be completed in end of FY 2013 at Unit 3, in Dec, 2012 at Unit 4)
- At Unit 4, cover installation for fuel removal is on going.
- Preparation of Common Pool which stored removal spent fuel and construction of Dry cask temporary storage facility is on going.

Goal of Fuel removal from Unit 4 spent fuel pool
(Start by Nov. 2013, Complete by Dec. 2014)

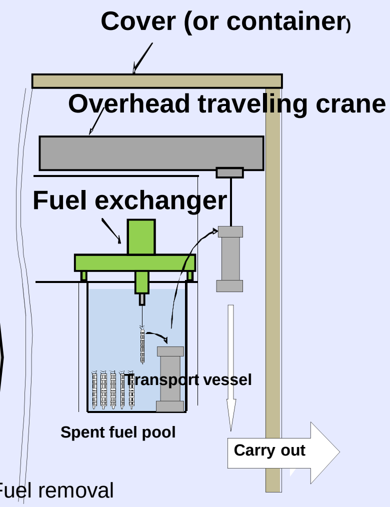


Debris removal from the upper part of the Reactor Building



Cover installation for fuel removal

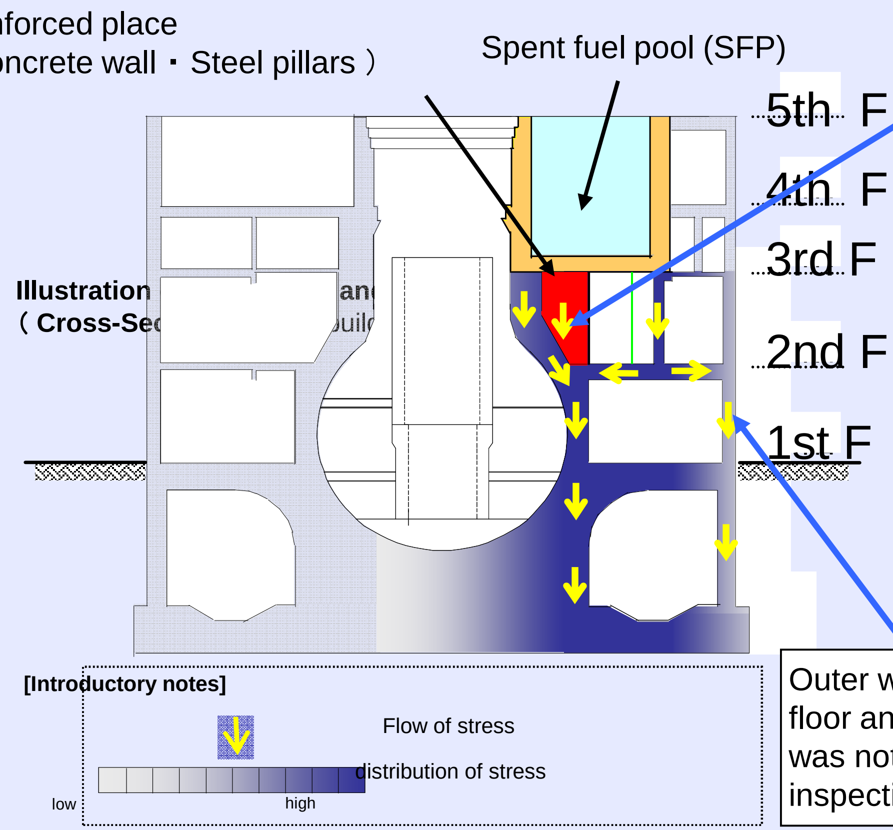
Mid 2013



Nov. 2013

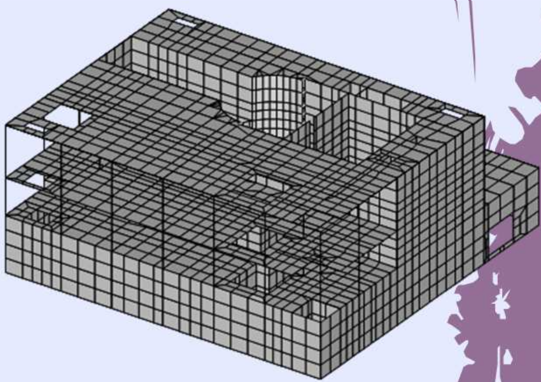
Structural integrity of the spent fuel pool and the Reactor Building at Unit 4

- We confirmed that the building, including the spent fuel pool, has a sufficient margin of seismic resistance even if an earthquake equivalent to the Tohoku-Pacific Ocean Earthquake (JMA Seismic Intensity Scale 6+) occurs in the area.
- We installed a support structure at the bottom of the spent fuel pool at the Unit 4. The structural integrity of the spent fuel pool has been confirmed by quarterly checks.(building tilt , no more than 1mm crack width, etc).



Shell wall (Not-damaged)

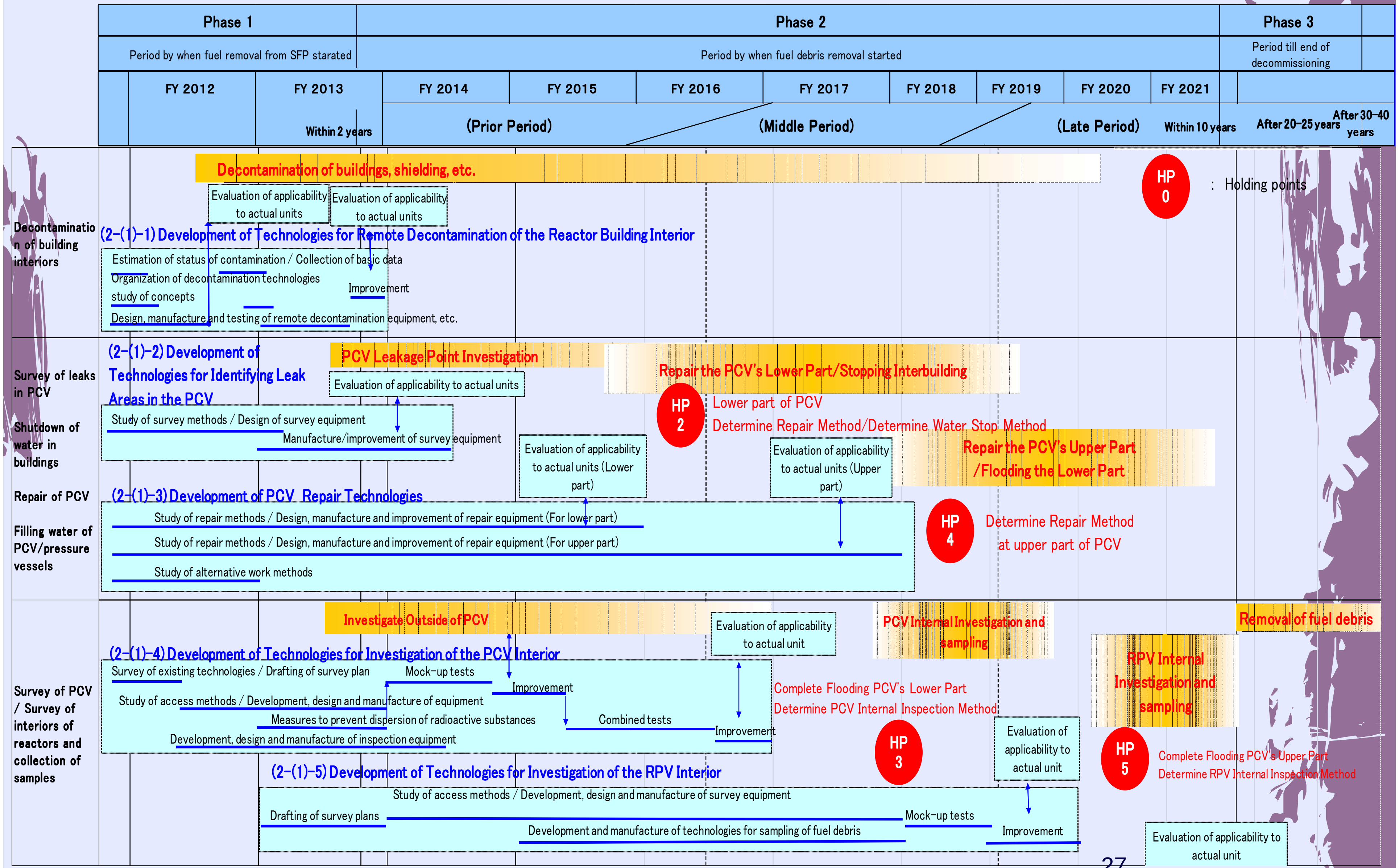
Outer wall between the first floor and the second floor was not damaged. (Visual inspection)



Seismic analysis model

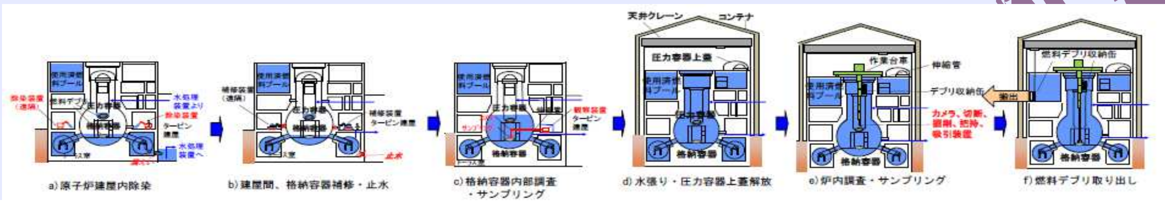
TECHNOLOGICAL CHALLENGES FOR FUEL DEBRIS REMOVAL

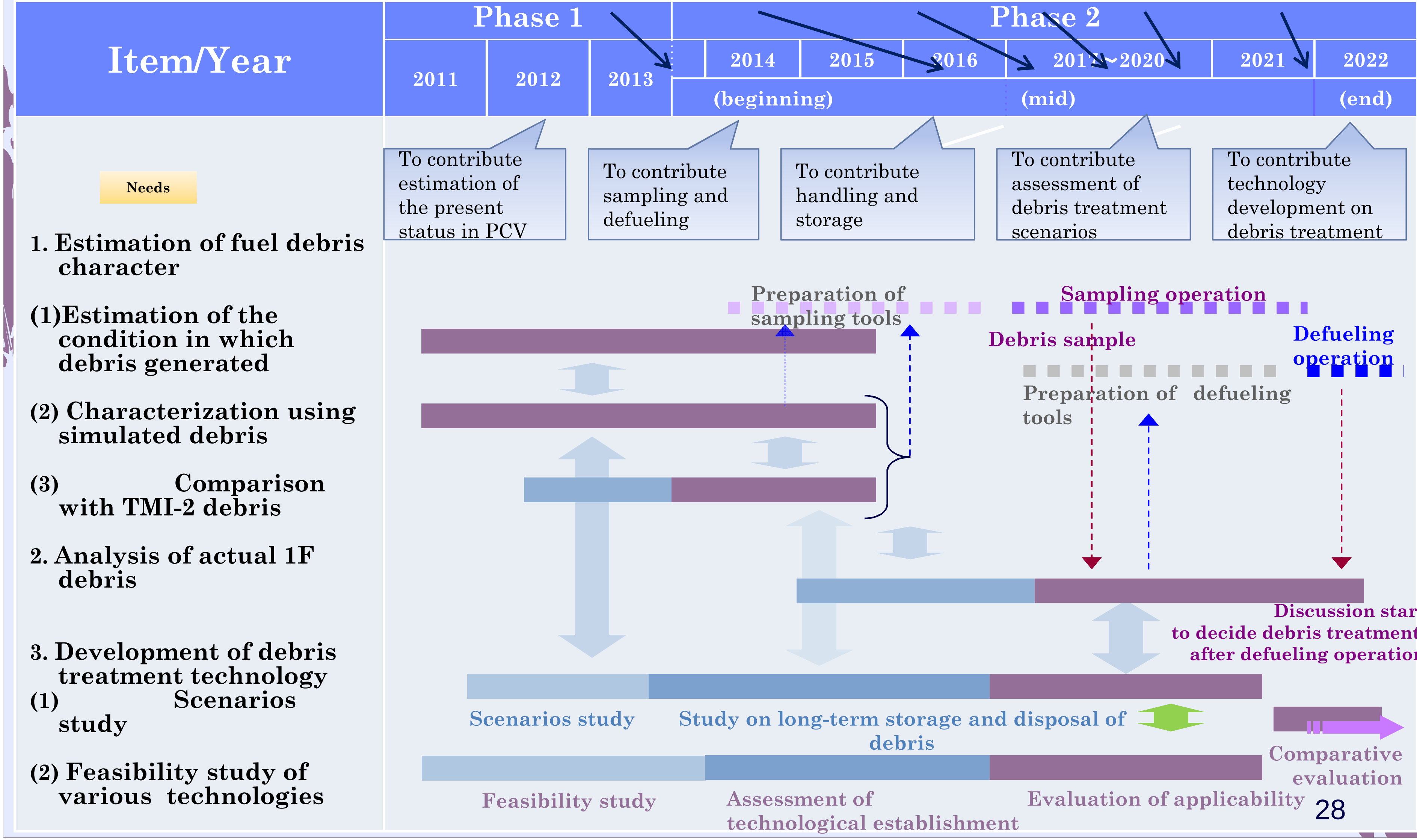
R&D Roadmap (Fuel Debris Removal)



R&D Schedule and On-site Needs

- Debris characterization and treatment study -





Challenges for fuel removal :

1) Development of Remote Equipment and Devices

- ■ Short-term
- ✓ Monitoring devices for the R/B under high dose environment
  - 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

Challenges for fuel removal:
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

Challenges for fuel removal:
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.

TECHNOLOGICAL CHALLENGES FOR RADIOACTIVE WASTE PROCESSING AND DISPOSAL

R&D related to processing and disposal of radioactive waste

	Phase 1		Phase 2								Phase 3		
	Period by when fuel removal from SFP starated		Period by when fuel debris removal started								Period till end of decommissioning		
	FY 2012	FY 2013	FY 2014	FY 2015	FY 2016	FY 2017	FY 2018	FY 2019	FY 2020	FY 2021			
		Within 2 years	(Prior Period)			(Middle Period)			(Late Period)		Within 10 years	After 20–25 years	After 30–40 years

Main event

- ▼Step2 Completion
- SFP Fuel Removal Start (Unit 4) ▽
- Fuel Debris Removal Start (First unit) ▽
- Fuel Debris Removal Completed (All units) ▽
- Decommissioning Completed (All units) ▽

(3) R&D related to processing and disposal of radioactive waste

Management of radioactive waste

Storage and management of radioactive waste

Implementation of measures for long-term stable storage

(3-1) Development of Technologies for the Processing and Disposal of Secondary Waste produced by the Processing of Contaminated Water

- Survey of characteristics of secondary waste
- Study of measures for long-term storage
- Study of technologies for manufacture of waste blocks
- Verification of applicability of existing concepts of disposal / Identification of problems

Installation of Waste Form Manufacturing

Manufacture of Waste Form / Deliver and disposal

HP 11: Plan for Disposal and Installation of the Manfacturing Equipment of the Waste Form

HP 10: Determine Specification of Physical Form of Waste in order to Easily Treat Waste and Its Production Method

Processing and disposal of radioactive waste

(3-2) Development of Technologies for the Processing and Disposal of Radioactive Waste

HP 8: Confirm Applicability of Present Disposal Concept in Accordance with Waste Characteristics

HP 9: Confirm Safety Plan for Waste Processing/Disposal

- Survey of characteristics of rubble, etc.
- Verification of applicability of existing concepts of disposal / Identification of problems (Rubble, etc.)
- Study of properties (Dependent on period of occurrence of specific waste product) / Development of technologies for manufacture of waste blocks
- Verification of applicability of existing concepts of disposal / Identification of problems (Waste from disassembly, etc.)
- Solution of problems of existing technologies
- Solution of problems of existing technologies
- Formulation of concepts of processing and disposal for waste to which existing technologies cannot be applied / Development of technologies

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.

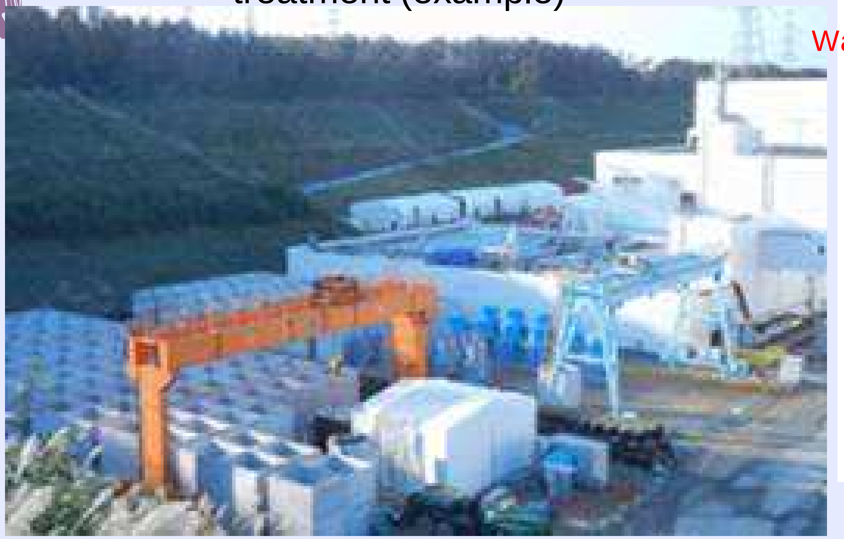
The installation of a hot lab near 1F must also be considered, as large volumes of high-dose, untransportable samples are expected to be generated accompanying decontamination and fuel debris removal.

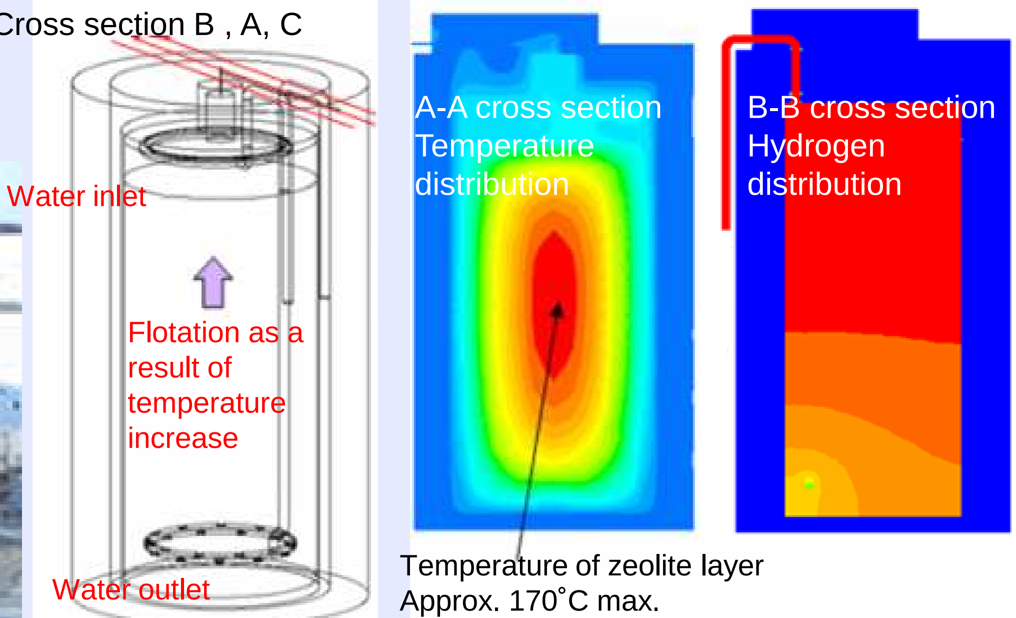
R&D Issues for Radioactive Waste Processing and Disposal

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)

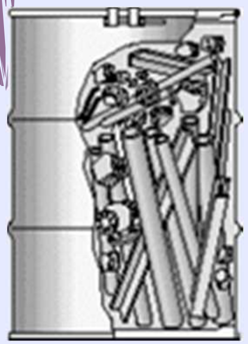
Output: Long-term storage method for each type of waste

R&D Issues for Radioactive Waste Processing and Disposal

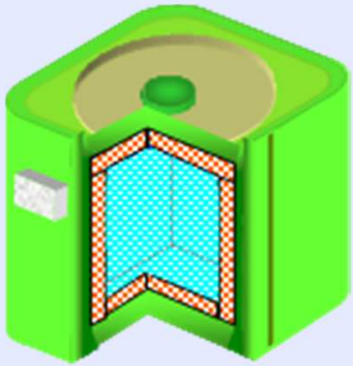
3. Processing technologies

- Can technologies used for existing processing technologies be applied?

Examples of waste package

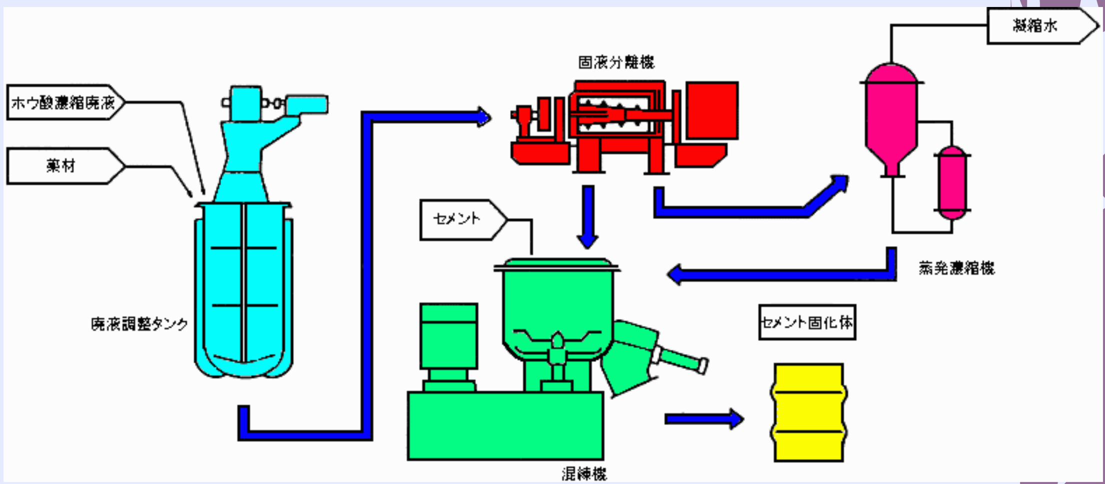


Drums



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

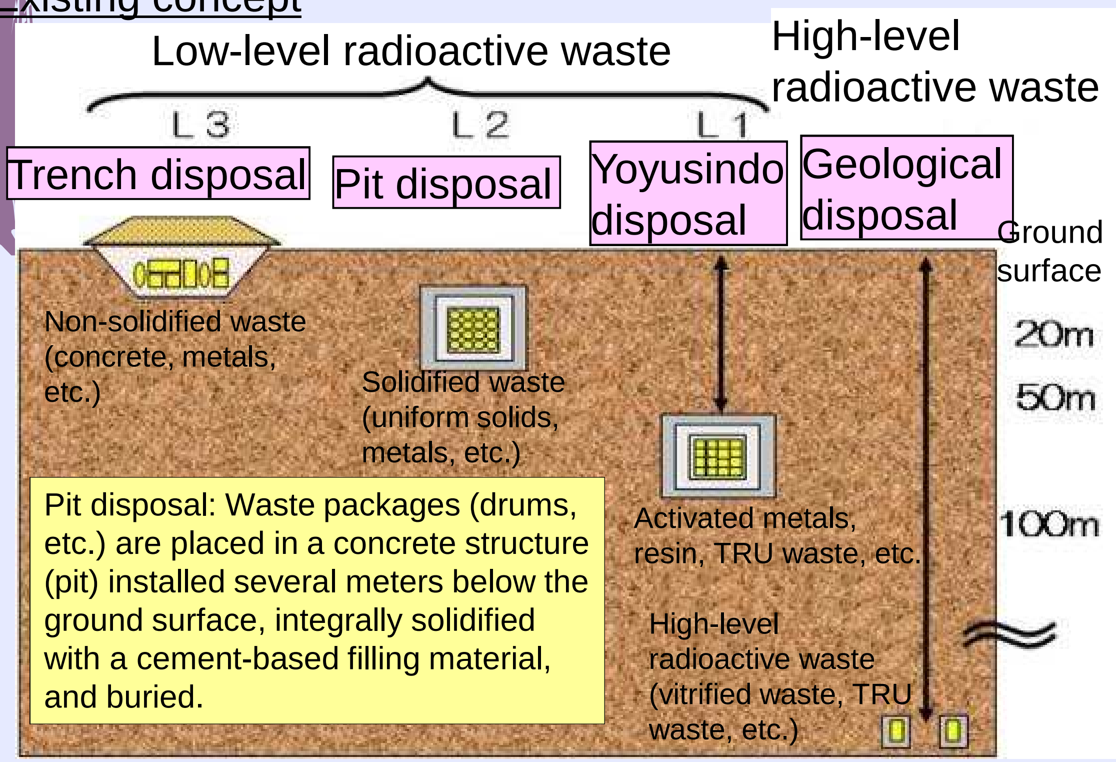
Source: Japan Atomic Industrial Forum Inc. (ed.), *Radioactive Waste Management: Technical Development and Plans in Japan*, July 1997, p.81.

R&D Issues for Radioactive Waste Processing and Disposal

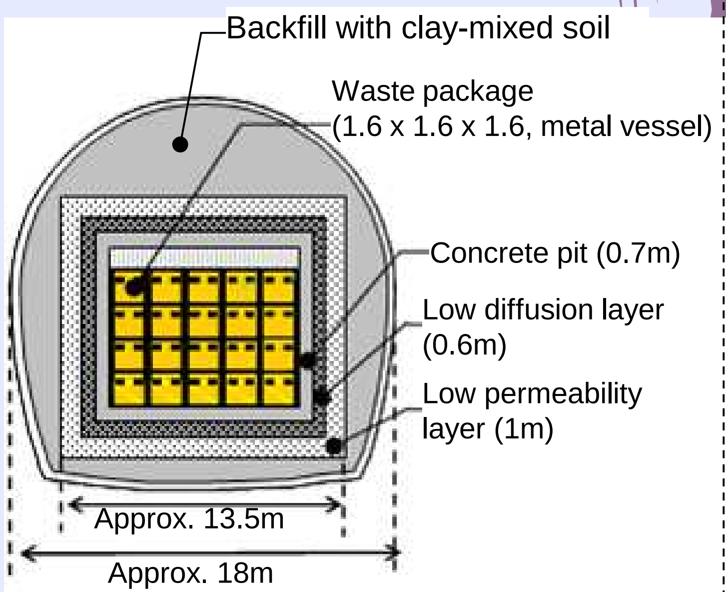
4. Disposal technologies

- 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.)

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

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