Mid- and long-term roadmap and action plan for decommissioning of the reactors #1 to 4 of the TEPCO Fukushima Dai-ichi Nuclear Plant3

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Outline of the presentation

1. Overview of Earthquake, Tsunami and Nuclear Accident and Lessons Learned

2. Current Status of Fukushima Daiichi NPS (1F)

3. Current Topics

4. Mid-and-long Term Roadmap for Decommissioning

5. Mid-to Long-term Process In Preparation for Fuel Debris Removal

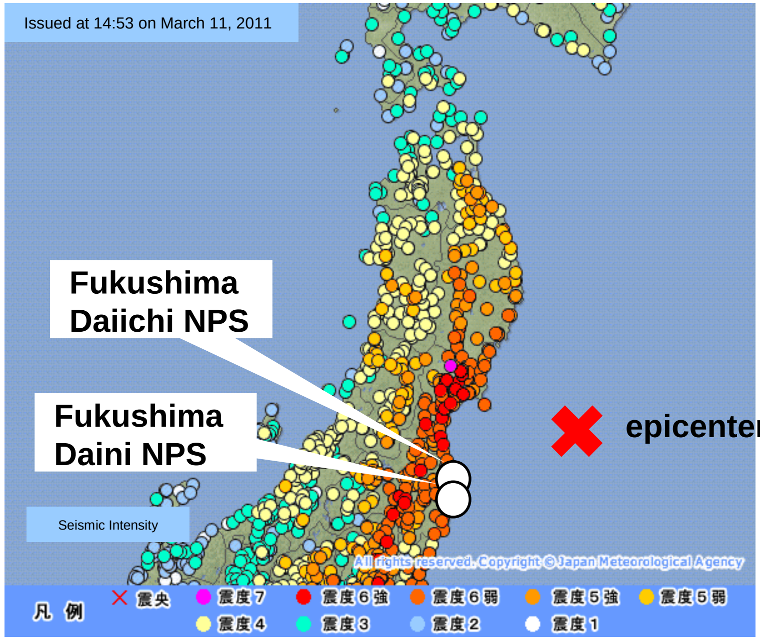
6. Remaining Challenges for Fuel Debris Retrieval

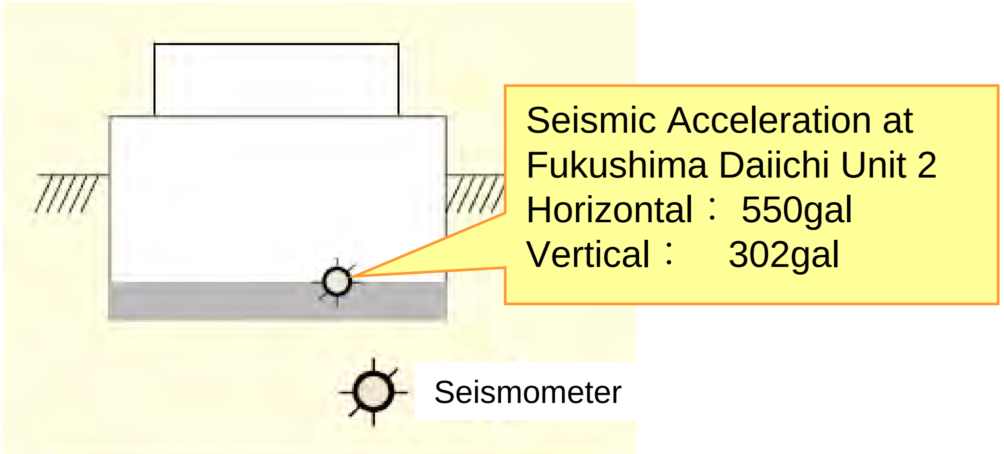
1. Overview of Earthquake, Tsunami and Nuclear Accident and Lessons Learned

Tohoku Pacific Ocean Earthquake

- **Time:** 2:46 pm on Fri, March 11, 2011.
- **Place:** Offshore Sanriku coast (northern latitude of 38.062 degrees, east longitude of 142.516 degrees), 24km in depth, Magnitude 9.0
- **Intensity:** **Level 7** at Kurihara in Miyagi prefecture
  - **Upper 6** at Naraha, Tomioka, Okuma, and Futaba in Fukushima pref.
  - **Lower 6** at Ishinomaki and Onagawa in Miyagi pref., Tokai in Ibaraki pref.
  - **Lower 5** at Kariwa in Niigata pref.
  - **Level 4** at Rokkasho, Higashidori, Mutsu and Ohma in Aomori pref., Kashiwazaki in Niigata pref.

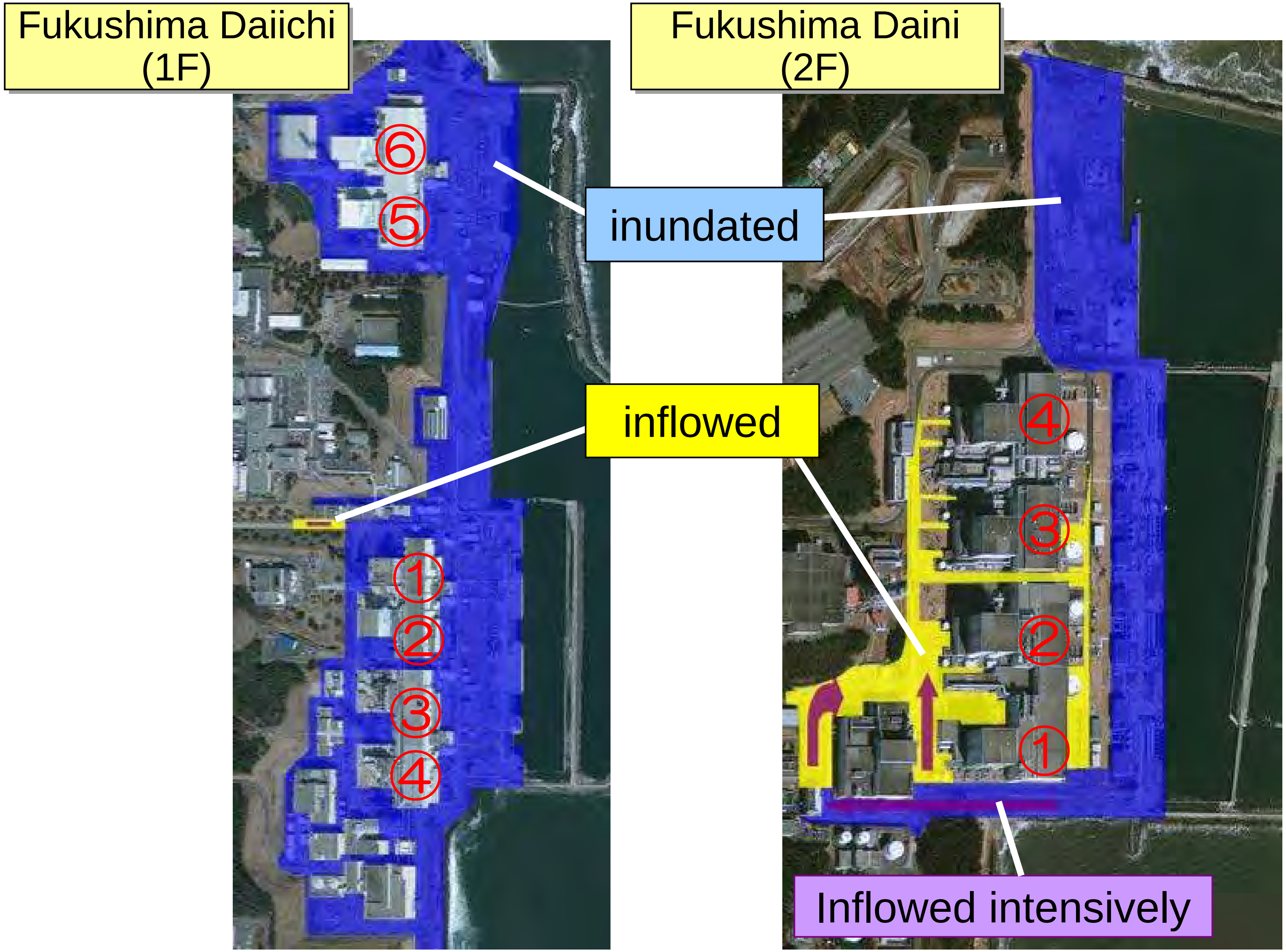
【Epicenter】





* gal: a unit of acceleration defined as cm/s².

Inundated and Inflowed Area at 1F and 2F



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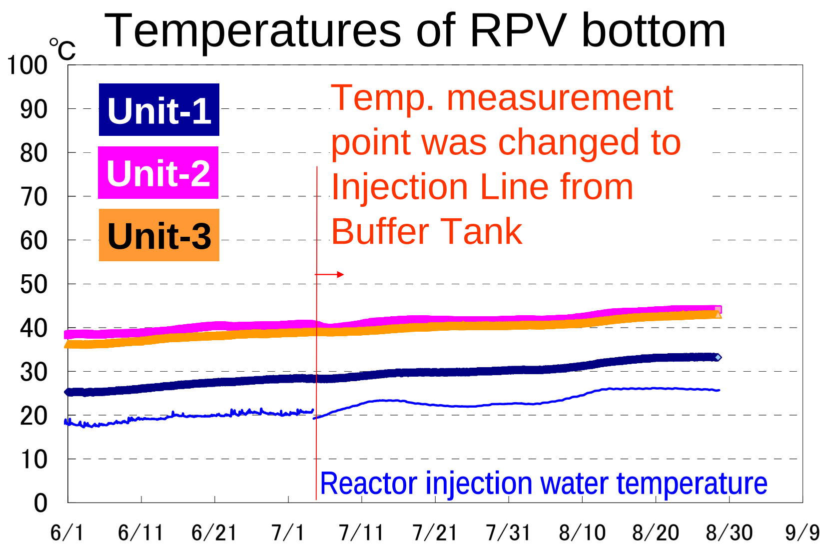
Summary of Lessons Learned

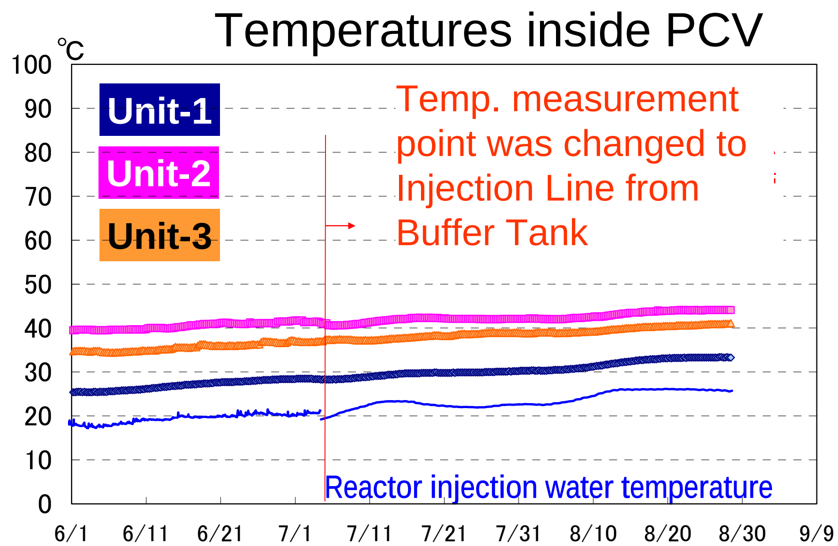
- The 1F accident was caused by the simultaneous loss of multiple safety functions due to far beyond design basis of tsunami. The main factors of the accident are **"the simultaneous loss of total AC power and DC power for a extended period of time"** and **"the loss of the heat removal function of the emergency seawater system for a extended period of time."**
- Preparations had been previously made to receive power from neighboring units in the event that AC power and DC power were not available. During the accident, direct tsunami damage was so widespread that the neighboring units were all in the same condition.

> "Carefully consider the robustness of current design of nuclear power plants and emergency preparedness against **beyond design basis events** that could lead to **common cause failures** regardless of their assumed probability demonstrating a continuous **learning organization**."

2. Current Status of 1F

Status of Core & Spent Fuel Pool Cooling

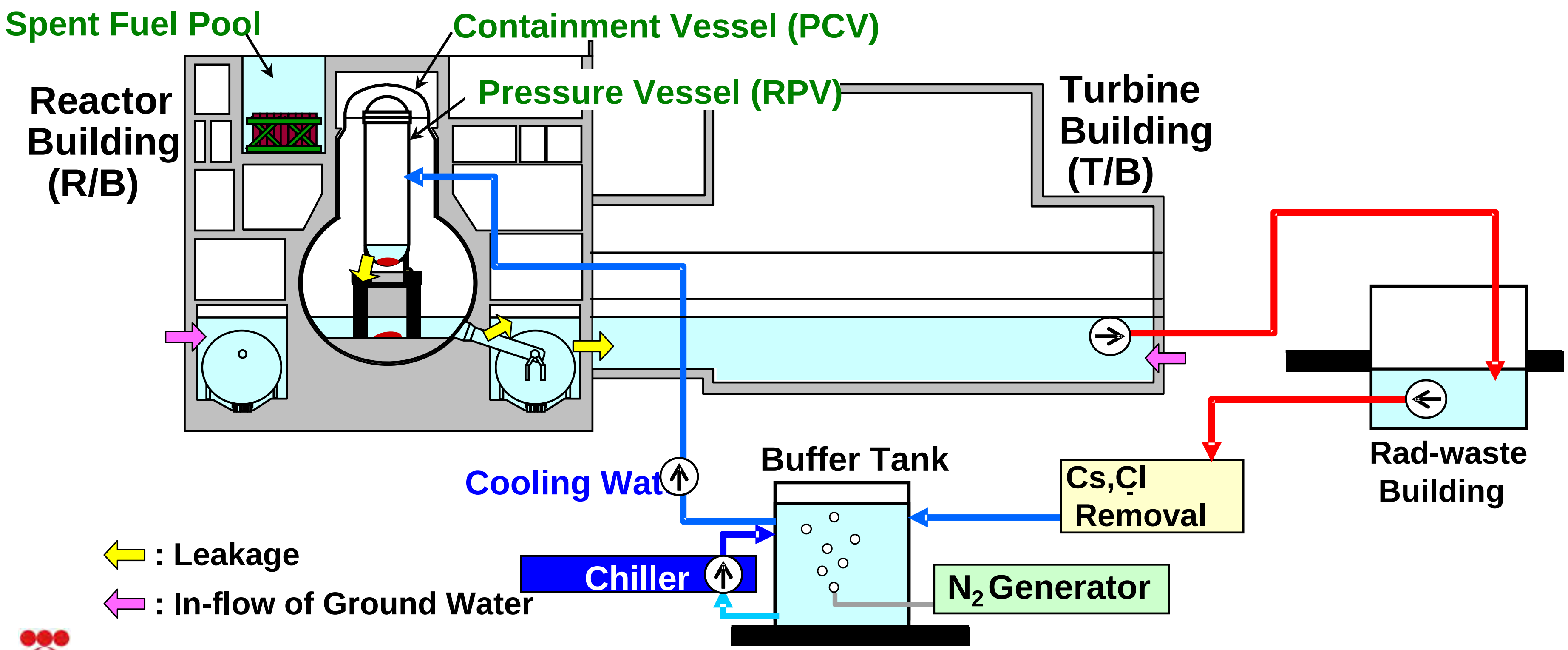




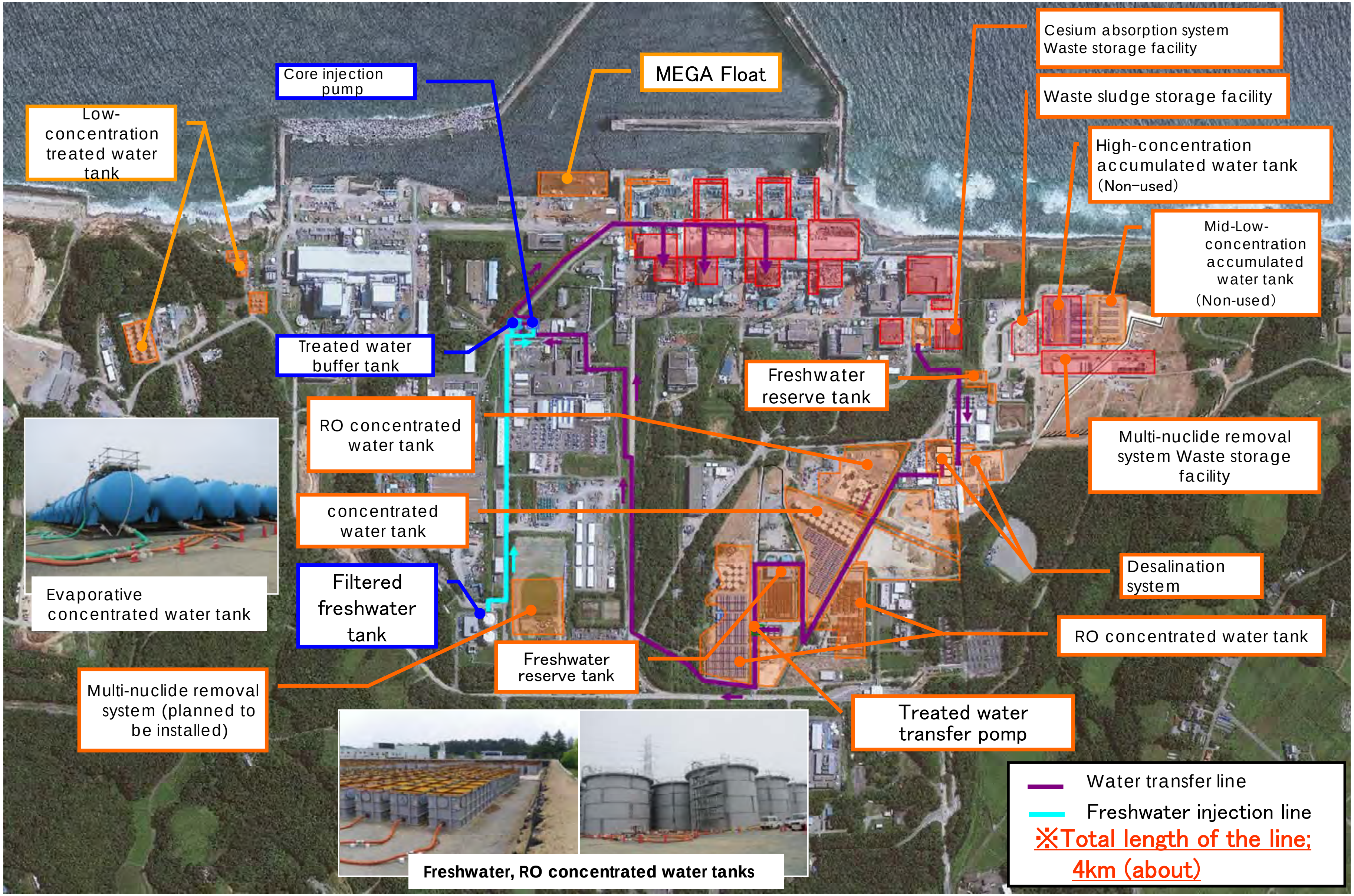
		Unit1	Unit 2	Unit 3	Unit 4	Unit 5/6
Shutdown		○	○	○	(Shutdown for Outages in 3/11)	
Cooling	Reactor	○ Cooled by Circulation Water System			—	○ Cold Shutdown
	Spent Fuel Pool	○ Cooled by air-cooled heat removal system				○
Containment		△ Contaminated water accumulated in building				○

Circulating Water Cooling of 1F Units 1~3

- Cooling water is leaking from RPV, PCV and R/B to T/B
  →Accumulated water in T/B is re-used as a coolant after cleaned with Cs & Cl^- removal system
- In-flow of ground water is increasing the amount of "contaminated water" to be processed by multiplex, diversity, independency systems.



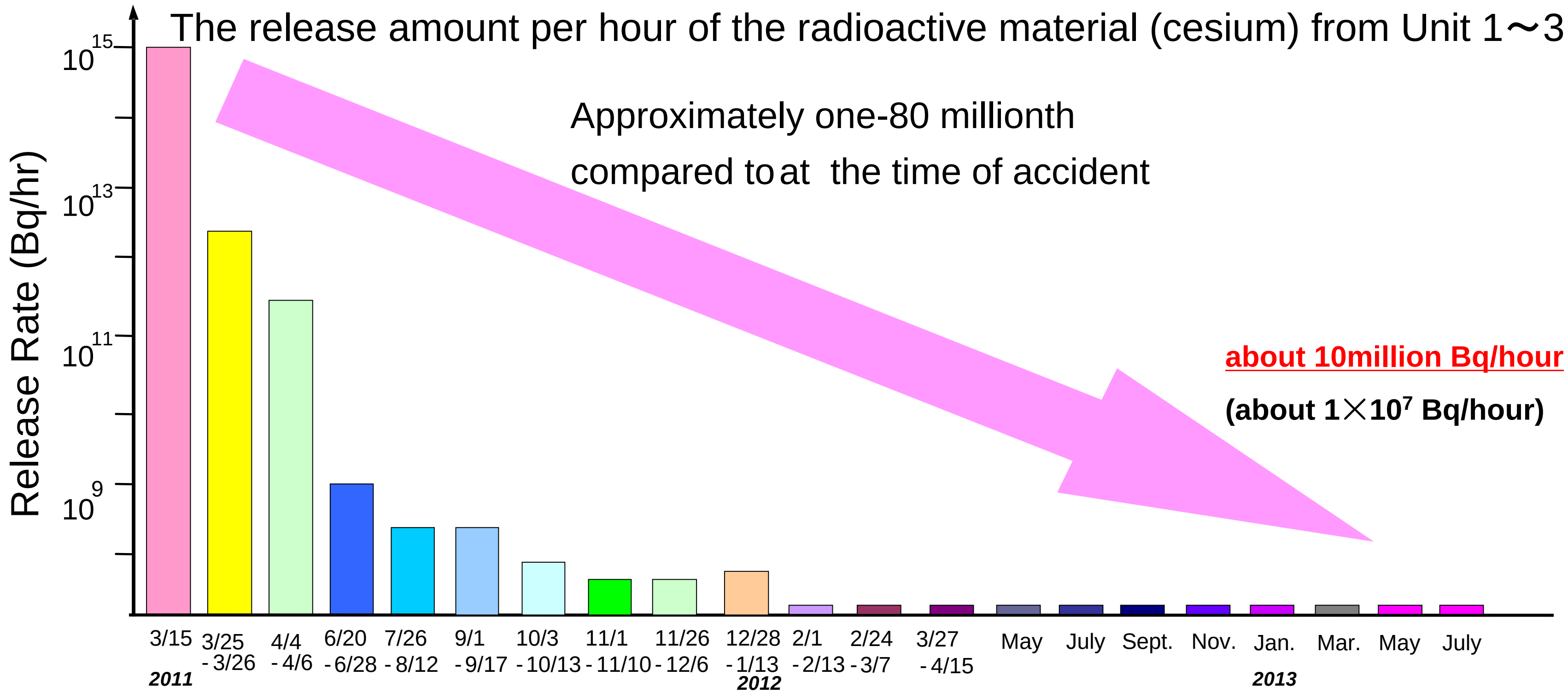
Status of Accumulated Water Storage Tanks



Controlling the Release of Radioactive Materials

- **The amount of radioactive materials (cesium) released from Unit 1-3 PCV is assessed based on airborne radioactive material concentrations (dust concentration) at the top of Reactor Buildings**
  - →**Calculated the assessed value of total release amount (as of May 2013) as about 10 million Bq/hr.**
  - →**About one-80 millionth compared to immediately after the accident.**
- **Accordingly, assessed the exposure dose at site boundary as 0.03mSv/yr. at maximum.**

(Excluding effect of already released radioactive materials) Note: Exposure limit established by law is 1mSv/yr.

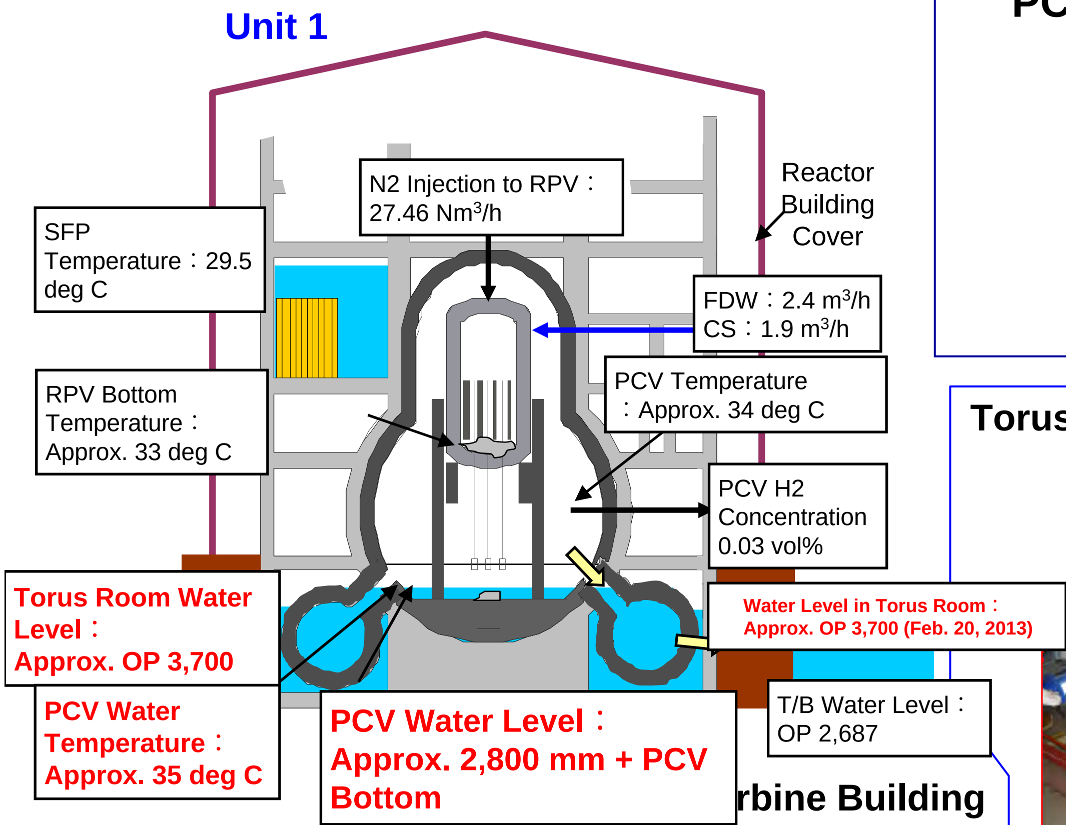


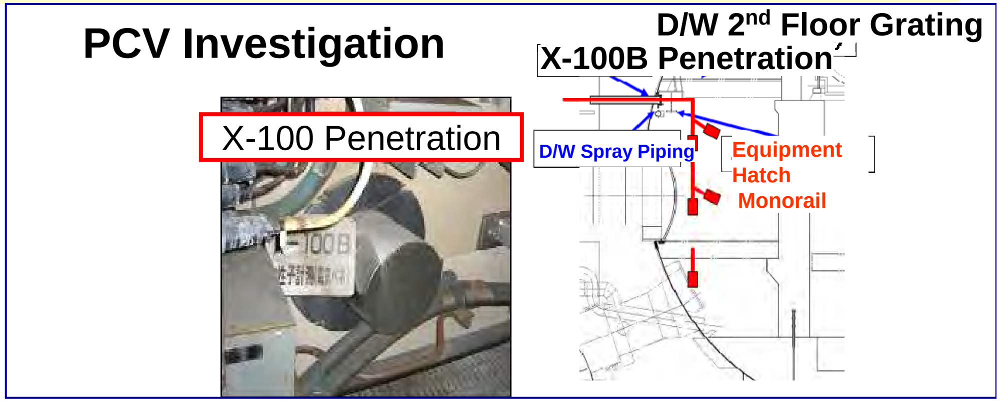
Radioactive particle (Cesium) release per hour from Units 1 to 3

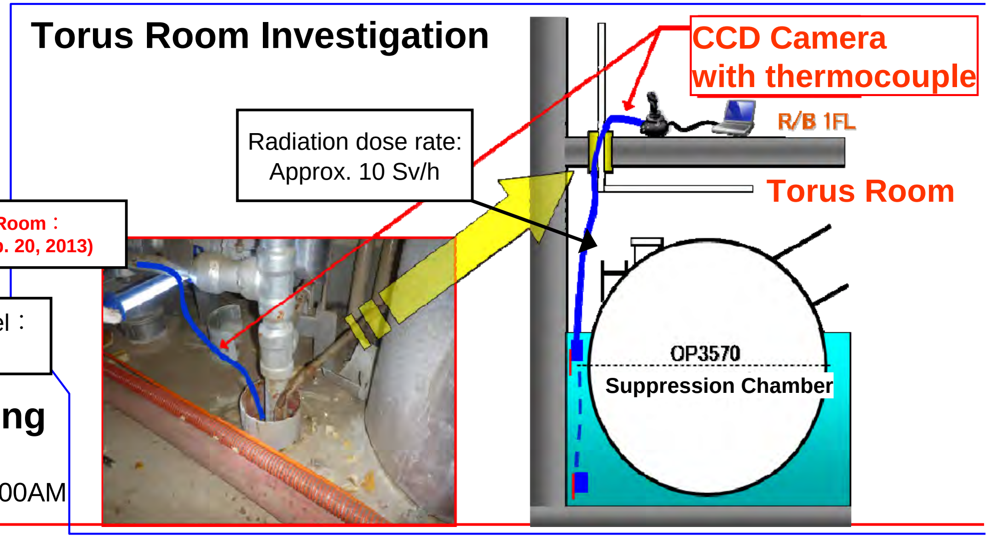
3. Current Topics

Current Status of Unit 1

- **PCV investigation with CCD camera** (2012/10)
  - ⇒**Water Level: Approx. 2,800 mm + PCV Bottom**
  - **Water Temperature：Approx. 35 deg C**
- **Torus Room Investigation with CCD camera.** (2012/6)
  - ⇒ **Torus Room Water Level: Approx. OP 4,000, Temperature: 32-37 deg.C**





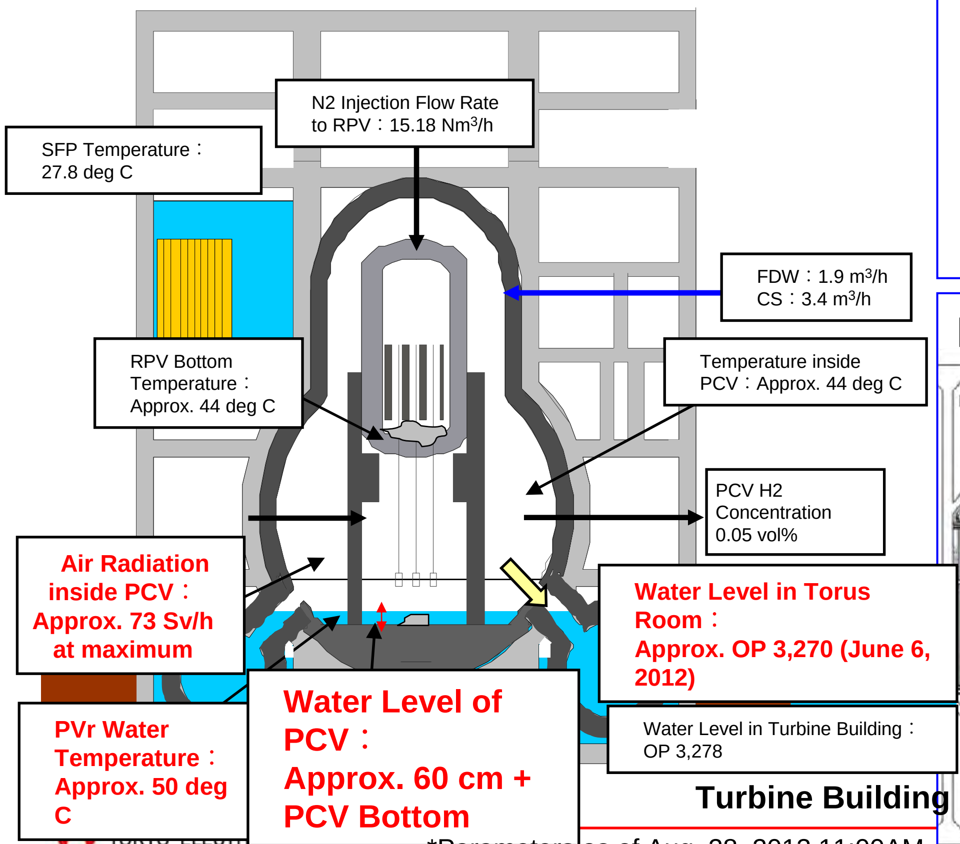


*Parameters as of Aug. 28, 2013 11:00AM

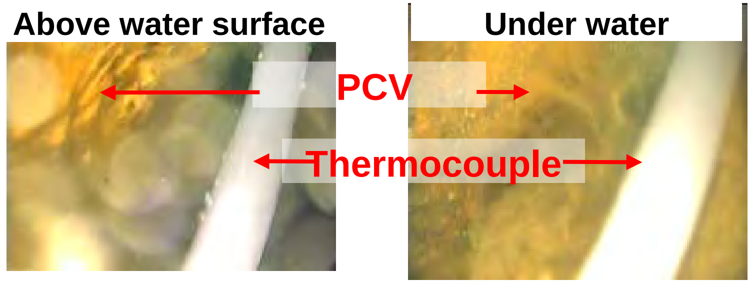
Current Status of Unit 2

- **PCV Investigation by Borescope** (2012/1, 3)
  - ⇒**Water Level: Approx. 600 mm + PCV Bottom,**
    Water Temperature：Approx. 50 deg C
- **Robot survey in the Torus Room** (2012/4)
- **Water level measurement in the Torus Room** (2012/6)
  - ⇒**Torus Room Water Level OP3270**

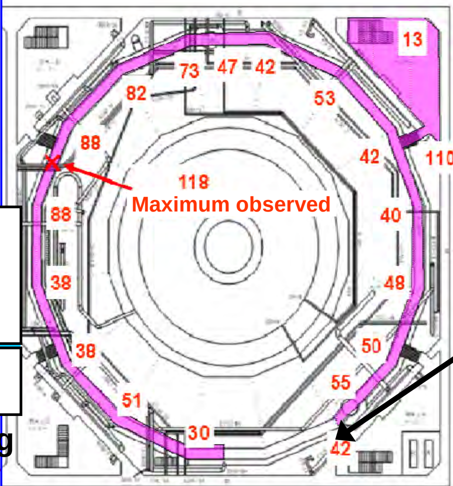
Unit 2



PCV Investigation



Robot survey in the Torus Room



Access Route

S/C Manhole (Southeast)

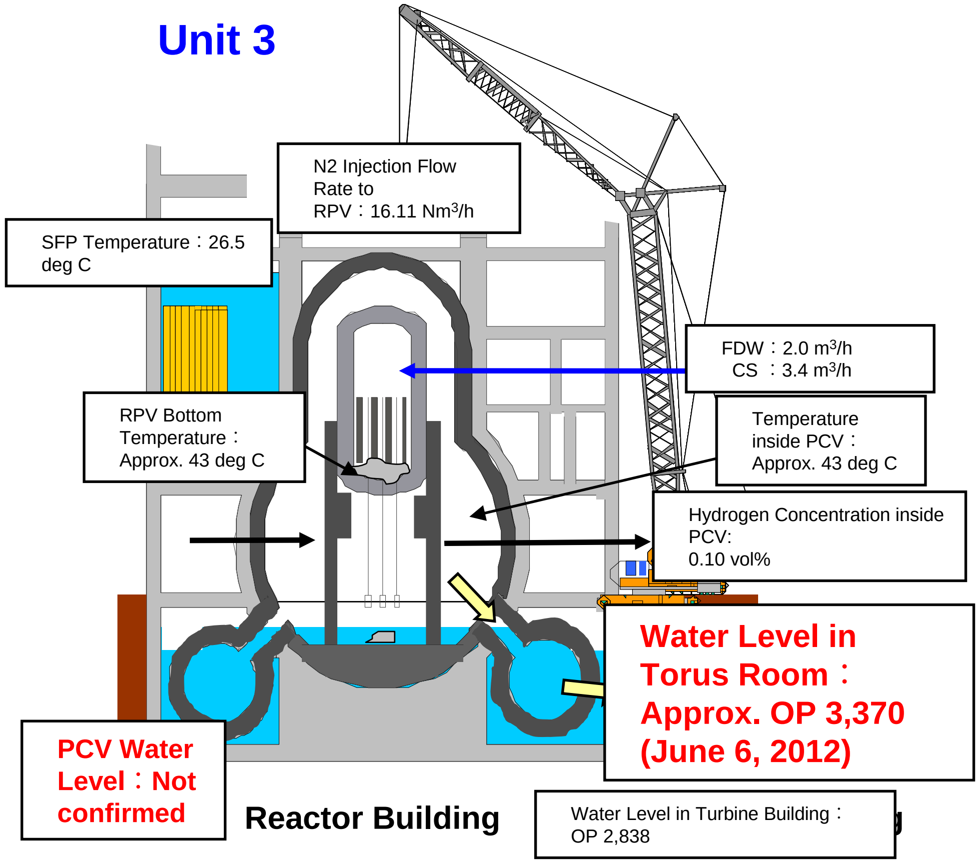
Red：Radiation (mSv/h)

*Parameters as of Aug. 28, 2013 11:00AM

Current Status of Unit 3

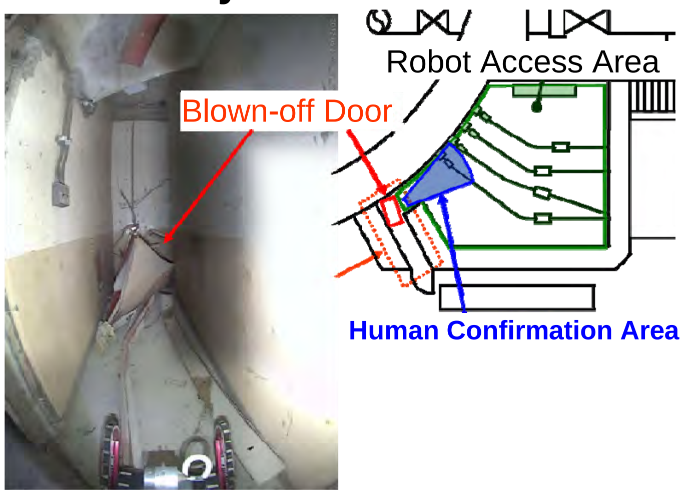
- **Robot survey in the TIP room in the Reactor Building** (2012/3)
- **Water level measurement in Torus Room**(2012/6, 7)

  ⇒ **Torus Room Water Level：Approx. OP 3,370**



*Parameters as of Aug. 28, 2013 11:00AM

Robot Survey in the TIP room



Water Level Survey in Torus


Northwest staircases area

	Water Level
Torus Room	OP 3370
Staircase area	OP 3150

Plan to remove spent fuels in Unit 4

- ✓The cover for fuel removal will be installed in order to improve work environment and to prevent radioactive materials from scattering and releasing during the work.
- ✓Start of fuel removal at Unit 4 is planned at the end of 2013.

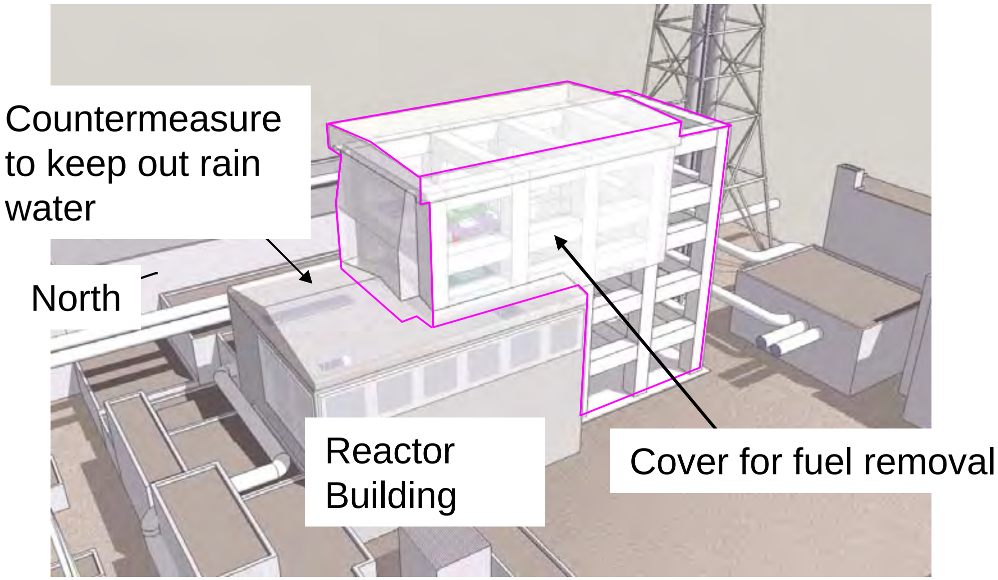


Image of the cover for fuel removal in Unit 4
(This picture shows only a image of the general plan.)

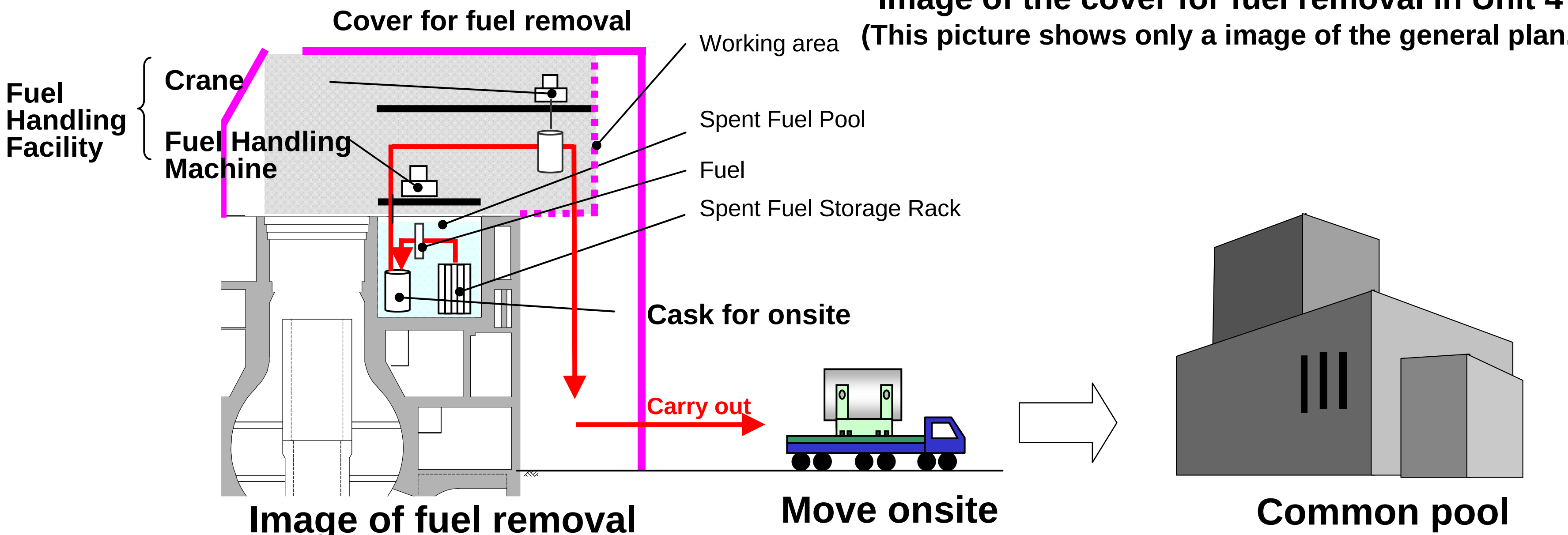
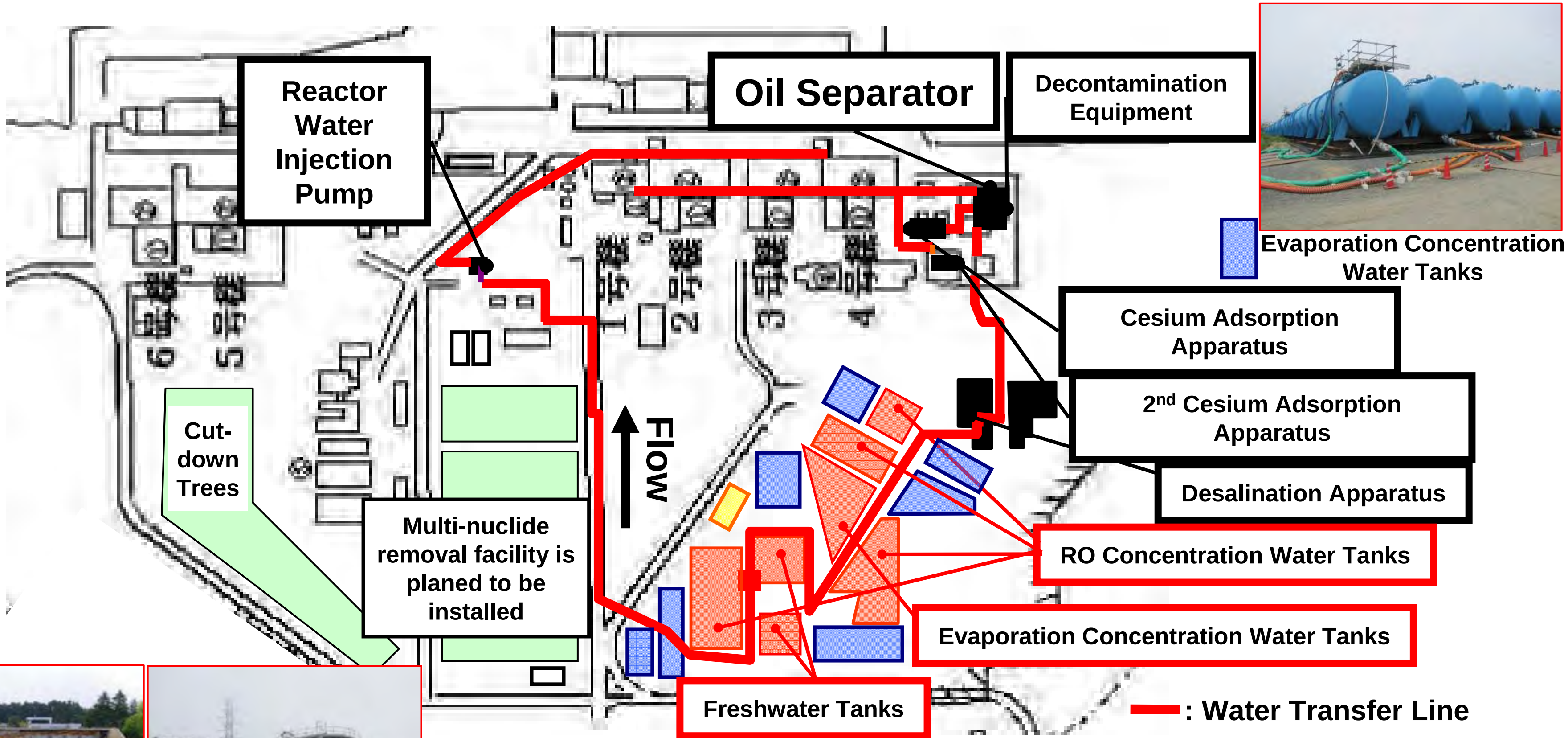


Image of fuel removal

Accumulation of Contaminated Water

✓The capacity of existing tanks is approx. 400ktons (as of Apr.2013).
✓Additional installation of tanks are planned to increase the capacity to Max. 700 ktons.



Arrangement of Water Processing Facility in Units 1 ~ 4

: Water Transfer Line
: Existing Tank Area
: Additional Tank Area
: Underground Cistern


Fresh Water, RO Concentration Tanks

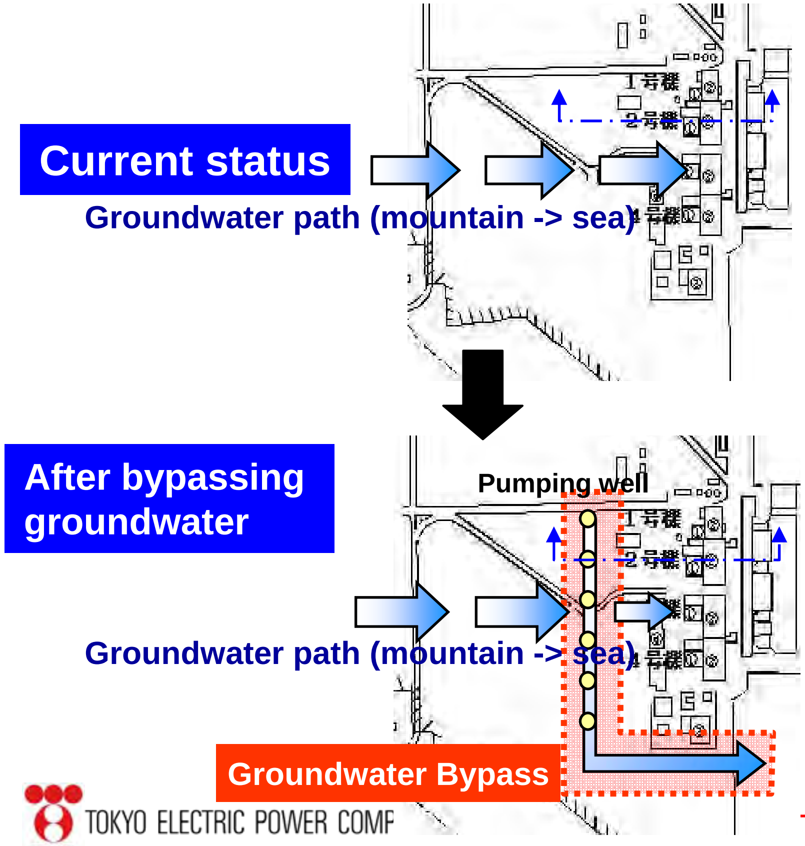
Groundwater Bypass

Groundwater bypass : Suppressing groundwater inflow to the buildings by changing the water path via pumping up the water flowed from the mountain side.

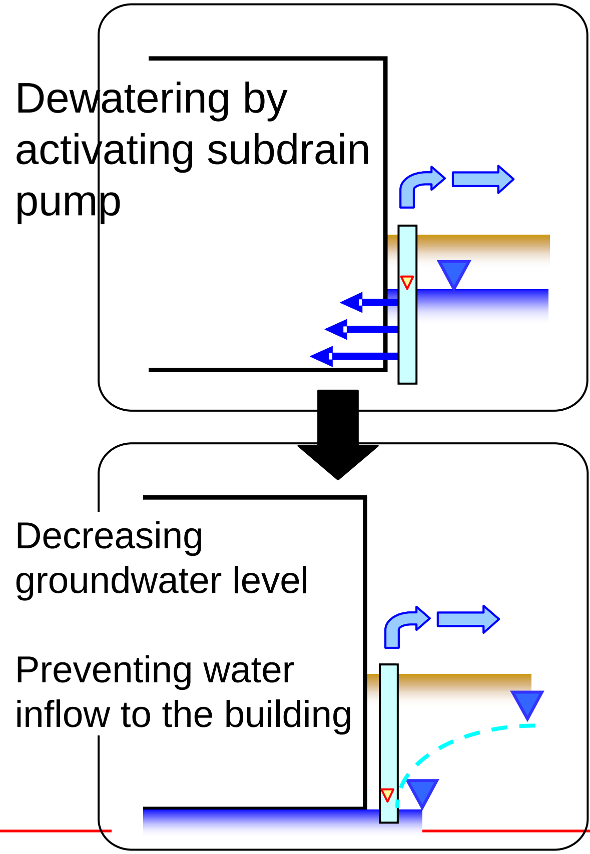
Pumping up groundwater (subdrain*) : Suppressing groundwater inflow to the buildings by decreasing groundwater level via pumping up the subdrain water.

*In order to balance groundwater level, groundwater in subdrain pits is periodically pumped up.

Groundwater bypass

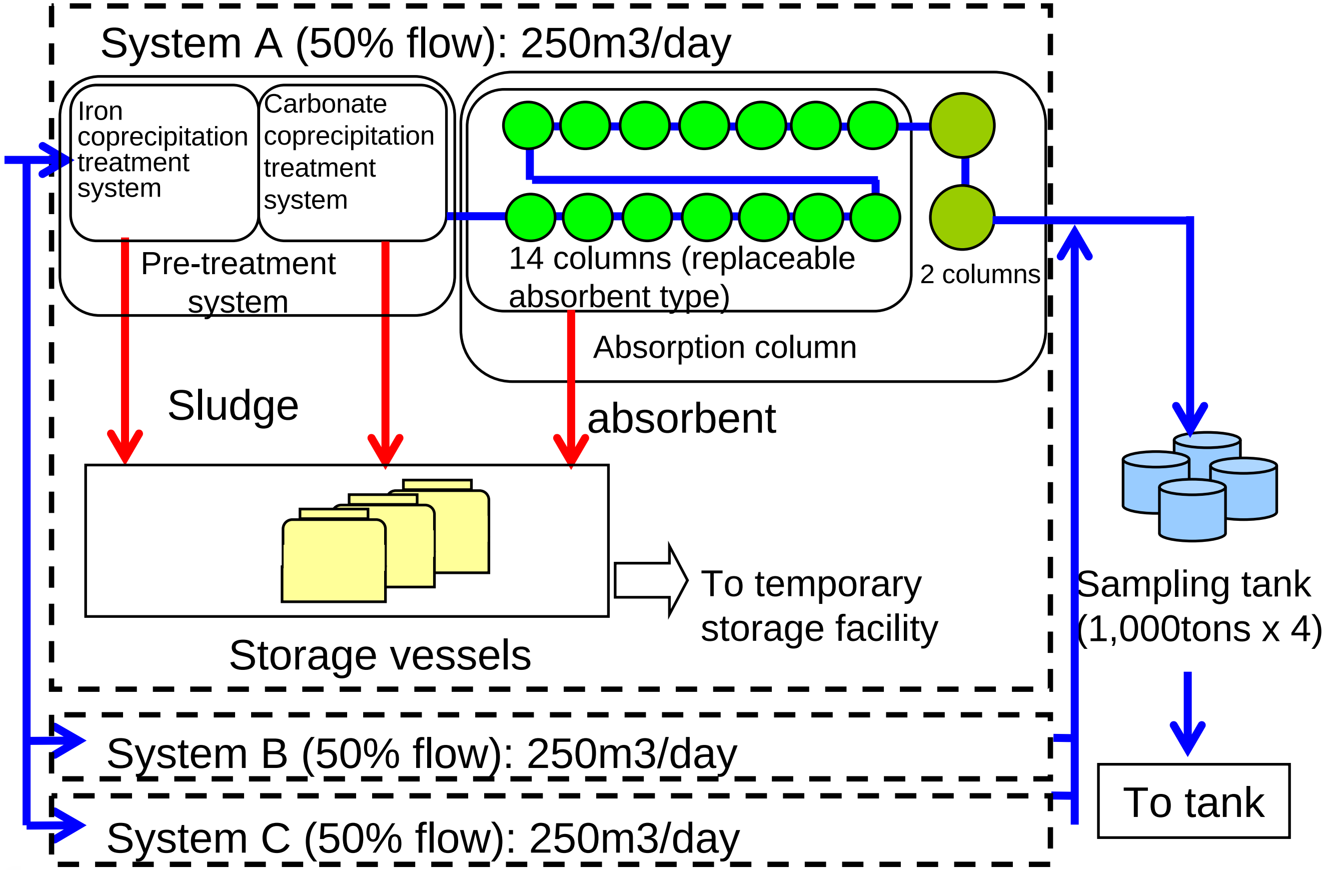


Pumping up groundwater (subdrain)

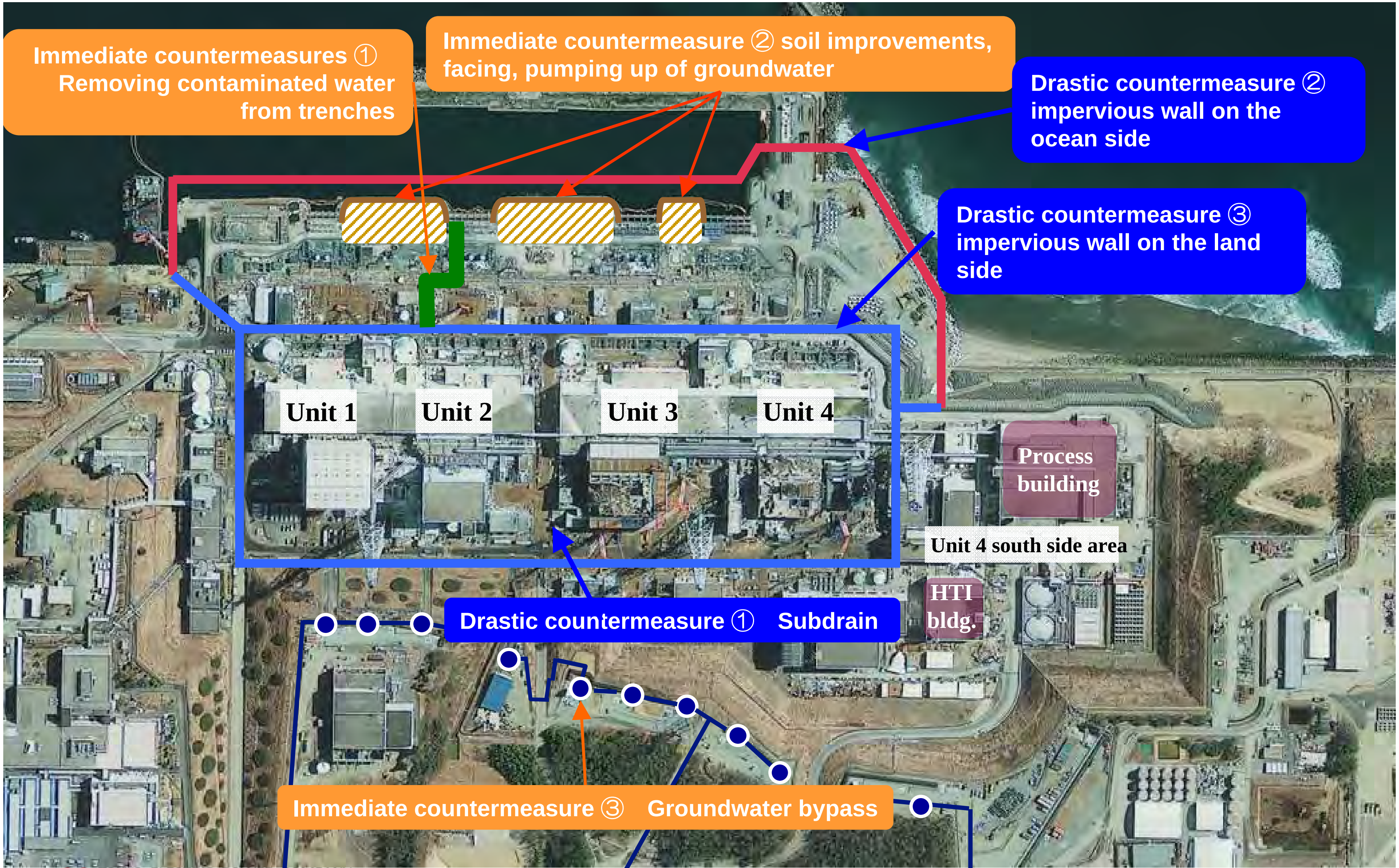


Multi-Nuclides Removal Equipment

Treatment Water by
① Desalination sys
② Cs absorption sys



Overall contaminated water countermeasure plan



4. Mid-and-long Term Roadmap for Decommissioning

Mid-and-long Term Roadmap

■ Primary Target

Present all possible schedules pertaining to the main on-site works and R&D.

■ Target Timeline and Holding Points

Regarding the schedules, established holding points, which are significant to judge whether to go ahead in accordance with the schedule, to implement additional R&D, or to re-schedule the process.

Step 1, 2	Phase 1	Phase 2	Phase 3
	Present	At the end of 2013	2020 / After 30-40 Years
Achieved Stable Conditions	**Period to the start of fuel removal from the spent fuel pool**	**Period to the start of fuel debris removal**	**Period to the end of decommissioning**
- Quasi-Cold shutdown -Sufficient Suppression of Emissions	- Commence the removal of fuels from the spent fuel pools - Reduce the radiation impact due to additional emissions from the whole site and radioactive waste generated after the accident (secondary waste materials via water processing and debris etc.) Thus maintain the effective radiation dose to be less than 1 mSv / year at the site boundaries caused by the aforementioned. - Maintain stable reactor cooling and accumulated water processing and improve their credibility. - Commence R&D and decontamination towards the 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 the insides of buildings, restoring PCVs and filling PCVs with water. Then commence the removal of fuel debris (Target: within 7 years) - Continue stable reactor cooling - Complete the processing of accumulated water - Continue R&D on radioactive waste processing and disposal, and commence R&D on the reactor facilities decommission	- Complete the fuel debris removal (in 20-25 years) - Complete the 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.

Fuel Debris Removal

- **Plan to start fuel debris removal in the first unit within 10 years after completion of Step 2.**
- **Removal of fuel debris will be implemented in accordance with the following steps in light of the site situation, safety requirements, and R&D progress of the remote control technologies required in the operations.**

(1) Reactor Building Decontamination

(2) PCV Leakage Point Inspections

(3) Stopping Inter-building Water Leakage PCV Lower Parts Repair

(4) Filling the Lower Part with Water

(5) Internal PCV Inspection and Sampling

(6) PCV Upper Parts Repair

(7) Filling PCV and RPV with Water⇒ Open the upper cover on RPV

(8) Internal RPV Inspection and Sampling

(9) Fuel Debris Removal

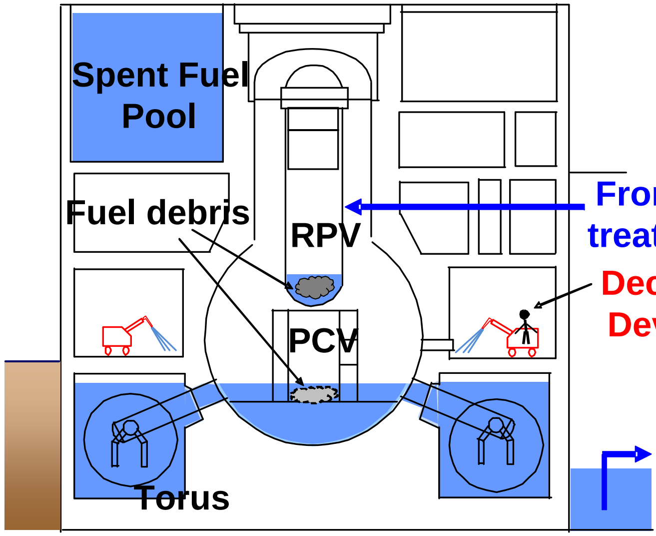
Major Challenges in Decommissioning procedures

- Final goal is to defuel from the Reactor Building (R/B) and to clean up Fukushima Daiichi site.
- Defueling procedure would be much more complicated than TMI-2 case due to differences like:

	TMI-2	Fukushima Daiichi
R/B Damage	Limited	Damaged by H_2 explosion (Units 1,3,4)
Water Boundary	RV remained intact	Both RPV/PCV have leakage (Units 1~3)
Fuel Debris Location	Remained in RV	Fallen out from RPV
Bottom of the Vessel	Simple bottom head structure	Complicated structure with Control Rod Drives

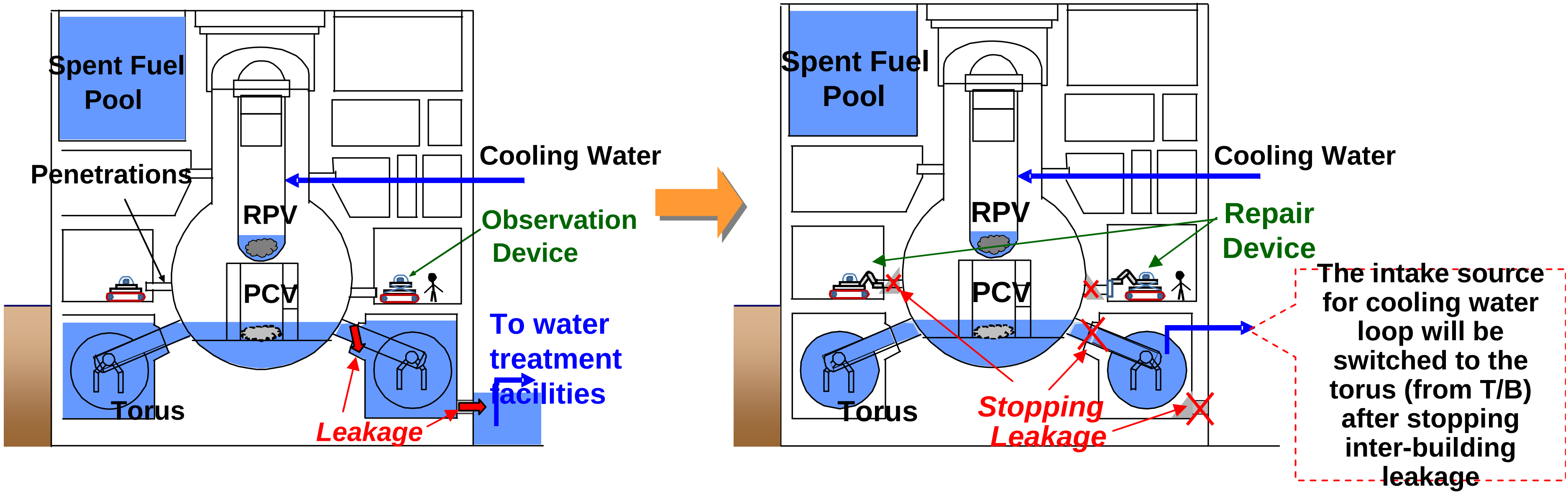
- TMI-2 Experience can be utilized more efficiently for post-defueling procedures in decommissioning.

Step 1: Reactor Building Decontamination



- **Decontamination of the area is essential to following procedures.**
  - Feasibility of high-pressure washing, coating, scraping and etc. are investigated in the National R&D program.
  - Combined usage of shielding maybe necessary
- **Major Challenges and Difficulties:**
  - High dosage (~ 5 Sv/h).
  - Obstacles like rubble scattered in R/B.
  - Smaller space due to the compact design of BWR4

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

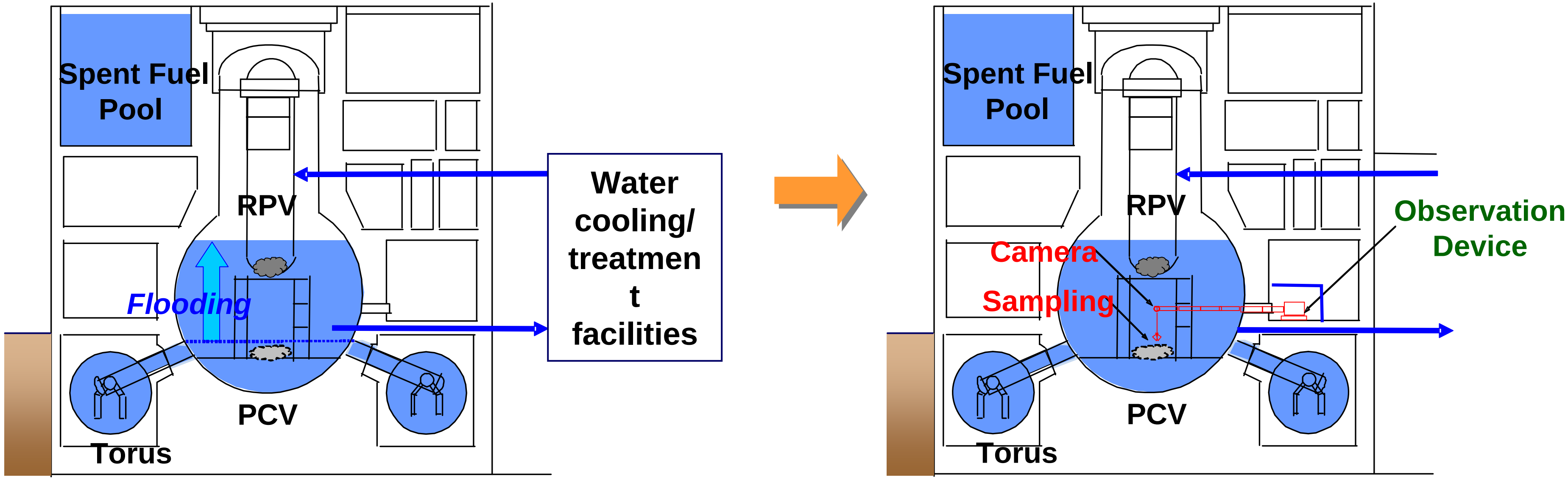


- Leaking Locations will be investigated from Outside of PCV and will be repaired

- Major Challenges and Difficulties:

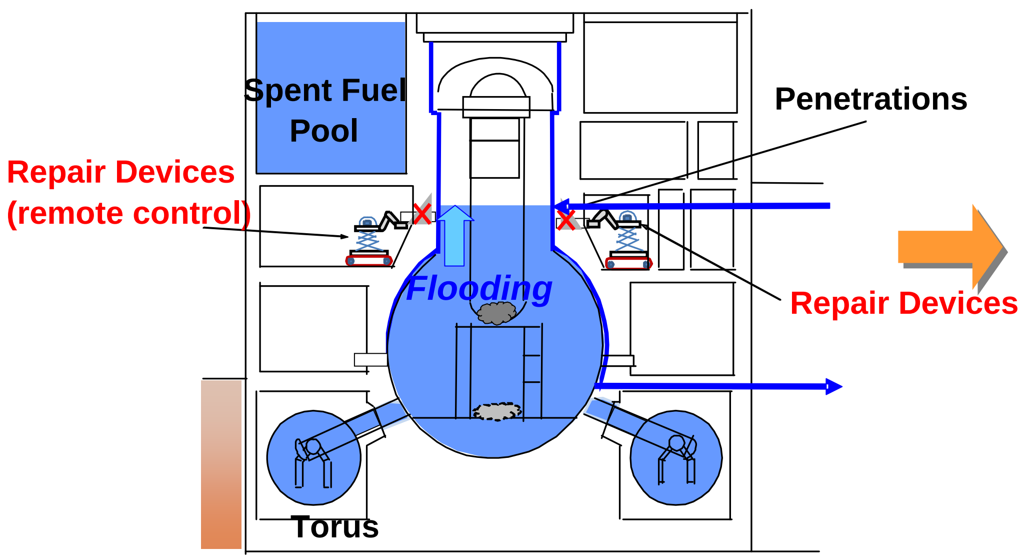
- High dose rate and humidity of PCV inside.
- Major part of "suspicious locations" are underwater with poor visibility.
- Repair work has to be conducted while highly radioactive cooling water is running for continuous fuel cooling

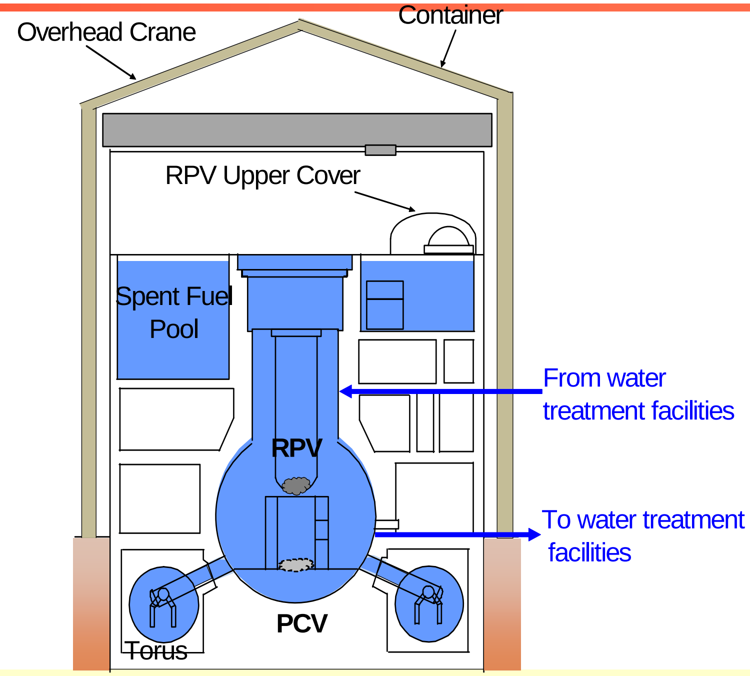
Steps 4, 5: Flooding of the Lower PCV, PCV Inspection & Sampling



- **Filling the lower PCV with water (Flooding)**
- **Distribution and Characteristic of 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



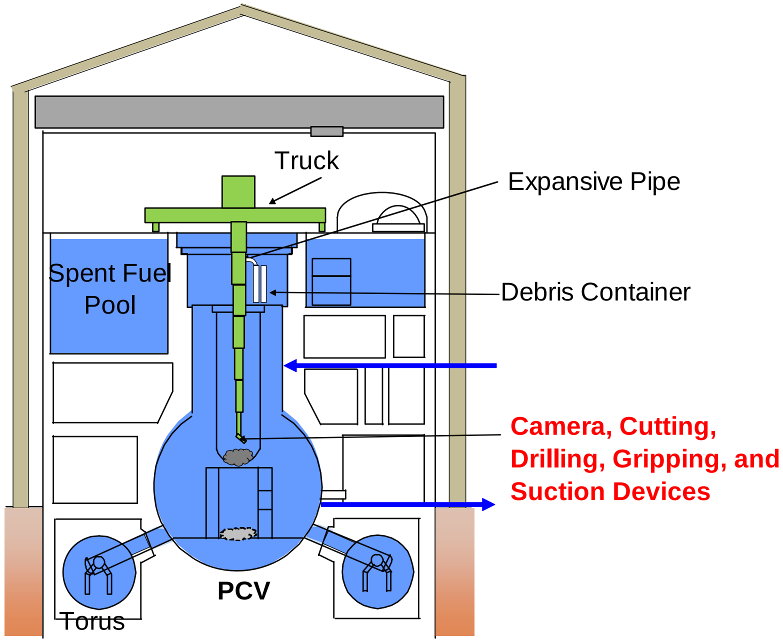


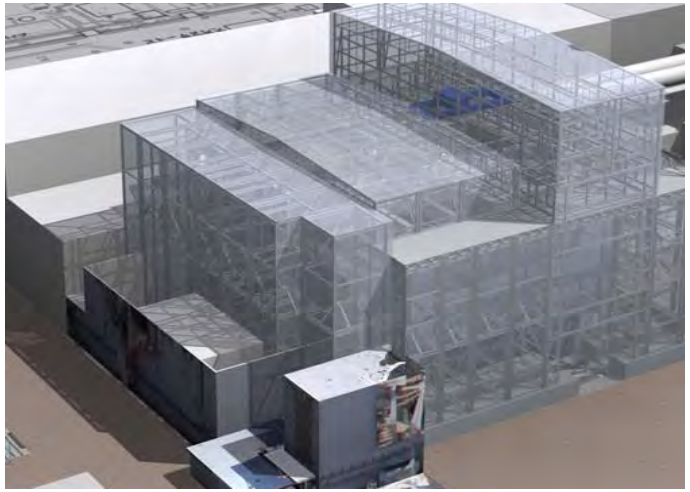
(1) Filling entire PCV/RPV with water after repairing upper PCV
(2) R/B container and overhead crane will be installed for defueling.
(3) RPV/PCV top heads will be removed after sufficient water is attained

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

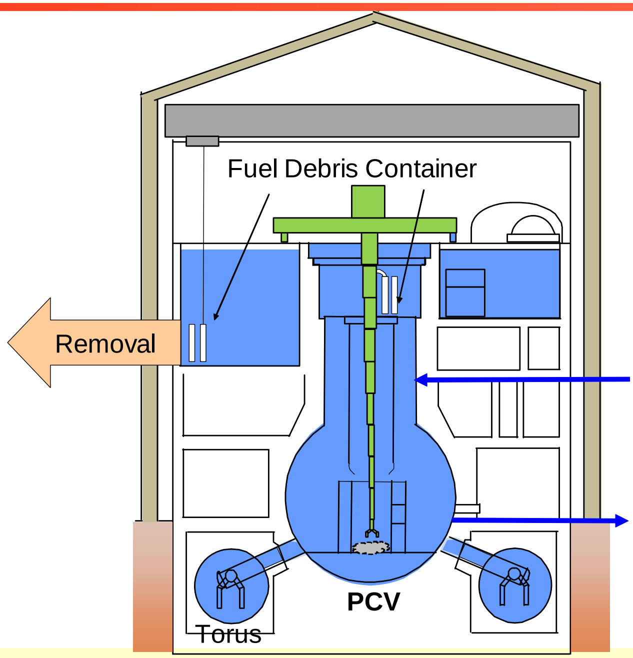
Step 8: Internal RPV Inspection& Sampling





- **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 device
  - 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 has much more complicated one than PWR)
  - Debris may have fallen even out of RPV (Debris remained in RV in TMI-2)
  - Diverseness of Neutronic-, Mechanical- and Chemical- property of debris as mixture with different types of metal and concrete
  - Subcritical assessment
  - Store the removed debris

R&D Programs for Decommissioning

Black: On going
Blue: Planned

1. Removal of spent fuel from Spent Fuel Pool

- **1.1 Long-term Integrity of Spent Fuel Assemblies (FY2011–2015)**
- 1.2 Damaged spent Fuel Processing (FY2013–2017)

2. Preparation for removal of fuel debris

- **2.1 Fuel debris removal using remote control equipment and devices**
  - **2.1.1 Remote Decontamination of the Reactor Building Interior (FY2011–2013)**
  - **2.1.2 Identifying Leak Areas in the PCV (FY2011–2014)**
  - **2.1.3 PCV Repair Technologies (FY2011–2017)**
  - **2.1.4 Investigation of the PCV Interior (FY2011–2016)**
  - 2.1.5 Investigation of the RPV Interior (FY2013–2019)
  - 2.1.6 Removal of Fuel Debris and Internal Structures in the Reactor (FY2015–2021)
  - 2.1.7 Containment, Transport and Storage of Reactor Fuel Debris (FY2013–2019)
  - **2.1.8 Assessment of RPV/PCV Integrity (FY2011–2016)**
  - **2.1.9 Controlling Fuel Debris Criticality (FY2012–2018)**
- **2.2 Ascertaining and analyzing reactor core status**
  - **2.2.1 Analysis of Accident Progression to estimate reactor status (FY2011– 2020)**
- **2.3 Ascertaining the characteristics of and preparing to process fuel debris**
  - **2.3.1 Study of Characteristics using Simulated Fuel Debris (FY2011–2015)**
  - 2.3.2 Analysis of Properties of Actual Fuel Debris (FY2015–2020)
  - **2.3.3 Development of Technologies for Processing of Fuel Debris (FY2011–2020)**
  - **2.3.4 Establishment of a new accountancy method for Fuel Debris (FY2011–2020)**

3. Processing and disposal of radioactive waste

- **3.1 Processing of Secondary Waste from the Contaminated Water Treatment (FY2011~)**
- **3.2 Processing and Disposal of Radioactive Waste (FY2011~)**

5. Mid-to Long-term Process In Preparation For Fuel Debris Removal

Technical Challenges for Fuel Debris Removal

Decontamination of Reactor Buildings

- Various targets of decontamination; floor, wall, ceiling….
- Not only structural objects, but puddles and atmospherics should be decontaminated.
- Technologies for coating or shielding the radiation sources will also required.

Inspection of Inner PCV & Leaking Points

- Most inspection (photographing, dose measurement, acoustic diagnostics) will be done in the contaminated water or in little/crowded space.
- Various situation such as high temp, high humidity, under water….
- All measurement instruments must have high tolerability to radiation and long distance control system

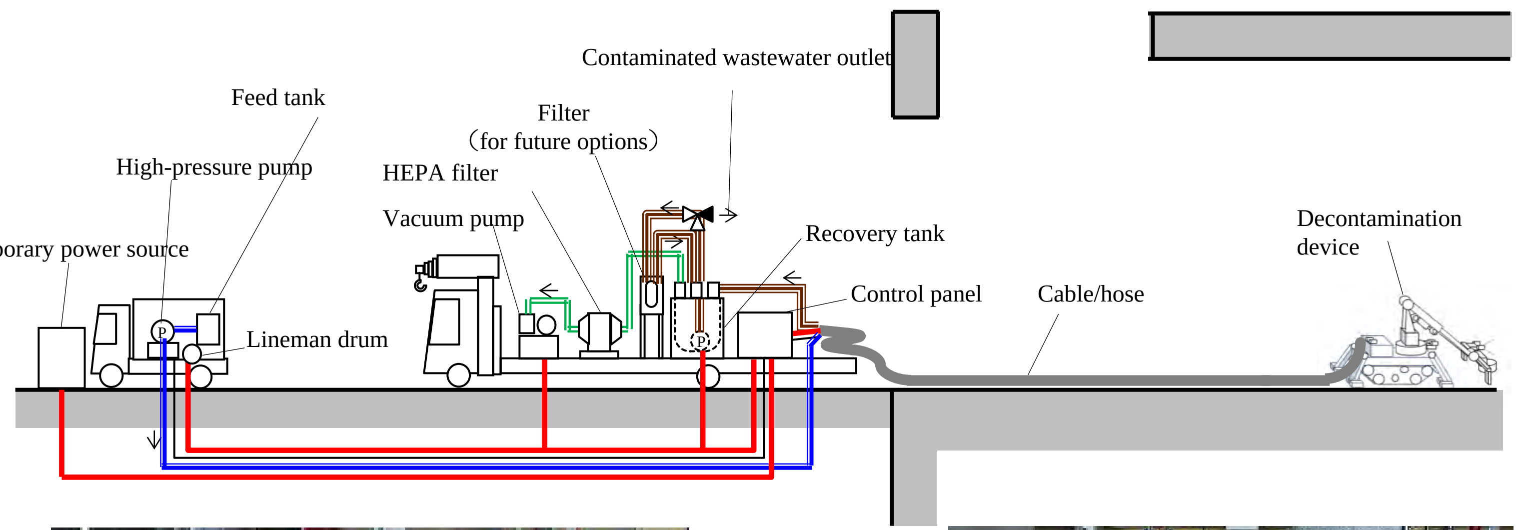
Repair Works for PCV & Leaking Points

- Leakage mending methods under the highly contaminated water
- Water injection to a reactor cannot be stopped during the PCV/leakage repair.

Building internal decontamination (High water pressure Decontamination device

Mechanical decontamination of surfaces by spraying high-pressure water on objects of decontamination.

Concrete services can be ground down by increasing the pressure.



With arm extended

In motion

Building internal decontamination
(Unit 1～3 reactor building contamination survey results)

Dose level/radiation source surveys of the Units 1 through 3 reactor buildings, and analysis of contamination samples have been conducted in order to formulate a decontamination plan

	Plant	Floor (reactor building)	Remote survey using robot			Survey by workers: Contamination status survey				
			Dose rate survey	Radiation source survey	Surface conditions survey	Floating surface contamination survey Deposited surface contamination survey			rmeated contamination survey	
						Floor	Walls	Equipment	Floor	Walls
Survey scope	Unit 1	1F	●	●	●	●	●	●	●	●
		2F				●				
		3F				●				
	Unit 2	1F	●	●	●	●			●	
		2F				●				
		3F				●				
	Unit 3	1F	●	●	●	●			●	
Survey objectives			Confirmation of dose rate distribution inside building	Confirmation of relative dose rate distribution	Confirmation of surface conditions of floor, walls, and equipment services	Contamination distribution confirmation			Contamination distribution confirmation	
Survey details			Measurement of dose rate at heights of 0.05 m and 1.5 m above floor in approximately a 3m mesh	Measurement of dose rate distribution using a gamma camera	Videography of floor surfaces, wall services, and equipment services using a camera	Collection of surface sediments with brush, etc., and adhered sediments with paint stripper, for analysis			Concrete core sampling and analysis	

Does/radiation source survey results

●Dose rate survey results
Unit 1 : 3.2～8.9mSv/h
Unit 2 : 6.8～30.3mSv/h
Unit 3 : 15.8～124.7mSv/h

●Radiation source survey results
the primary hotspots are containment vessel penetration seals, water pressure control units (HCU) and the Unit 3 equipment hatch railing

Radiation source survey(γ camera) results example
(Unit 3 South side HCU)

Building internal decontamination (Unit 1, 3)

Background

- There is a plan to begin Fukushima Daiichi Unit 1 and Unit 3 field debris removal preparations inside the reactor building, such as conducting a containment vessel leak survey, etc., in September 2013

- Dose rate surveys have shown that the radiation environment inside reactor buildings is from 200~4700Sv/h on the south side of Unit 1 and an average of 50mSv/h at Unit 3. it is necessary to bring these levels down to 5mSv/h in accordance with building internal work procedure objectives.

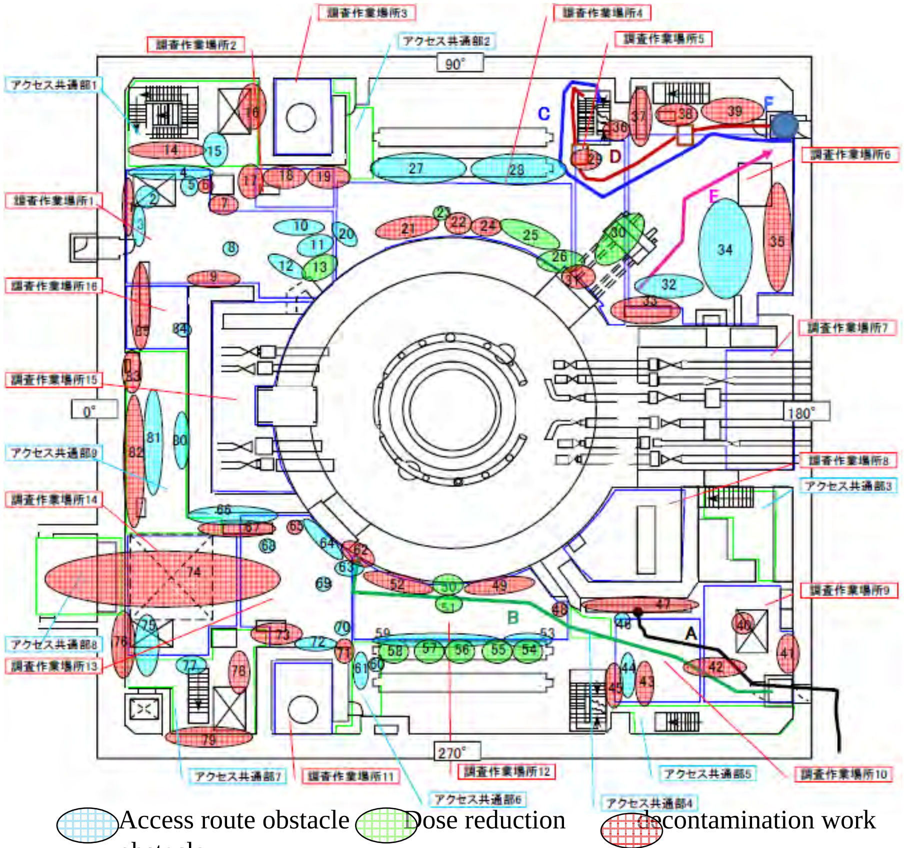
- As a result of the hydrogen explosions that occurred the inside of the Fukushima Daiichi Unit 1 and Unit 3 reactor buildings is littered with debris, such as concrete fragments and ducts, etc. this debris must be removed before decontamination devices can be brought in. At Unit 1 it is necessary to move the temporary shielding you need the equipment hatch.

Objective

Before decontamination work can commence, obstacles, such as debris, must be removed by unmanned equipment in order to reduce dose rates and secure access routes for decontamination devices and internal surveys of the PCV.

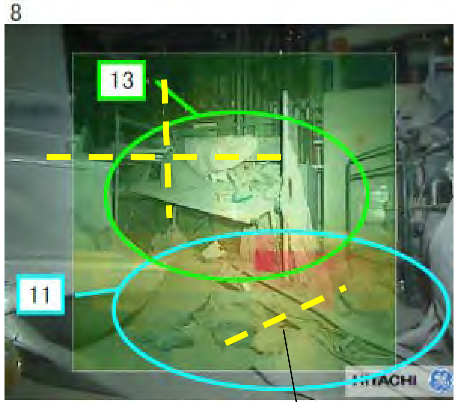
Building internal decontamination (Unit 3 example)

【Target Area】



Unit 3 1FL optical distribution

【Examples of debris and removal concept】



Material

N2 hose and HCU fence

Fallen duct

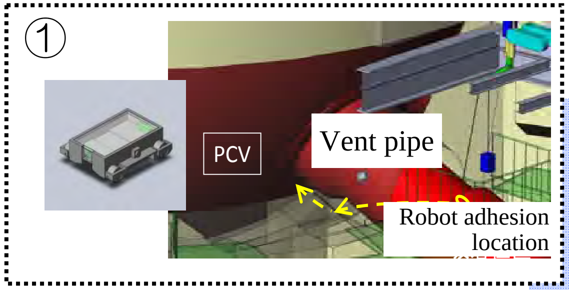
Hoses and cables need to be organized

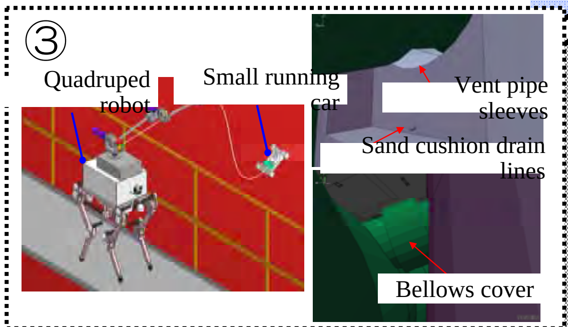
Large objects and objects attached to supports need to be cut free

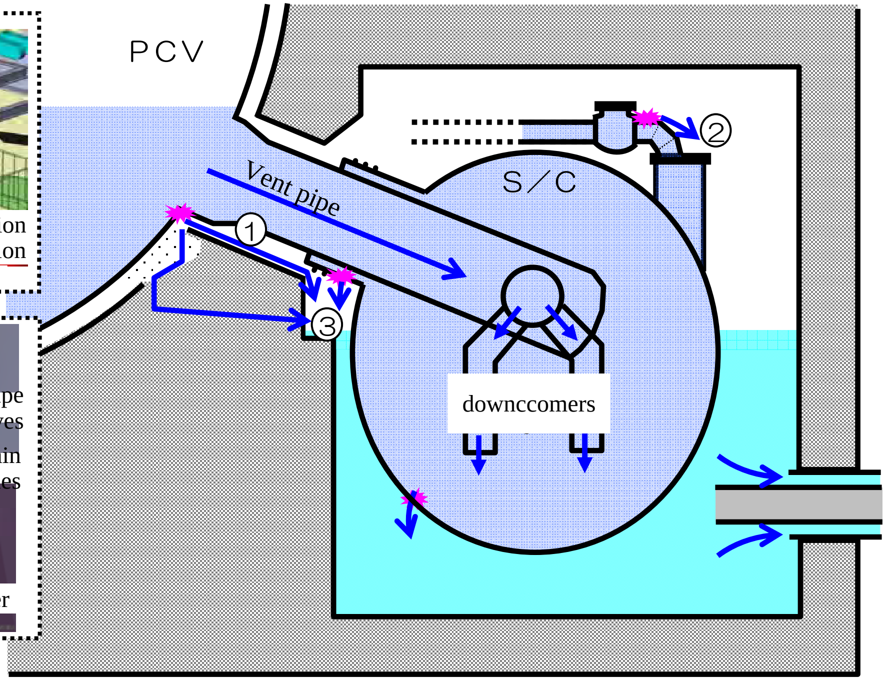
※The achievements of the government project entitled “Creating General Dose Reduction Plans” have been leveraged to formulate the scope of debris removal

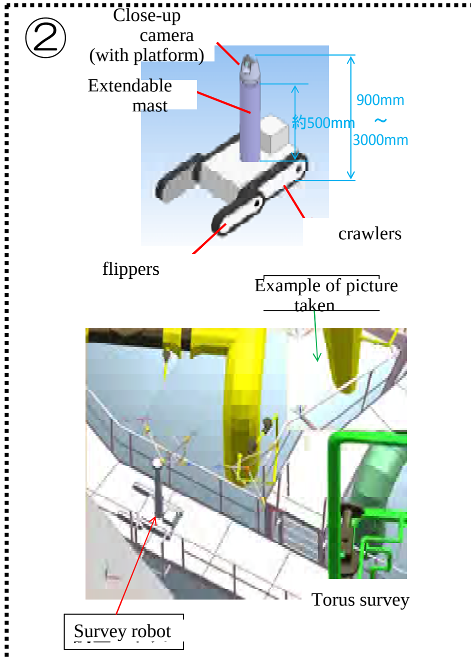
PCV Leak survey and repair (Devices for surveying the bottom of PCV)

	Main development organization	Develops device	Characteristics	Location
Open air robot	Government PJ	Vent pipe joint survey robot	This robot adheres itself to the surface of the outside of the vent pipe and approaches joints between bent pipes and the D/W from between the vent pipe and concrete wall in order to survey the damage	Diagram ①
		Robot for surveying the upper part of the S/C	This robot checks for leaks from structures at the top of the S/C, which is high up (Approx. 3m at its highest), after accessing it from the catwalk outside the Torus	Diagram ②
	Developed independently by manufacturers	Quadruped robot (&small running car)	This robot is used to ascertain conditions (advance survey) inside the S/C, such as the presence of leaks, within the scope that can be photographed from near the area beneath the vent pipe Unit 1's triangular corners are currently submerged and cannot be accessed.	Diagram ③









PCV Leak survey and repair (Submersible robot)

◆The necessity to develop submersible robot technology

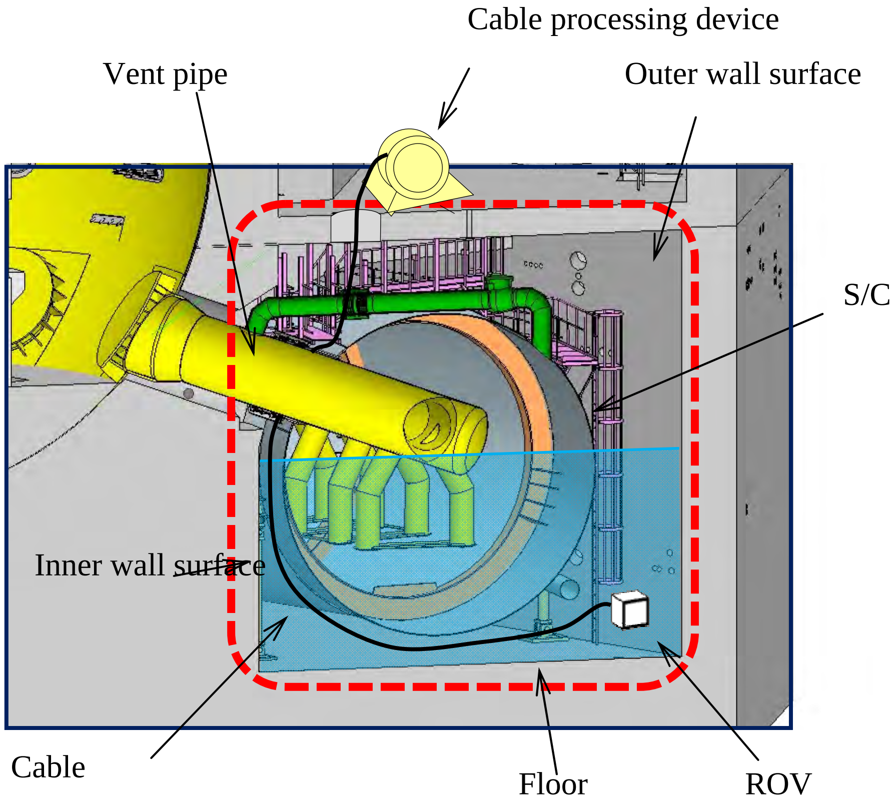
Eventually a submersible robot will be used to survey the inside of the containment vessel and pressure vessel, which are filled with water, however fundamental technology that allows the robot to self-locate does not exist.

Required equipment

- Submersible robot

Required technology

- Self-location technology
- Long cable processing technology
- Shape/water flow detection technology



◆Schedule

- FY2012: Element tests
- FY2013: Combination tests
- FY2014: Application of real device

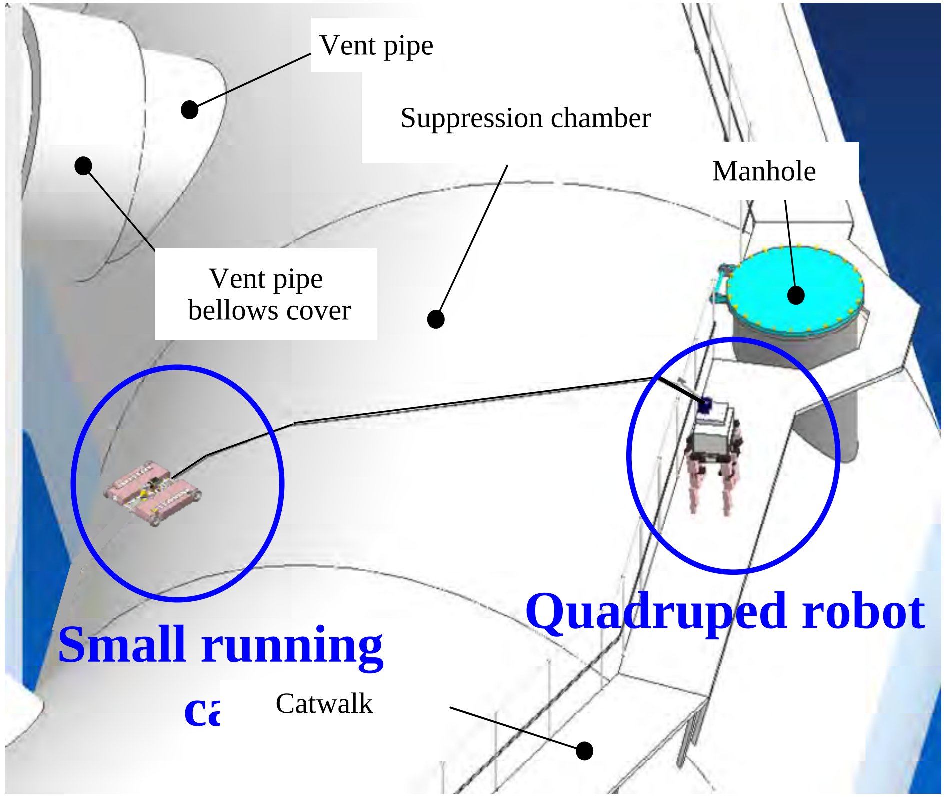
PCV Leak survey and repair (Quadruped robot (objective/background))

Objective/Background

■Being used (Unit 2) before robot developed by government PJ in order to detect leaks from the bottom of the containment vessel as quickly as possible. Survey results will be used as feedback for government PJ equipment and device development.

■Whereas a survey of one area was completed on December 11 of last year, thereafter the three nonconformities stemming from the robot occurred. An expert working group has been established under the jurisdiction of the remotely operated task force (TF) and improvement measures are being deliberated.

■Mockup tests of Unit 5 using the improved robot have been completed so the survey will recommence on March 5.



313mm(L)×327mm(W)×47mm(H)

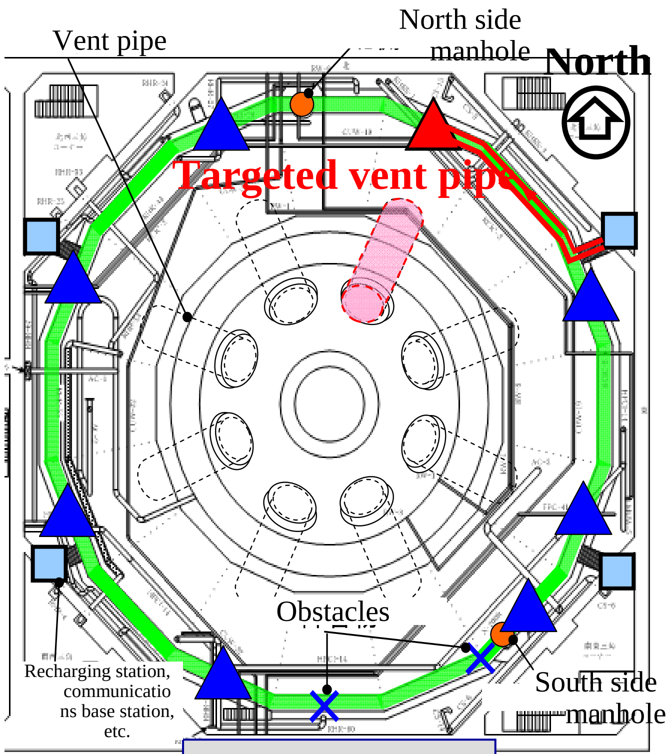
Quadruped robot **Small running car**

■Specific locations within the torus can be accessed using the quadruped robot

■After being put in position a small running car attached to the end of the quadruped robot arm will be affixed to the top part of the S/C and moved near the vent pipe in order to take pictures and record sounds.

PCV Leak survey and repair (Quadruped robot （survey results）)

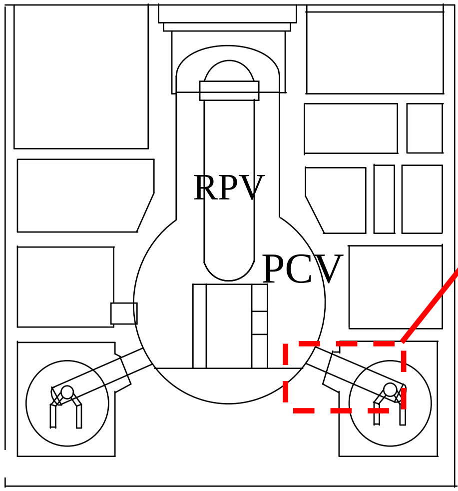
■Implementation Date：December 11, 2012
■Survey Target: Refer to left diagram



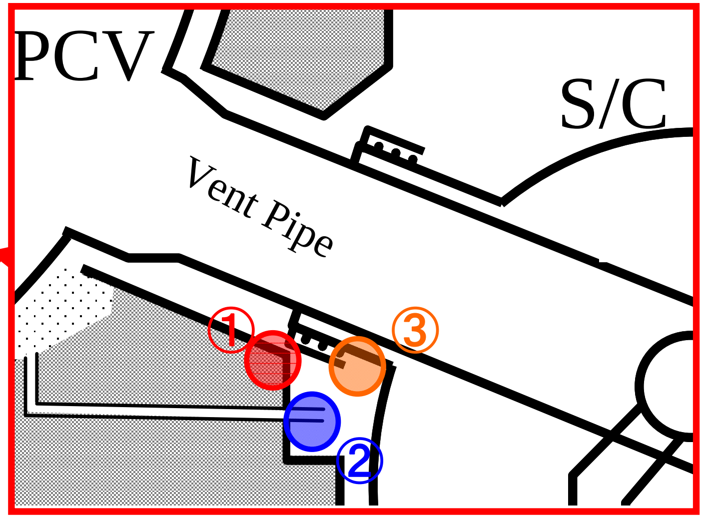
Torus diagram

Quadruped robot arrival location
(vent pipe survey location)

▲ : Locations surveyed this time
▲ : Locations not yet surveyed
△ : Locations surveyed
― : Travel route



PCV cross-section



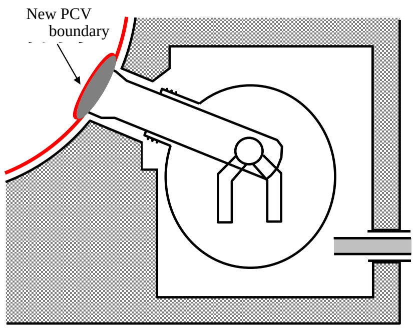
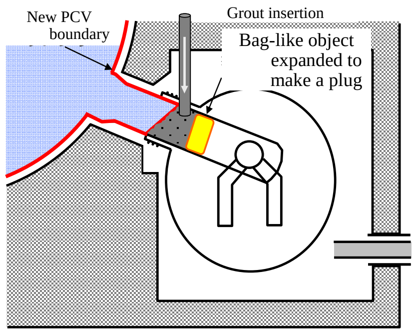
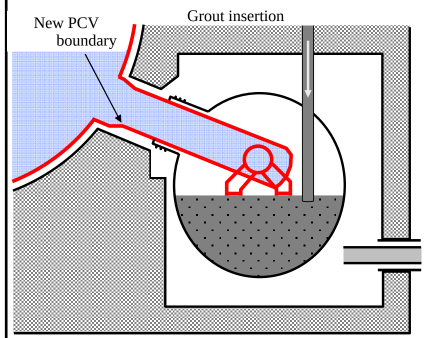
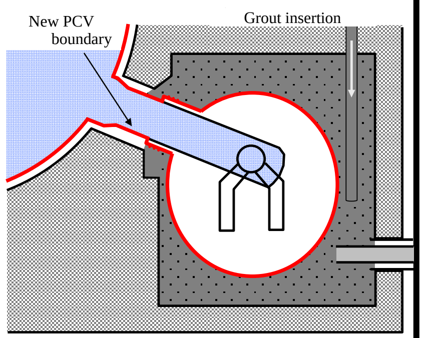
Enlarged view of area beneath pipes

Vent pipe sleeve end

San cushion drain pipe end

Bottom of vent pipe bellows cover

PCV Leak survey and repair (Methods for repairing the bottom of the PCV)

	Stopping leaks at the jet deflector	Stopping leaks at the vent pipe	Stopping leaks at the downcomers	Stopping leaks at the torus
Concept diagram				
Characteristics	The dry well becomes the only boundary and the suppression chamber is removed from being a boundary (minimizing of boundaries)	The dry well and part of the vent pipe become boundaries and the suppression chamber is removed from being a boundary	The dry well, vent pipe, vent header, and downcomers become boundaries, and it suppression chamber is removed from being a boundary	The suppression chamber and system piping connected to the special chamber become boundaries (maximizing boundaries)
Primary issues	Eight location secured for inserting leak stopping material into the drywall that nozzles	A location secured for inserting leak stopping material into the vent pipe	･Route secured for inserting filler into the suppression chamber ･It is necessary to confirm the presence or absence of debris inside the suppression chamber prior to inserting leak stopping material	･The torus, which contains many obstacles, must be completely filled without gaps with leak stopping material ･It is necessary to confirm the presence or absence of debris inside the torus prior to inserting leak stopping material

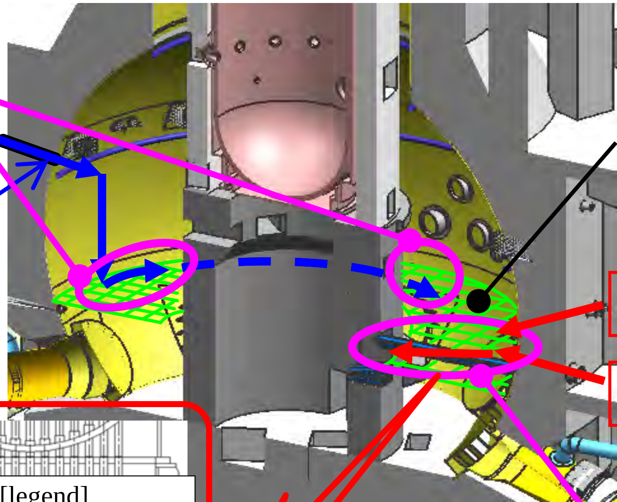
PCV internal survey (Future plans)

Unit 1: server devices inserted into the PCV from spare penetration seal (X-100B) Equipment moved to above the first floor grating to survey the outside of the pedestal
Unit 2: CRD exchange rail and vicinity of pedestal opening to be surveyed from penetration seal (X-53) If the amount of information acquired from the survey through X-53 is insufficient survey equipment will be inserted through the CRD equipment hatch (X-6)

"Confirmation of conditions outside pedestal"
③ Access through Unit 1 X-100B

Unit 1 X-100B

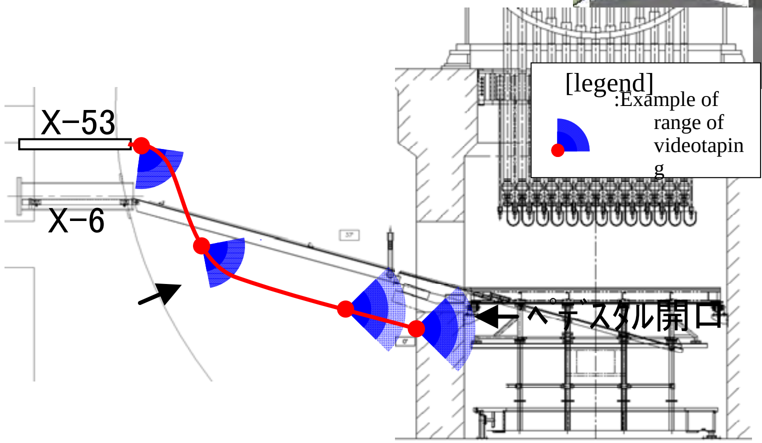
: Access route



Grating

Unit 2 X-53

Unit 2 X-6



Scope of advanced survey from X-53

"Confirmation of conditions outside pedestal"
① Access through Unit 2 X-53

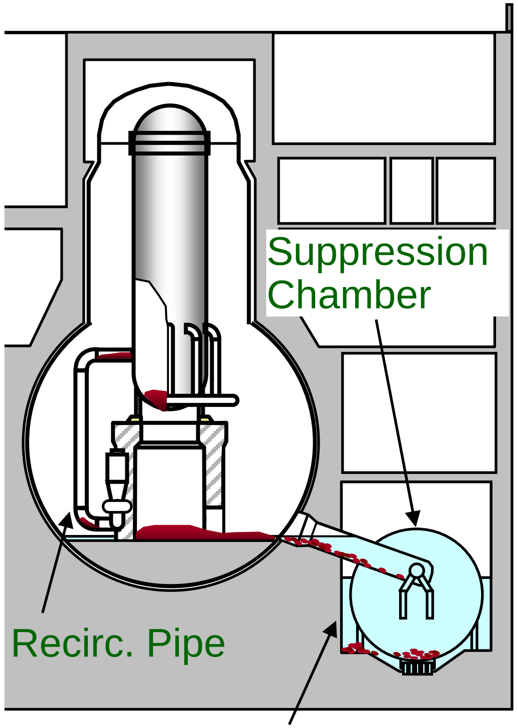
② Access from Unit 2 X-6

Preliminary survey implementation items and accessories

Advance survey: Survey on inside of PCV in preparation for detailed survey (survey to ascertain the location of fuel debris)

6. Remaining Challenges for Fuel Debris Retrieval

Items to be Tackled



1. Identification of debris location

- SA codes predicts that molten debris has fallen downward, out of RPV
- No enough evidence at this moment to deny the existence of debris in recirculation pipes, suppression chamber or torus room
- Attempts such as further visual inspections, SA code improvement and MUON technology are continuing

2. Debris Sampling

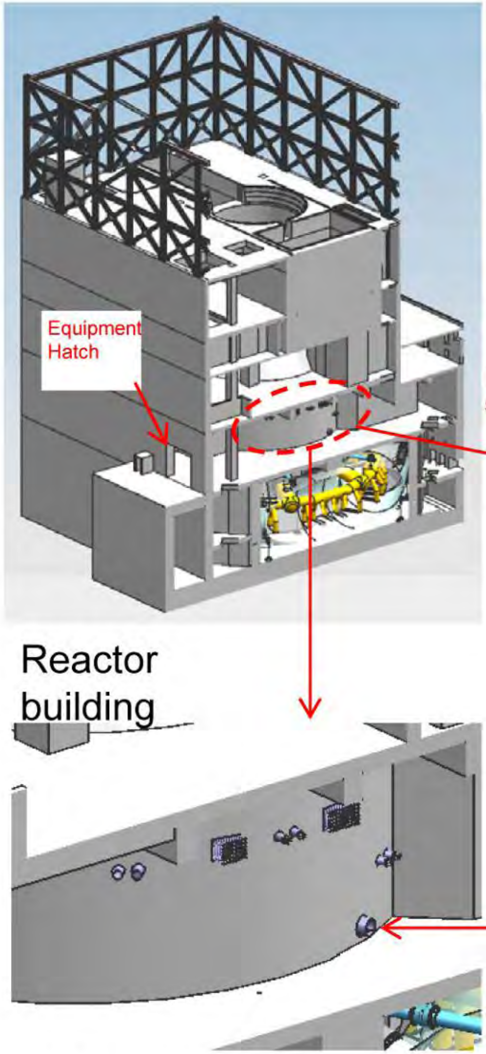
Analyses of actual debris samples will be valuable for subsequent processes of decommissioning, however;

- Large number of samples can be required to assure enough representativeness of various forms of debris
- Debris properties are needed to take out debris samples (Chicken and Egg situation)

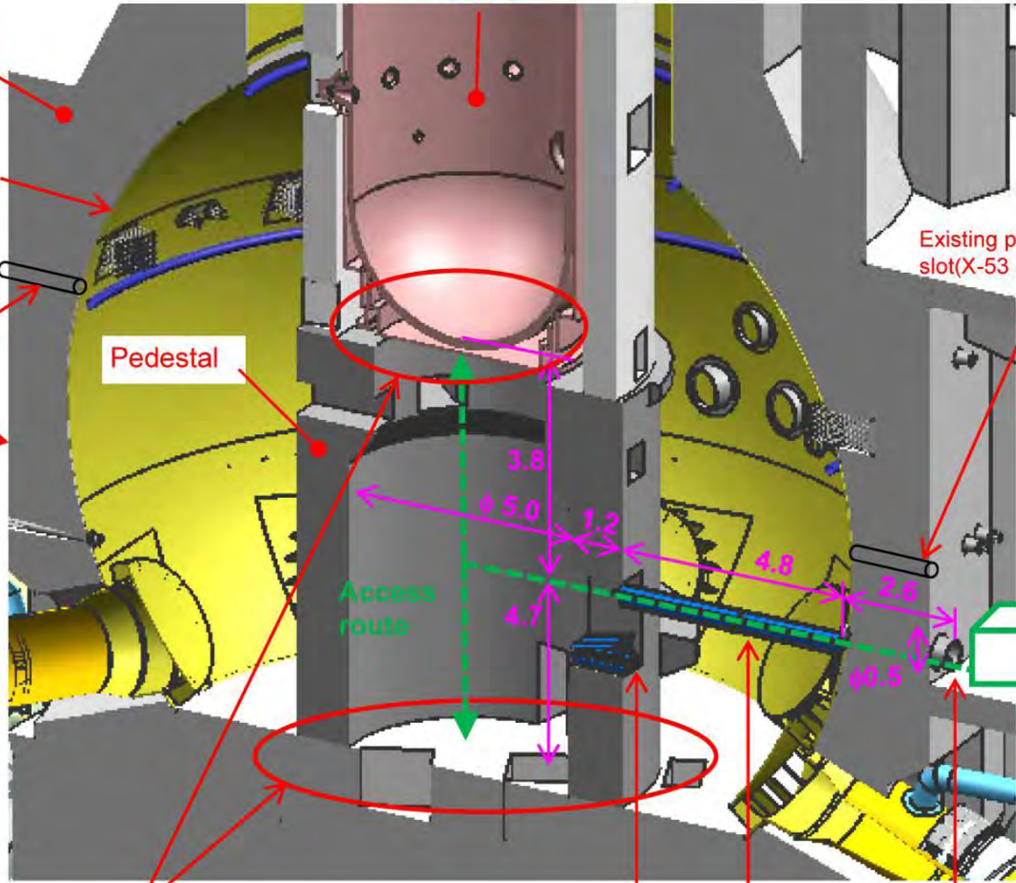
3. Debris Property Evaluation (Main Topic of this Presentation)

Simulate Debris samples can be useful

Identification of Fuel Debris Location



Reactor building, first floor



Sectional drawing, investigation area, and outline dimensions (m)

Current Situation toward Debris Retrieval

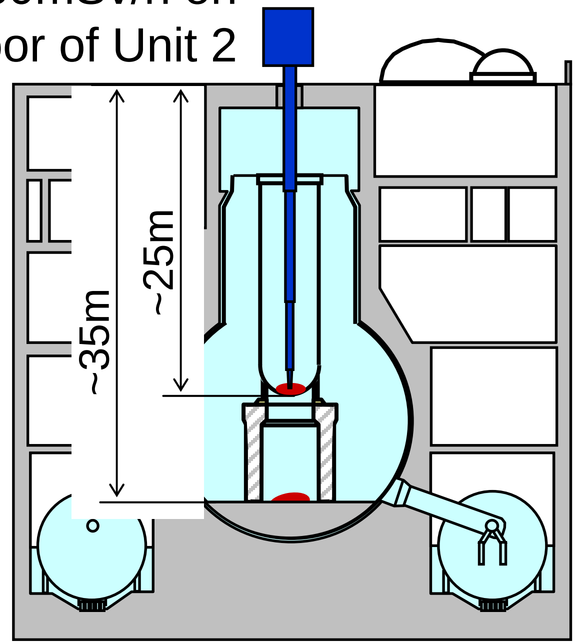
Limited accessibility to debris:

- High dose rate (~880 mSv/h on the top floor)
- Damaged reactor building structure
- Physical distance between Operating Floor and PCV bottom

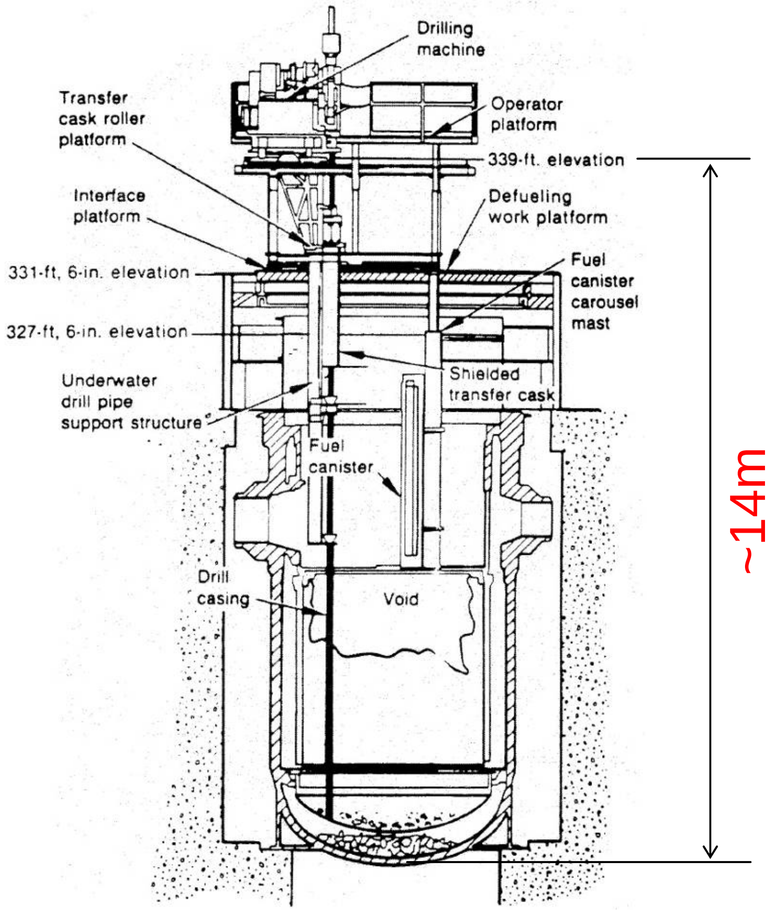
Remote operation capability required:

- Core boring
- Plasma arc
- Shearing
- Bulk removal (Vacuum, Gripping)

~880mSv/h on
Operating Floor of Unit 2

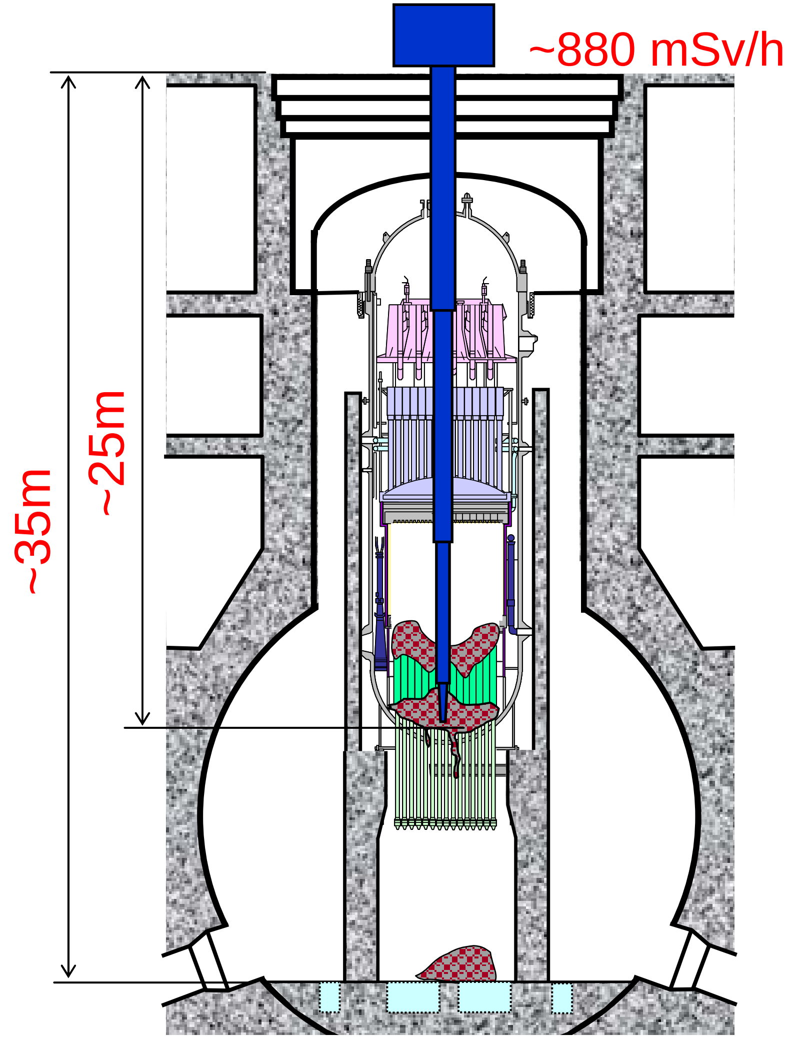


Comparison with the TMI case



Core Boring Machine for TMI-2

The Cleanup of Three Mile Island Unit 2,
Project 2558-8 Final Report, EPRI NP-6931 (1990)



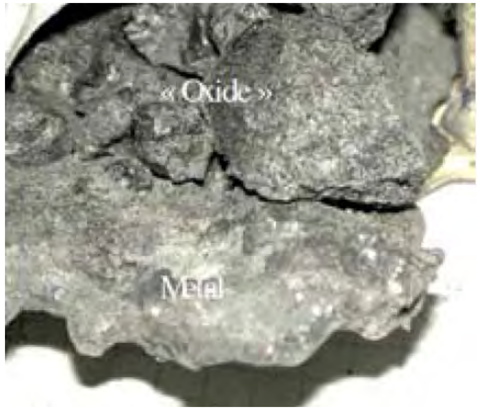
Fukushima Daiichi

More elaborate tool development is important

Available Information about Fuel Debris

Necessary properties of debris:

- Hardness
- Toughness
- Workability
- Machinability



Available properties are limited.

- Various information from TMI-2 and SA-related research programs are available
- But not directly applicable due to the BWR-PWR differences and Fukushima-specific conditions
  - > U/Zr ratio
  - > Larger amount of metal (Fe/Ni) mixture (from RPV Internal structure and RPV itself)
  - > Concrete mixture (from MCCI (Molten Core-Concrete Interaction))
  - > Duration period of high temperature condition

International Studies on Molten Corium

Multiple international projects working on molten corium have been conducted

- OECD/NEA Projects
  - > RASPLAV-1, 2 (Chemical Property of corium),
  - > MASCA-1, 2 (In-Vessel Retantion),
  - > MCCI-1, 2 (MCCI)
- European Projects
  - > SARnet-1,2(,3) (SA code ASTEC)
- ISTC (International Science and Technology Center) Projects
  - > METCOR, CORPHAD, PRECOS (Corium phase diagram)

Main focus was on Chemical- or Thermal-properties and reaction

Few mechanical property information was extracted from those projects

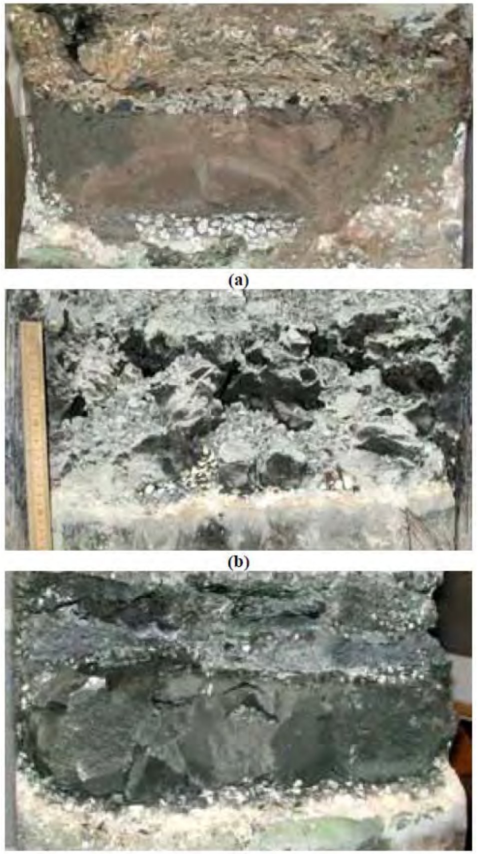


Figure 3-9. Axial Debris Morphology for Test: (a) CCI-1, (b) CCI-2, and (c) CCI-3.

OECD MCCI Project Final Report
OECD/MCCI-2005-TR06(2006)

Current Activities for decommissioning

- Due to the much more complicated situation than TMI-2;
  - So many uncertainties still remain
  - Many R&D activities are needed to be conducted in parallel to the defueling procedures
- Government-supported R&D team has been organized.
  - Government (METI, MEXT)
  - National Labs. (JAEA, AIST etc.) and CRIEPI
  - Fabricator (Toshiba / Hitachi GE / Mitsubishi Heavy Ind.)
  - Academic experts
  - TEPCO (and Japanese LWR owner's group)
- Thirteen R&D projects have been commenced. (Nineteen projects are planned)

- With perspective of enhancing technological basis for nuclear decommissioning for the future, International Research Institute for Nuclear Decommissioning **(IRID)** was founded in August.

- Reaching out for advice and counsel to world community steadily
  US, UK, France, Germany, Russia, Ukraine and Other Countries

Summary

- Situation in Fukushima is assumed to be much more complicated than the case of TMI-2
- Tentative plan is to start Defueling from RPV within 7 years.
- It is assumed that the Defueling process can take over 20 to 25 years to complete.
- Government supported R&D activities are commenced to achieve defueling and Fukushima Daiichi-Cleanup successfully by IRID.
- Many unexpected situations are expected. Flexible program management will be necessary.
- Advices and counsels from the world community would be very much appreciated.