TOSHIBA
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Efforts for the restoration at Fukushima Daiichi Nuclear Power Plants

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TOSHIBA CORPORATION
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TOSHIBA eco style

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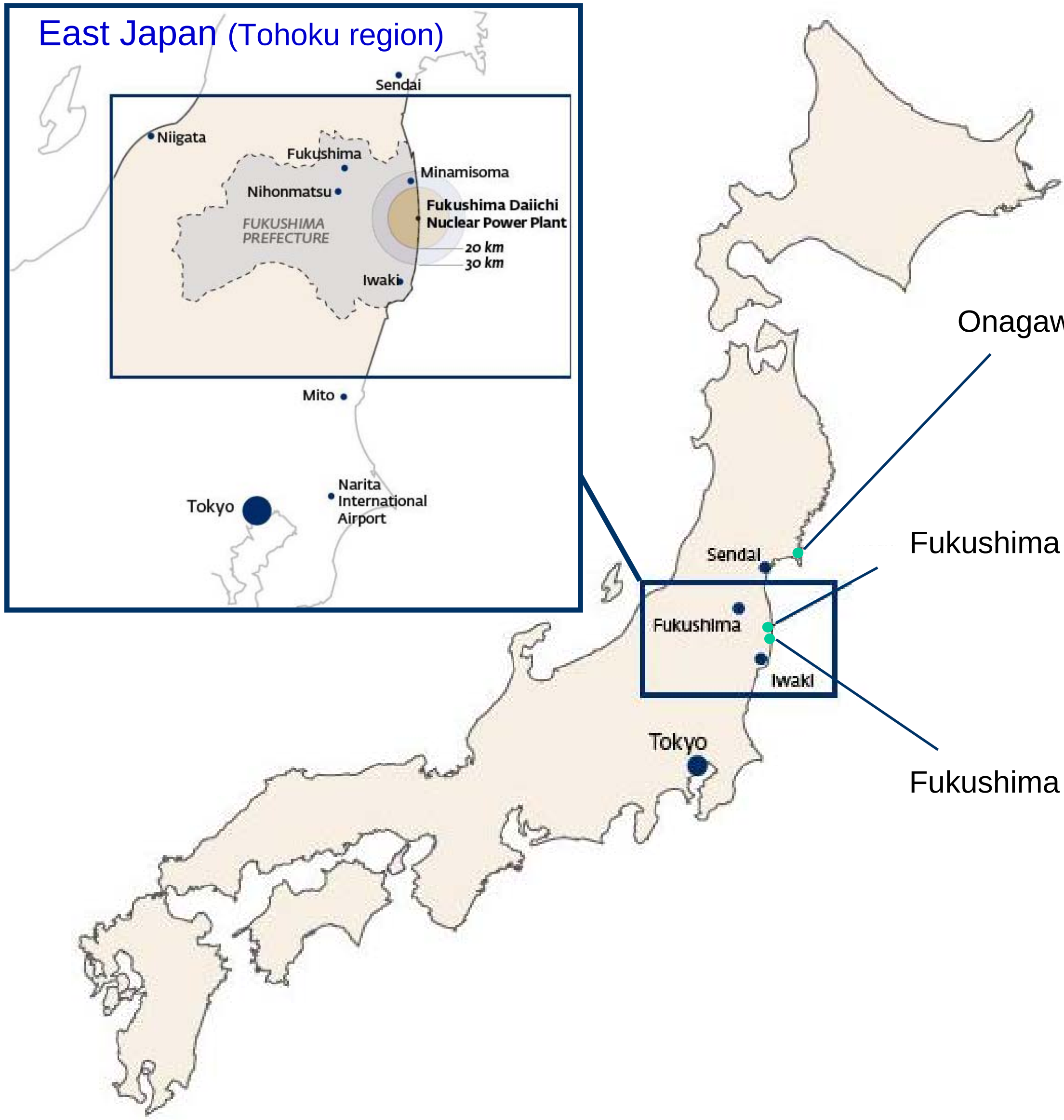
- Overview of Plant Status After Earthquake and Tsunami
- Restoration Activities for Fukushima NPP
- Mid- and long-term Countermeasure
- International Cooperation
- Conclusion

13 Plants Struck by the Earthquake and Tsunami



<u>Plant status at time of earthquake</u>

Onagawa	Unit1: 524 MW Unit2: 825 MW Unit3: 825 MW	In operation
Fukushima I	Unit1: 460 MW Unit2: 784 MW Unit3: 784 MW	In operation
	Unit4: 784 MW	Out of operation (No fuel in RPV)
	Unit5: 784 MW Unit6:1,100 MW	Out of operation
Fukushima II	Unit1: 1,100 MW Unit2: 1,100 MW Unit3: 1,100 MW Unit4: 1,100 MW	In operation

RPV: Reactor Pressure Vessel

Plant Status at each site

Onagawa Nuclear Power Station

- One of 5 off-site power line and 6 of 8 EDGs were available
- All plants achieved cold shutdown by using those electric power supply systems by March 12, 2011

Fukushima Dai-Ni (2nd) Nuclear Power Station

- One of 4 off-site power lines and 6 of 12 EDGs were available
- Safety related motors and pumps were replaced
- Transformers were replaced from Kashiwazaki NPP
- All plants achieved cold shutdown by using tie-line of those power supply systems by March 14, 2011

Fukushima Dai-Ichi (1st) Nuclear Power Station

- All of electric power supplies were lost on Units 1 to 4
- Only one EDG was available on Units 5 and 6

EDG: Emergency Diesel Generator
NPP: Nuclear Power Plant

Reactor Scram Response → Loss of off-site Power due to Earthquake → Emergency DG startup → Reactor Cold Shutdown

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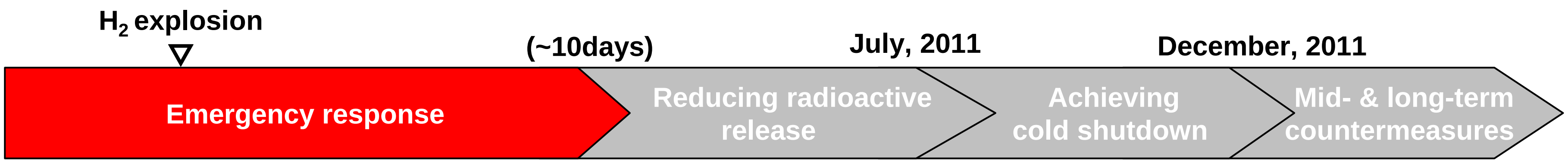
1. Emergency Response

(Initial actions after the accident)



Overview of Emergency Response

Emergency response → **Reducing radioactive release** → **Achieving cold shut-down** → **Mid- & long-term counter-measures**

▲ March 11, 14:46

▲ Unit 1 Hydrogen explosion (March 12)

▲ Unit 3 Hydrogen explosion (March 15)

▲ Approx. 10 days

Objective	Activities taken by Toshiba
◆ Recovery of electric power supply	• Supply and laying of cables • Supply of car batteries for I&C
◆ Core cooling	• Supply and connection of hoses and cables for seawater injection • Supply of 52 sets of submerged pump
◆ Avoidance of hydrogen explosion	• Plan to drill holes on the R/B roof • Mock up test
◆ Cold shutdown of units 5 & 6	• Utilize of the last D/G, cabling and panel installation • Installation of pumps and piping

I&C: Instrumentation and Control   R/B: Reactor Building   D/G: Diesel Generator

Emergency Response

■Preparation of emergency measures

- **Recovery of Electric Power Supply**
  - ➢Car batteries for I&C power supply (2,000 units)
  - ➢Installation of Cables
    - High-voltage cables: 2,000m
    - Low-voltage cables : 23,400m
- **Urgent core cooling by seawater injection**
  - ➢Connection hose and cables
  - ➢Submerged pumps (52 sets)
- **Avoidance of hydrogen Explosion**
  - ➢Drill the roof of reactor building
    (Water jet and core drill)
  - ➢Mock up test before explosion of Unit 3

Submerged pump•hose

Drill the Holes

H_2 explosion ▽ — (~10days) — July, 2011 — December, 2011

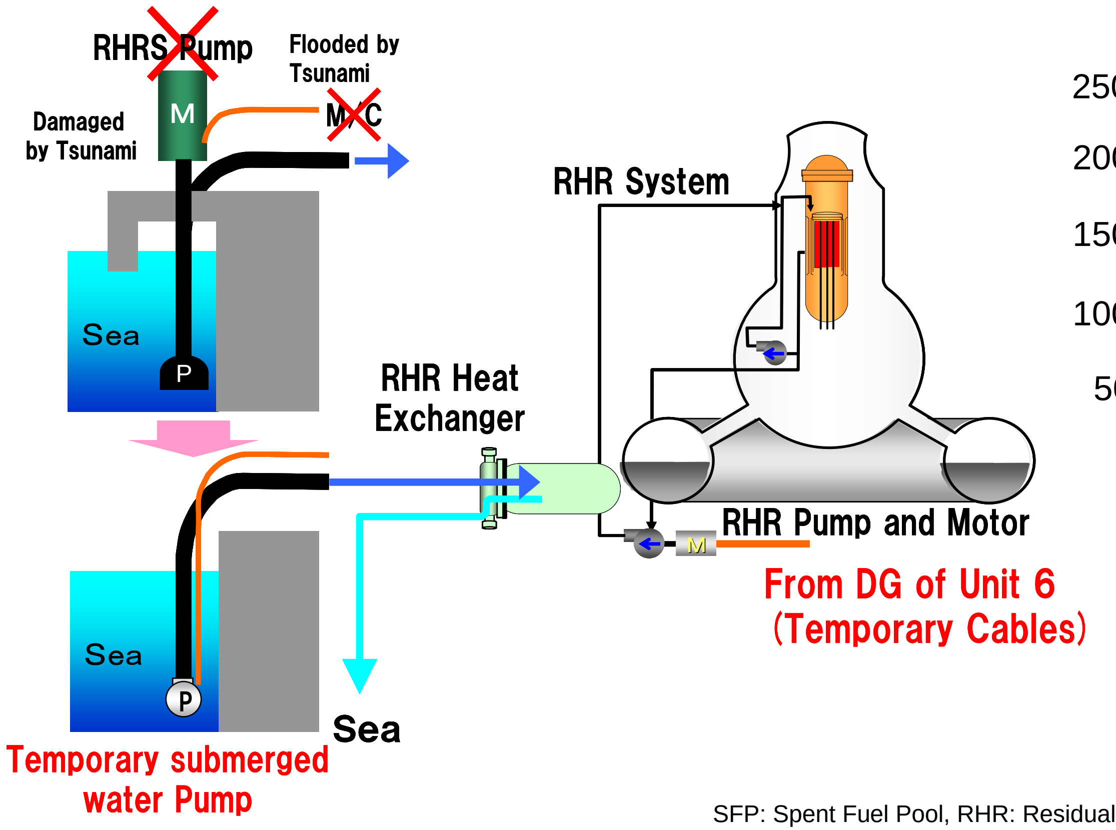
Emergency response → Reducing radioactive release → Achieving cold shutdown → Mid- & long-term countermeasures

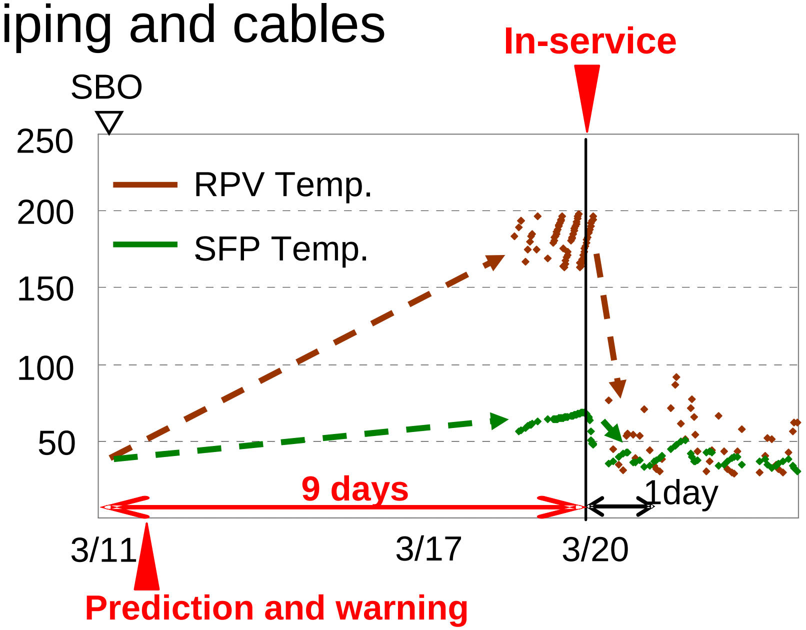
I&C: Instrumentation and Control   HVAC: Heating Ventilation and Air Conditioning and Cooling System

Activities for Reactor cooling of Unit 5

■Prediction of core damage risk of Unit 5

- Observed and understood the plant condition and predict future trend considering current plant condition
- Predicted the risk of core and spent fuel damage
- Designed and installed components, piping and cables

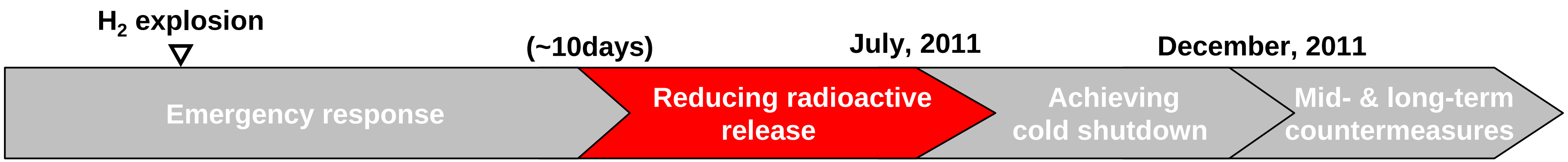




With the installed system operation, temperature began to fall on the first day

SFP: Spent Fuel Pool, RHR: Residual Heat Removal System, RHRS: Residual Heat Removal Sea System

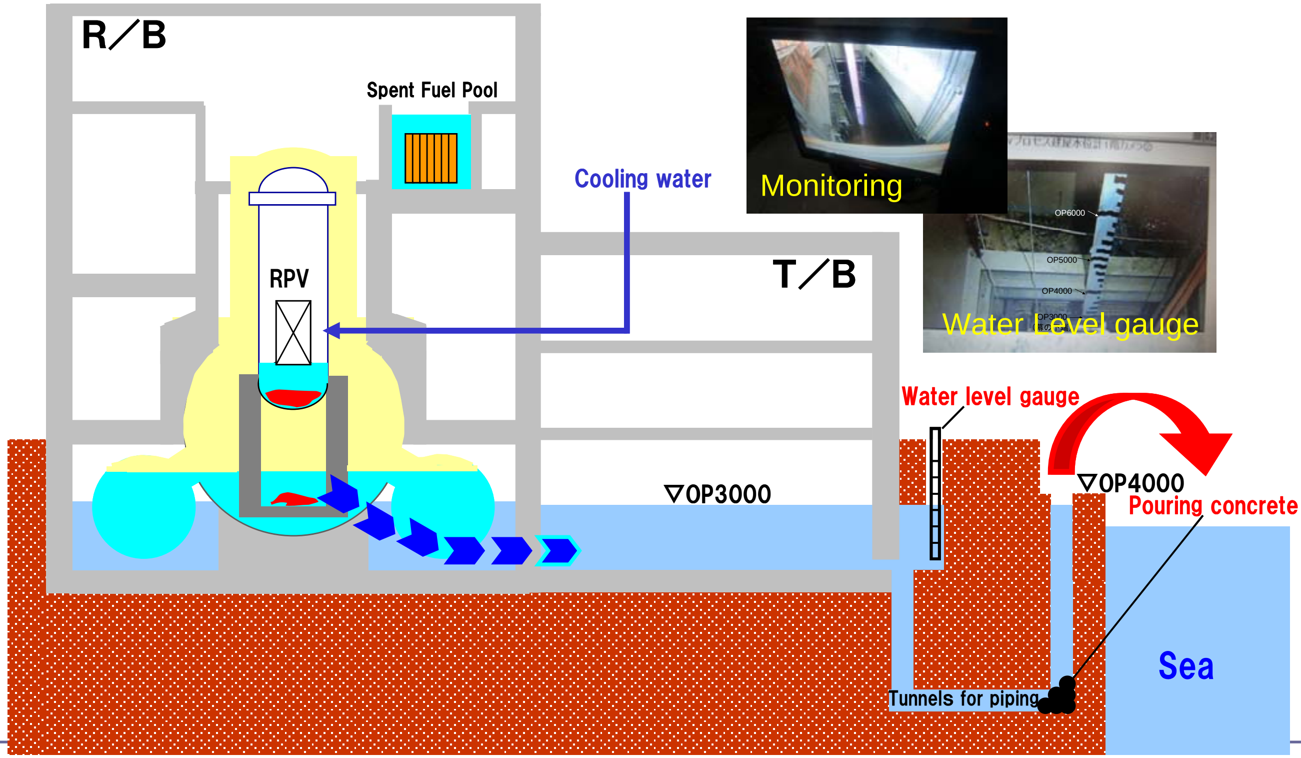
2. Reducing Radioactive Release



Reduction of Overflow Risk

■ Risk prediction, proposal, and urgent on-site work

- Evaluated overflow risk
- Installed water level gauge in T/B pit
- Proposed water treatment facility based on the risk evaluation
- Poured concrete by civil team to avoid excess release of contaminated water to sea



T/B: Turbine Building

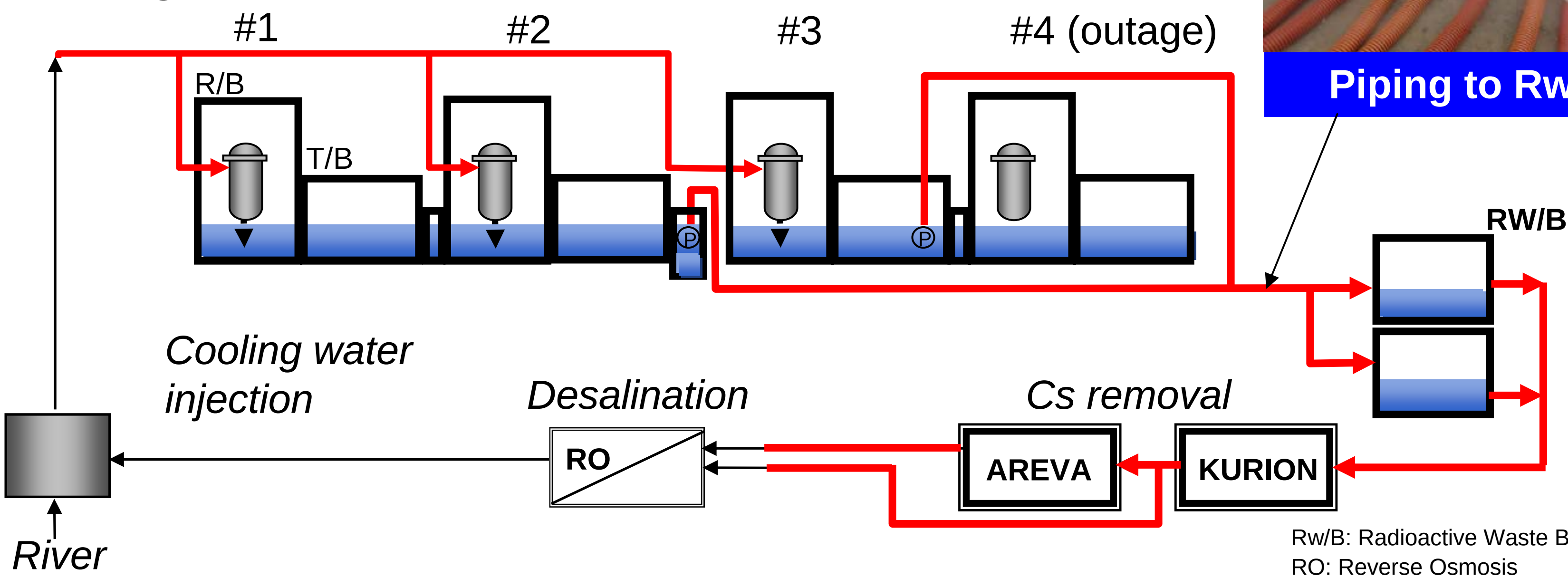
R/B: Reactor Building

Establish the water treatment system

■ Highly contaminated water accumulated in T/B

- Nearly 70,000 tons of contaminated water as of April 19, 2011
- Urgent water transfer is required to Rw/B
- Established recirculation loop for water treatment system
- Huge volume of construction

Piping to Rw/B



Rw/B: Radioactive Waste Building
RO: Reverse Osmosis
Cs: Cesium

Transfer piping installation 4,100m with 3,000welding points

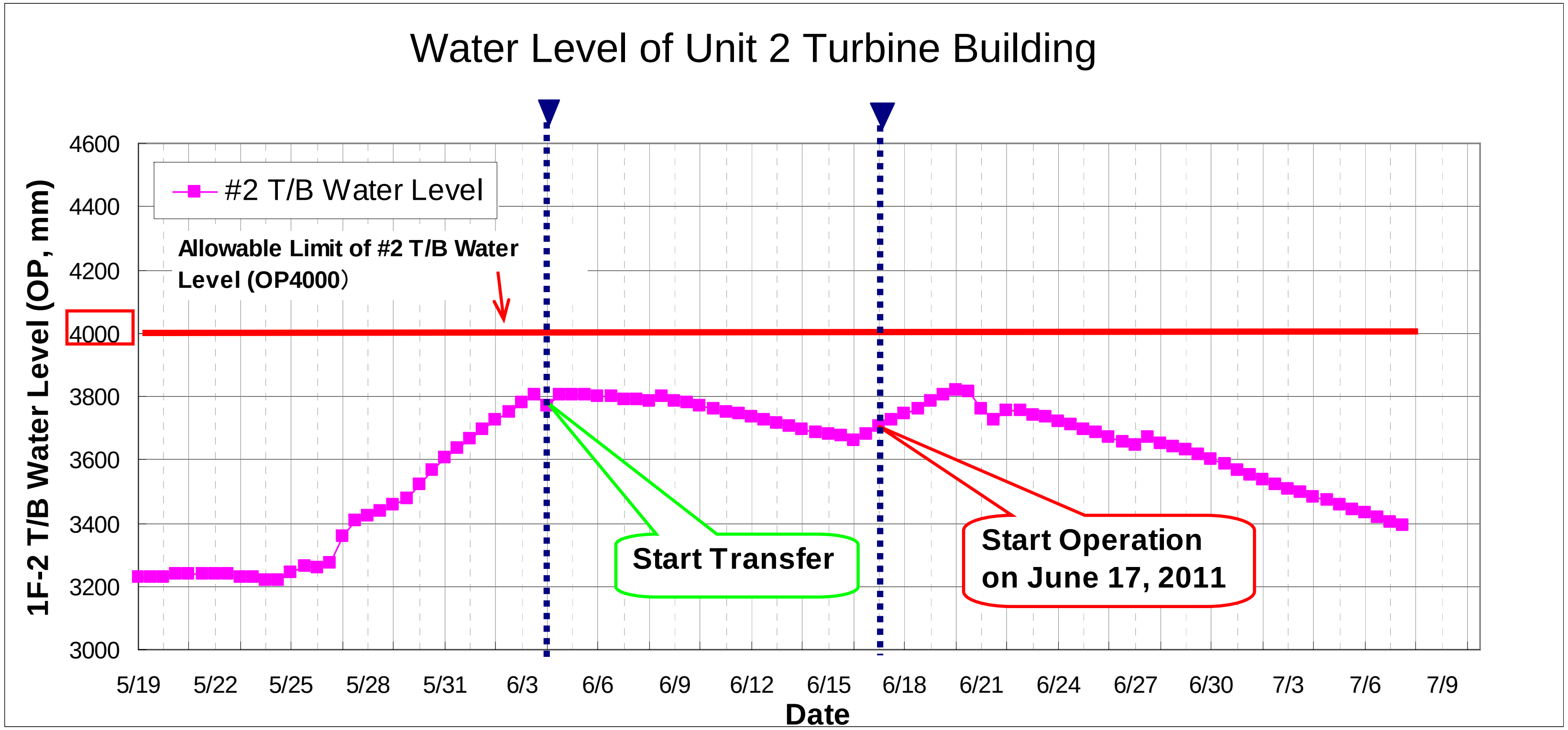
Installation of 1st Water Treatment System

International collaboration

- KURION & AREVA systems was integrated by Toshiba site work
- 24-hrs-a-day work to meet schedule

Just two months for delivery

- Designed started on April 11, and delivered on June 17



Installation of 2nd Water Treatment System

■ Simplified Active water Retrieve and Recovery System

- Increase the stability and redundancy
- Ready for operation within only 2.5 months from proposal under severe conditions
- Major role among water treatment systems since October, 2011

■ Major Characteristics

- Reduction of media changes
- Shielding design for workers
- Improvement of DF
- Stable operation

Simplified Active water Retrieve and Recovery System (SARRY)

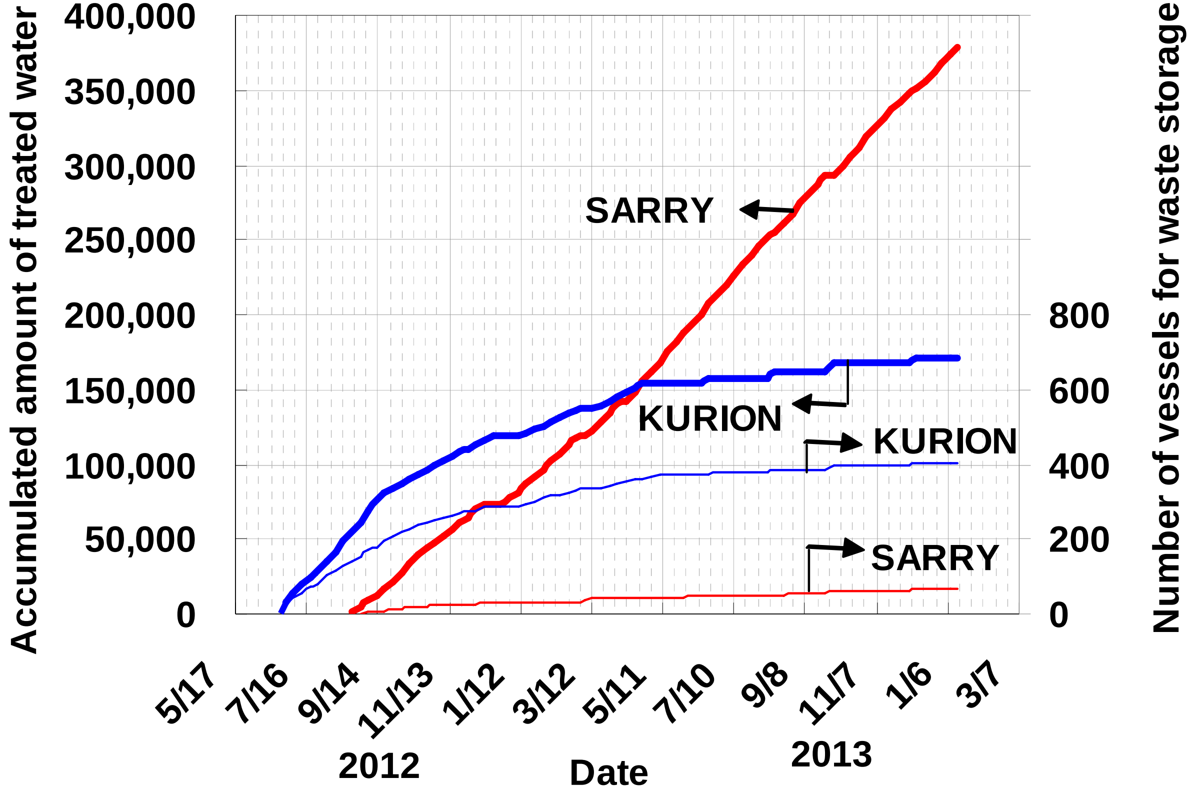
DF: Decontamination Factor

System performance comparison

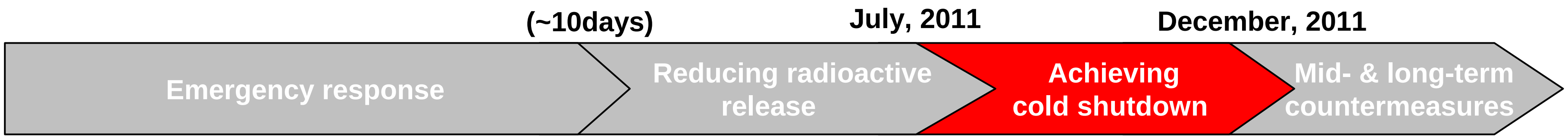
■ System performance is better in each respect

	SARRY	KURION	AREVA
Cesium Removal DF	1×10^6	$1 \times 10^{2\sim5}$	1×10^3
Tereated Water/Vessel	5,568 m^3/vessel	425 m^3/vessel	-
Max Radiation Exposure*	<1mSv/h	30mSv/h	-

* surface



3. Achieving Cold Shutdown



Achieve Cold Shutdown

■ Improve reliability for core cooling

- ◆ Installed another injection line using Core Spray line to enhance redundancy and to make direct cooling possible

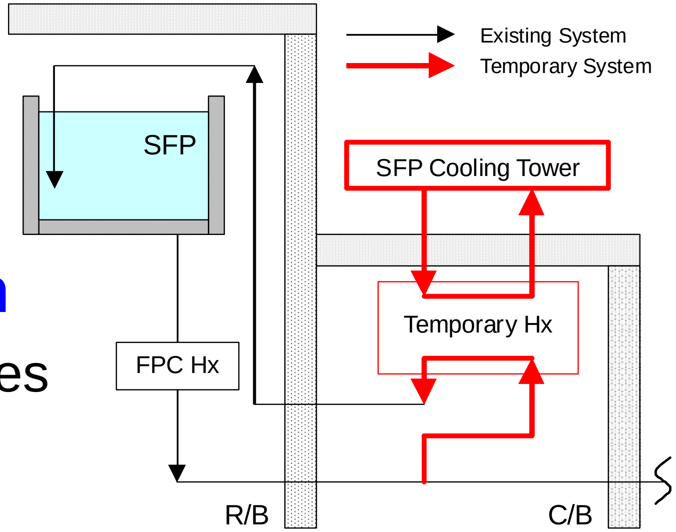
■ Install temporary SFP cooling system

- ◆ Installed within a week in the severe dose rate area in Unit 2
- ◆ Remarkable temperature reduction from approx. 70 °C to 40 °C on the first day

■ Improve reliability of N_2 gas injection

- ◆ Installed three additional N_2 injection facilities to reduce the risk of further hydrogen explosions

SFP Cooling Tower



H_2 explosion ▽ | (~10days) | July, 2011 | December, 2011

Emergency response → Reducing radioactive release → Achieving cold shutdown → Mid- & long-term countermeasures

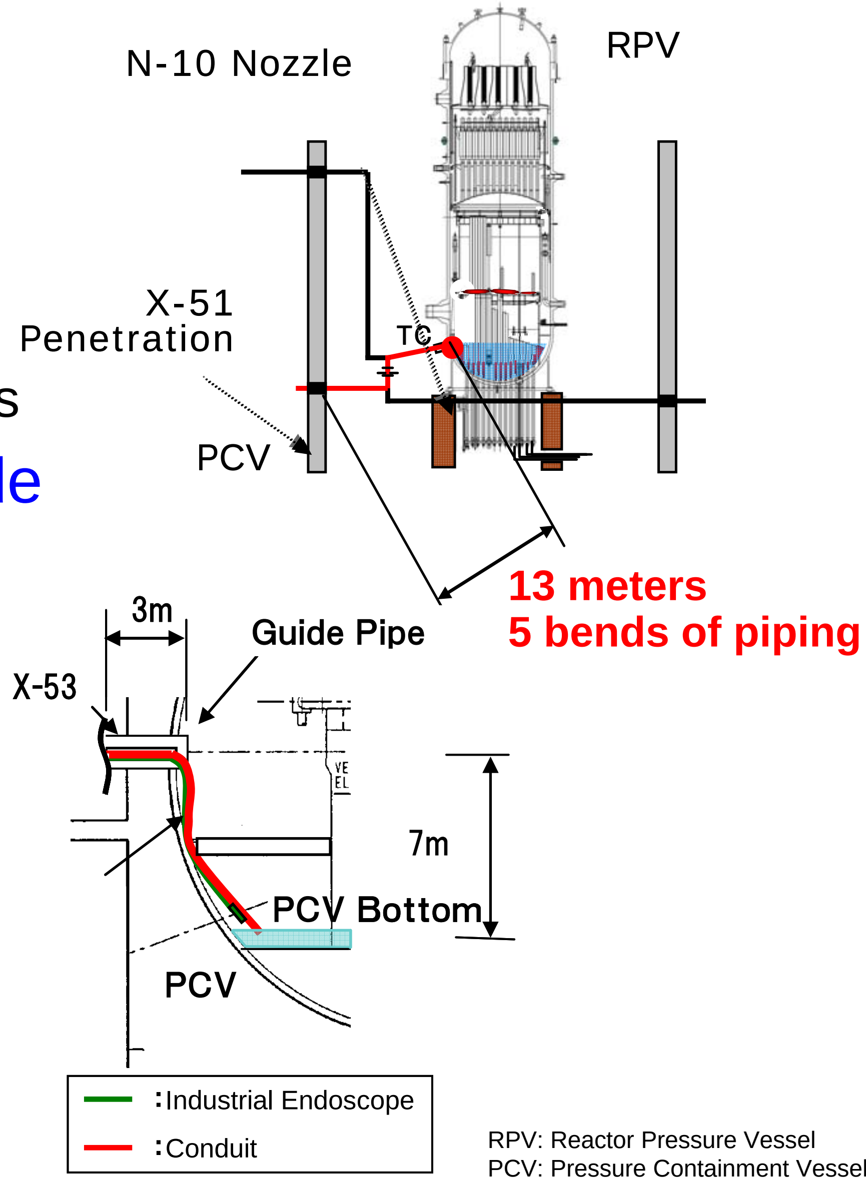
Continuous Monitoring of Plant Parameters

■ Improve reliability of RPV temperature monitoring

- Existing thermocouples of RPV have been broken in Unit 2
- Installed alternate thermocouple under severe radiation conditions

■ Direct observation of PCV inside

- Industrial endoscope
- Performed 1st and 2nd entry into PCV of Unit 2
- Evaluated water level within the PCV



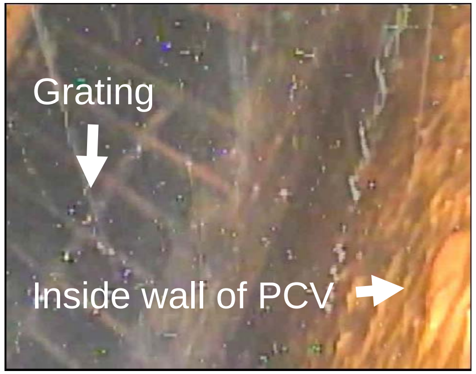


Photo of PCV inside in Unit 2

RPV: Reactor Pressure Vessel
PCV: Pressure Containment Vessel

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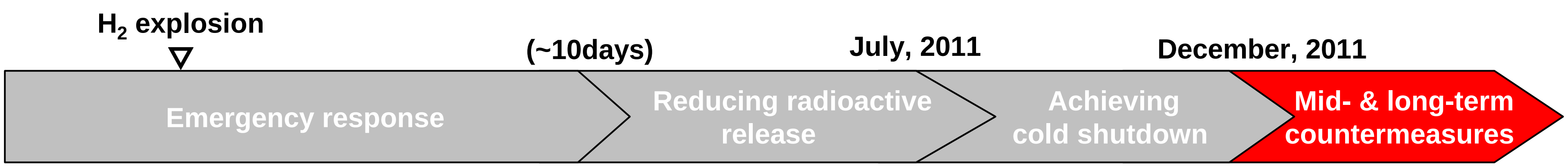


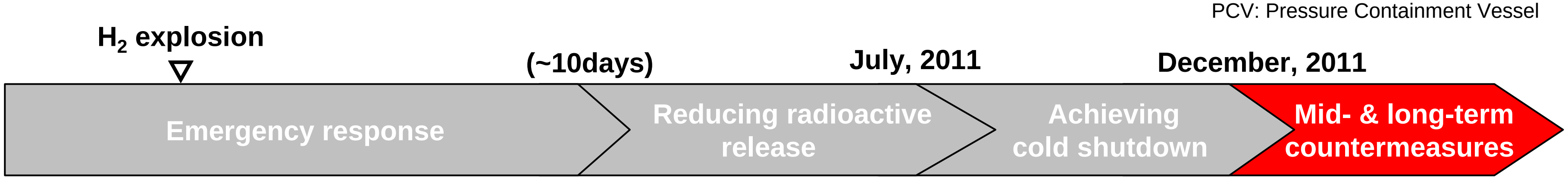
Major Activity Areas of Mid- and Long-term

■Three major areas of activities

- ◆ New additional water treatment system to reduce the risk of stored treated water further
- ◆ Spent fuel removal from SFP
- ◆ Core debris removal from PCV

SFP: Spent Fuel Pool

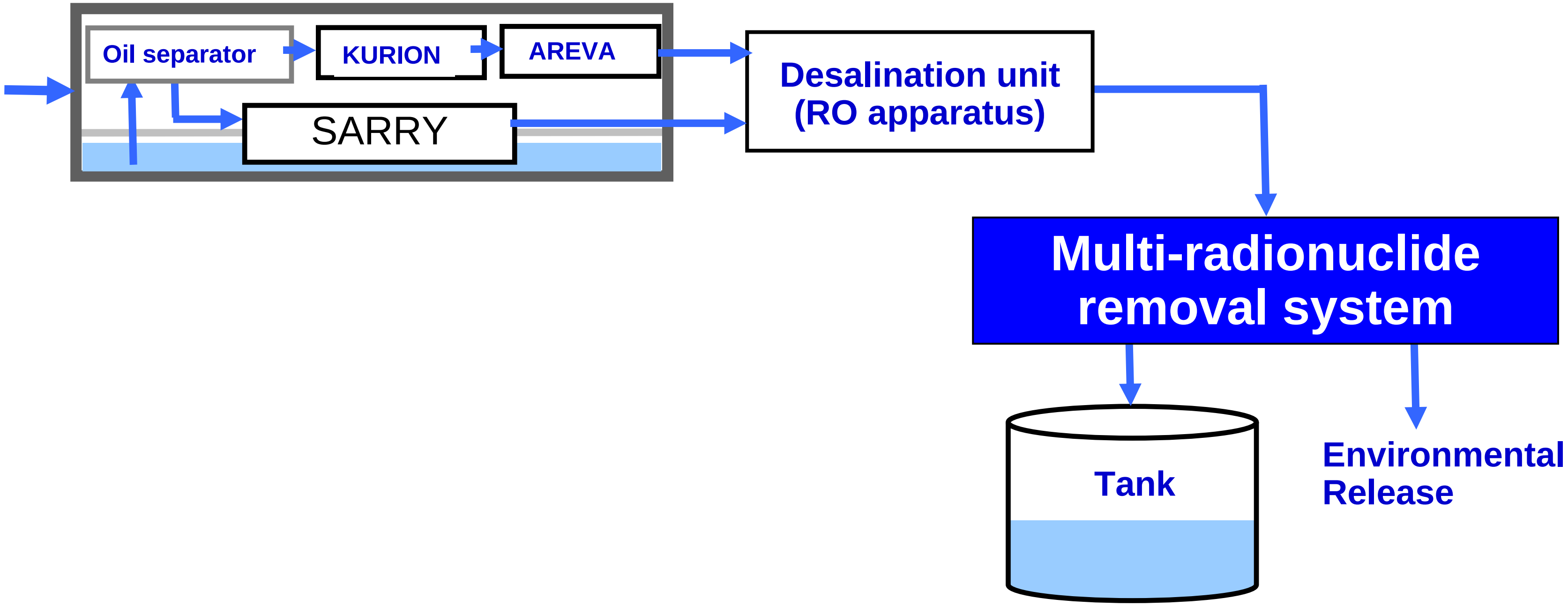
PCV: Pressure Containment Vessel



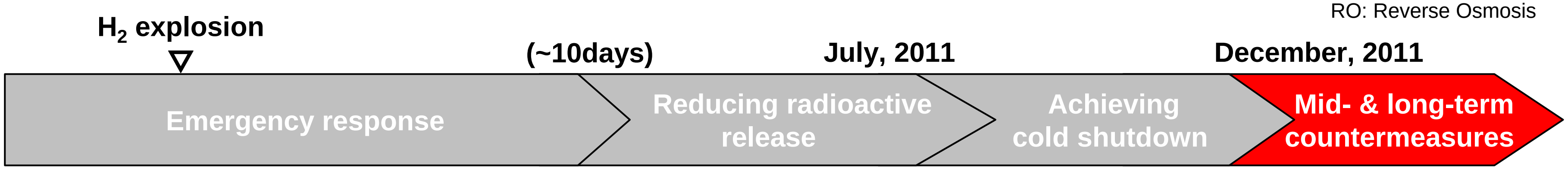
New Accumulated Water Treatment System

■ MRRS (Multi Radionuclide Removal System)

- Increase of accumulated amount of treated water
- Expect further risk reduction of stored water



RO: Reverse Osmosis



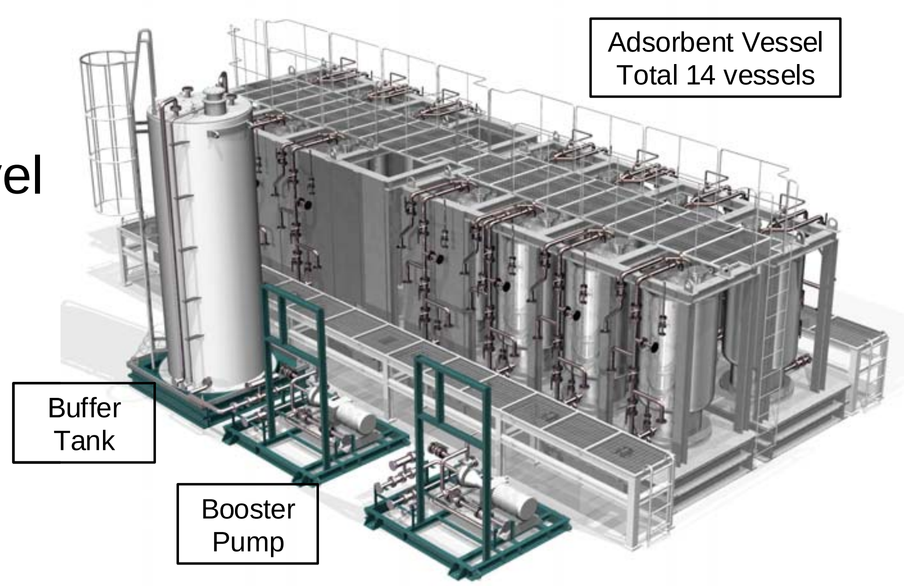
Outline of MRRS System

■ MRRS (Multi Radionuclide Removal System)

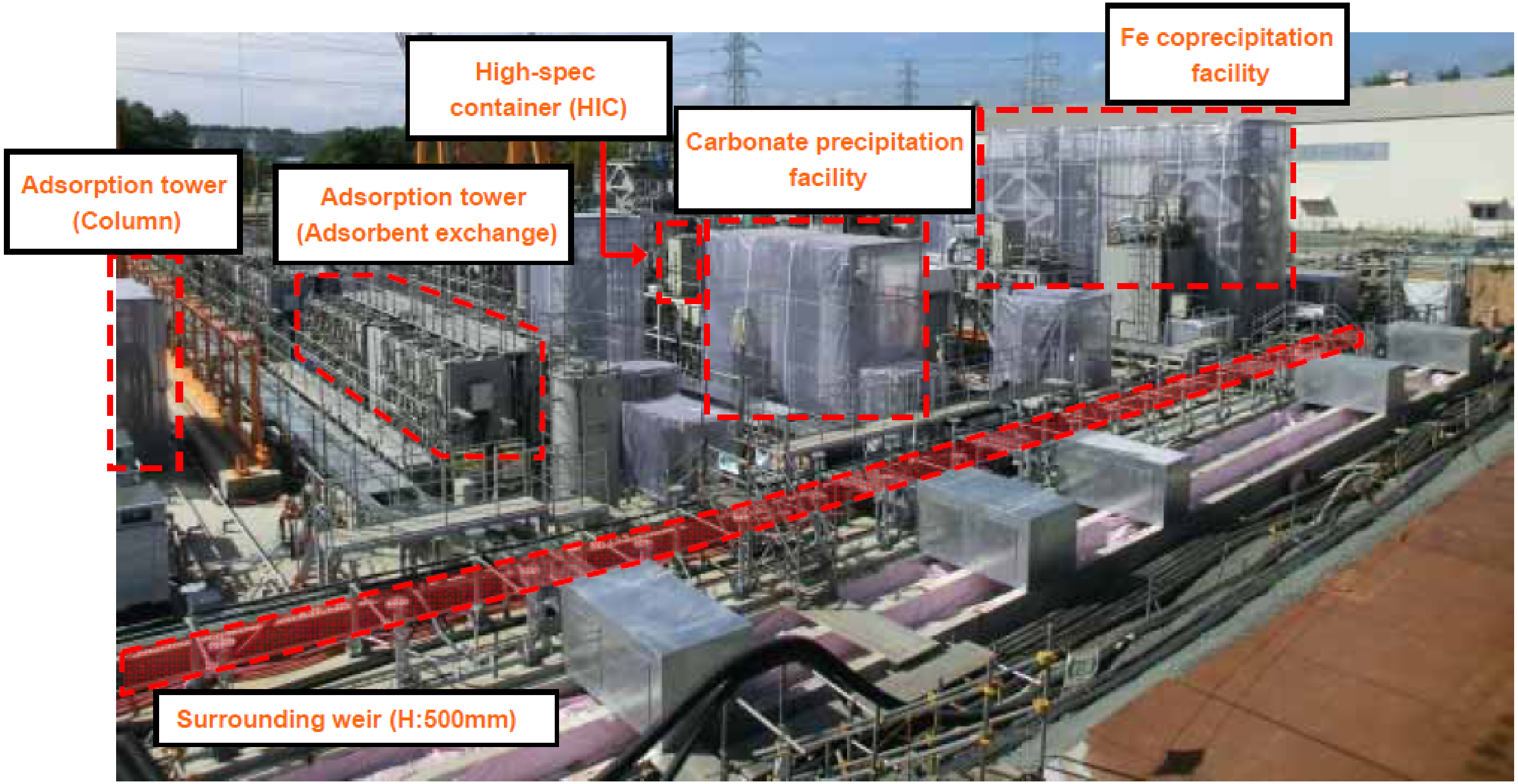
- Conceptual design by EnergySolutions
- Detailed design and manufacturing by Toshiba

■ Performance

- Remove all residual radioactivity to below non-detectable level (less than about 1Bq/L depending on nuclide)
- Strontium was identified as the major nuclide
- With MRRS, the radioactivity level will become lower by two order of magnitude.



Overview of MRRS



As of September, 2012
Cited from TEPCO release

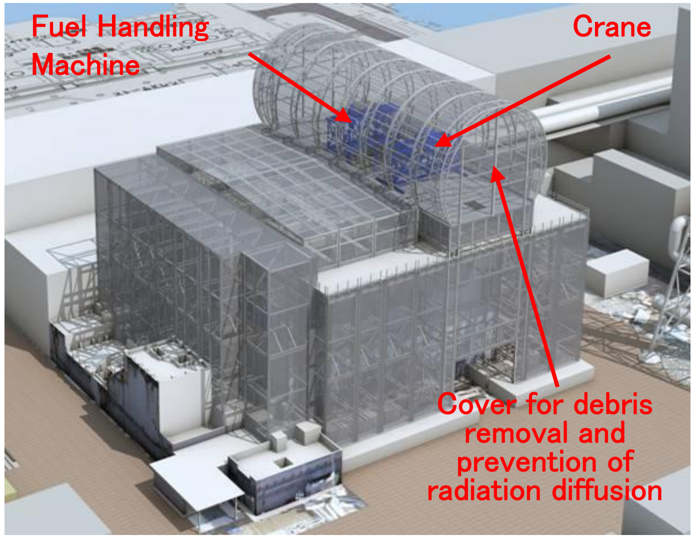
- The system has already been installed at the Fukushima site, and is now waiting for approval by NRA

TEPCO: Tokyo Electric Power Company
NRA: Nuclear Regulatory Authority

Spent Fuel Removal form SFP of Unit 3

■Development of fuel removal system

- Collaborate with U.S. team, e.g., Westinghouse and U.S. venders
- Develop remote control fuel handling machines, crane and transfer vessel
- Radiation condition: over 800mSv/h at a maximum
- Removal work to be started from the end of 2014



Fuel Removal System of Unit 3

Item	2012	2013	2014	2015
System Design Basic Design				
Detail Design Fabrication				
Installation and Test				
Spent Fuel Removal				

Schedule for Fuel Removal

Leakage inspection for PCV Vent Pipe

■ Develop Quadruped robot with compact inspection vehicle

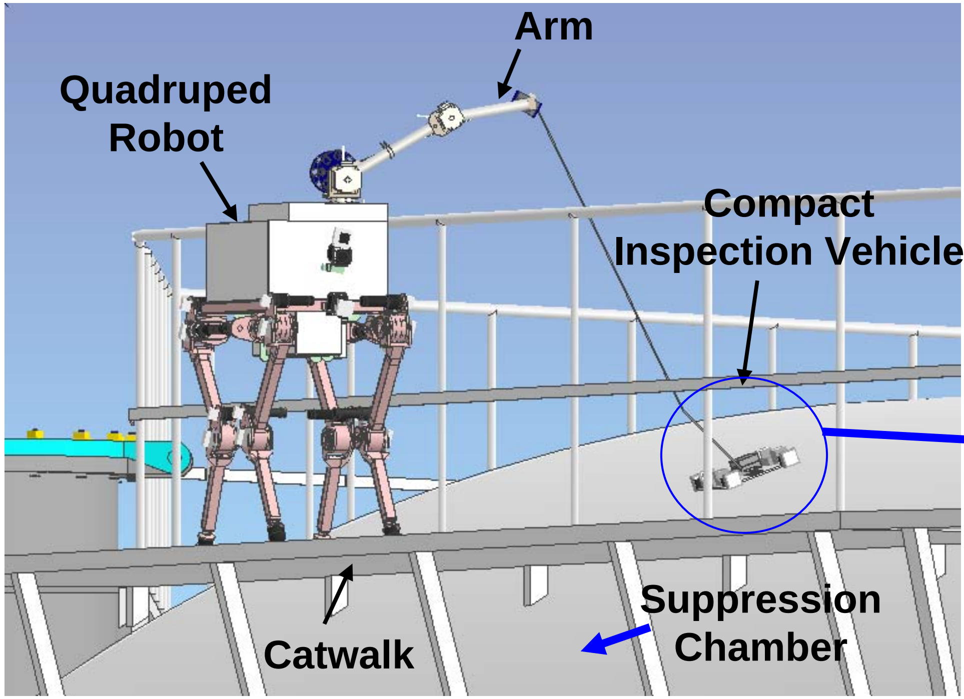
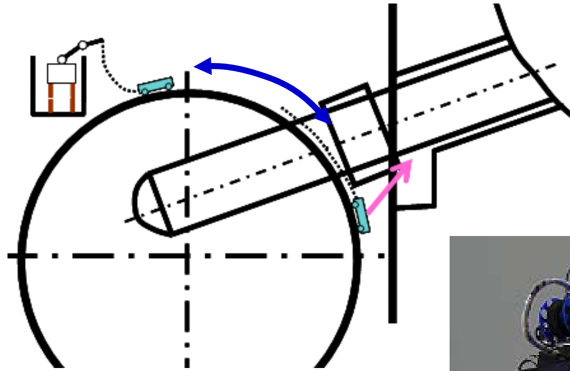
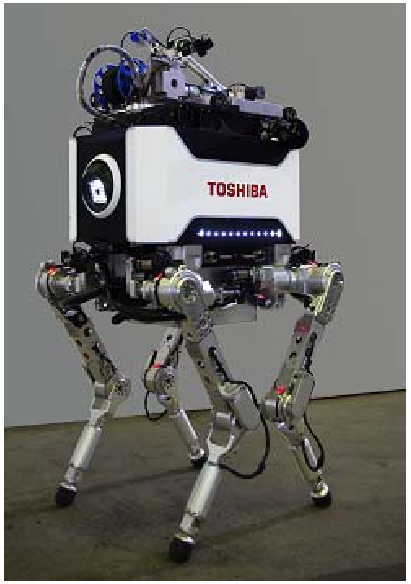


Image of vent pipe inspection by Quadruped Robot for Unit 2



Compact Inspection Vehicle



Quadruped Robot

Reference: TEPCO HP
URL: http://photo.tepco.co.jp/date/2012/201212-j/121211-01j.html

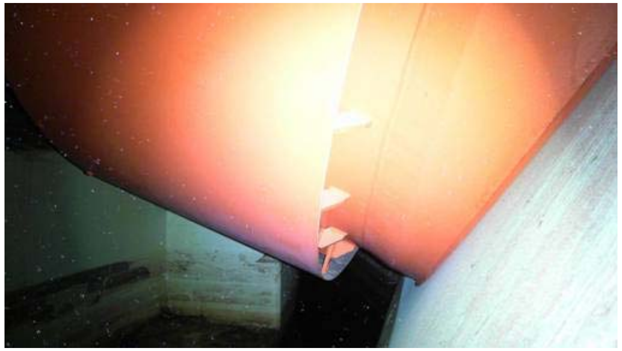
Inspection results for PCV Vent Pipe

■ Quadruped robot performed leakage inspection

- Inspected vent pipe of PCV in Unit 2 on December 11, 2012
- No leakage was found
- Seven other vent pipes will be inspected in the near future

Edge of vent pipe sleeve

Edge of sand cushion drain pipe



Lower part of vent pipe bellows cover

Reference: TEPCO HP

URL: http://photo.tepco.co.jp/en/date/2012/201212-e/121211-02e.html

(~10days) July, 2011 December, 2011

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■Toshiba's international partners

- **Mt. Fuji-team : Toshiba, Westinghouse, B&W, Shaw, and Exelon**
  - Issued "Total Management Plan" reflecting TMI experiences with an eye toward 10-year restoration in April and in May, 2011
  - Promoted SAMG with Exelon to improve plant safety
- **Install equipment for inspection and restoration**
  - T-HAWK (US: Westinghouse and Honeywell)
  - **S**implified **A**ctive water **R**etrieve and **R**ecover**y** System (US: Shaw, etc)
  - **M**ulti **R**adionuclide **R**emoval **S**ystem (US: EnergySolution)
  - Spent Fuel Removal System on Unit 3（US: Westinghouse)
- **Toshiba is investigating available technologies with Russia, Germany, UK, and Kazakhstan on waste management and core debris removal**

TMI: Three Mile Island Nuclear Power Station
SAMG: Severe Accident Management Guideline

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Conclusion

- Since March 11, 2011, Toshiba has taken a key vital role of restoration at all steps, such as:
  - Prediction and evaluation of the plant,
  - Planning of various recovery plan,
  - Design, engineering and manufacturing,
  - Site execution
- Toshiba will continue its activities at the Fukushima site in cooperation with the Japanese government and TEPCO
- In addition, Toshiba greatly appreciates international support for these challenges

TEPCO: Tokyo Electric Power Company

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