

# Challenges for Fuel debris retrieval with Robotics technologies at Fukushima Daiichi NPS

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TOKYO ELECTRIC POWER COMPANY

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- 1. Fuel Debris Retrieval*
- 2. PCV Surveys with robotics*
- 3. Lessons learned*
- 4. Conclusion*

Installation work of PCV gas injection line in Reactor Building at Unit 3  
(in high radioactive dose rate)

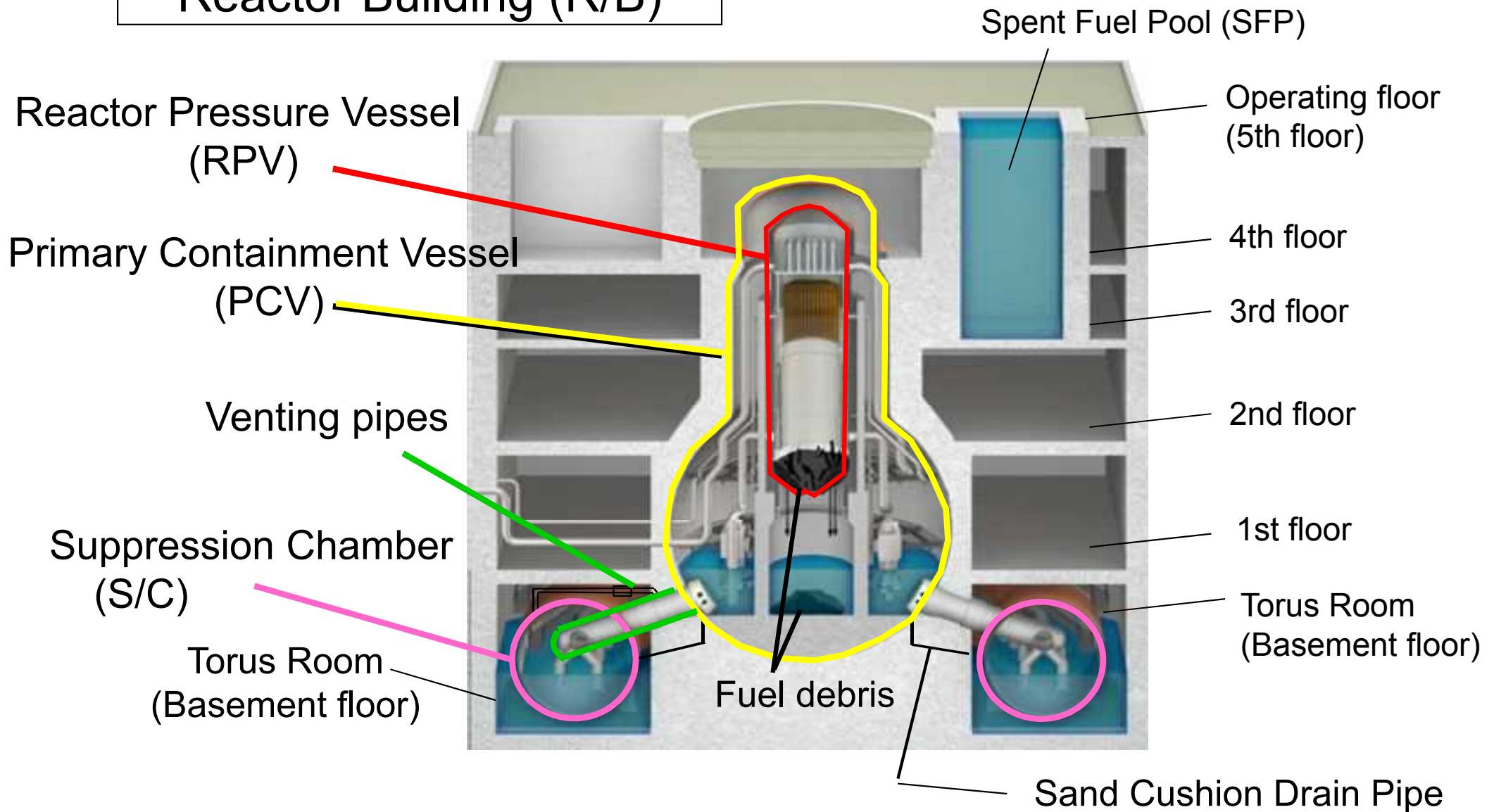


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# *1. Fuel Debris Retrieval*

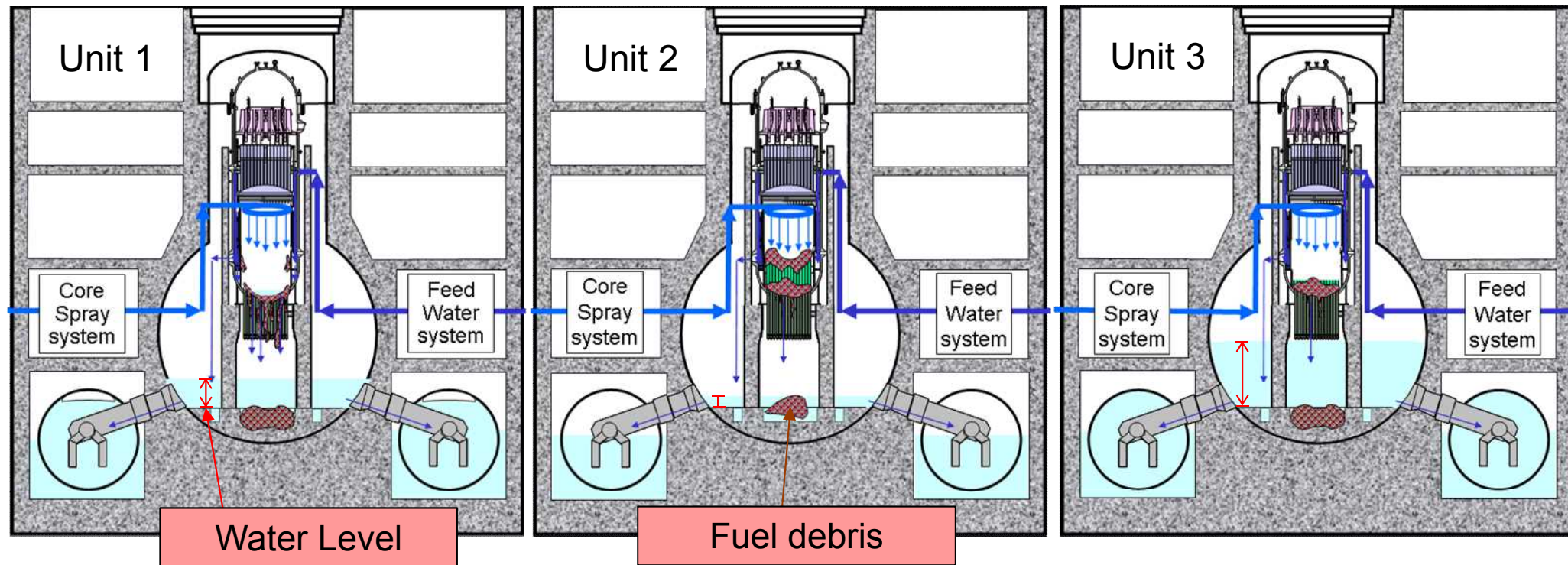
# Cross-section image of the Reactor Building (R/B)

## Reactor Building (R/B)



# Current status

- Fuel melt down in unit 1-3 is estimated and fuel debris Distribution is uncertain.
- PCV damage status is different in unit 1-3.



	Unit 1	Unit 2	Unit 3
<b>PCV water level</b>	about 3m	about 0.3m	about 6.5m

About accident progress analysis or more information,

[http://www.tepco.co.jp/en/press/corp-com/release/2015/1264602\\_6844.html](http://www.tepco.co.jp/en/press/corp-com/release/2015/1264602_6844.html)

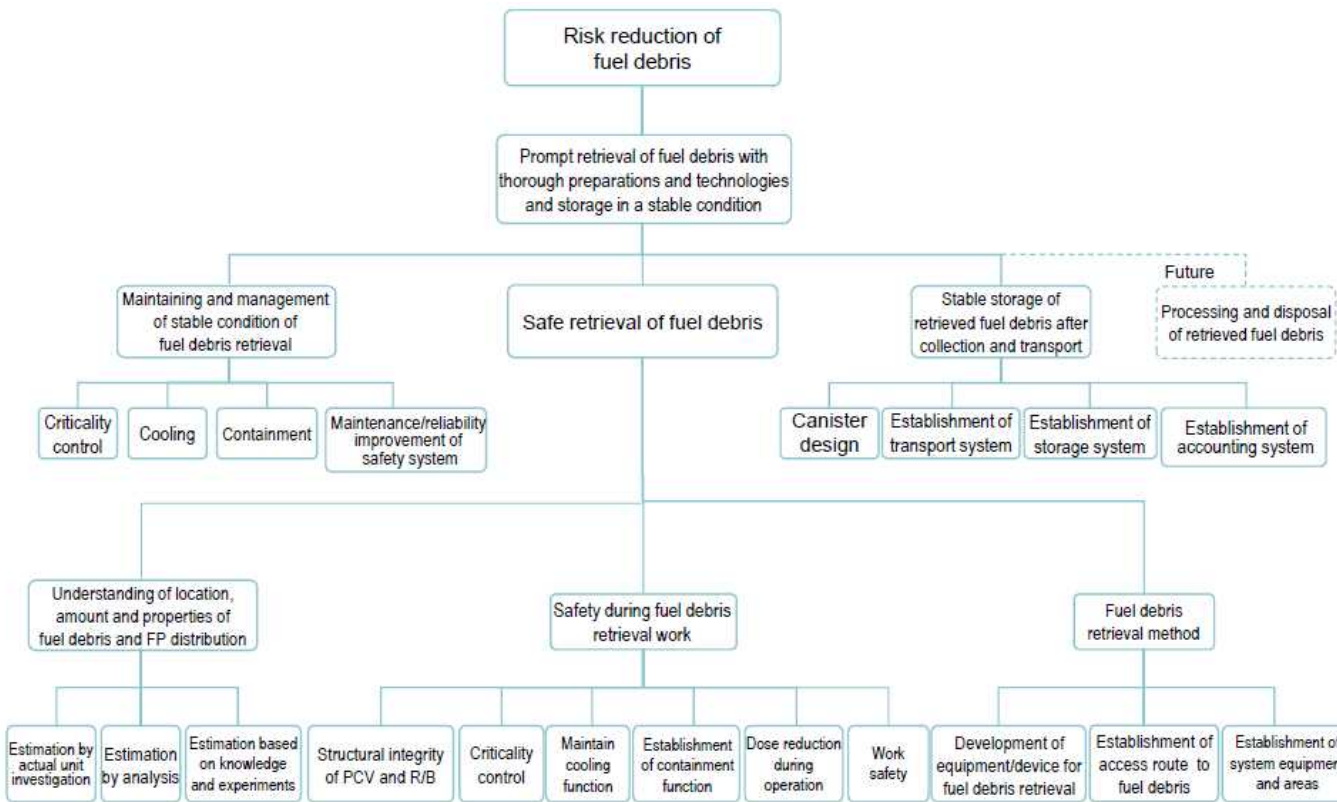
<http://www.tepco.co.jp/en/decommision/index-e.html>

# Activities for risk reduction of fuel debris

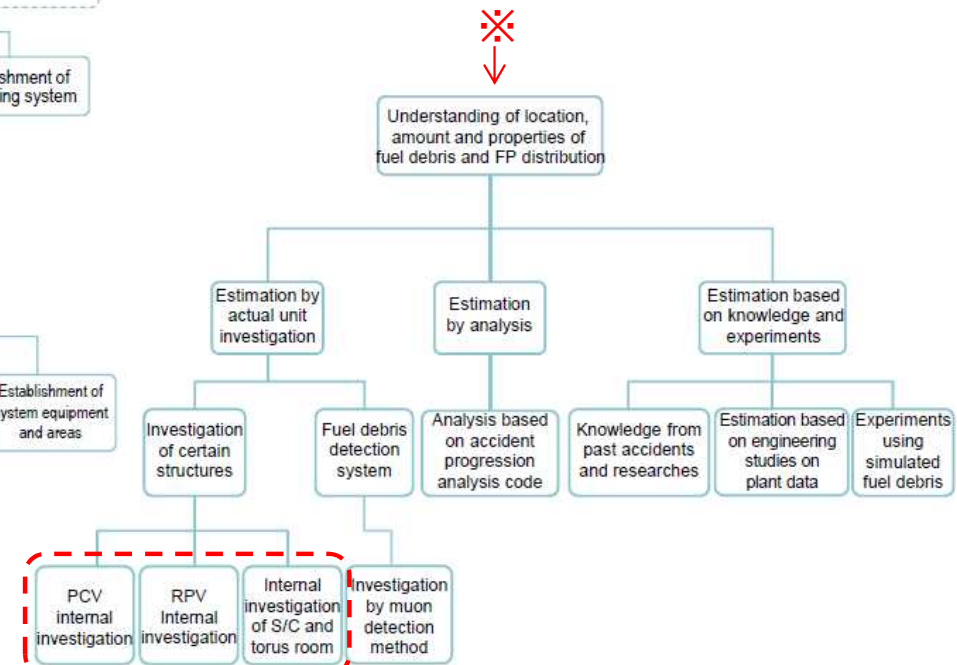
- Fuel debris retrieval is the activity for risk reduction.
- Various developments are required for fuel debris retrieval.

Quoted from “Strategic Plan”:

“Technical Strategic Plan 2015 for Decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company”,  
Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF)



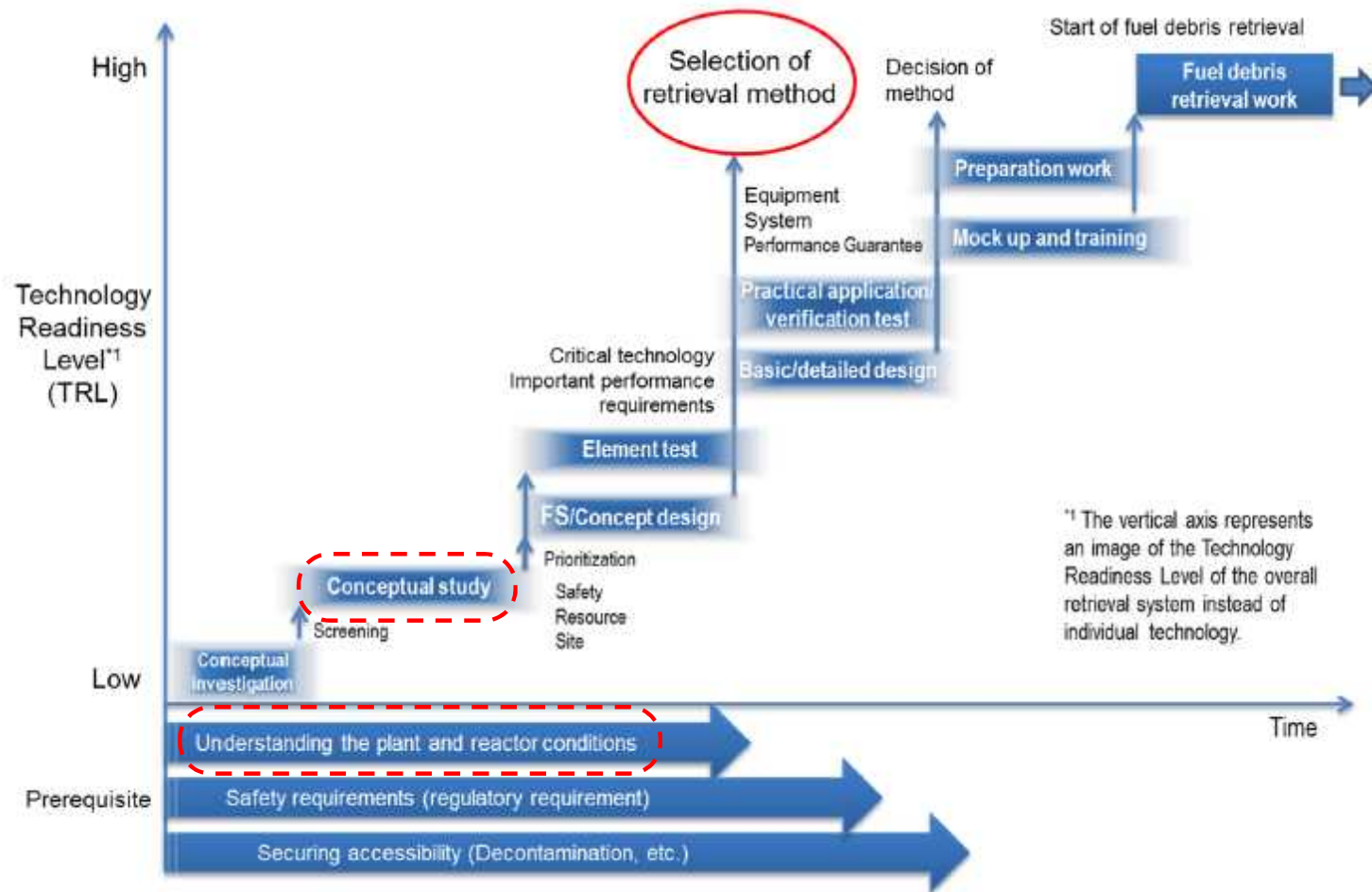
Logic tree on risk reduction for fuel debris



Logic tree for understanding the conditions of reactor vessels and fuel debris

# Processes toward fuel debris retrieval

- Information of the plant condition is required for plan of fuel debris retrieval.



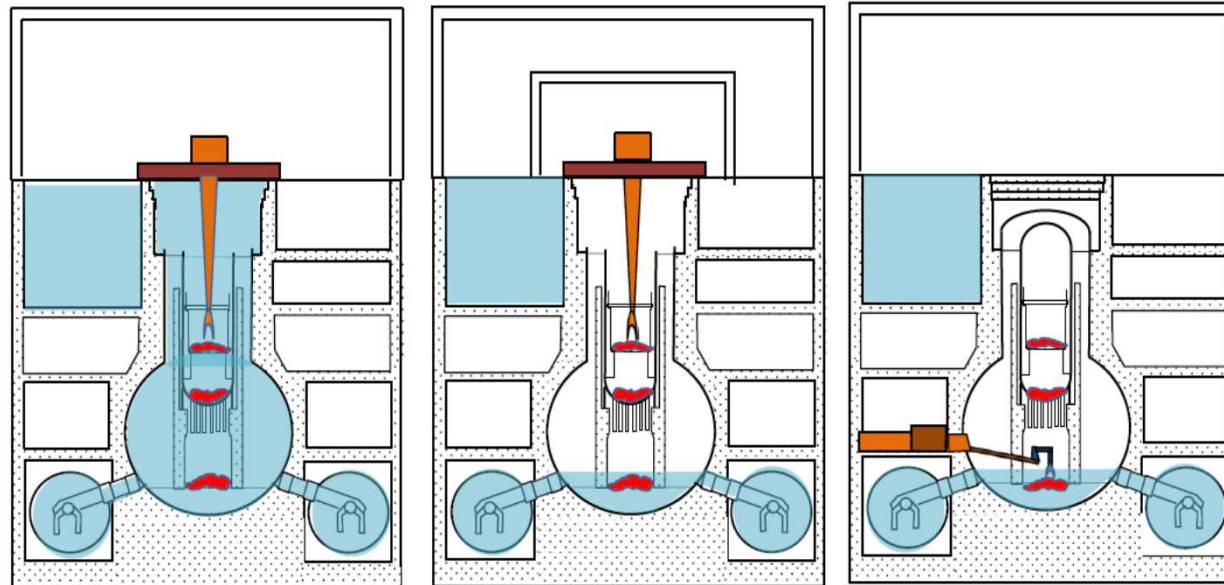
Processes toward fuel debris retrieval

Quoted from "Strategic Plan":

[http://www.dd.ndf.go.jp/ddwp/wp-content/themes/theme1501/pdf/SP2015\\_20150624\\_en.pdf](http://www.dd.ndf.go.jp/ddwp/wp-content/themes/theme1501/pdf/SP2015_20150624_en.pdf)

# Conceptual examples of fuel debris retrieval methods

- Information of the plant condition is required for plan of fuel debris retrieval.



Images of the options for fuel debris retrieval method

Fuel Debris	Submersion	Partial submersion	Partial submersion
Access	Top	Top	Side
Challenge	Water tightness, Seismic integrity	Radioactive dust dispersion, Radiation shielding	

Quoted from "Strategic Plan":

[http://www.dd.ndf.go.jp/ddwp/wp-content/themes/theme1501/pdf/SP2015\\_20150624\\_en.pdf](http://www.dd.ndf.go.jp/ddwp/wp-content/themes/theme1501/pdf/SP2015_20150624_en.pdf)

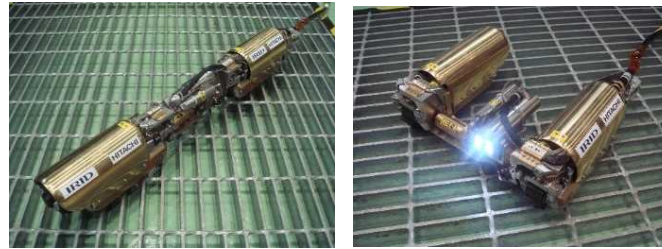


# PCV survey

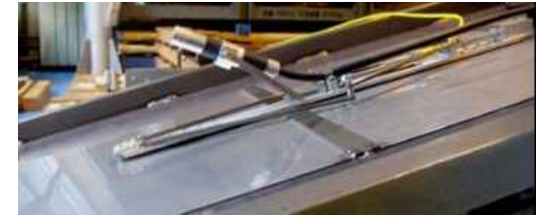
[Unit 3] PCV boundary Survey (PCV Hatch)



[Unit 1] PCV internal Survey (on the Grating Floor)



[Unit 2] PCV boundary Survey (on the Rail)



[Unit 1] PCV boundary Survey (above the S/C)



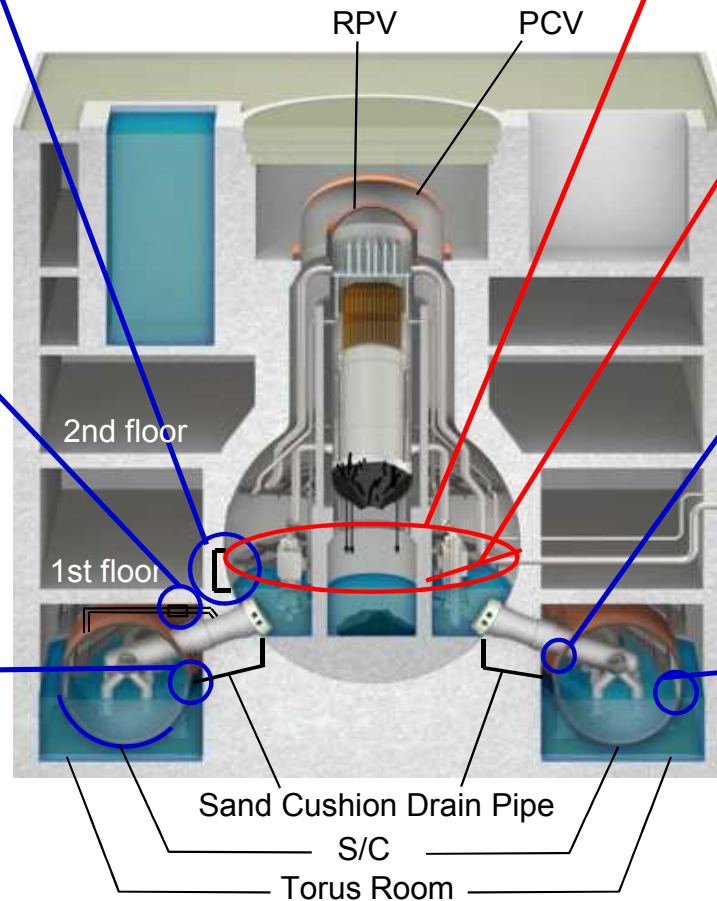
[Unit 2] PCV boundary Survey (under the Venting Pipes)



[Unit 1] PCV boundary Survey (under the Venting Pipes)



[Unit 2] PCV boundary Survey (measurement of S/C water level)

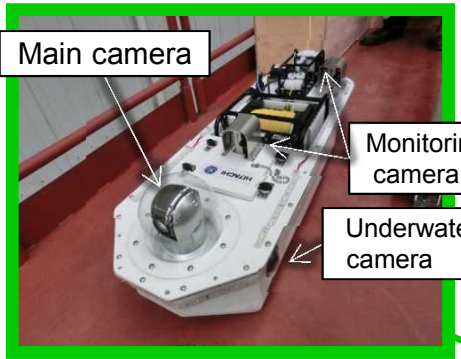


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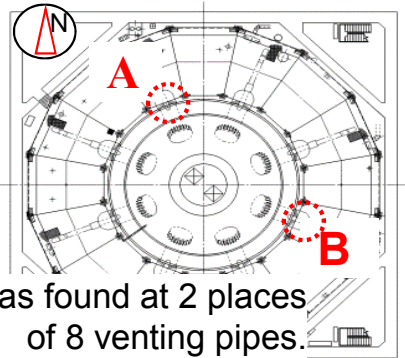
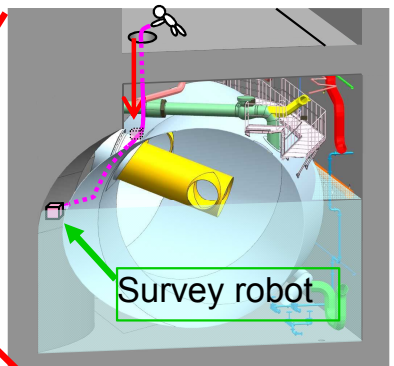
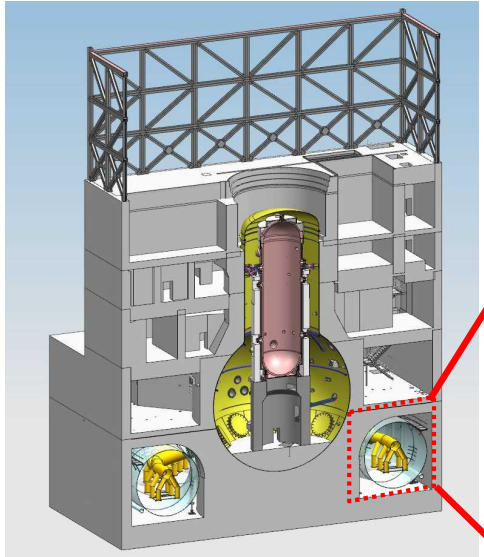
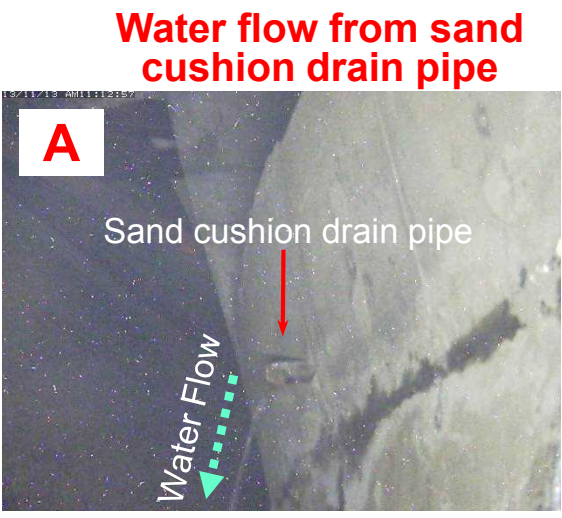
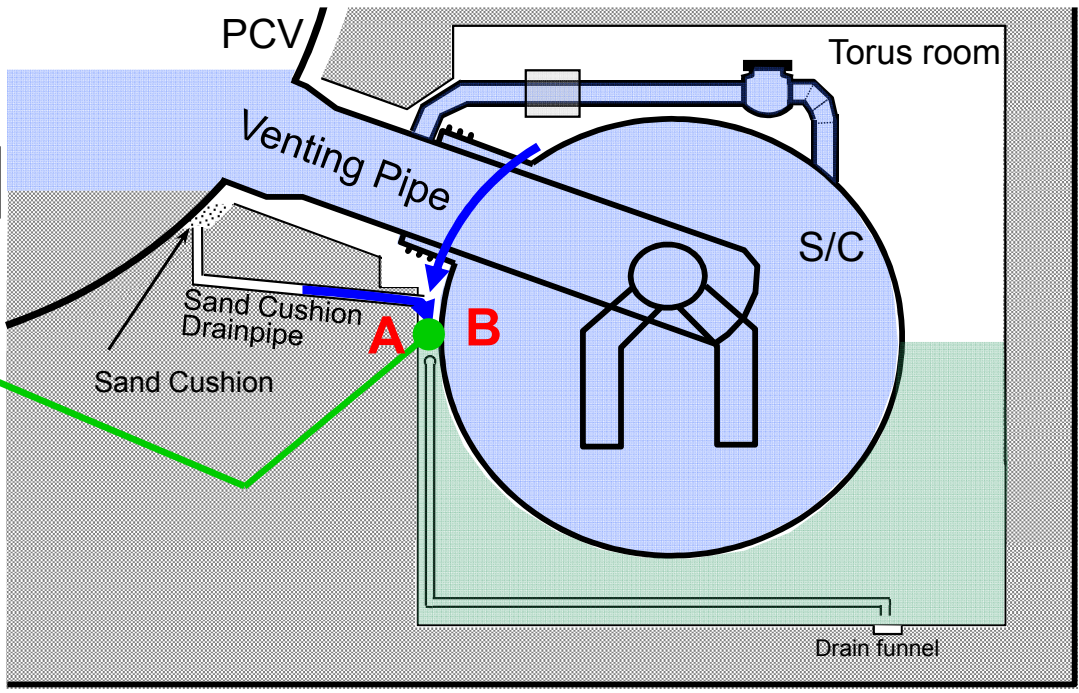
## *2. PCV Surveys with Robotics*

# Unit 1 surveys (survey under venting pipes)

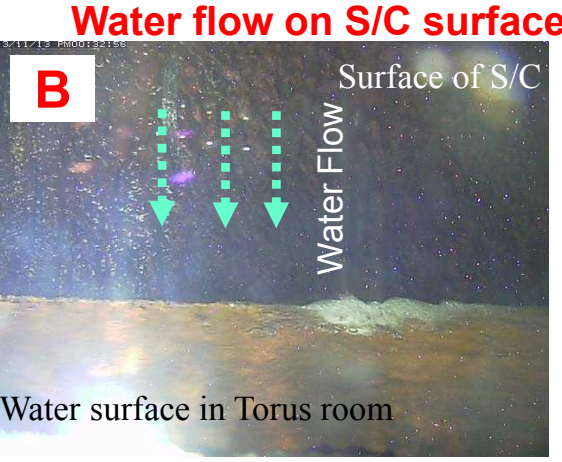
- Water leakage was found in sand cushion drain pipe. (November 2013)
- It indicates the possibility of D/W shell damaged.



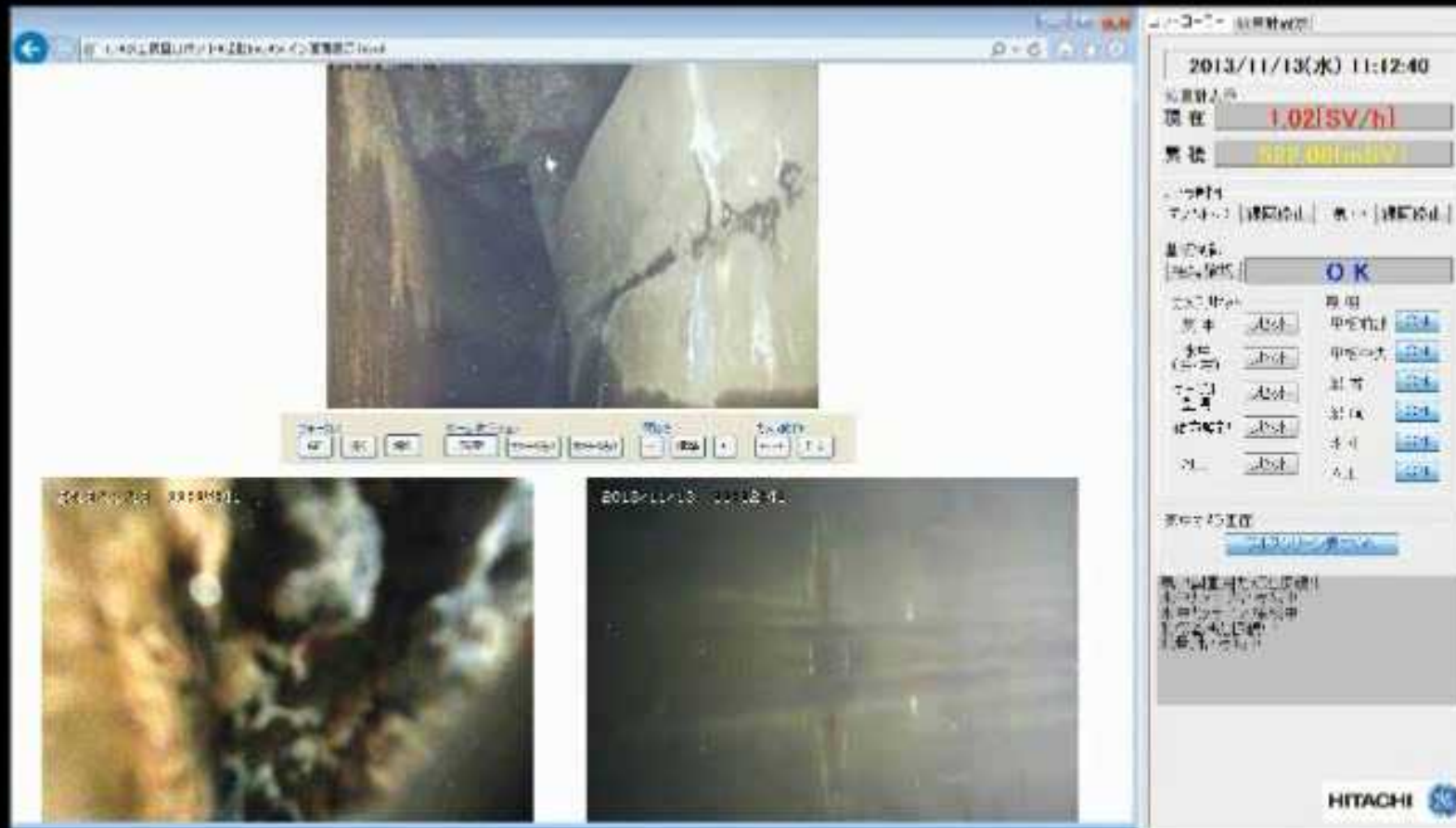
Above water boat(Hitachi-GE)



Leakage was found at 2 places of 8 venting pipes.



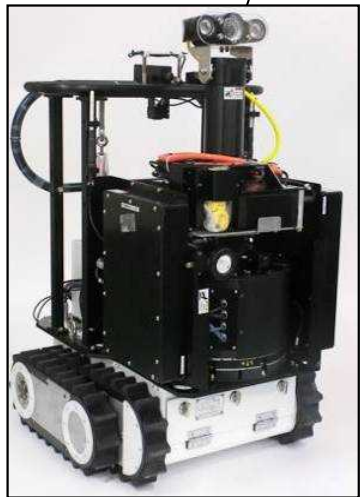
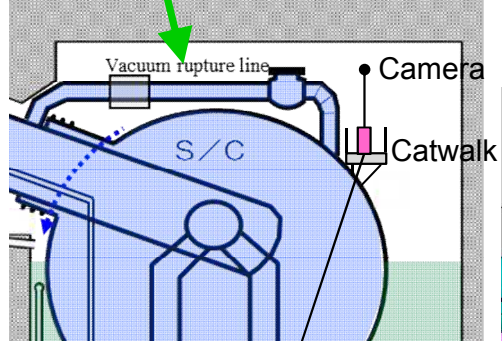
# Video of Unit 1 surveys (Survey under venting pipes)



# Unit 1 surveys (Survey above S/C)

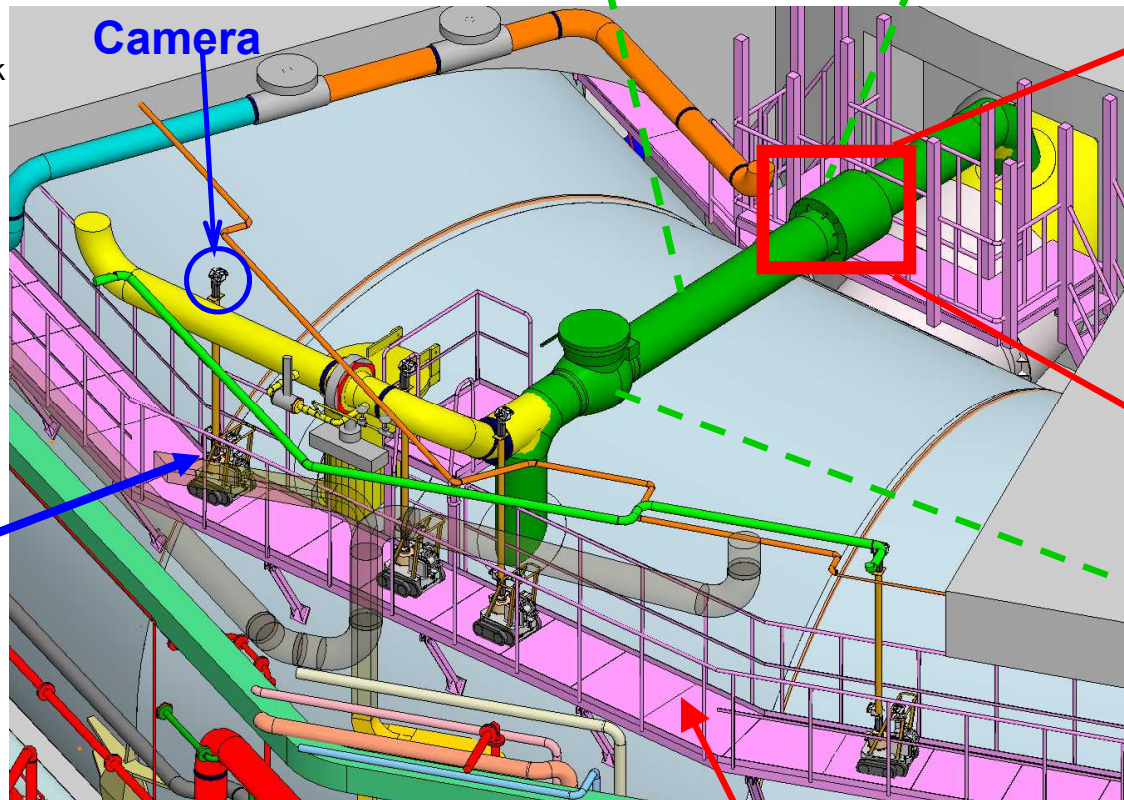
- Water leakage was found at the bellows cover on the vacuum breaker.
- No other leaks were found. line (May 2014)

## Vacuum breaker line



Investigation device for the upper part of the S/C (IRID)

## Vacuum breaker line Bellows (expansion joint)



Catwalk



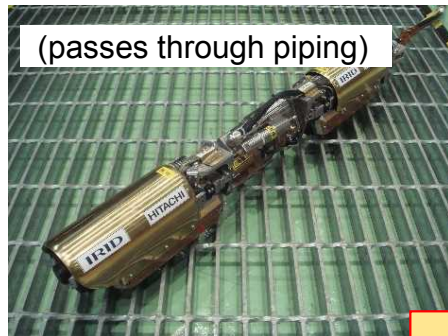
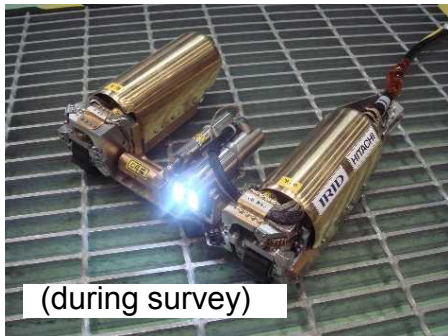
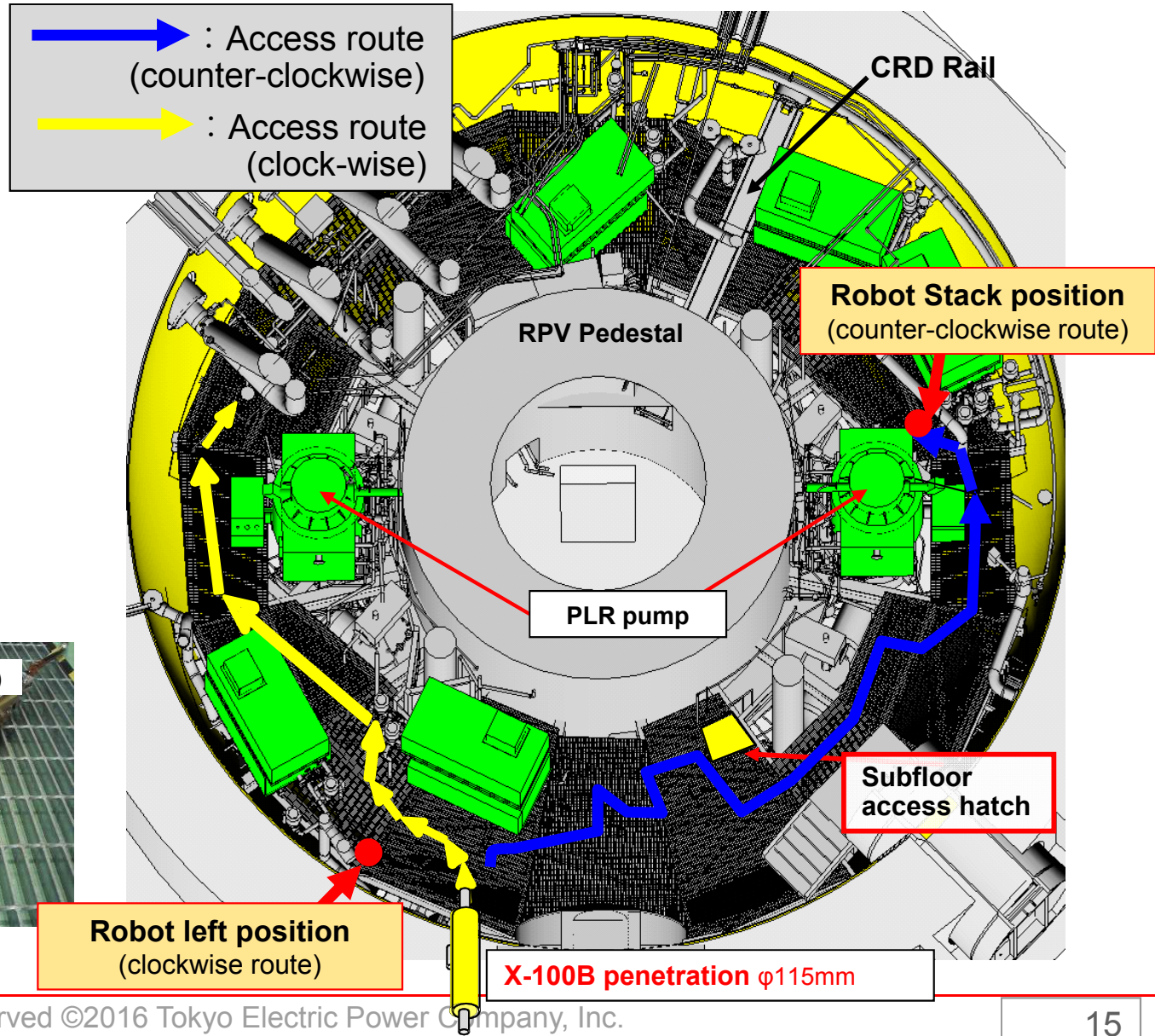
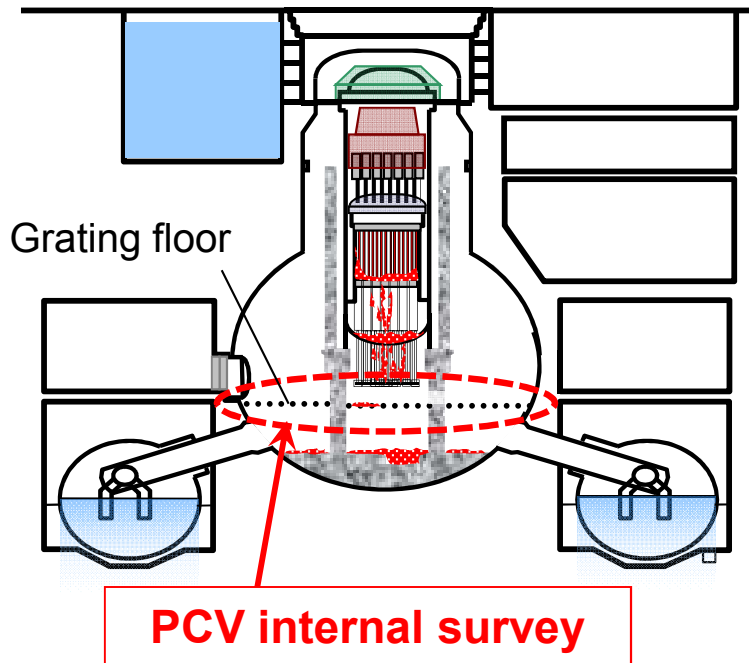
Vacuum breaker

# Video of Unit 1 surveys (Survey above S/C)



# Unit 1 surveys (Survey of the inside of the PCV)

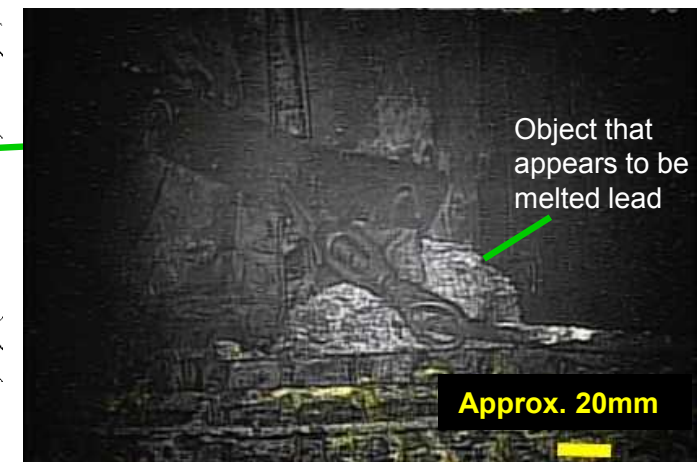
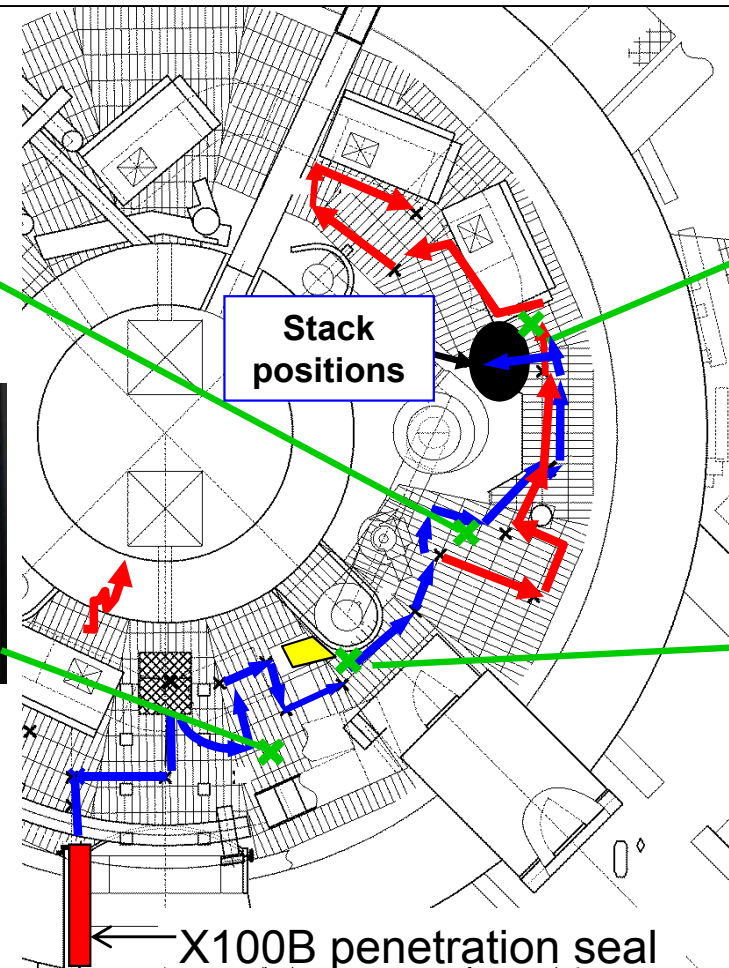
■ Transformable robot was used for PCV internal survey. (April 2015)



PCV internal survey device(IRID)

# Unit 1 surveys (Survey of the inside of the PCV)

- Detected Dose rate: Approx. 5-10Sv/h and Temp. Approx. 18-21 degree C.
  - Does not appear to be dependent upon a specific location.
- No apparent damage was found
  - On the equipment above the grating on the first floor of the PCV.
- Melted lead was found a lot. (Melting point 328 degree C)



- ✕ Primary fallen objects
- Planned route
- Actual route (April 10, 2015)

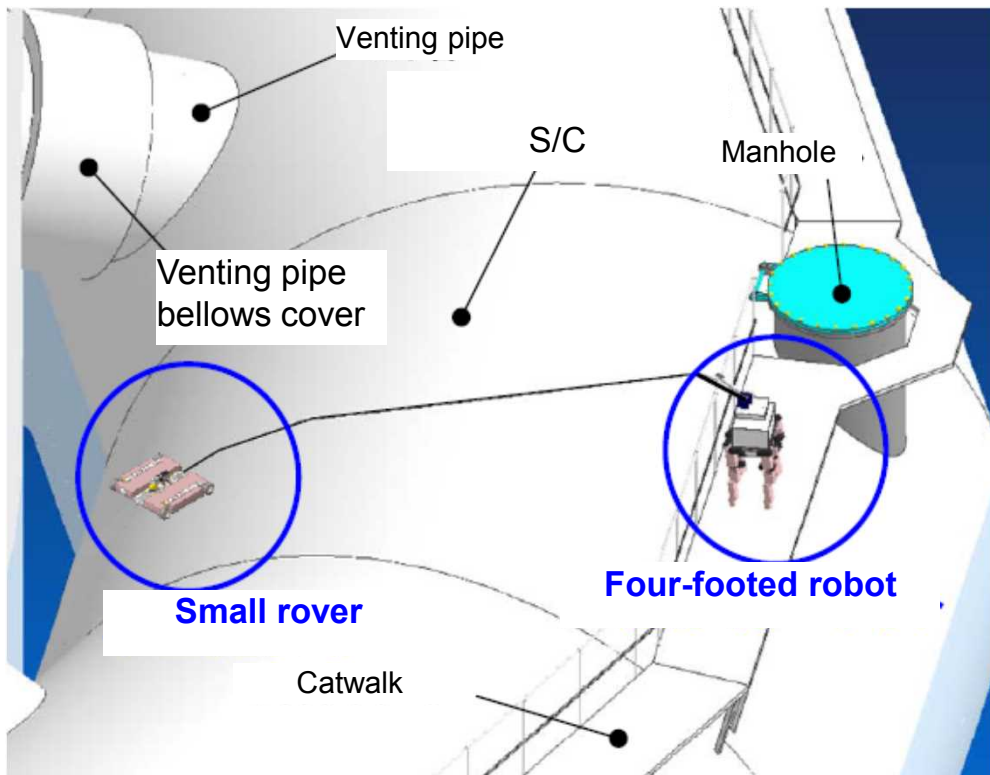


# Video of unit 1 surveys (Survey of the inside of the PCV)



# Unit 2 surveys (Survey under venting pipes)

- A pair of Four-leg walking robot and small rover was used for survey.
- No leak was found.(December 2013 to March 2014)



Four-leg walking robot



313mm(L) × 327mm(W) × 47mm(H)  
(Toshiba)

Small rover

## Survey results



Venting pipes sleeve end



Bottom of venting pipe bellows cover

## Video of Unit 2 surveys (Survey under venting pipes)

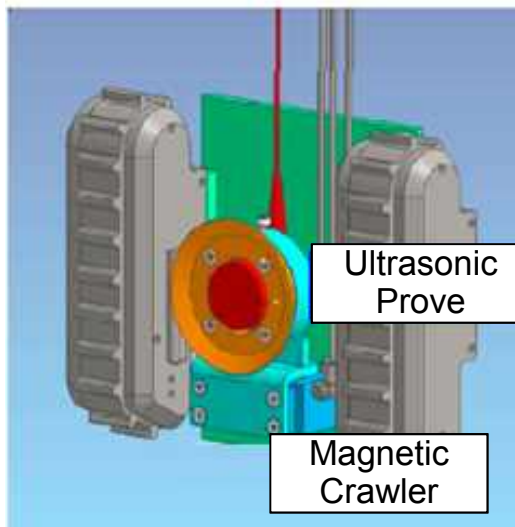


# Unit 2 surveys (Measurement of water level in S/C)

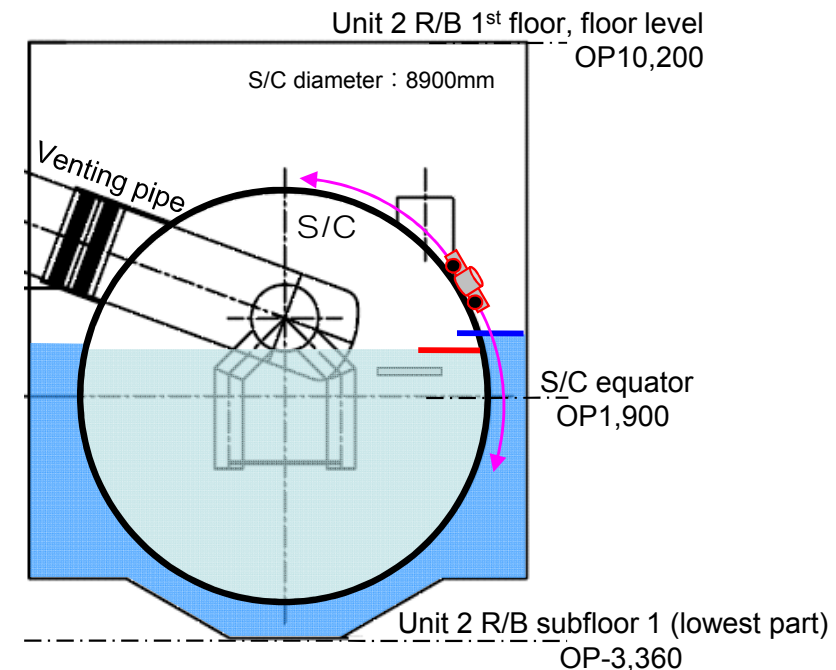
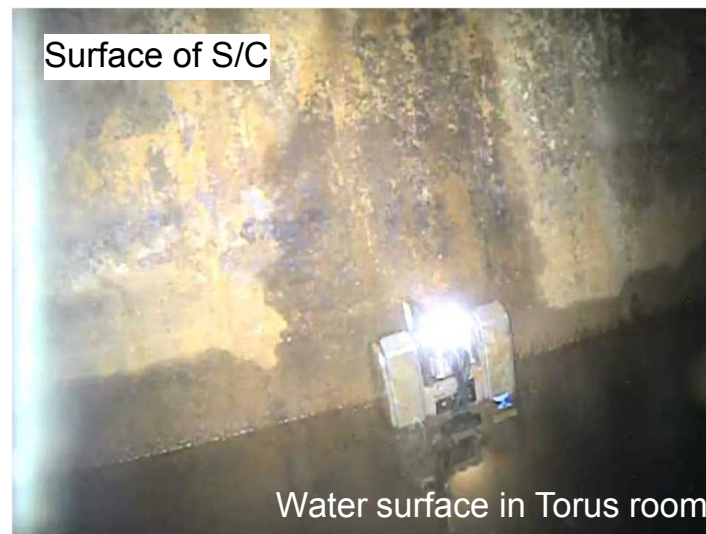
- Water level in S/C was same as in Torus room. (January 2014)
- It suggests a leakage at submerged parts of S/C or connecting pipes.

Measurement date	January 14	January 15	January 16
Water level inside the S/C	Approx. OP3,210	Approx. OP3,160	Approx. OP3,150
Water level in Torus room (reference)	Approx. OP3,230	Approx. OP3,190	Approx. OP3,160
Water level difference	Approx. 20mm	Approx. 30mm	Approx. 10mm
Measurement method	Measurement of direct distance of submerged structures		

[Addendum] It is assumed that water levels inside the S/C are being affected by the level of accumulated water in the torus

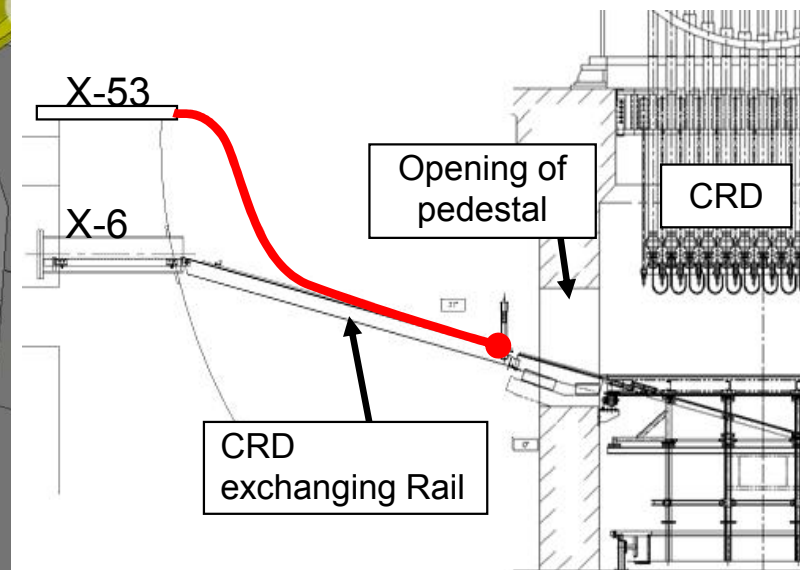
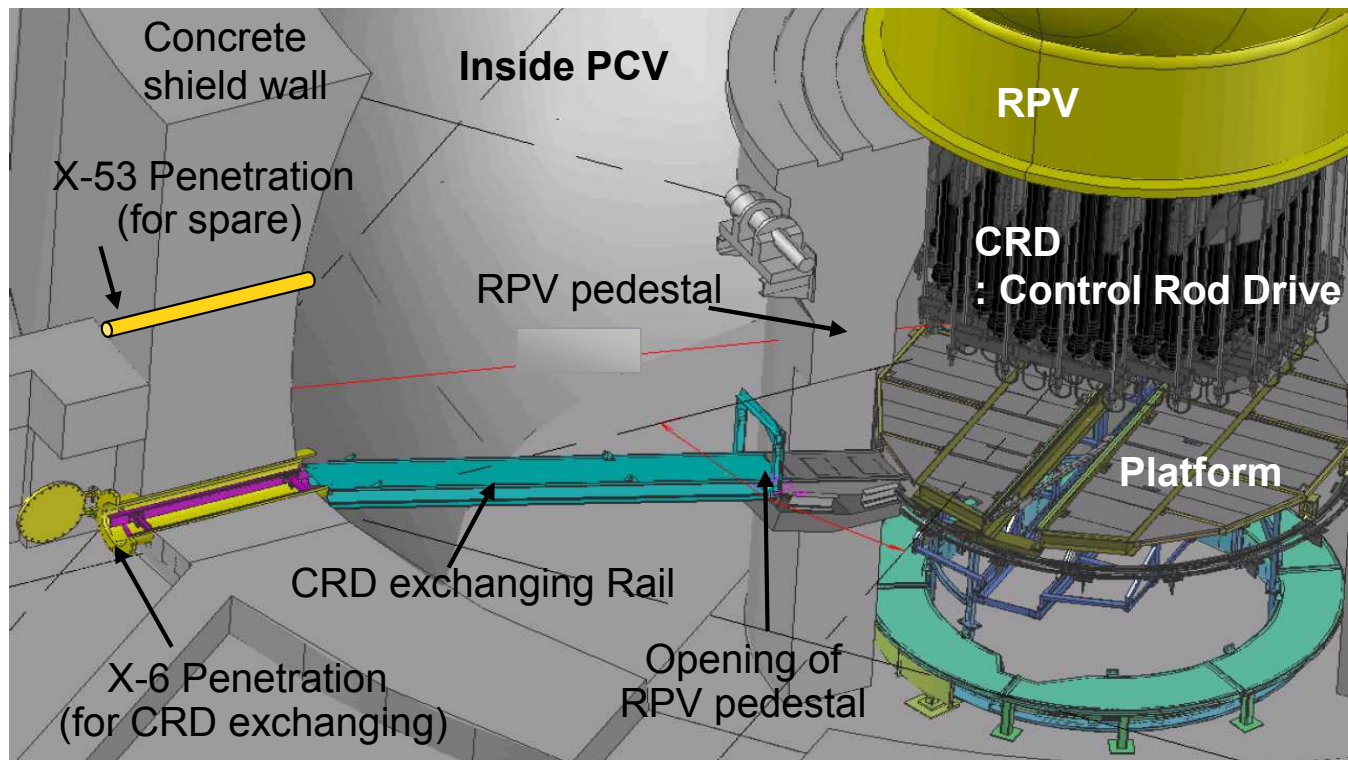


S/C water level measurement device (ATOX)



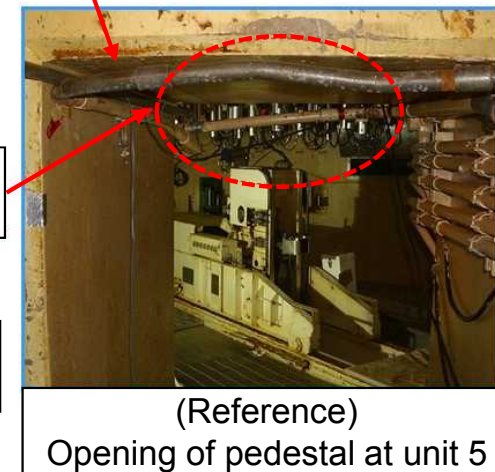
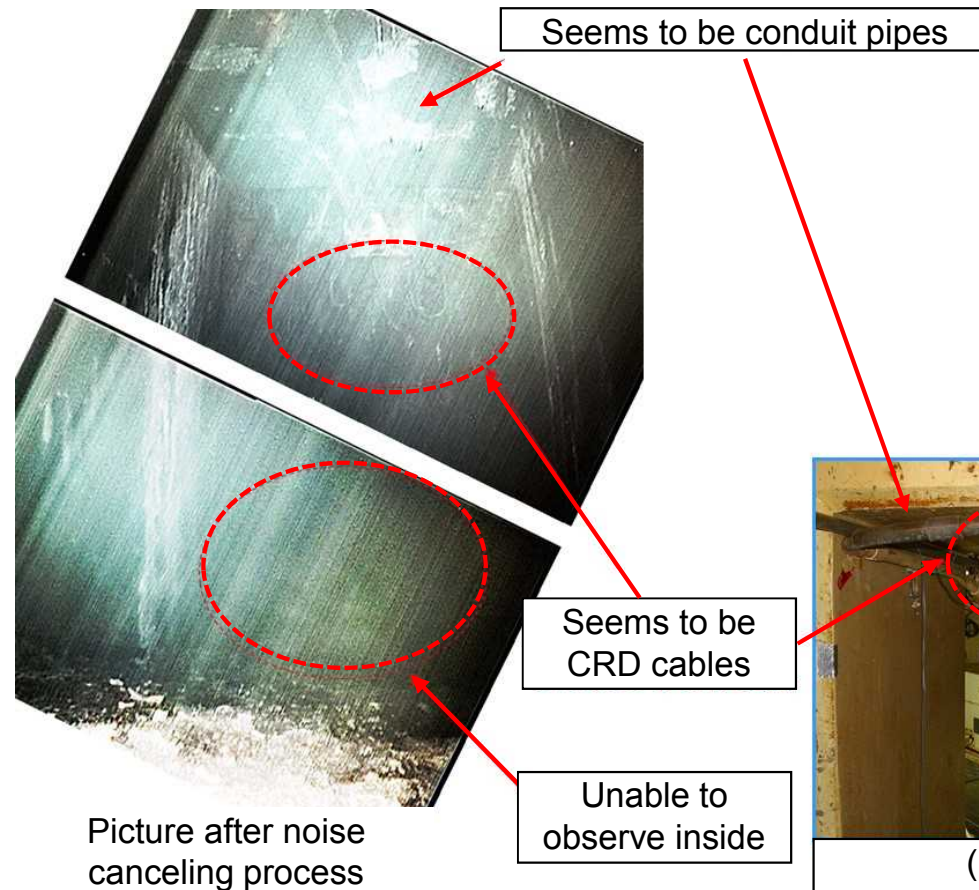
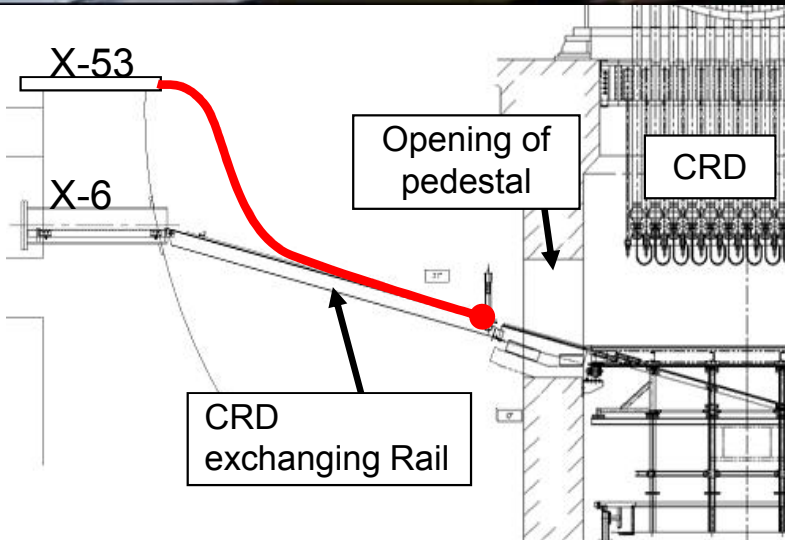
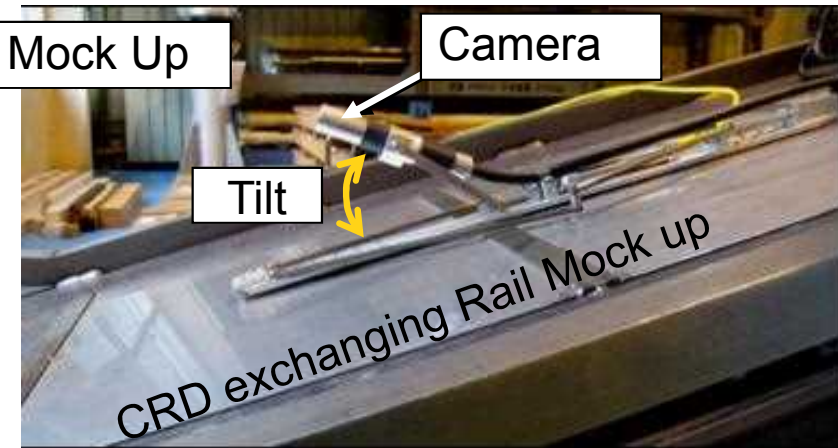
# Unit 2 surveys (Survey of the inside of the PCV)

- PCV internal survey was conducted at Unit 2. (March 2013)



# Unit 2 surveys (Survey of the inside of the PCV)

- Cables were identified at bottom of the RPV and suggested that huge collapse doesn't happen at bottom and under the RPV.
- Detected dose rate on the CRD rail was 24-36 Sv/h.
  - Significant increase doesn't appear at near the opening of pedestal.



# Unit 2 surveys (Survey of the inside of the PCV)



Zoom up to the cables identified.

# Unit 3 surveys (PCV equipment hatch)

- A small robot was used survey the PCV equipment hatch seal. (November 2015)
- Rust was found down from around the water levels inside the PCV, but no leaks are found.

① Small survey device (when used to hold a smart phone)

180° expandable

Camera lens

LED light

Smart phone

Device

PCV boundary survey (PCV Hatch)

Rust has accumulated on the floor, some areas are moist (dark areas)

No water in rail grooves

PCV water level

Small survey device (TEPCO R&D center)

- weight : 0.8kg
- length : 319mm
- width : 77mm
- height : 105mm



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## *3. Lessons Learned*

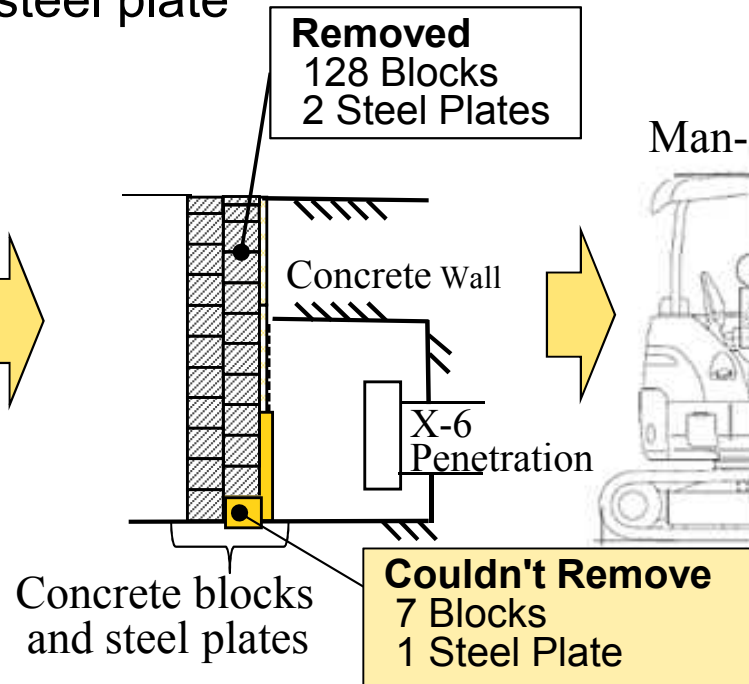
# Lessons Learned (1)

## Case1

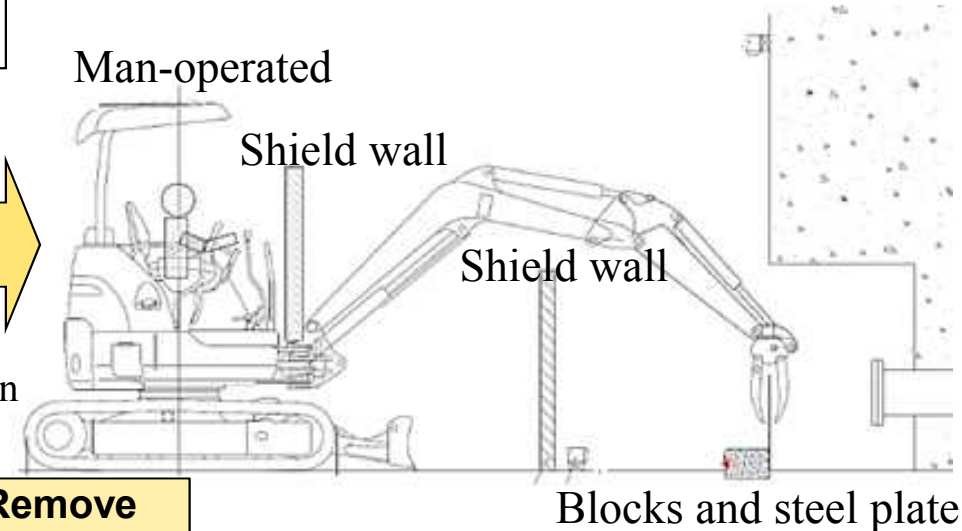
[Plan]  
Remote Robot Work  
(Shield block removal at X-6, Unit 2)



[result]  
Some Block Remained  
By block stuck and unexpected steel plate



[recovery]  
Man-Operated Work  
With heavy machinery

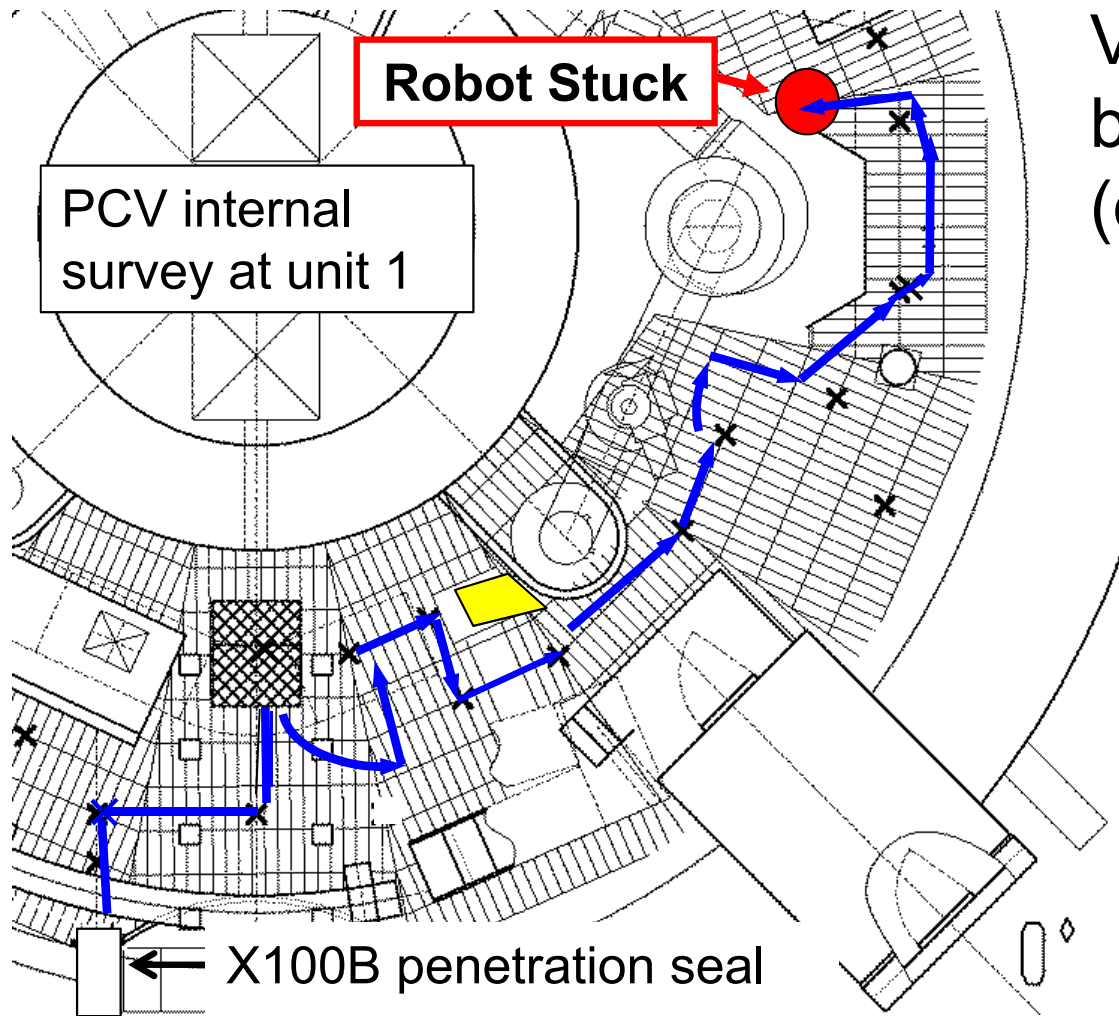


### ■ Caused by

- Unexpected stack of concrete blocks. Rust condition was difficult to predict.
- Unexpected steel plates.
- Unexpected structure of floor groove under the blocks.

# Lessons Learned (2)

## Case2



Vehicle robot stuck at the gap between the floor grating plates.  
(doesn't mean project failed)

### ■ Caused by

- Floor gap of grating plates (height and width) was expected with margin and operation training done, but actual gap was greater than simulated.
- No detailed engineering drawing exists for existing grating floor plates.

## Lessons Learned (3)

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- 2 cases were both caused by “Unknown”.
  - Difficulty in predict the plant conditions
  - Difference between documents and present condition.
  - Or no document.

### How to treat the Unknown?

The unknown condition continues on in this Deconditioning work.  
The key of the project.

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## *4. Conclusion*



## 4. Conclusion

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- Lots of useful information have been obtained even though various restrictions exist.
  - Examples of restrictions:
    - Equipment had to be developed uncertainty about conditions of access routes
    - Application of electronics is restricted due to extremely high dose rate inside the PCV.
    - Limited space to install robots into the PCV, such as PCV penetration, require robots to be miniaturized.
    - Handling of cables in PCV without human-help
- Improvement of flexibility and reliability is essential in order to adjust various situations (sometimes unexpected happens), as more severe conditions are expected in future surveys.
- How to face the Unknown might be a key of this mission.

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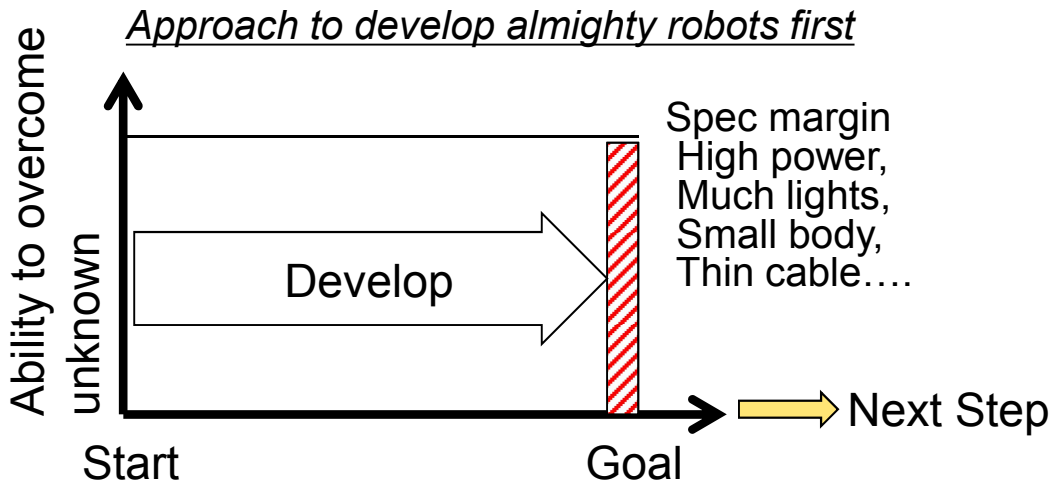
*Thank you for attention.*

# For Panel Discussion

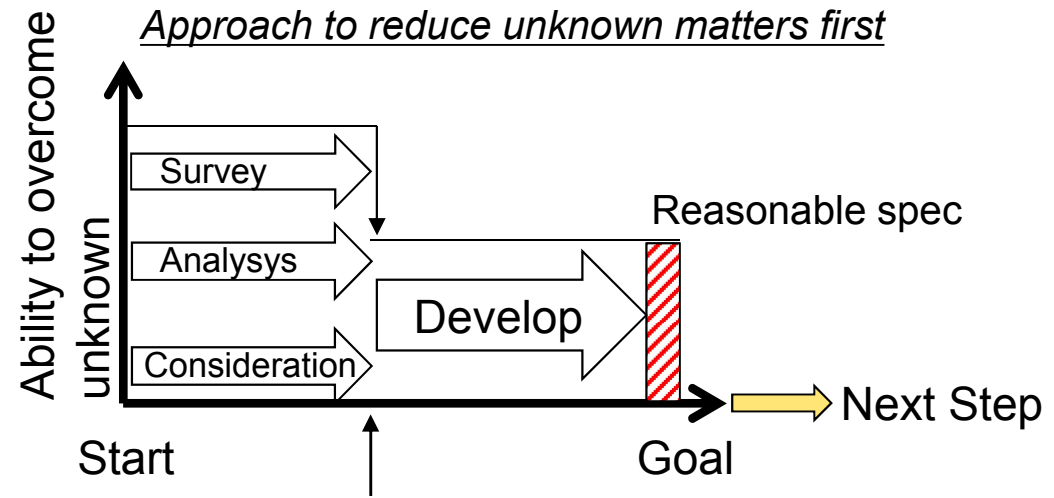
**Extreme difficulty** in fuel debris retrieval

↳ **Due to unknown matters**

↳ **How to treat unknowns?**  
*The key for success!*



Various unknowns may spoil development.



Re-planning with new findings may take time.  
Development may not be eased.



**Balance is important!**