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IROS2015, Hamburg, Germany

Robot Technology for Nuclear Decommissioning of Fukushima Daiichi Nuclear Power Station

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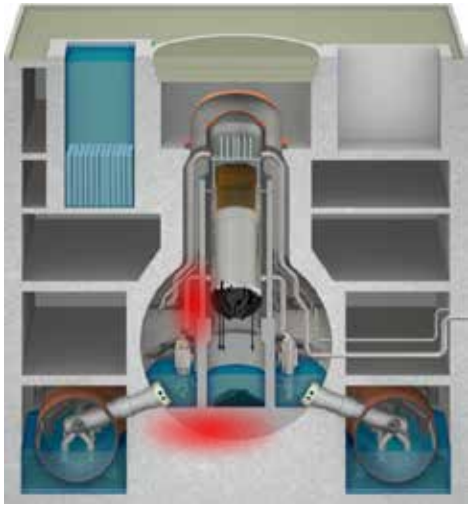
*The contents of this presentation include the results of "Establishment of basic technology for decommissioning and safety of nuclear reactors for power generation in 2013 (technological study and research concerning forming an idea for processing and disposing of radioactive waste resulting from the accident)", a project commissioned by the Ministry of Economy, Trade and Industry, and the 2013-2014 subsidiary for decommissioning and contaminated water measures (development of technologies for processing and disposing of waste resulting from the accident).
*Plant information included in this document is taken from TEPCO's official website.

Outline of Today's Talk

- About IRID
- Robots for the decontamination task
- Robots for the RPV inspection task
- Summary







I extend my sincere condolences for all the victims, and express my hearty sympathy to all the evacuees due to the Earthquake

About IRID

Research & Development Consortium for the decommissioning of the Fukushima Daiichi NPS

Founding Members (18)

- National Research Institutes(2):
  Japan Atomic Energy Agency (**JAEA**),
  National Institute of Advanced Industrial Science and Technology (**AIST**).

- Manufacturers(4):
  Toshiba Corporation, Hitachi-GE Nuclear Energy, Ltd.,
  Mitsubishi Heavy Industries, Ltd., ATOX (since May 29, 2014).

- Electric utilities etc. (12):
  Tokyo Electric Power Company (hereinafter called as EPC) (**TEPCO**),
  Hokkaido EPC, Tohoku EPC, Chubu EPC, Hokuriku EPC, Kansai EPC,
  Chugoku EPC, Shikoku EPC, Kyushu EPC, The Japan Atomic Power Company,
  J-POWER, Japan Nuclear Fuel Limited.

Scope of Business

IRID gathers knowledge and ideas from around the world for the purpose of R&D in the area of nuclear decommissioning under the integrated management system.

Over 700 researchers participate in IRID and engage in the R&D projects at their facilities

R&D for Decommissioning

Promote collaboration for Decommissioning with Domestic and International Parties

Development of Human Resource for R&D

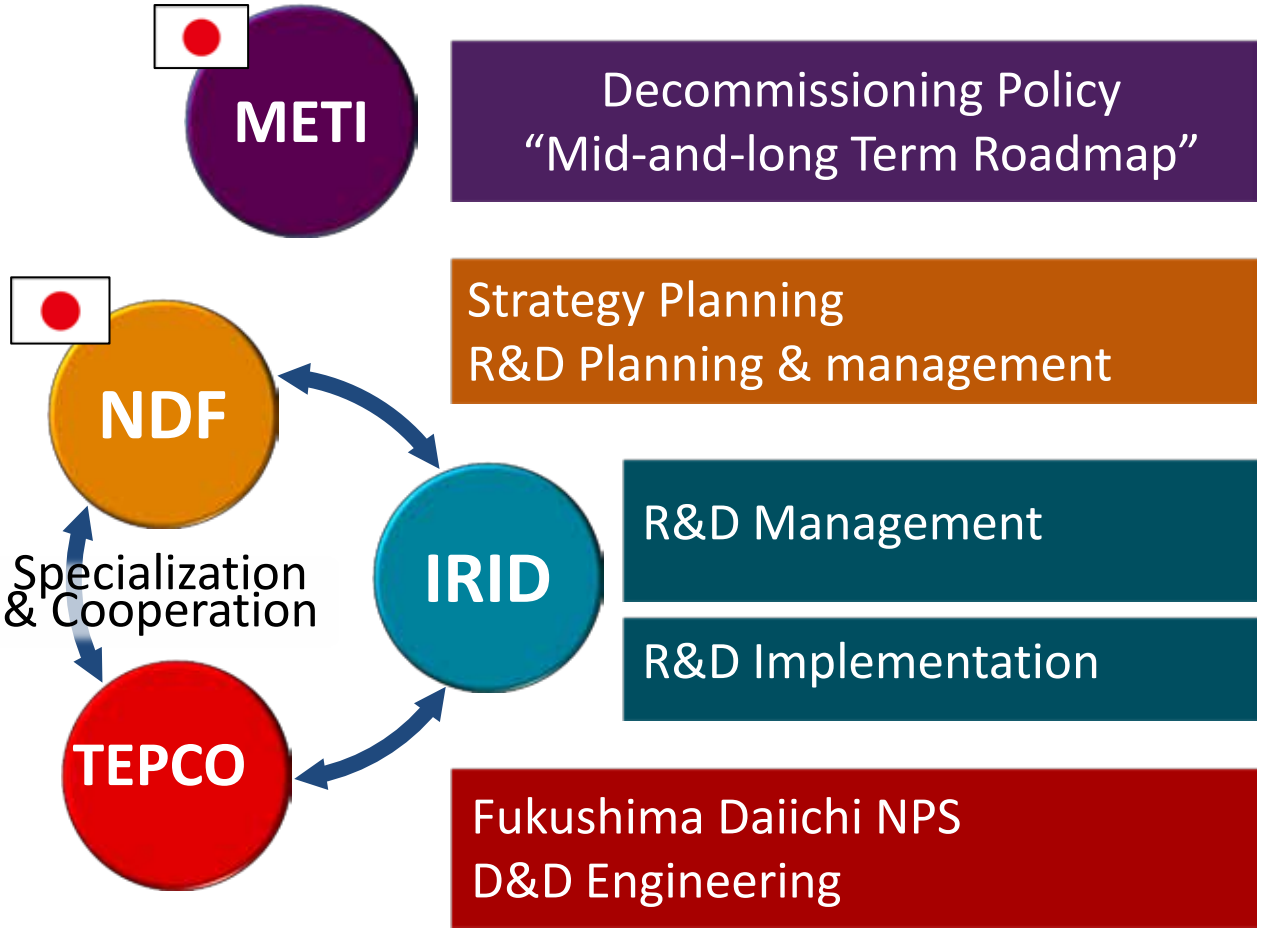
R&D projects:

・Investigation of damaged PCV and preparation of repair tools
・Preparation for fuel debris retrieval
・Treatment and disposal of radioactive waste

15 projects (FY2015)

For more information >> ***http://www.irid.or.jp/en***

Relationship Diagram

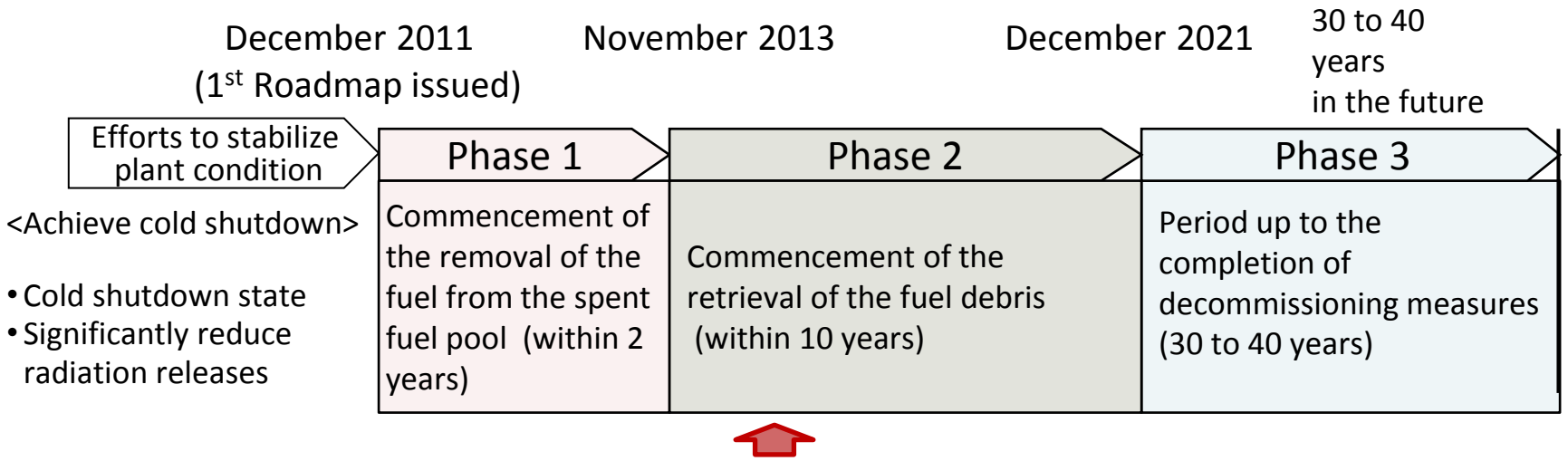


METI: Ministry of Economy, Trade and Industry (http://www.meti.go.jp/)

NDF: **N**uclear Damage Compensation and
Decommissioning **F**acilitation Corporation (http://www.ndf.go.jp/)

Mid-and-Long-Term Roadmap

SAFETY AND RISK REDUCTION IN FUEL REMOVAL

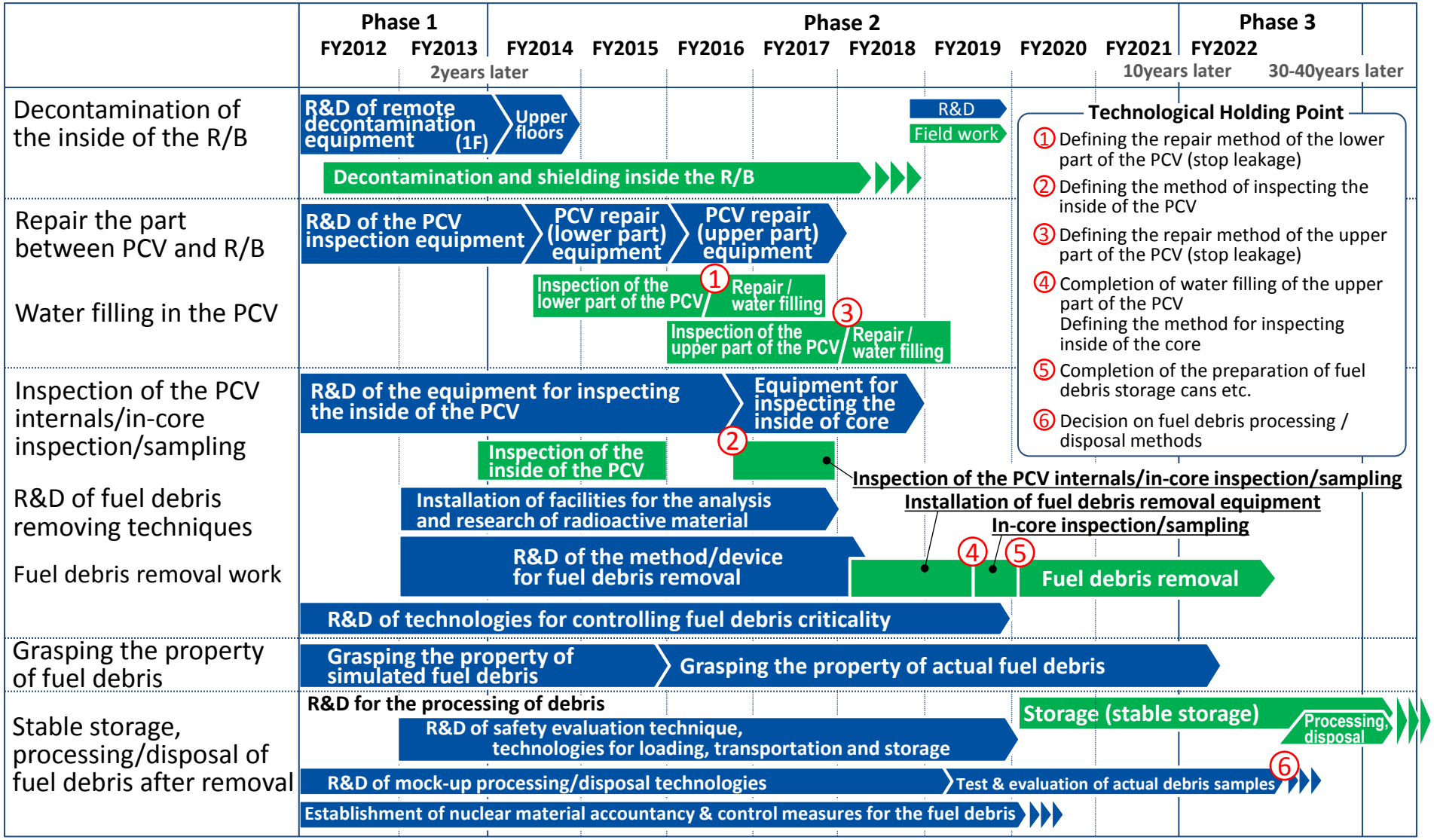


Mid-and-Long-Term Roadmap was amended on June 12, 2015 and the target time frame (milestone) was specified.

【Fuel Debris Retrieval】

- Decision of principle plan for fuel debris retrieval of each Unit — within 2 years
- Confirmation of fuel debris retrieval method for the first Unit — by the first half of FY2018
- Commencement of fuel debris retrieval from the first Unit — by December 2021

Fuel debris retrieval plan on Mid-and-Long-Term Roadmap (Unit 2)



Fuel debris retrieval procedure

Current

Technology R&D

Fuel Debris Retrieval from 2021

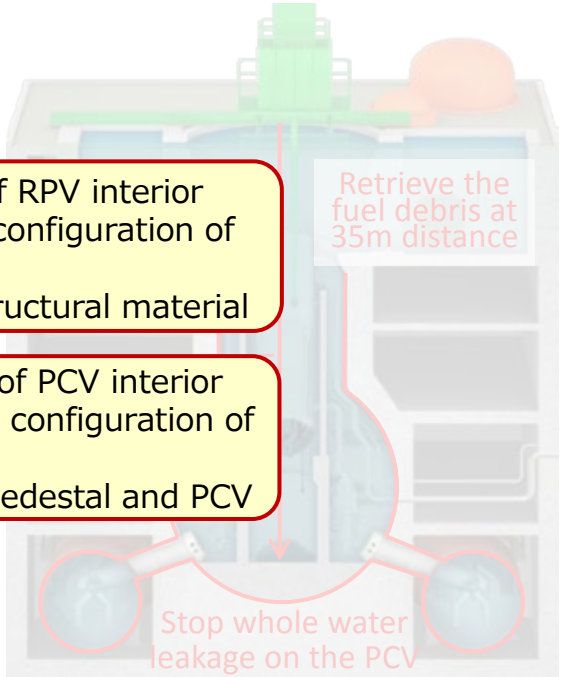
Removal of fuel from Spent fuel pool

Decontamination of work area and walkway

Investigation of RPV interior
・Location and configuration of fuel debris
・Damage of structural material

Investigation of PCV interior
・Location and configuration of fuel debris
・Damage of Pedestal and PCV

Investigation and stop of water leakage from PCV



Submersion method

Retrieve the fuel debris at 35m distance

Stop whole water leakage on the PCV

Most favorable approach for minimizing the radioactive exposure of workers

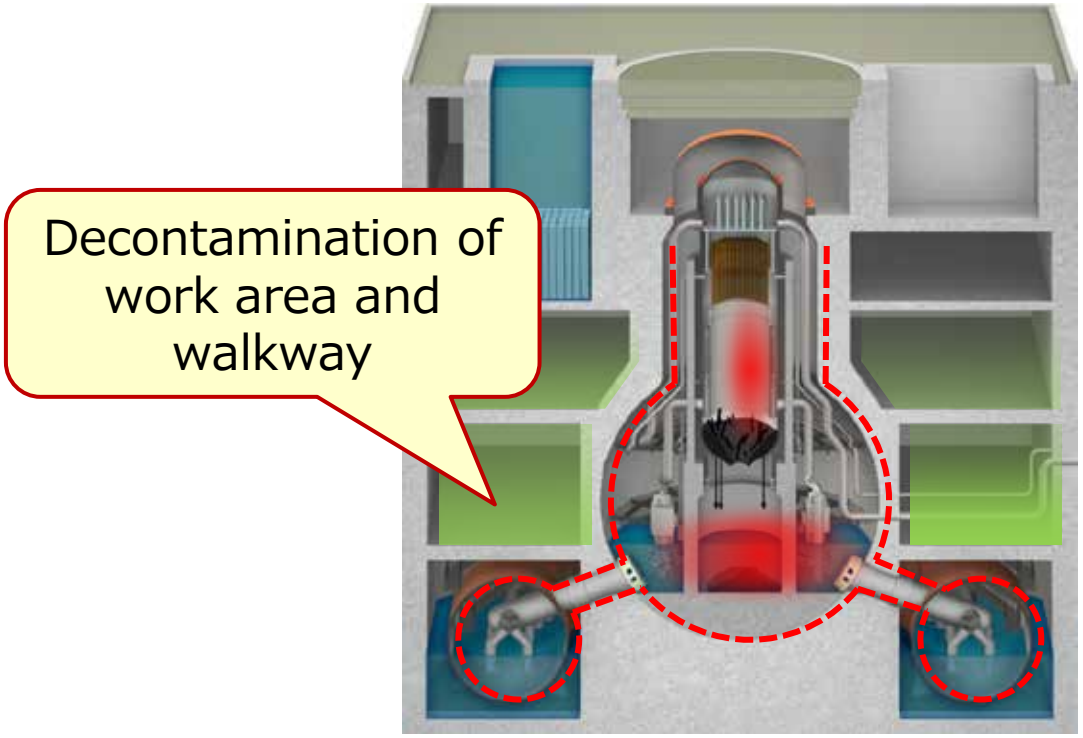
In-air method

Dose rate
*PCV 100 Gy/h
*RPV 1k Gy/h
*Requirement level for equipment R&D

Ensure boundaries

Operate and maintain the equipment in the PCV boundary

Research and Development for the decontamination task

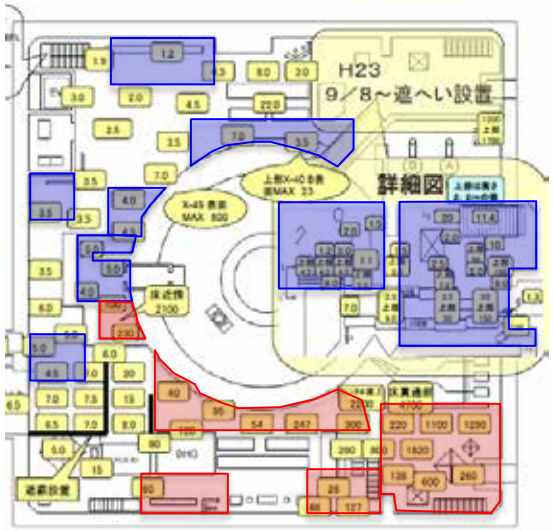
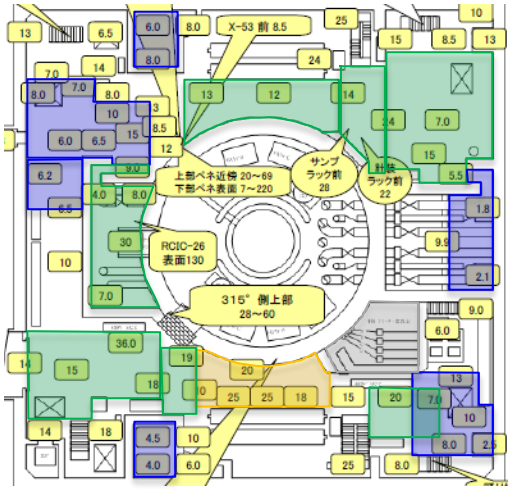


Dose rate goal for decontamination equipment

◆ Development goal of the decontamination equipment

(the needs for PCV leakage investigation repairing work, and overall dose reduction scenario)

3 mSv/h for work area　　5 mSv/h for access route

	Unit 1	Unit 2	Unit 3
Needs for dose reduction* and the dose rate			
Building conditions	The dose rate s are low in whole; about 1 to 10mSv/h The rates have been high in south area, some parts in southeast area measures5,000mSv/h	Used to be 2～60mSv/h (In 2014 Oct, the rates were about 5~10mSv/h because of decontamination in lower/middle parts and shielding)	The dose rates are high in whole; about 20～100mSv/h

* mapping results of the dose rates at planned operation area(with needs of dose reduction) derived from PCV investigation and repair project

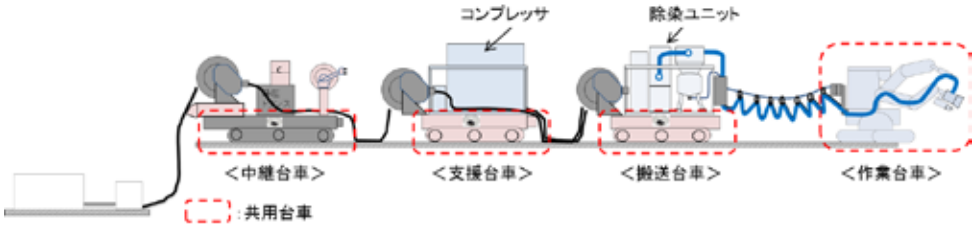
: 3mSv/h to10mSv/h　: 10mSv/h to 20mSv/h　: 20mSv/h to 50mSv/h　: more than 50mSv/h　: out of study due to the lack of data

Overall Plan（Developed decontamination equipment and development status）

Upper floors

・FY2013：design

・FY2014-2015：production, verification test, applicability study of actual device

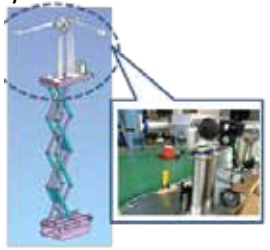


上部階用除染装置の概念図（ブラスト装置を搭載した例）

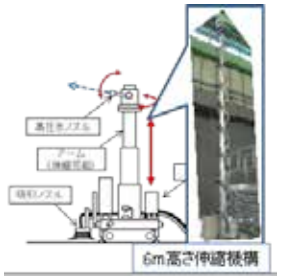
High places

・FY2013：design, production

・FY2014-2015：improvement, verification test, applicability study of actual device



Dry ice blast

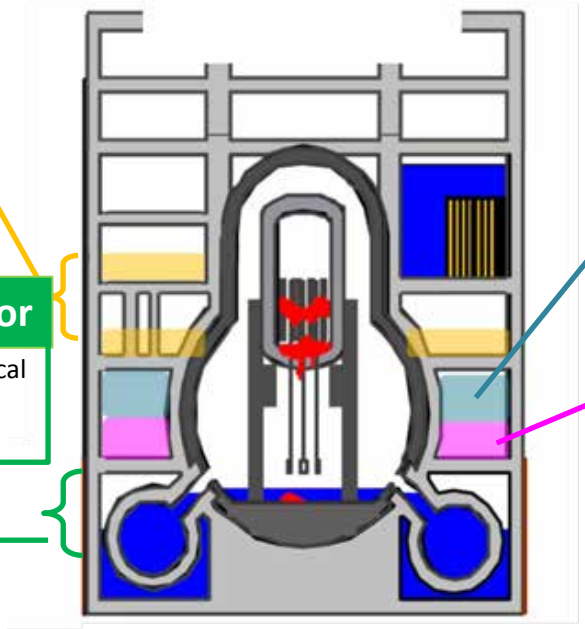


High pressure water jet

Suction /blast

Underground floor

・FY2014：Study of technical challenges ,development planning



Low places ＜Development completed＞

・FY2011-2012：design, production, test in 2F

・FY2013 ：improvement, verification test (factory, 1F)

Suction /blast

High pressure water jet

Dry ice blast

Development of technology for remotely operated decontamination in reactor buildings

For Low Places

Suction/blast

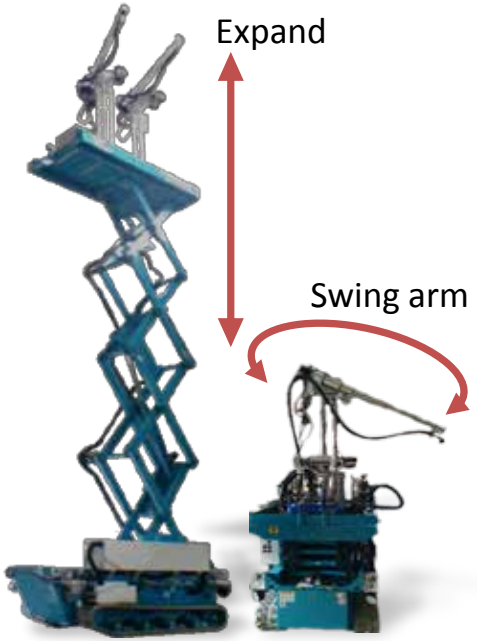
High pressure water jet

Dry ice blast

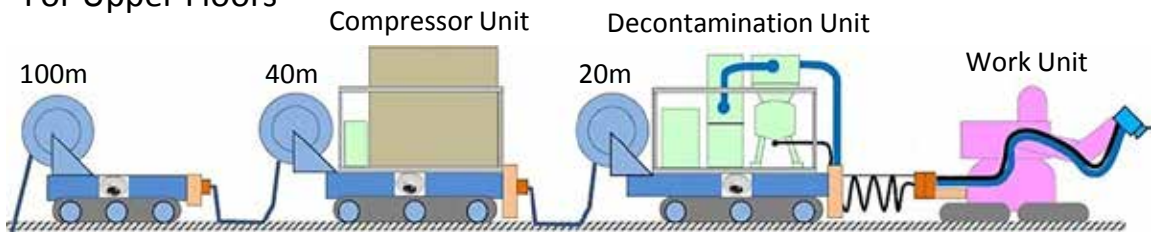
- Contamination condition is the combination of loose material and fixing material
- Dose comes from low place, high place, side wall and hot spot

Ground floor of Reactor Building

For High Places

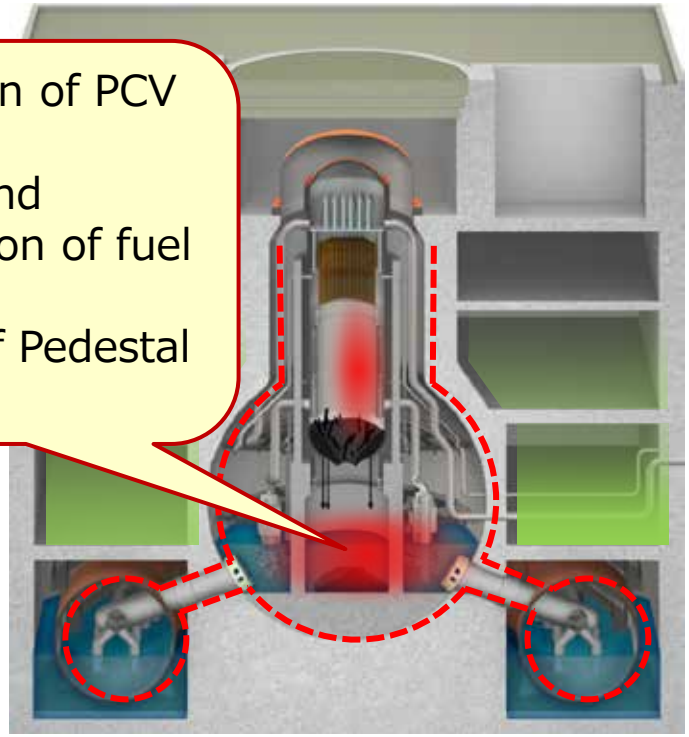


For Upper Floors



Each unit is lifted up to the upper floor with the Lifter in continuity

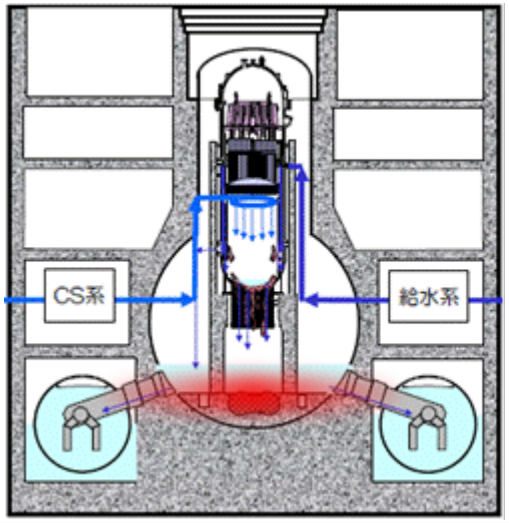
Research and Development for the RPV inspection task



Development plan for investigation method and device

Set the development plan based on estimated condition of RPV and PCV of Unit 1 to Unit 3 (*1)

Unit 1

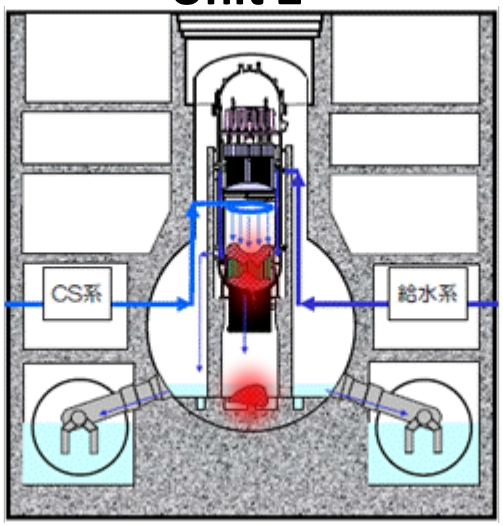


・Almost all of melted fuel have been fallen down to the bottom of RPV plenum and little fuel have left in RPV.

⇩ Development plan

・There is a possibility that fuel debris exists even outside of the pedestal, and investigation **outside the pedestal** should be conducted as priority.

Unit 2

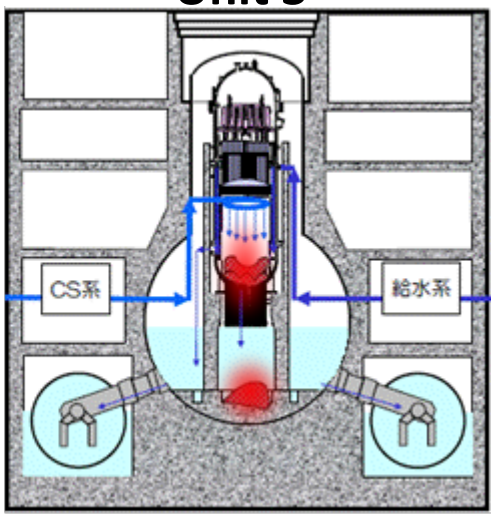


・While some part of melted fuels has fallen down to the bottom of RPV lower plenum and PCV pedestal, the other part may have been left inside RPV.
・Presumed that more fuel than having estimated may have fallen down to PCV in Unit 3.

⇩ Development plan

・As the possibility that fuel debris spread outsides the pedestal is lower compare with Unit 1, investigation **inside the pedestal** should be developed as priority.
・As in Unit 3, the water level inside the PCV is high, penetration which will be used in Unit 1 and 2 must be submerged, other methods should be examined.

Unit 3



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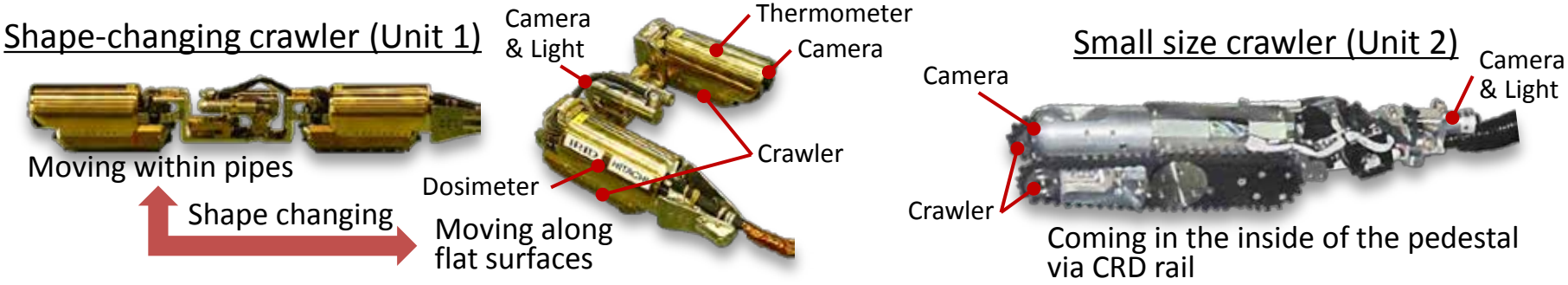
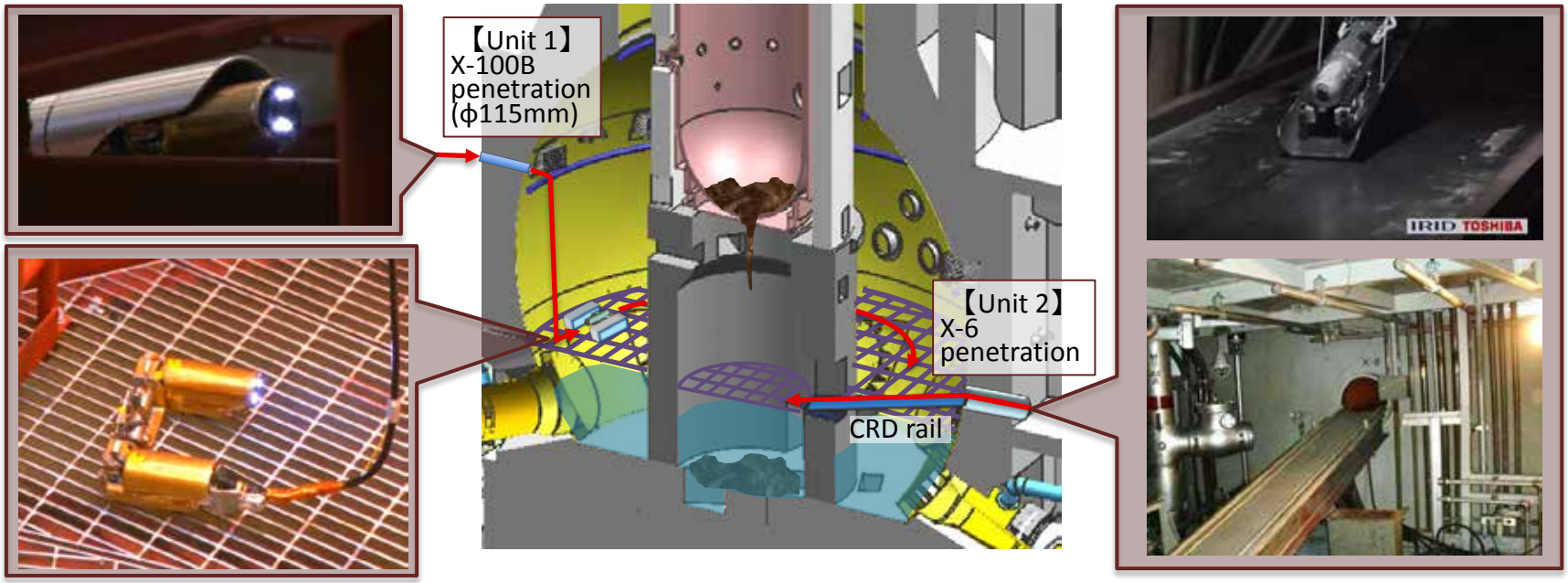
*1 : [Reference] TEPCO's webpage Dec. 13, 2013 "The first progress report related to estimated state of reactor core and RPV of Fukushima Daiichi NPS Unit 1, 2 and 3, and unsolved issues"

Development of technology for investigation inside the PCV

Investigation methods and remotely operated devices have been developed to identify conditions inside the PCV and determine the situation regarding fuel debris.





Development Steps (for Unit 1)

[Investigated area] : - Outside the pedestal on the basement floor
- Near the access entrance of RPV pedestal

(1) Investigations from the X-100B penetration（FY2015）: B1 (Completed), B2

(Currently, dose rate near the X-6 penetration is very high.)

(2) Investigation from X-6 (FY2016～FY2017): B3

(After decontamination near X-6 penetration)

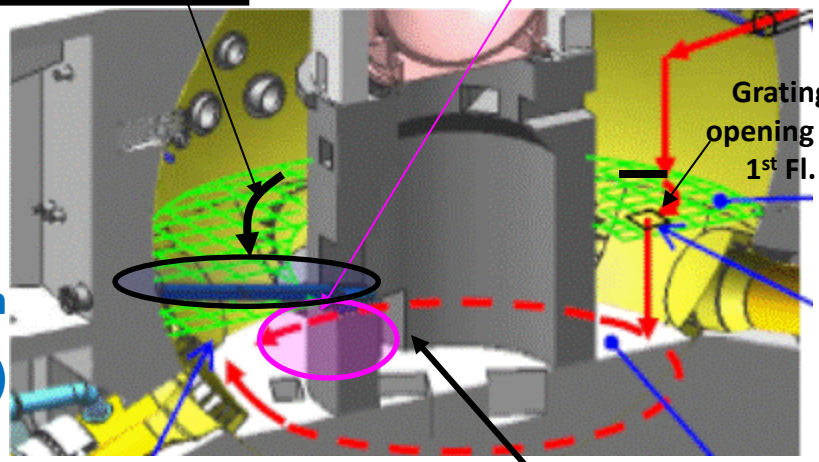
Investigation to obtain information using debris shape measurement apparatus outside the pedestal on the basement Fl.

B1. Investigation outside the pedestal on the first Fl (grating).

Completed in April, 2015

B2. Investigation outside the pedestal on the basement Fl.

Depending on result of B2 investigation, B3 may be conducted.



B3. Investigation outside the pedestal on the basement Fl. And workers entrance

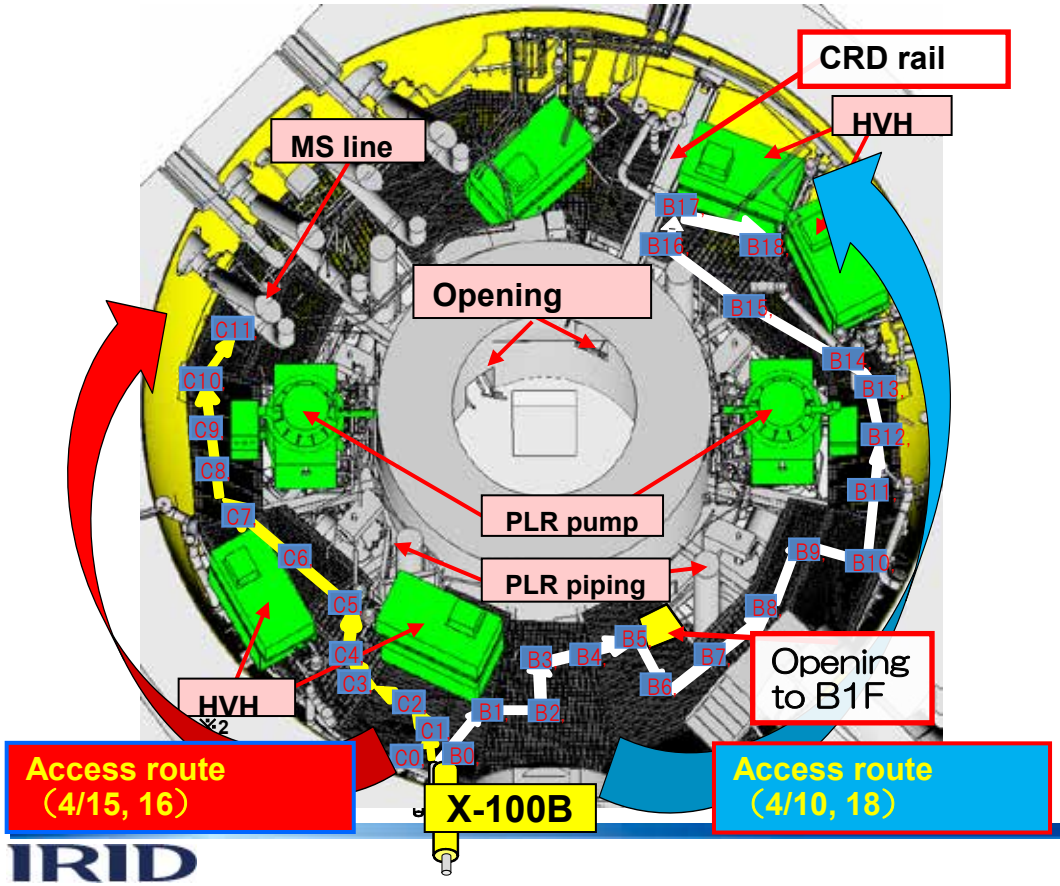
Investigation inside the pedestal may be conducted depending on the investigation of Unit 2.

B1 investigation completed in April, 2015

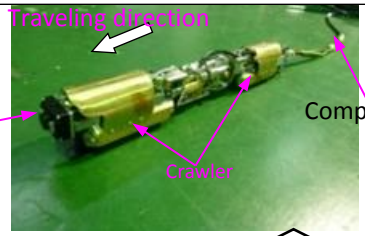
(1)Overview of equipment

- Shape-changing crawler equipment
- Inserted from the narrow access entrance (X-100B penetration ：ϕ100mm)
- Travel on grating stably.

(2) Image of investigation route



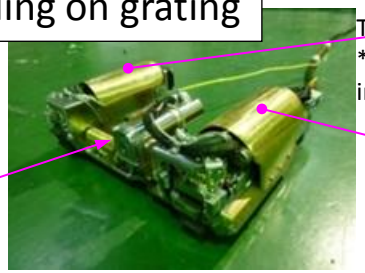
Traveling through penetration on PCV



Board camera
*Use when traveling through piping.

transformation

Traveling on grating

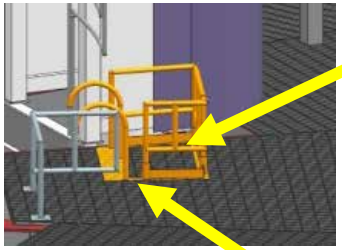


Features of equipment

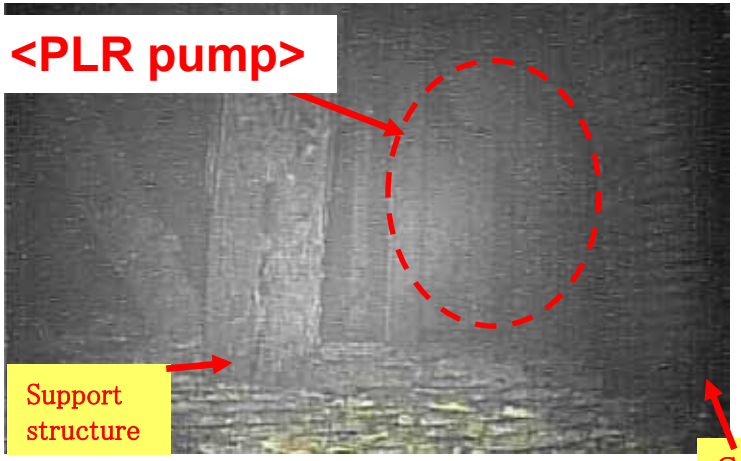
Achievement of B1 investigation

item	Observed result
Opening on grating to the lower floor	**<Potential access path>** to the lower floor during next B2 investigation **No interference around the opening**
CRD rail	**<Potential access path>** to the inside of pedestal **Could not be observed well** (difficult access due to narrow access route)
General observation	**<Existing components>** **No serious damage** (PLR pump & piping, pedestal wall, HVH, etc.,) **<measurement results at 12 locations>** **Temperature 17.8~21.1 ℃** **Dose rate 4.7~9.7 Sv/hr**

<Opening>



<PLR pump>



<CRD rail>

(Mock up facility)

Development Steps (for Unit 2)

[Investigated area] : - On the platform (Upper surface of platform, CRD housing)
- Basement floor

(1) Investigation from X-6 penetration（Φ115mm）(FY2015) : A2

(2) Investigation from X-6（Enlarge hole）(FY2016～2017) : A3,A4

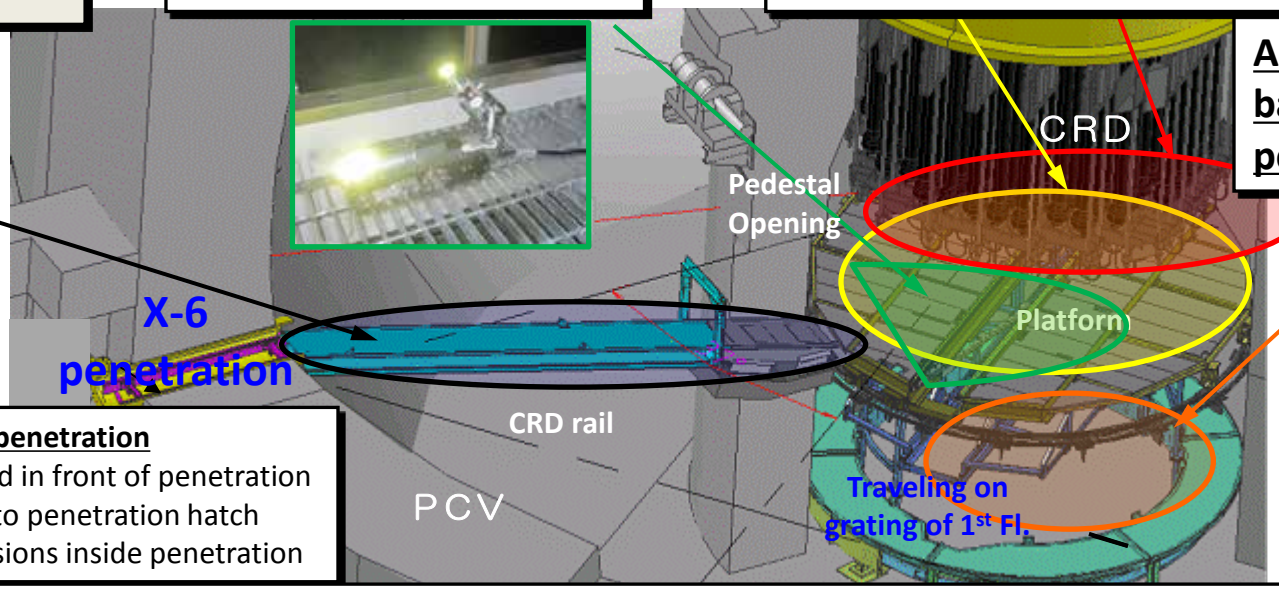
・Insert debris visualization system, investigate inside pedestal.

A1. Investigation on CRD rail(Conducted in Aug.2013)

A2. Investigation on platform inside pedestal

A3. Investigation of CRD Hsg and on platform (detail)

A4. Investigation on basement inside pedestal



Step to use X-6 penetration
- Remove shield in front of penetration
- Pierce a hole to penetration hatch
- Remove inclusions inside penetration

Based on the result of internal investigation from A2 to A4, investigation outside pedestal may be conducted.

Lessons learned and future issues

IRID is responsible for Researching and Developing technology that is indispensable for the decommissioning of the Fukushima Daiich Nuclear Power Station

< Lessons Learned >

- Robot Technology is indispensable for the decommissioning tasks
- But, there are lots of difficulties;
  - Luck of TRUE specification
  - Requirement of high reliability in short term project
  - Based on Man-Machine systems

< Future Issues >

- System complexity
- interdisciplinary knowledge
- Risk reduction vs. cost and efficiency

Call for **challengers** in the field of Robotics and Automation.

Implementing Technology in Society

For Your Information

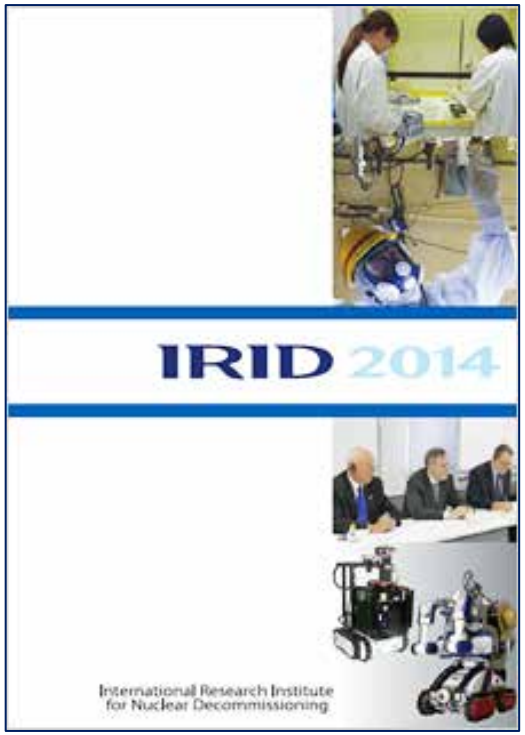
- **TEPCO homepage** “Decommissioning Plan of Fukushima Daiichi Nuclear Power”
  http://www.tepco.co.jp/en/decommision/index-e.html

- **METI homepage** “Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1-4”
  http://www.meti.go.jp/english/earthquake/nuclear/decommissioning/

- **TEPCO VIDEO** “Use of robots for reactor stabilization and decommissioning at Fukushima Daiichi Nuclear Power Station”(2015.02.15)
  http://www.tepco.co.jp/en/news/library/archive-e.html?video_uuid=raf8si47&catid=61795

- **IRID Homepage**
  http://www.irid.or.jp/en/

For Your Information



Overview of IRID

http://www.irid.or.jp/_pdf/pamphlet2014_eng.pdf

Annual Report

http://www.irid.or.jp/_pdf/pamphleth26_eng.pdf