IRID

International Workshop on the Use of Robotic Technologies
at Nuclear Facilities

R&D on Robots for the Decommissioning of Fukushima Daiichi NPS

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Introduction

IRID is the Technology Research Association to develop technologies required for the decommissioning of the Fukushima Daiichi NPS

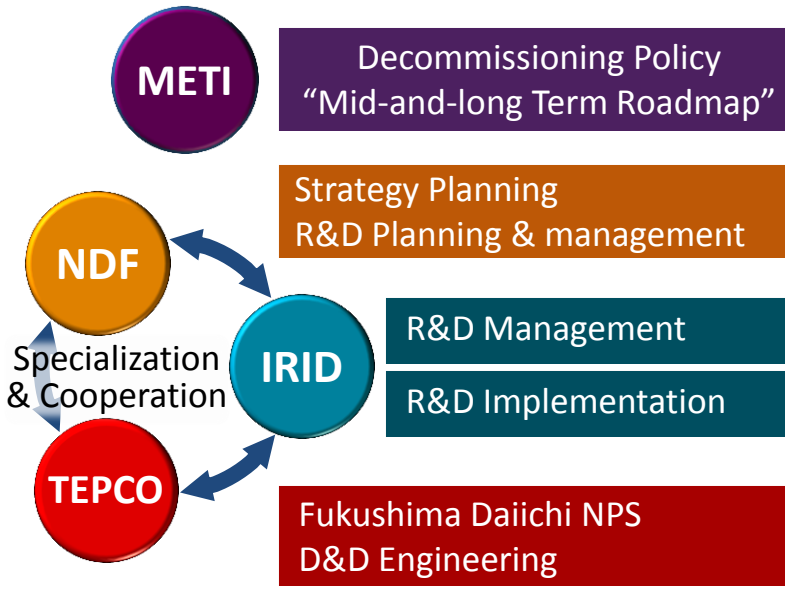
Organization

- R&D Management
  - R&D Management
  - R&D Strategy Planning
  - Administration
- R&D Implementation
  - Membership:
    National R&D Agencies(2)
    /Manufacturers(4) / Electric Utilities(12)
  - Over 700 researchers participate in IRID and engage in the R&D projects at their facilities

Scope of business

- Nuclear decommissioning technology R&D
  - Fuel Removal from Spent Fuel Pool
  - Preparation of Fuel Debris Retrieval
  - Treatment and Disposal of Radioactive Waste
- Promotion of cooperation on nuclear decommissioning with international and domestic organizations
- Human resource development

Relationship Diagram



METI: Ministry of Economy, Trade and Industry

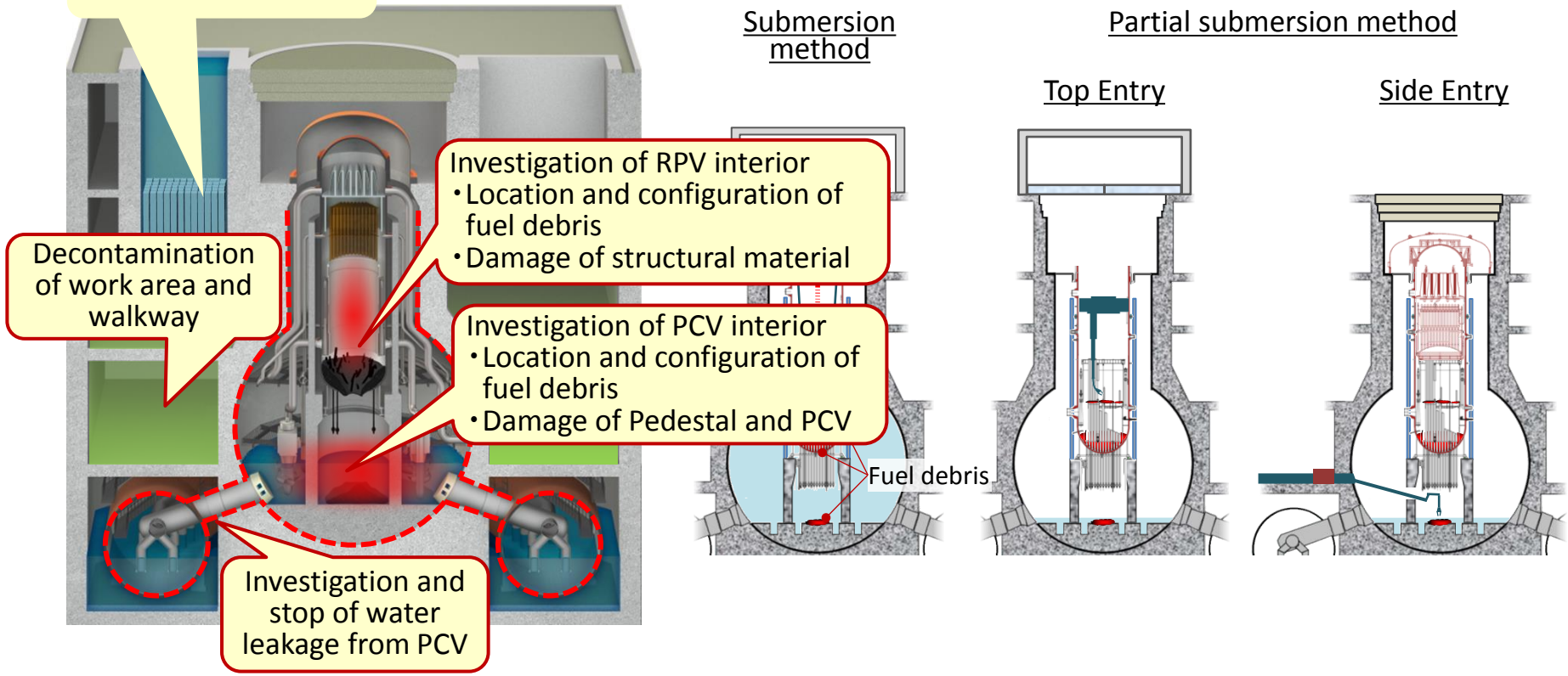
NDF: Nuclear Damage Compensation and Decommissioning Facilitation Corporation

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

Fuel debris retrieval procedure

Robot technology is utilized for decontamination in the reactor building, investigation of water leakage from the PCV, investigation of the PCV interior, etc., according to the Mid-and-Long-Term Roadmap indicating the decommissioning procedure of Fukushima Daiichi.

Current → Technology R&D → Fuel Debris Retrieval from 2021

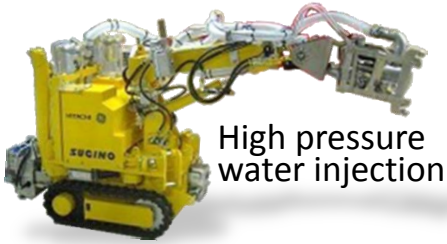


Development of technology for remotely operated decontamination in reactor buildings

Robots capable of accessing various places such as low places like floors, high places where pipes and trays are located and narrow places, and decontaminating various types of contaminants such as loose contaminants like dusts and fixed contaminants that penetrate into and fixate on concrete .

For Low Places

Suction/blast



High pressure water injection

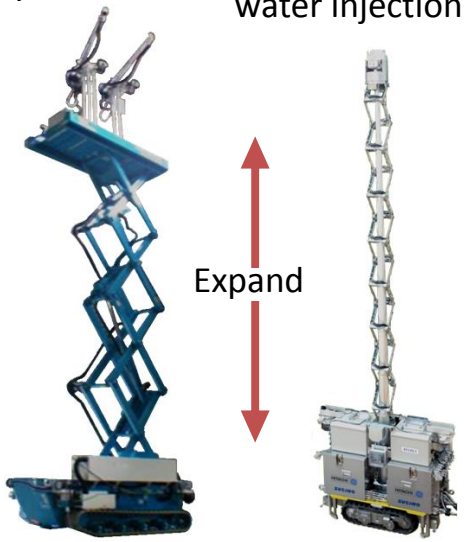
Dry ice blast

Ground floor of Reactor Building

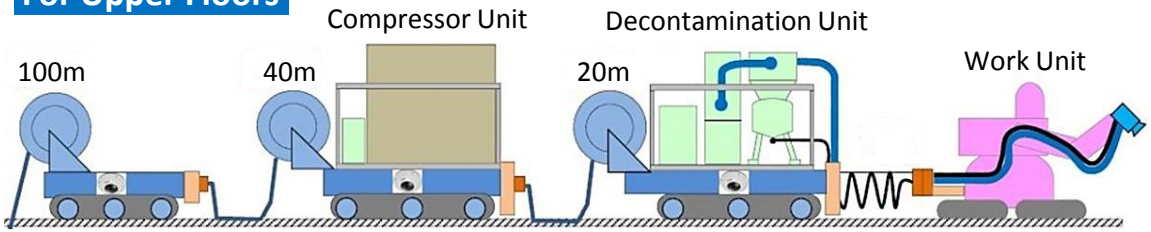
For High Places

Suction/
Dry ice blast

High pressure water injection



For Upper Floors

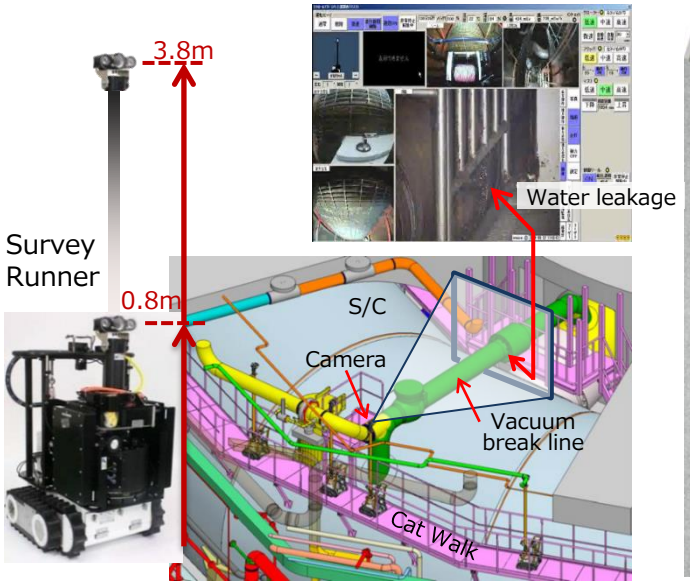


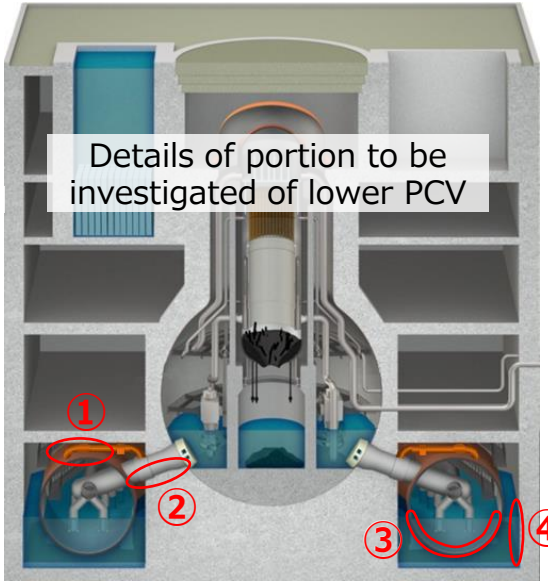
Each unit is lifted up to the upper floor with the Lifter in continuity

Development of technology to identify leakage points in the PCV

Equipment to investigate water leakage from the PCV etc., which is designed to be adaptable to various environments , including elevated locations, high radiation dose areas, narrow spaces, and underwater areas

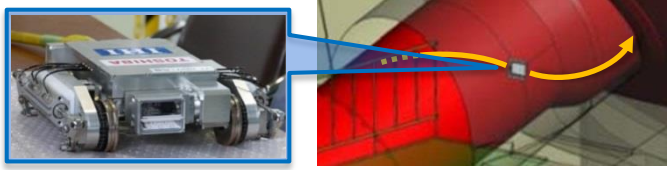
① Upper part of S/C survey equipment





② Exterior surface survey equipment for Vent Pipe

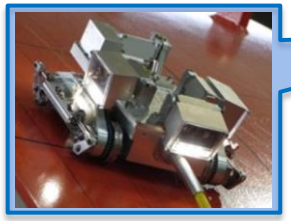
To search a water leakage on the junction of the Vent pipe and the PCV



VT-ROV

③ Exterior surface survey equipment for lower part of S/C

To search a hole (>30mm) on the S/C surface under water

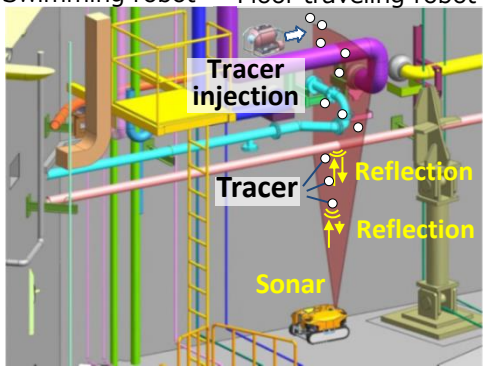


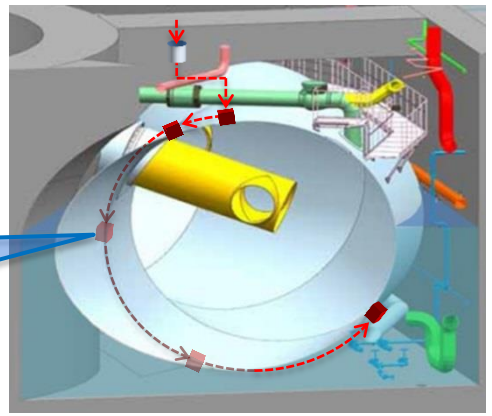
SC-ROV

④ Wall penetration survey equipment of torus room

Swimming robot

Floor traveling robot





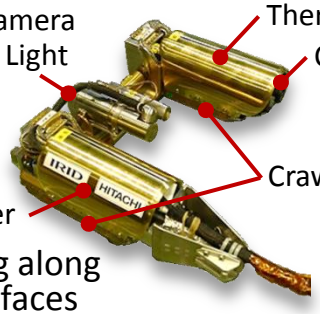
Development of technology for investigation of the PCV interior

Robots capable of going through a 100 mm-diameter guide pipe and moving around a wide area in the PCV and having a radiation resistance strong enough to capture images and measure temperatures, radiation doses, under high radiation doses, in dark or vapor atmospheres

Shape-changing crawler (Unit 1)

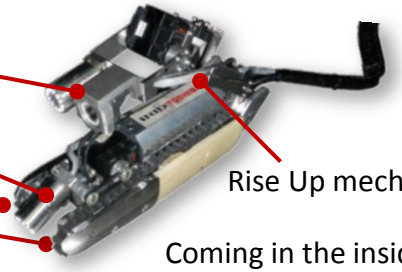
Moving within pipes

Shape changing

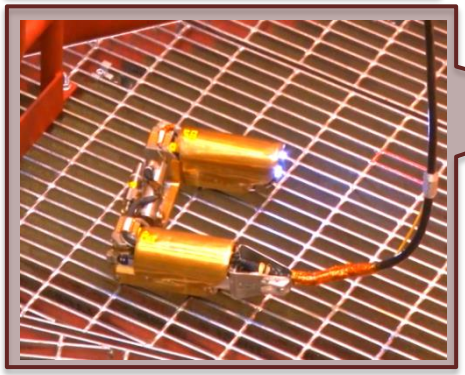


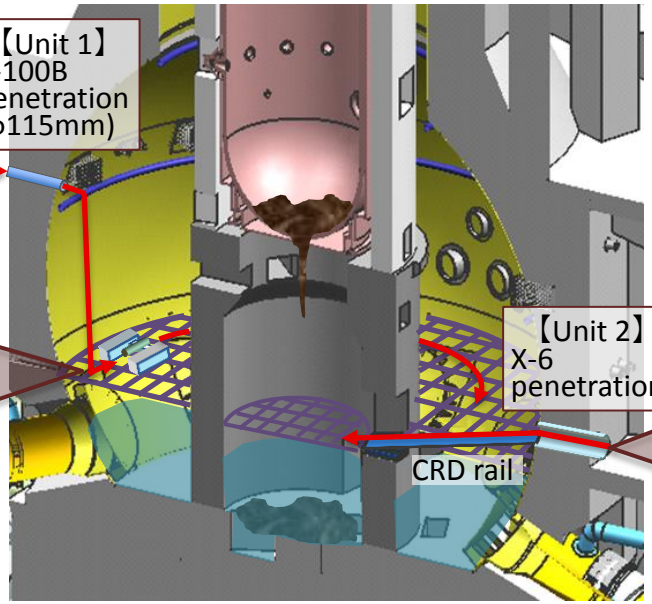
Moving along flat surfaces

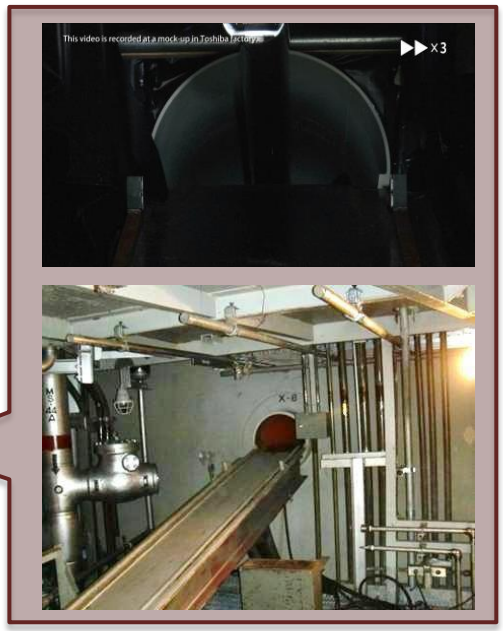
Small size crawler (Unit 2)



Coming in the inside of the pedestal via CRD rail



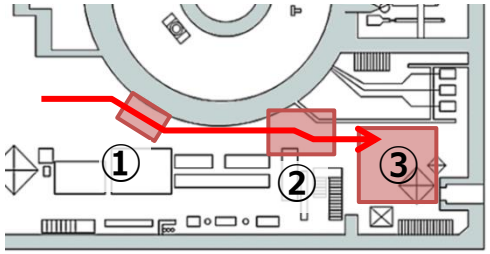




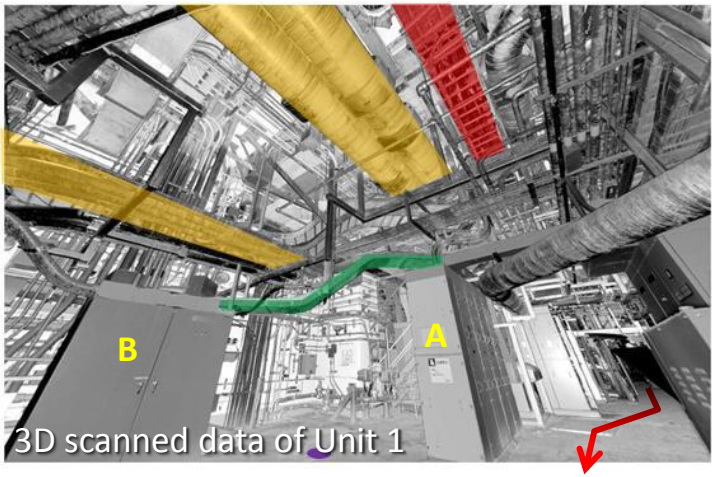
Utilization of 3D data on the reactor building interior

(Decontamination)

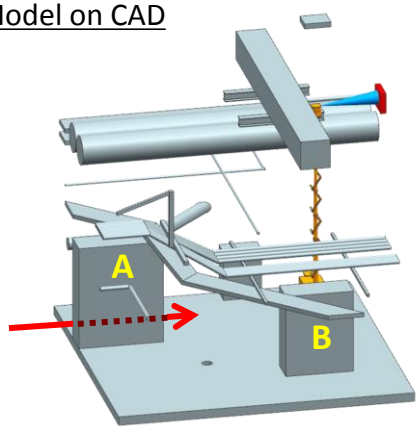
3D data of the reactor building captured through laser scanning is utilized to study methods to approach high and narrow places to be decontaminated and to design the mockup facility simulating the structural condition and arrangement of each Unit.



Traveling route from outside of Unit 1 to the target area of decontamination



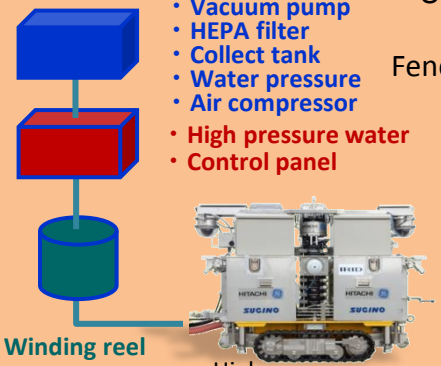
3D Model on CAD



Designing Mock up facility

Integration test at mock-up facilities

- Vacuum pump
- HEPA filter
- Collect tank
- Water pressure
- Air compressor
- High pressure water
- Control panel



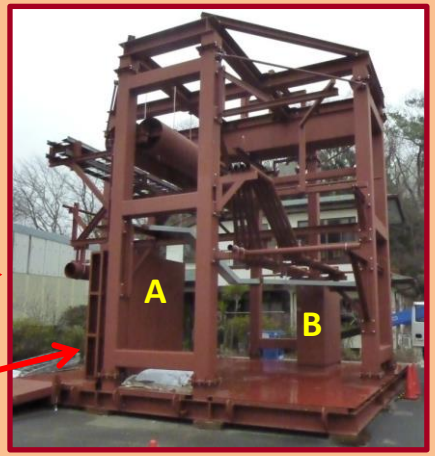
High pressure water injection platform truck

①Narrowest place

Slope to step over the auxiliary pipes and wiring

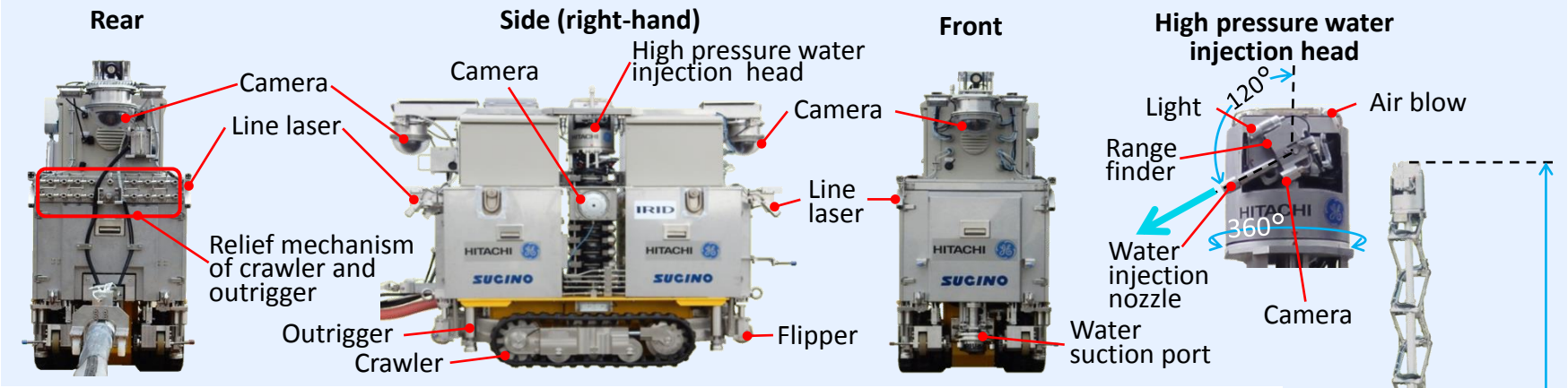
②Dogleg passage in narrow place

③Target area of decontamination



Evaluation of robot performance (Decontamination)

Robot that meets specified requirements not only for decontamination performance but also for remote control , linkage with other system components and safety performance



Evaluation Item	Target
Decontamination performance	**Work area 3mSv/h, Travel pass 5mSv/h** • to remove 80% contaminated material • to collect injected water on the floor < 1mm water level @ flat floor < 10mm water level @ hollow place
Remote control performance	**Decontamination work** • to access to 8m high place and operate the decontamination work **Travelling** • to move the machine dragging a long harness behind through the narrow passage in the mock up facilities
Safety performance	• to avoid falling down during the decontamination work @ 8m high place • to make emergency stop on abnormal condition • to draw the machine back using traction tool on emergency stop state

Reliability improvement through testing

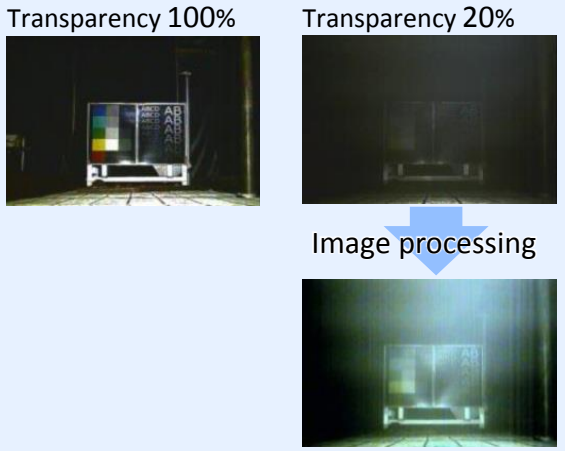
(Investigation of the PCV interior)

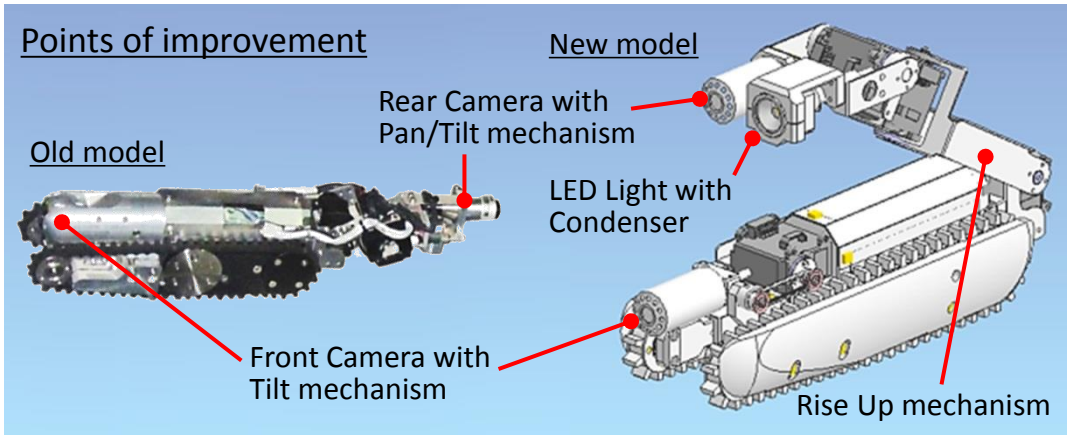
To develop a highly reliable robot, it is vital to repeatedly examine robots under environments that simulates the PCV.

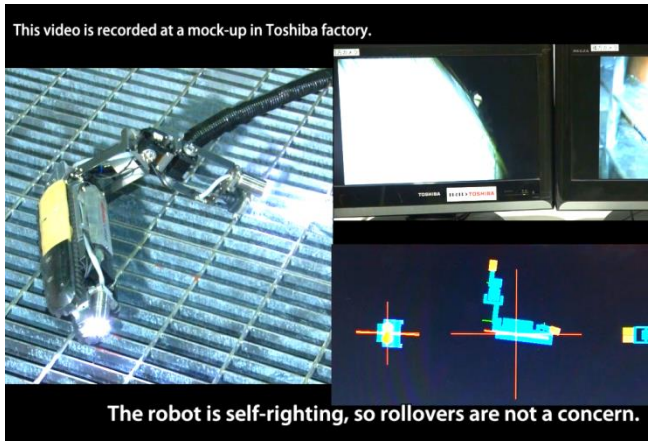
Improved points at postulated severe situation in the PCV

- Dark and foggy circumstance
  - LED light with condenser and distant from the camera
  - Image processing
- Difficulty in grasping site situation though remote control operation
  - Two cameras give a good visual field, overlooking picture around of the robot and close up picture in front of the robot
  - Rear camera gives wide area view with Pan/Tilt mechanism
- Roll over
  - Self-righting using the rise up mechanism
- Out of control
  - Cable delivery system has the cable cutoff mechanism

Visibility test in water vapor







Development of a step-by-step investigation

(Investigation of the PCV interior)

Since the situation inside the PCV is not much known, we have divided the investigation of the fuel debris in the PCV into several steps in order to reflect results from the current investigation step to the next step.

Steps for the PCV interior investigation

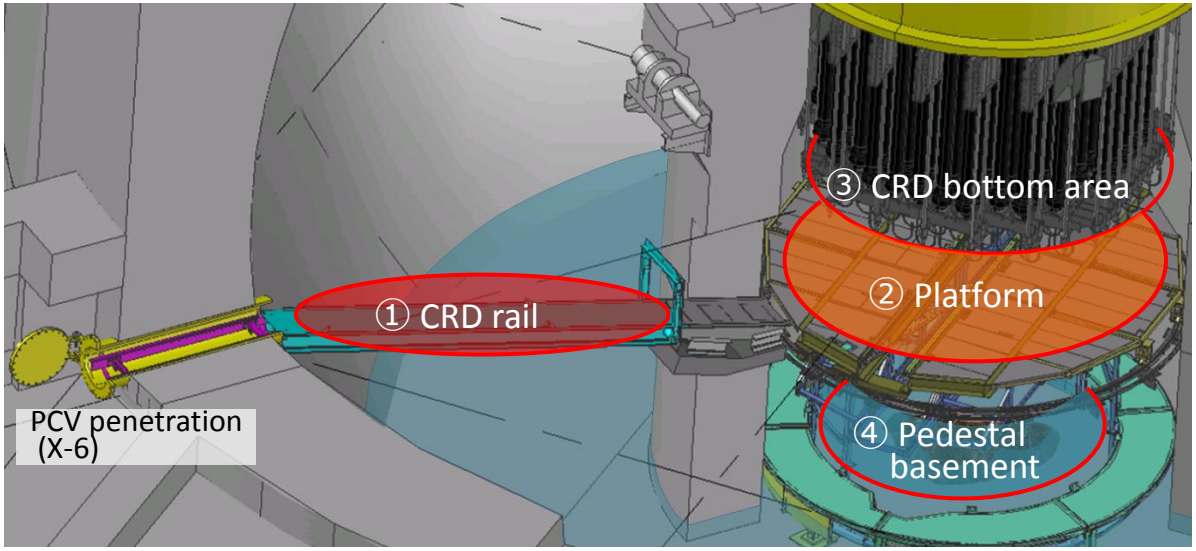
① CRD rail condition (2014)

② Platform condition (on-going)

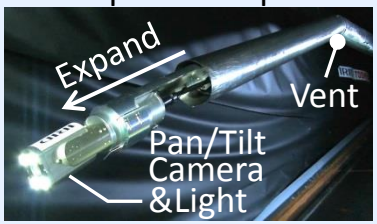
③ CRD bottom area condition (from FY2016)

④ Pedestal basement condition (from FY2017)

Refine the Procedure and method of the Fuel Debris Retrieval

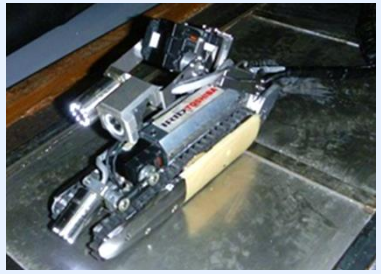


Camera on foldable and expandable pole



Deposit removing robot

Investigation robot



CRD: Control Rod Drive

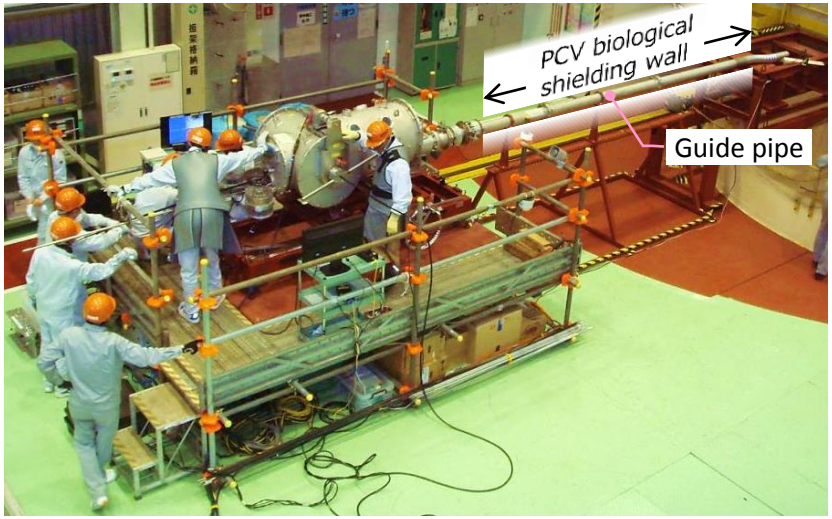
Technology for preventing radioactive material diffusion

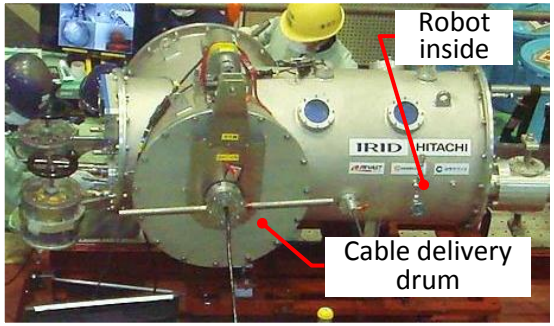
(Investigation of the PCV interior)

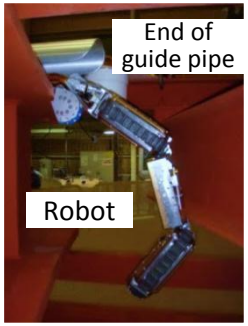
Before putting the robot into the PCV, we must build a boundary to avoid an opening of the PCV from diffusing radioactive materials .

Radioactive material diffusion preventing device (Chamber)

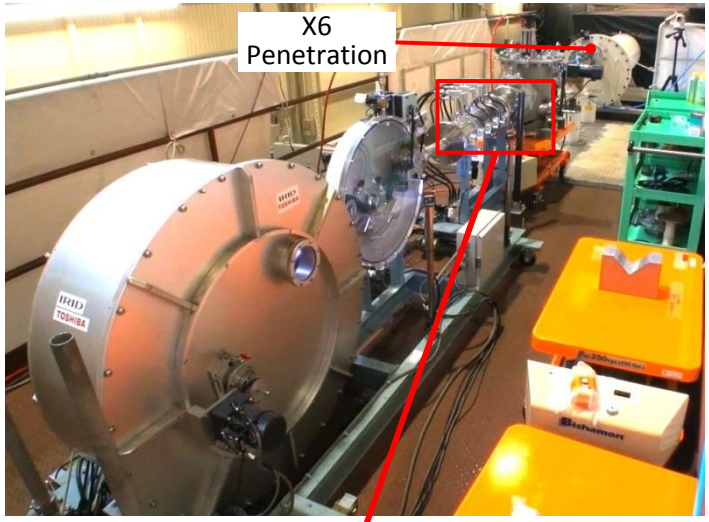
Shape-changing crawler (Unit 1)

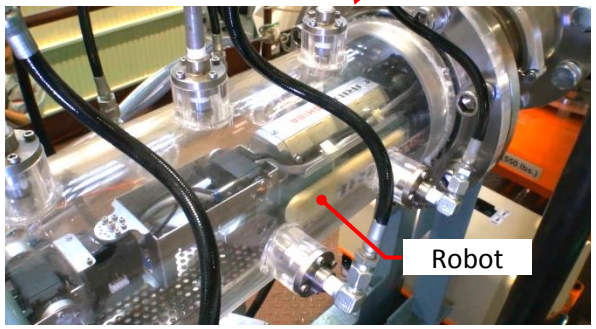






Small size crawler (Unit 2)



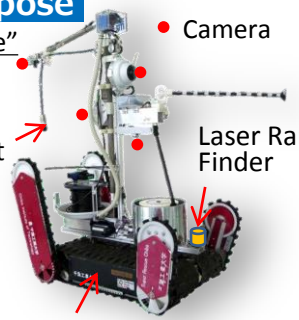


Radioactive resistant performance

The requirement for radioactive resistance of each robot is specified, according to a dose rate of a place where the robot works.

General purpose

Field robot "Quince"



Dose tolerance test (Cobalt 60)

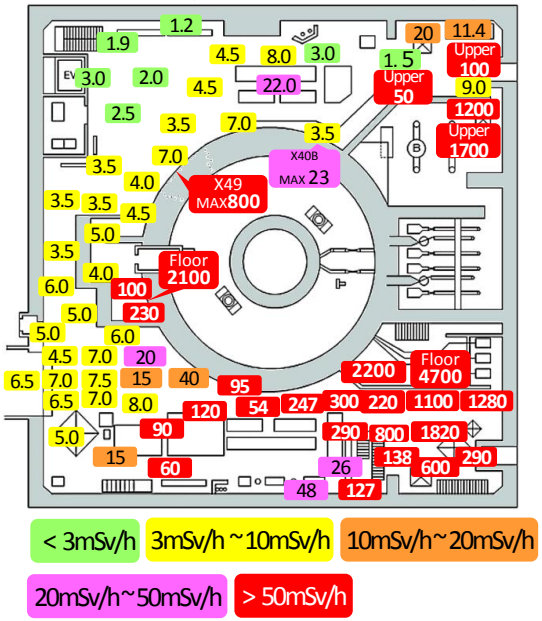
Component parts	Dose tolerance
Laser range finder	124Gy(Sv)
CCD camera	169Gy(Sv)
CPU module, Battery, Motor driver, Radio Tx/Rx, LAN HUB, etc…	> 200Gy(Sv)

Management guideline

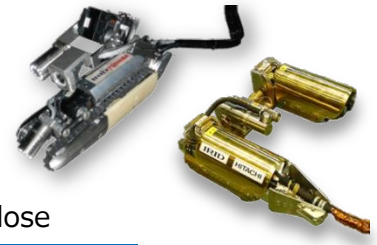
- Unmanned heavy machine
  20Sv total dose
- Portable field robot
  30Sv total dose

- "Guideline on Rad-Hardness Estimation and Management for Robotics, Unmanned Construction Machine and others" 2011.4.27 (Original document is Japanese)
- "Radiation resistance and decontamination of robots in the field of atomic energy"
  IEEE Telerobotics Summer School 2013 , Shinji Kawatsuma, Japan Atomic Energy Agency, Japan

Dose rate map in the Unit 1
(measured 2012 ~ 2013)



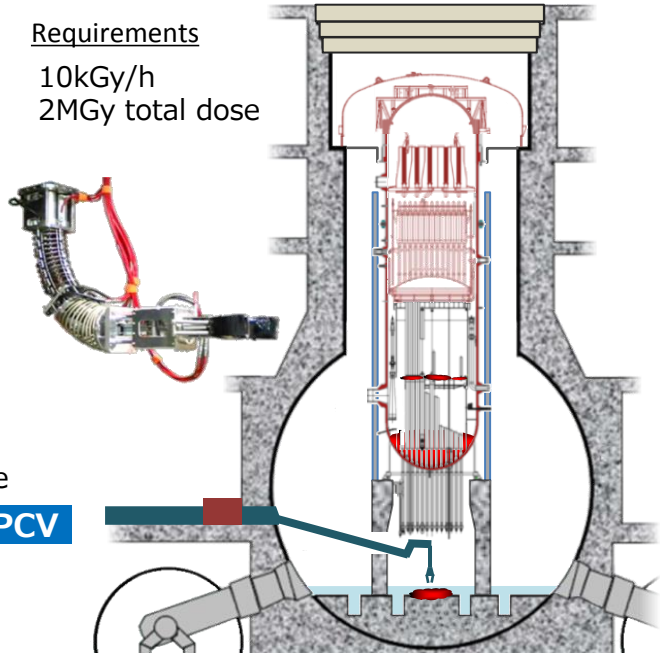
Investigation of Inside PCV



Requirements
100Gy/h
1000Gy total dose

Fuel debris retrieval

Requirements
10kGy/h
2MGy total dose



Decontamination

Requirements
3Sv/h~20Sv/h
1000Sv ~2000Sv total dose

Investigation of leak of PCV

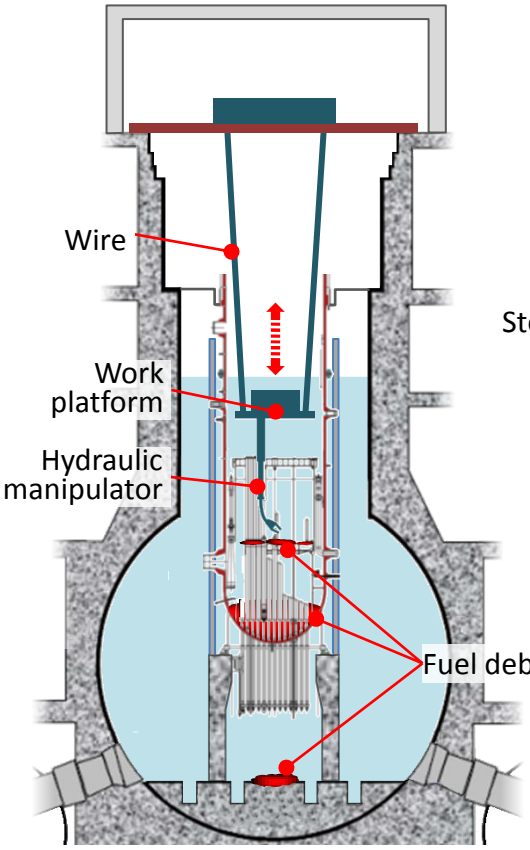
Requirements
4Sv/h~10Sv/h
200Sv total dose

Study of fuel debris retrieval method

We will study multiple method for fuel debris retrieval to meet different condition of damaged PCV and scattering fuel debris at each unit

Submersion method

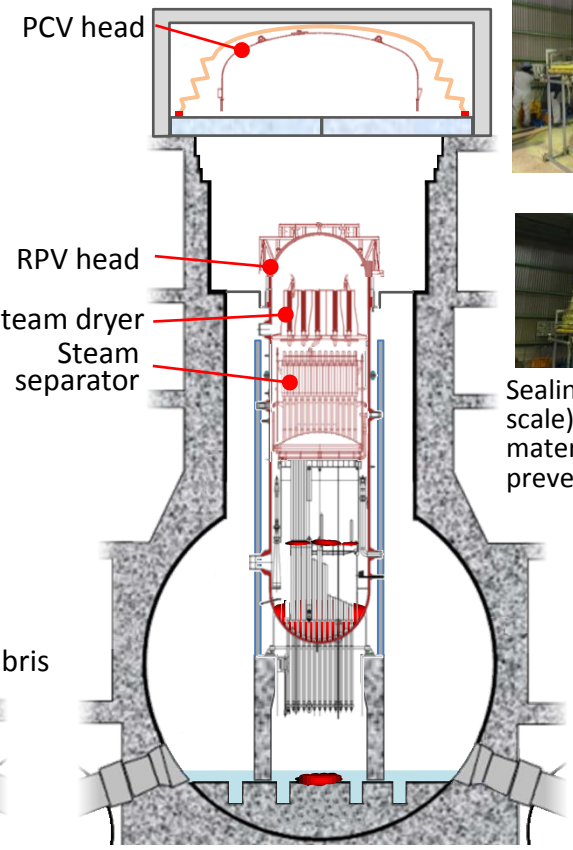
Most favorable approach for minimizing the radioactive exposure of workers

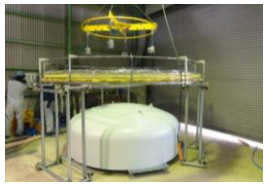


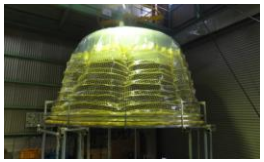
Partial submersion method (In-air work)

Development of technology which prevents scattering radioactive materials from PCV is needed to remove PCV contents in-air work

Top entry







Sealing a PCV head (1:4 scale) with Radioactive material diffusion preventing film

Side entry

When fuel debris spreads over pedestal outskirts, the side entry method is to be selected

Thank you for your attention