R&D Activities at IRID

International Research Institute for Nuclear Decommissioning
Outline of IRID

1. Name
   International Research Institute for Nuclear Decommissioning (IRID)

2. Location of Main Office
   5F 3Toyo Kaiji Building, 23-1 Nishi-shinbashii 2-chome, Minato-ku
   Tokyo 105-0003, Japan
   website: [http://www.irid.or.jp/en](http://www.irid.or.jp/en)

3. Membership (18)
   **Research Institutes:** Japan Atomic Energy Agency (JAEA),
   National Institute of Advanced Industrial Science and Technology
   **Manufacturers, etc.:** TOSHIBA Corporation, Hitachi-GE Nuclear Energy, Ltd.,
   Mitsubishi Heavy Industries, Ltd., ATOX Co., Ltd.
   **Electric Utilities, etc.:** Hokkaido Electric Power Co., Inc., Tohoku Electric Power Co., Inc.,
   Tokyo Electric Power Co., Inc., Chubu Electric Power Co., Inc.,
   Hokuriku Electric Power Company, Kansai Electric Power Co., Inc.,
   Kyushu Electric Power Co., Inc., The Japan Atomic Power Company,
   Electric Power Development Co., Ltd., Japan Nuclear Fuel Limited
IRID’s R&D projects in FY2015

**Decontamination/Dose Reduction**
- Remote Operated Decontamination Equipment (FY 2015)

**Repair and Water Leakage**
- Water Stoppage Technology of PCV (FY 2015)
- Full-Scale Test (FY 2015)

**Investigation/Analysis**
- Detection of Fuel Debris (FY 2015)
- Investigation Inside RPV (FY 2015)
- Investigation Inside PCV (FY 2015)
- Accident Progression Analysis (FY 2015)
- Identifying Properties of Fuel Debris (FY 2015-2016)

**Debris Retrieval**
- PCV/RPV Integrity Evaluation (FY 2015)
- Criticality Control in Fuel Debris Retrieval (FY 2015)
- Fundamental Retrieval Technology for Fuel Debris & Reactor Internals (FY 2015-2016)
- Collecting, Transferring and Storing of Fuel Debris (FY 2015-2016)
- Upgrading of Retrieval Method for Fuel Debris & Reactor Internals (FY 2015-2016)

**Characterization**
- Identifying Properties of Fuel Debris (FY 2015-2016)

**Radioactive Waste Treatment/Disposal**
- Solid Waste Treatment and Disposal (FY 2015-2016)

**Evaluation of Long Term Integrity of spent fuel** (FY 2015-2016)

**Water Stoppage of PCV**
- Repair and Water Leakage (FY 2015-2016)

**Investigation/Analysis in the Reactor**
- Accident Progression Analysis (FY 2015)
- Identifying Properties of Fuel Debris (FY 2015-2016)
IRID’s R&D projects in FY2015

Decontamination/ Dose Reduction

- Remotely Operated Decontamination Equipment (FY 2015)

- Repair and Water Leakage Stoppage of PCV
  - Water Stoppage Technology of PCV (FY 2015)
  - Full-Scale Test (FY 2015)

Investigation/Analysis in the Reactor

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Dose Rate Goals after decontamination

Dose rate reduction goals to be achieved using the decontamination equipment (the necessity of PCV leakage investigation and repair work, and overall dose reduction scenario)

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

<table>
<thead>
<tr>
<th>Necessity of dose reduction* and the dose rate</th>
<th>Unit 1</th>
<th>Unit 2</th>
<th>Unit 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose rate in the reactor building</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low as a whole: about 1-10 mSv/h</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Higher in south area and at some points in southeast area: 5,000 mSv/h</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before Oct. 2014: 2-60 mSv/h</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>After Oct. 2014: about 5-10 mSv/h (Decontamination in lower/middle parts and shielding were conducted)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High as a whole: about 20-100 mSv/h</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

- 3 mSv/h to 10 mSv/h
- 10 mSv/h to 20 mSv/h
- 20 mSv/h to 50 mSv/h
- More than 50 mSv/h
- Out of study due to the lack of data
Results and Future Plan of Decontamination Equipment Development

Upper floors

- FY2013: design
- FY2014-2015: production, verification test, applicability study of actual device

Underground floor

- FY2014: Study of technical challenges, development planning

High places

- FY2013: design, production
- FY2014-2015: improvement, verification test, applicability study of actual device

Dry ice blast

High pressure water jet

Suction/Blast

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
IRID’s R&D projects in FY2015

Repair and Water Leakage Stoppage of PCV

Water Stoppage Technology of PCV (FY 2015)

Full-Scale Test (FY 2015)

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Decontamination/ Dose Reduction

Remotely Operated Decontamination Equipment (FY 2015)

Investigation/Analysis in the Reactor

Detection of Fuel Debris (FY 2015)

Investigation Inside RPV (FY 2015)

Investigation Inside PCV (FY 2015)

Accident Progression Analysis (FY 2015)

Identifying Properties of Fuel Debris (FY 2015-2016)

Investigation

Characterization

Radioactive Waste Treatment/Disposal

Solid Waste Treatment and Disposal (FY 2015-2016)
Target Areas for Water Leakage Stoppage at PCV

**PCV Penetration (Small rooms)**
- Cement Depositing
- Cement deposition
- Cement wall

**Vent Piping, Down Comer**
- Cement Filling
- PCV
- Vacuum break line
- Vent tube
- Header
- Down comer
- T Quencher
- Torus room
- A half-scale test

**D/W Shell (repair)**
- Protective cover
- Non-cement material injection
- Bellows

**PCV Penetration (Open spaces)**
- Non Cement (temporal)
- Cement (Long term)

**S/C Support, Torus Room Penetrations**
- Cement Filling
- Torus room
- Torus room wall Penetrations
- Column support
- Seismic support

**PCV Connecting Piping in torus room**
- Cement Depositing
IRID’s R&D projects in FY2015

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- Solid Waste Treatment and Disposal (FY 2015-2016)

- Evaluation of Long Term Integrity of spent fuel (FY 2015-2016)

- Fundamenta Retrieval Technology for Fuel Debris & Reactor Internals (FY 2015-2016)

- Collecting, Transferring and Storing of Fuel Debris (FY 2015-2016)
## Assessing Conditions inside Reactor by Muon Observation Technology

<table>
<thead>
<tr>
<th>Transmission Method</th>
<th>Scattering Method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transmission ratio is measured</strong></td>
<td><strong>Scattering angle is measured</strong></td>
</tr>
<tr>
<td>Can detect existence/non-existence of an object on Muon flying direction (two-dimensions)</td>
<td>Can detect existence/non-existence of an object at Muon scattering area (three-dimensions)</td>
</tr>
<tr>
<td>Can image fuel debris at a spatial resolution of about 1 m</td>
<td>Can Image fuel debris at a spatial resolution of about 30 cm</td>
</tr>
<tr>
<td><strong>Detector: One small-size detector (easy installation and quick application)</strong></td>
<td>Detector: One pair of large-size detectors (needs wider space and longer time to install)</td>
</tr>
<tr>
<td></td>
<td>Can distinguish heavy element such as Uranium</td>
</tr>
</tbody>
</table>

![Diagram showing transmission and scattering methods](image.png)
Measurement by Transmission Method

- Detectors were installed at the north and north-west corners of Unit 1 reactor building (late January, 2015)
- Measured from February through May
- Detectors were shielded by 10 cm thick iron plates

Detectors were installed at the north and north-west corners of Unit 1 reactor building (late January, 2015). Measured from February through May, detectors were shielded by 10 cm thick iron plates.
Estimation of Fuel Debris Location Based on Comparison between Design Image and Measurement

- Measured data, though it does not clearly indicate, shows that equipment, etc. are detected at locations where they are supposed to exist based on the design documents.

- The boundaries of the PCV and the RPV in the image acquired from measurement matches those in the image drawn from design data.

- High density material (fuel debris) is not detected at the area where fuel assemblies are originally installed.
Measurement by Scattering Method

- Detectors will be installed in front of the R/B and 2nd Floor in T/B (Operation Floor) at Unit 2
- Background radiation should be eliminated by shielding and algorism
- The detector in front of the R/B should be shielded by 8 cm thick iron plates
- The detector on the second floor of the T/B will not be shielded because of low background radiation

![Diagram showing detector placements and radiation paths](image-url)
IRID’s R&D projects in FY2015

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- Remote Operated Decontamination Equipment (FY 2015)

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- Investigation Inside PCV (FY 2015)
- Investigation Inside RPV (FY 2015)
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Investigation
- Detection of Fuel Debris (FY 2015)

Repair and Water Leakage Stoppage of PCV
- Water Stoppage Technology of PCV (FY 2015)
- Full-Scale Test (FY 2015)

Repair and Water Leakage Stoppage of PCV

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- Collecting, Transferring and Storing of Fuel Debris (FY 2015-2016)

Radioactive Waste Treatment/Disposal
- Solid Waste Treatment and Disposal (FY 2015-2016)

Investigating Properties of Fuel Debris (FY 2015-2016)

Characterization
- Identifying Properties of Fuel Debris (FY 2015-2016)
Investigation inside the PCV (Unit 1)

[Investigated area] 1st floor grating outside the pedestal
[Steps for investigation and device development]

(1) Investigation from X-100 penetration (FY 2015)
   1. Acquire information about the grating area on the 1st floor (access point to the basement, etc.): B1 (finished)
   2. Acquire images showing the outside of the pedestal on the basement floor (esp. access entrance and nearby vent tube) following the results of investigation at the torus room using a small boat in November 2013: B2 (planning)

(2) Investigation from X-6 penetration (FY 2016-2017) (after decontamination around the X-6 penetration)
   1. Acquire further information about outside the pedestal on the basement floor by using fuel debris shape measurement apparatus: B3

B1. Investigation outside the pedestal on 1st floor grating (completed in April 2015) : from X-100B penetration

B2. Investigation outside the pedestal on the basement floor (planned to be done in FY 2015) : from X-100B penetration

B3. Investigation outside the pedestal on the basement and access entrance (FY 2016-2017) : from X-6 penetration

Investigation inside the pedestal is planned to be conducted after investigation of Unit No.2 finishes.

Necessity of further investigation will be decided according to the results of B2
B1 Investigation Completed in April, 2015

(1) Overview of equipment
- Shape-changing crawler equipment
- Inserted from the narrow access entrance (X-100B penetration: φ100 mm)
- Travel on the grating stably.

(2) Image of investigation routes
## Results of B1 Investigation

<table>
<thead>
<tr>
<th>Investigated area</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Access point to the basement</strong></td>
<td>• For the next investigation (outside the pedestal on the basement), it is confirmed that <strong>there is an access point to the basement</strong> and <strong>no obstacles around it</strong></td>
</tr>
</tbody>
</table>
| **CRD rail**                      | • **Could not reach to the CRD rail**  
• **Could not recognize the CRD rail by evaluation of image-processed pictures**, which were taken from the farthest reaching point by the investigation camera |
| **En route of investigation**     | • **No major damage was found** inside the PCV equipment (HVH, PLR Line, pedestal wall, etc.)  
• At every investigating point, **temperature and dose rate were recorded.** |

*Images at mock-up facility*

- **Access point to the basement**
- **PLR pump**
- **Support**
- **Conduit**
- **CRD Rail**
Investigation inside the PCV (Unit 2)

[Investigated area] - On the platform inside the pedestal (Upper surface of platform and CRD housing)
- Basement floor

(1) Investigation from X-6 penetration (Φ115 mm) (FY2015): A2
(2) Investigation from X-6 (Enlarge hole) (FY2016-2017): A3 and A4
  - Insert debris visualization system, investigate inside the 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 results of internal investigation from A2 to A4, investigation outside pedestal may be conducted.
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**Fundamental Retrieval Technology for Fuel Debris & Reactor Internals (FY 2015-2016)**

**Upgrading of Retrieval Method for Fuel Debris & Reactor Internals (FY 2015-2016)**

**Radioactive Waste Treatment/Disposal**
- Solid Waste Treatment and Disposal (FY 2015-2016)

**Evaluation of Long Term Integrity of spent fuel (FY 2015-2016)**

**Investigation**
- Identification of Fuel Debris (FY 2015)

**Identification**
- Characteristics of Fuel Debris (FY 2015-2016)

**Full-Scale Test**
- Water Stoppage Technology of PCV (FY 2015)

**Analysis**
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**Retrieval**
- Collecting, Transferring and Storing of Fuel Debris (FY 2015-2016)

**Radioactive Waste Treatment and Disposal**
- Solid Waste Treatment and Disposal (FY 2015-2016)

**Identification of Fuel Debris**
- Characteristics of Fuel Debris (FY 2015-2016)

**Fundamental Retrieval Technology**
- Retrieval Technology for Fuel Debris & Reactor Internals (FY 2015-2016)

**Upgrading of Retrieval Method**
- Retrieval Method for Fuel Debris & Reactor Internals (FY 2015-2016)

**Radioactive Waste Treatment**
- Solid Waste Treatment and Disposal (FY 2015-2016)

**Full-Scale Test**
- Water Stoppage Technology of PCV (FY 2015)

**Identification**
- Characteristics of Fuel Debris (FY 2015-2016)
Study of fuel debris retrieval method

We will study multiple methods for fuel debris retrieval to meet different conditions of damaged PCV and scattering fuel debris at each unit.

**Submersion method**
- Most favorable approach for minimizing the radioactive exposure of workers

- Wire
- Work platform
- Hydraulic manipulator
- Fuel debris

**Dry method (partial submersion, in-air work)**
- Development of technology which prevents scattering radioactive materials from PCV is needed to remove PCV contents in-air work

- Top access
- Shield plug
- PCV head
- RPV head
- Steam dryer
- Steam separator
- Hydraulic manipulator

- Side access
- Access rail
- Hydraulic manipulator

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

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

Most favorable approach for minimizing the radioactive exposure of workers.
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**Radioactive Waste Treatment/Disposal**
- Solid Waste Treatment and Disposal (FY 2015-2016)
## Characteristics of Nuclear Waste Generated from Fukushima Daiichi NPS Accident

<table>
<thead>
<tr>
<th>Type of Waste</th>
<th>Characteristics</th>
</tr>
</thead>
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| Rubble/Felled and removed trees/soil, etc. | • Large quantity and widely distributed  
  • Poor experience with the treatment and disposal of felled and removed trees and soil  
  • Surface contamination by scattering/diffusion is main contamination and some contamination is penetrating contamination caused by accumulated water |
| Secondary waste by water treatment     | • Poor experiences of treatment and disposal  
  • Difficult to collect the waste  
  • Partial estimation of quantity and kind of nuclide may be possible based on the characteristics of water treatment equipment |
| Fuel debris/Demolishing waste          | • Large amount and high dose rate  
  • Difficult to sample actual waste due to low accessibility at present |
### Comparison between Wastes from Accident and Operation

<table>
<thead>
<tr>
<th>Item of uncertainty</th>
<th>Waste from operation</th>
<th>Waste from accident</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation of waste [quantity, type, period]</td>
<td>◎</td>
<td>△</td>
</tr>
<tr>
<td>Handling (collecting/classifying) [difficulty]</td>
<td>◎</td>
<td>△</td>
</tr>
<tr>
<td>Characterization [sufficiency of information, difficulty of sampling, representativeness of sample]</td>
<td>○</td>
<td>△</td>
</tr>
<tr>
<td>Technologies for processing and packaging waste</td>
<td>○</td>
<td>? ~ △</td>
</tr>
<tr>
<td>Burial and disposal methods and safety assessment</td>
<td>△ ~ ○</td>
<td>?</td>
</tr>
<tr>
<td>Regulations, technical standards, guidelines, siting</td>
<td>△ ~ ○</td>
<td>?</td>
</tr>
</tbody>
</table>

◎: Fully understood or good prospect, ○: Fair prospect, △: Limited, ? : Cannot be discussed

- **Waste generated from operation has its own problem but is fairly under control.**
  - Information on basic properties of waste, including quantity at present, future change, activity and chemical substances contained in individual waste is identified.
  - Both unprocessed and processed wastes are appropriately stored and managed in accordance with the current regulations.
  - Regulations and standards, as well as disposal method and safety assessment method, have been in place.

- **Many uncertainties poses important technical problems to disposal of the accident-generated waste at the Fukushima Daiichi.** **Solving these uncertainties and bringing the waste under control are the major goals** of countermeasures and technology development.
Fuel debris retrieval at the Fukushima Daiichi Nuclear Power Station is expected to be more difficult compared to that of the accident at the Three Mile Island 2 (TMI-2). It is necessary to put domestic and international wisdom together to develop the whole strategy, method and equipment for fuel debris retrieval.

In order to complete the fuel debris retrieval, it is necessary to clarify the purpose and goal of relating each project, and then, to develop technologies flexibly by planning with an aim to achieve not partial but overall optimization.

In making strategy, it is important to consider end-state (what you wish to achieve at the end), study various feasible options and always prepare alternative options.
Thank you for your attention