PROGRESS REPORT 2018

IRID

International Research Institute
for Nuclear Decommissioning

IRID gathers knowledge from aroun R&D of nuclear decommissioning under an integrated management sy

Decommissioning of Fukushima Daiichi is unique, unprecedented and extremely difficult gathering global knowledge considering the technological challenges.

Greeting

Ever since its establishment in August 2013, the International Research Institute for Nuclear Decommissioning (IRID) has been fully committed to an urgent challenge—research and development (R&D) of technologies required for the decommissioning work of the Fukushima Daiichi Nuclear Power Station (NPS) including strengthening the foundation of decommissioning technology. In August 2014, the Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF) was reorganized from the Nuclear Damage Liability Facilitation Fund. Since then, the division of roles among relevant organizations engaging in the decommissioning has been clarified: The NDF formulates strategies and R&D plans for the decommissioning; The Tokyo Electric Power Company (TEPCO) implements on-site operation; and IRID conducts R&D of technology required for the decommissioning. The four key players, including the government, have been working closely together in the effort to decommission the Fukushima Daiichi NPS.

As a result, the situation inside the primary containment vessel (PCV) and the reactor have been gradually ascertained through the development of technology for investigation inside the PCVs and indentification of fuel debris by cosmic rays. Meanwhile, the technological challenges to be tackled have been also clearer.

Reflecting the revision of “Technical Strategic Plan 2017 for Decommissioning of the Fukushima Daiichi NPS of TEPCO Holdings, inc.” (Strategic Plan 2017, hereinafter) by NDF, which provides the technological basis for the NDF Mid-and-Long-Term Roadmap for Decommissioning of the Fukushima Daiichi NPS of TEPCO Holdings, inc. (Mid-and-Long-Term Roadmap, hereinafter) in September 2017, the Mid-and-Long-Term Roadmap was revised by the government.

There it has been expressed that the fuel debris retrieval method would prioritize the retrieval of debris from the bottom of the PCVs focusing on “Partial submersion side access” method. The R&D for fuel debris retrieval is just about to enter a crucial phase.

To proceed with a safe and secure decommissioning of the Fukushima Daiichi NPS, IRID is committed to its responsibility of making steady achievements in R&D for the reconstruction of Fukushima, and gathering knowledge from all over the world. We sincerely appreciate your kind guidance and continued support.

January 2018

International Research Institute for Nuclear Decommissioning

President
Hideo Ishibashi

CONTENTS

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tasks in the world. IRID is promoting R&D by

What IRID aims for

Purpose

To conduct testing and research for the decommissioning of nuclear power stations, and implement projects aimed at improving the technological level of IRID member organizations and to put technologies they develop into practical use.

Basic principles

We devote ourselves to research and development (R&D)
of technology for the current, most urgent challenge
– the decommissioning of the Fukushima Daiichi Nuclear Power Station –
from the standpoint of strengthening the foundation of nuclear decommissioning technology

Our Principles in Action

1. We work on R&D projects effectively and efficiently while advancing integrated project management to develop and propose the best technologies and systems that are able to be applied on site at the Fukushima Daiichi NPS at an early stage, in the face of numerous extremely difficult technological challenges

2. We build an optimal R&D structure through cooperation with relevant organizations as well as IRID member organizations and gathering knowledge from Japan and abroad.

3. We actively promote efforts to develop and secure human resources who will comprise the next generation of those working in nuclear decommissioning and related technologies, including efforts to collaborate with universities and research institutions.

4. We strive to release information on our R&D activities and results to obtain the understanding of Japanese people, including those in Fukushima, and the international community to relieve their anxieties.

5. We form an international research hub (center of excellence) through our R&D activities and contribute to the acceleration of the decommissioning of the Fukushima Daiichi NPS and improvement of technological capabilities in the international community

Organization Profile

1. Name of the Organization

International Research Institute for
Nuclear Decommissioning (IRID)

2. The Head Office

5F, 3 Toyokaiji Building, 2-23-1 Nishi-Shimbashi,
Minato-ku, Tokyo 105-0003, Japan
TEL:+81 3 6435 8601

3. Date of Establishment

August 1, 2013 Based on the Research and Development Partnership Act, the Ministry of Economy, Trade and Industry has approved the establishment.

4. Scope of Work

- R&D for nuclear decommissioning
- Promotion of cooperation on nuclear decommissioning with relevant international and domestic organizations
- Human resource development for R&D

5. Memberships (18 organizations)

<National research and development corporation>
Japan Atomic Energy Agency
National Institute of Advanced Industrial Science and Technology
<Plant manufacturers, etc.>
TOSHIBA ENERGY SYSTEMS & SOLUTIONS 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 Company (TEPCO) Holdings, Inc.
Chubu Electric Power Co., Inc. Hokuriku Electric Power Company
The Kansai Electric Power Co., Inc. The Chugoku Electric Power Co., Inc.
Shikoku Electric Power Company, Inc.
Kyushu Electric Power Co., Inc.
The Japan Atomic Power Company Electric Power Development Co., Ltd.
Japan Nuclear Fuel Limited

6. Board of Directors

President	: Hideo Ishibashi
Vice president	: Tamio Arai
Managing Director	: Tadashi Kawamura
Directors	: Hirotsugu Fujiwara, Satoshi Ueda, Hiroto Uozumi, Ei Kadokami, Masahiro Seto, Koichi Noda, Jun Matsumoto, Goro Yanase
Auditor	: Atsushi Isobe

7. Number of Employees

943 *(Excluding Directors)

*Including those who are engaged in the research of this organization at member corporations.

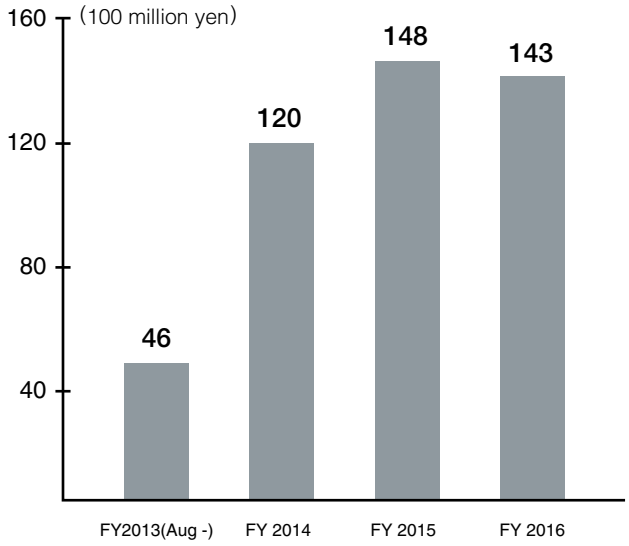
(As of October 1, 2017)

* History of Establishment

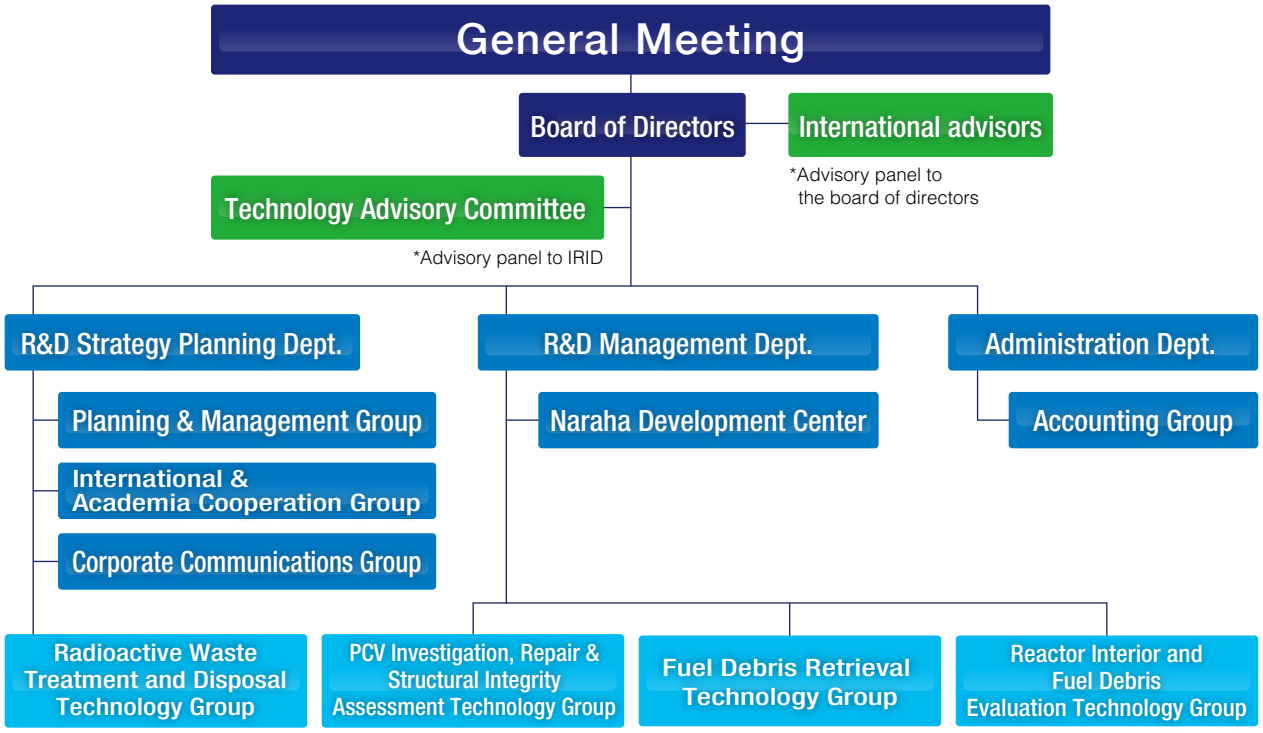
The 1st report of Mid-and-Long-Term actions for the Fukushima Daiichi Nuclear Power Station was created in July 2011,four months later than March 2011 when the accident at Fukushima Daiichi Nuclear Power Station occurred. At that time, opinions that a dedicated national organization for the decommissioning was necessary were issued from experts, then focused by the Atomic Energy Commission.

In response to that situation, the establishment of a new organization was specifically expressed at the Council for the Decommissioning of TEPCO's Fukushima Daiichi NPS in March 2013. As a result of continuous study by establishing a preparation organization, a request for approval of the establishment of IRID was submitted to the Ministry of Economy, Trade and Industry in late July and approval was granted from the minister of the Ministry of Economy, Trade and Industry on August 1. Then, the operation was started after the General Meeting that is an autonomous legislative body of the organization was held on August 8, 2013.

* Project Costs



Organizational Structure

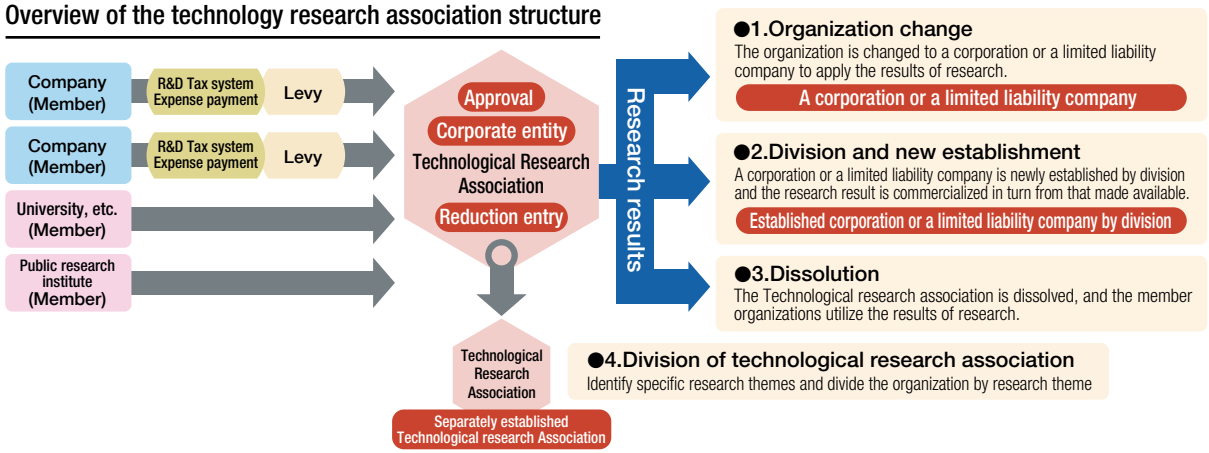


(As of January, 2018)

Reference: What is the technology research association?

The technology research association is a mutual aid organization (Non-profit common benefit corporation) to process joint research of technologies utilized in industrial activities for its own members. IRID selected "Technology research association" to organize itself. The clarity and flexibility of organizational management are considered as merits in addition to quick organizing.

Overview of the technology research association structure



Features of the Technological Research Association

- Each member provides researchers, research funds, equipment, etc. to execute joint research and the result is jointly managed and utilized by the members mutually.
- It is a joint research organization having a legal personality independent of its members.
- Transparency and reliability of organization operation are improved through the establishment of approval requests and submissions to the competent minister, holding general meetings of the members and board meetings, etc.
- Those who directly or indirectly utilize the result of joint research (corporate/individual, including foreign company and foreigner) can be a member.
- This can be utilized as a stage for industry-academia-government collaboration because universities, Research and Development Incorporated Administrative Agencies, technical junior colleges, local governments, foundations with research and development as the main purpose, etc. can join as members.

(Source) Excerpt from "What is the Technological Research Association?" Homepage of the Ministry of Economy, Trade and Industry.

Roles of IRID

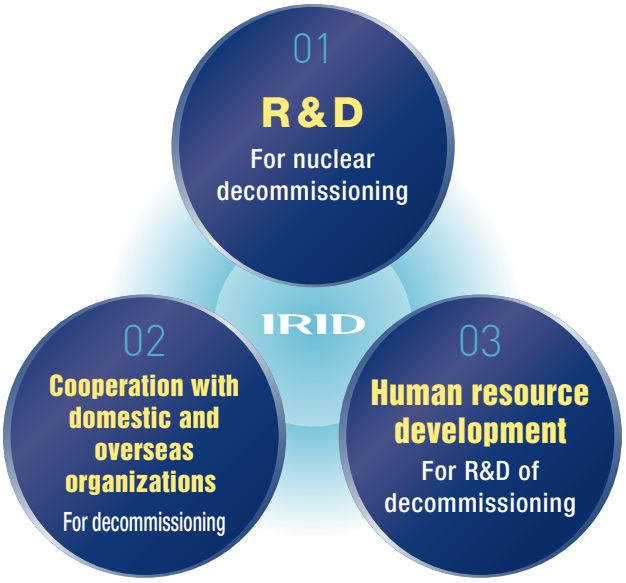
IRID works for R&D of decommissioning under a major goverment policy while closely cooperating with organizations involved in the decommissioning of the Fukushima Daiichi NPS. IRID has a three-pronged strategy; R&D of decommissioning, cooperation with domestic and overseas organizations and human resource development.

Activities of IRID

IRID is an organization composed of 18 corporates that are leading players for R&D of decommissioning the Fukushima Daiichi NPS.

Although it aims toward cultivation/accumulation of the technologies necessary for the entire decommissioning in this country, currently it is tackling R&D for the decommissioning of the Fukushima Daiichi NPS as an urgent challenge based on the Mid-and-Long-Term Roadmap of the government.

In addition, it is necessary to gather knowledge from Japan and abroad to process the decommissioning of the Fukushima Daiichi NPS, which is unprecedented in the world and extremely difficult, therefore, IRID promotes cooperation with related domestic and international organizations. Moreover, IRID is promoting the development of human resources necessary to continue the decommissioning work of the Fukushima Daiichi NPS.



A structure has been established in which three organizations cooperate closely together as one team and where each role for decommissioning the Fukushima Daiichi NPS is clarified: "Nuclear Damage Compensation Facilitation Corporation (NDF)" formulates strategies and R&D plans for decommissioning, "TEPCO Holdings" performs on-site operations, and IRID conducts R&D.

IRID is committed to the decommissioning activities of the Fukushima Daiichi NPS for its part in this structure through its R&D.

HISTORY Chronology of IRID activities

2013

〈August〉
- ○Establishment of International Research Institute for Nuclear Decommissioning (IRID) (Started with 17 corporates) First president Hajimu Yamana

〈September〉
- ○Holding the 1st workshop on development of human resources contributing to R&D.

〈December〉
- ○Holding the 1st "Technology Advisory Committee."

2014

〈January〉
- ○Holding the 1st "International Advisors meeting".

〈March〉
- ○Executing demonstration tests of suction/blast decontamination apparatus.

〈April〉
- ○Executing actual machine verification of low place decontamination apparatus. (Dry ice blast apparatus)
- ○Executing actual machine verification of low place decontamination apparatus (High pressure water decontamination apparatus)

〈May〉
- ○Executing the investigation of unit 1 suppression chamber (S/C) upper part by using investigation apparatus.
- ○With the joining of ATOX Co., Ltd., the organization became an 18-corporate structure as is current.

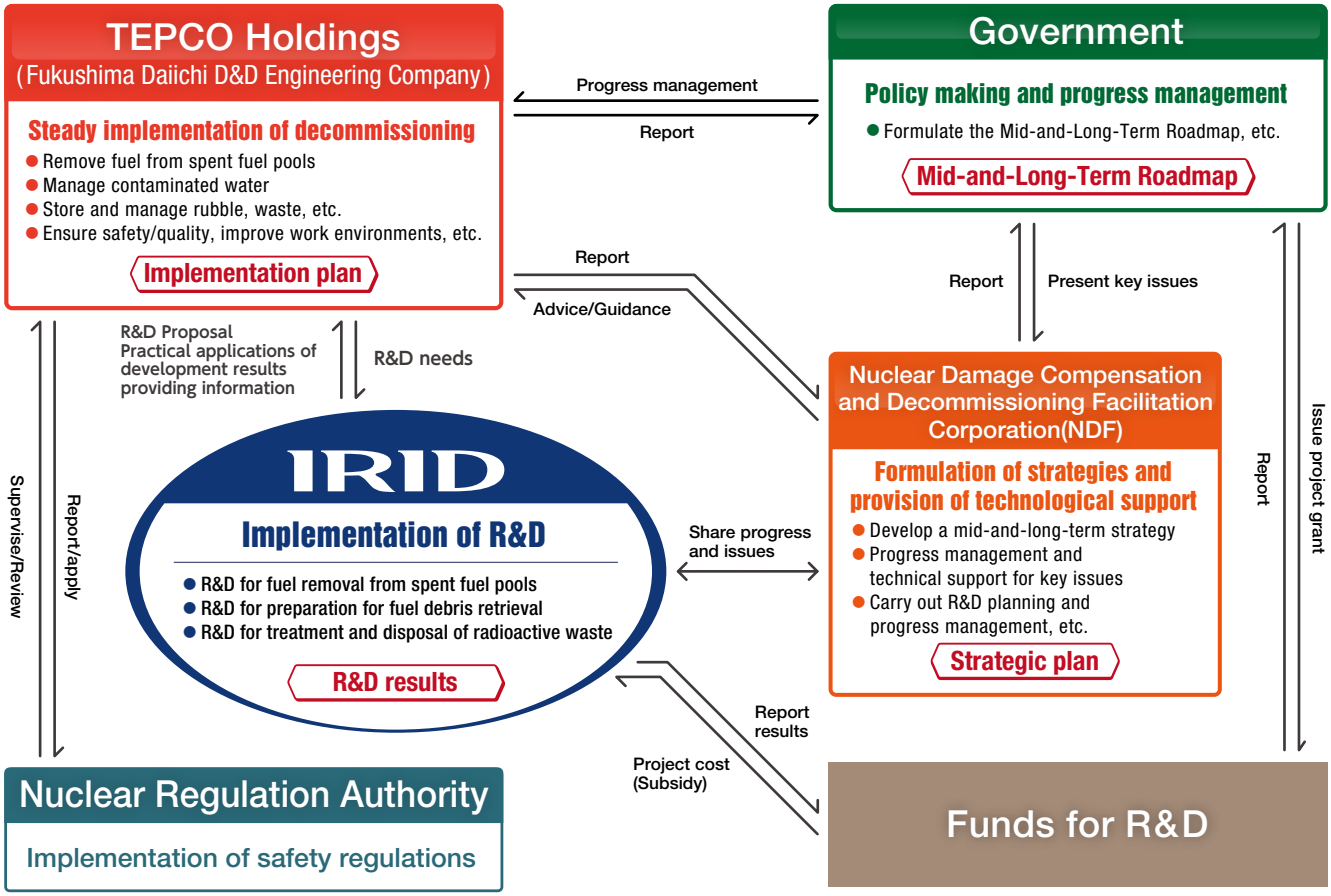
〈July〉
- ○Holding the 1st IRID Symposium 2014 (in Tokyo)
- ○Executing investigation of the wall of the unit 2 torus room by using a submersible robot and a floor traveling robot.

〈August〉
- ○Nuclear Damage Compensation Facilitation Corporation was restructured to Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF).
- ○Appointment of the 2nd president Hirofumi Kenda

〈September〉
- ○Executing the investigation of the unit 2 S/C lower outer surface by using investigation apparatus.

〈November〉
- ○Executing investigation of the spent fuel that was transferred to the common pool at Unit 4.
- ○Holding the 2nd "International Advisors meeting".

Roles of the Organizations for the Decommissioning Project of the Fukushima Daiichi NPS.



■…General ■…R&D ■…Human resources development ■…International relationship

2015

〈February – May, May – September〉
- ○Observing unit 1 by using muon transmission method technology.

〈April〉
- ○Executing investigation of inside unit 1 primary containment vessel(PCV) by using a robot, PMORPH 1.

〈July〉
- ○Holding the IRID Symposium 2015 (In Fukushima city)

〈December〉
- ○Developing an upper floor decontamination apparatus.
- ○Holding the 3rd "International Advisors meeting".

2016

〈March – July〉
- ○Observing unit 2 by using muon transmission method technology.

〈April〉
- ○Completing a "Full-scale mock-up facility" in the JAEA Naraha Remote Technology Center.

〈May〉
- ○Executing actual machine verification of a high place decontamination apparatus (Dry ice blast decontamination apparatus) on the 1st floor of the unit 3 reactor building.

〈August〉
- ○Holding the IRID Symposium 2016 (In Tokyo)

〈November〉
- ○Holding the 4th "International Advisors meeting

2017

〈February〉
- ○Executing investigation of inside the unit 2 PCV by using a scorpion robot.

〈March〉
- ○Executing investigation of inside the unit 1 PCV by using PMORPH 2.

〈May – September〉
- ○Observing unit 3 by using muon tomography.

〈June〉
- ○Executing a full-scale test by filling water stoppage material in the S/C.
- ○Appointment of the 3rd president Hideo Ishibashi

〈July〉
- ○Executing investigation of inside the unit 3 PCV by using a submersible ROV.
- ○Executing a full-scale test of reinforcement technology for S/C support columns.

〈August〉
- ○Holding the IRID Symposium 2017 (In Iwaki city)

〈December〉
- ○Holding the 5th International Advisors meeting

Roles of IRID

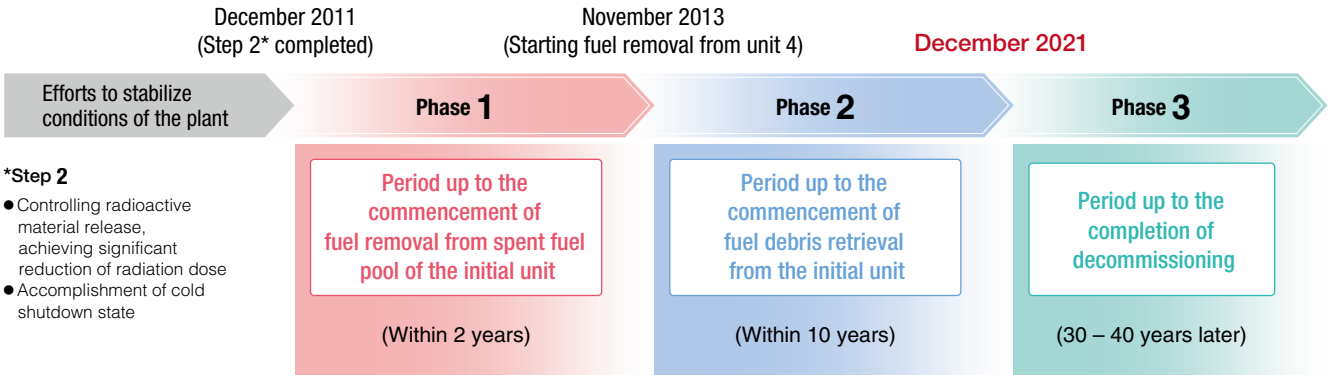
Overview of the Mid-and-Long-Term Roadmap (Revised on September 26, 2017)

Decommissioning of the Fukushima Daiichi Nuclear Power Station is processed based on the "Mid-and-Long-Term Roadmap for Decommissioning of the Fukushima Daiichi Nuclear Power Station of the Tokyo Electric Power Company Holdings, Inc." (Mid-and-Long-Term Roadmap) decided by the government.

The period until completion of the decommissioning work is divided into 3 phases: 1st phase – 3rd phase and the current period is the 2nd phase, "R&D to prepare for fuel debris retrieval."

The current Mid-and-Long-Term Roadmap revised in September 2017 (4th revision), in which the target processes (milestones) is described under the premise that it is subject to be revised depending on the on-site situation and R&D results, aims for starting fuel debris retrieval at the initial unit during 2021.

Phases in the Mid-and-Long-Term Roadmap



( ) represents the period from completing phase 2.

IRID has been engaged in various R&D activities under the Mid-and-Long-Term Roadmap. As a result, IRID successfully visualized inside the reactor by investigation inside the primary containment vessel using remote-operated robots and tomography utilizing a cosmic ray muon. On the other hand, technological issues to be overcome are also clarified.

IRID continues challenging those issues and does its best for the R&D required for the commencement of fuel debris retrieval from the initial unit during 2021.

◯Clarification of target processes (milestones)

For fuel debris retrieval

- Decision on fuel debris retrieval policy (September, 2017)
- Finalization of fuel debris retrieval methods for the initial Unit (FY2019)
- Start of fuel debris retrieval at the initial Unit (within 2021)

*Resource: Mid-and-Long-Term Roadmap (4th revision) on September 26, 2017

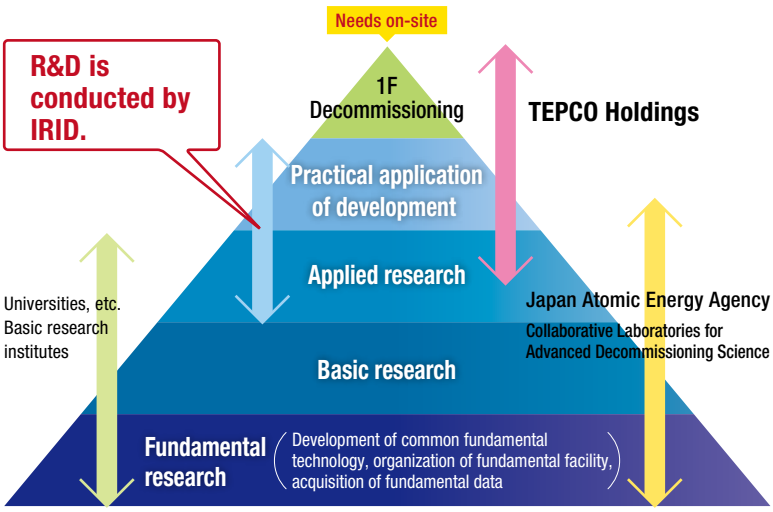
IRID R&D Scope

Decommissioning work

- Continuation of cold shutdown state of the reactor
- Treatment of accumulated water (Countermeasure for contaminated water)
- Reduction of radiation dose as a whole plant, preventing spread of contamination
- Fuel retrieval from spent fuel pool
- **Fuel debris retrieval**
- Plan for storage/control and treatment/ disposal of solid wastes
- Decommissioning plans of the nuclear reactor facility

R&D is conducted by IRID.

Overview of R&D



* The above chart was created based on the NDF Technology Strategy Plan 2017.

List of Government Subsidized R&D Projects Conducted by IRID

Subsidy Project of Decommissioning and Contaminated Water Management in the FY2015, and the FY2016 Supplementary Budgets

Ministry of Economy, Trade and Industry
Agency for Natural Resources and Energy

(As of end of November, 2017)*1

Project name	Project Summary	Period	Supplementary budget	Project Maximum Cost *2 (Subsidy Rate)
Development of Technology for Investigation inside the Primary Containment Vessel	(1)Formulation and upgrading of investigation plan and development plan (2)Development of equipment and systems to access and investigate specific areas (3)On-site demonstrations (4) Management of R&D	April 1, 2016- March 31, 2018	FY2015 (Conducted in FY2017)	4 billion JPY (Fixed)
Development of Technology for Detailed Investigation inside the Primary Containment Vessel	(1)Formulation and upgrading of investigation plan and development plan (2)Development of equipment and systems to access, and investigation and element technology (3)Management of R&D	April 3, 2017- March 31, 2018	FY2015 (Conducted in FY2017)	3.4 billion JPY (Fixed)
Development of Technology for Investigation inside the Reactor Pressure Vessel	(1)Establishment and upgrading of the investigation/development plans (2)Conceptual design of corrosion control system (3)Development and selection of reactor core investigation method (4)Design and construction plan of integrated investigation system (5)Management of R&D	April 1, 2016- March 31 2018	FY2015 (Conducted in FY2017)	2 billion JPY (Less than 50%)
Development of Fundamental Technologies for Retrieval of Fuel Debris and Internal Structures (Development of small size neutron detector)	(1)Identification and its feasibility study of neutron detection technology applicable to fuel debris retrieval, etc. at the Fukushima Daiichi Nuclear Power Station.	April 24, 2017- December 29, 2017	FY2016 (Conducted in FY2017)	2 billion JPY (Fixed)
Upgrading for identifying comprehensive conditions inside the reactor	(1)Integrated analysis and evaluation of conditions inside the reactor (2)Estimation/evaluation of behavior and characteristics of fuel debris and fission products for integrated analysis and evaluation (3)Management of R&D	April 1, 2017- March 31, 2018	FY2015 (Conducted in FY2017)	2 billion JPY (Fixed)
Fuel Debris Characterization/Development of Analysis Technology	(1)Estimation of properties of fuel debris in the reactor (2)Characterization using simulated debris (3)Development of element technology for fuel debris analysis	April 1, 2017- March 31, 2019	FY2016 (conducted in FY2017-FY2018)	650 million JPY (Fixed)
Development of Repair Technology for Leakage Sections in PCV	(1)Consideration and planning of process leading to water replenishment in the PCV (2)Development of the PCV lower part repair technology (3)Development of the PCV upper part repair technology (4)Consideration of environmental improvement concept for application of repair construction method in actual equipment (5)Management of R&D	April 1, 2016- March 31, 2018	FY2015 (Conducted in FY2017)	6 billion JPY (Less than 50%)
Full-scale Testing of Technology for Repairing PCV Leakage Points	(1)Full-scale tests of PCV lower part repair technology [1] Strengthening S/C support columns [2] Stopping water in vent pipes [3] Water stoppage by injecting filling in S/C (2)Confirmation of integrity of reinforcement materials and water stoppage materials after testing (3)Maintenance of VR data for preliminary simulation tests (4)Management of R&D	April 1, 2016- March 31, 2018	FY2015 (Conducted in FY2017)	4 billion JPY (Fixed)
Upgrading Approach and System for Retrieval of Fuel Debris and Internal Structures	(1)Technology development related to confinement function (2)Technology development related to collection and removal of dust generated by fuel debris (3)Study of monitoring system for nuclide-accompanying fuel debris retrieval. (4)Study of optimization, etc. related to securing safety of working method and system	April 3, 2017- March 31, 2019	FY2016 (conducted in FY2017-FY2018)	2 billion JPY (Fixed)
Development of Fundamental Technologies for Retrieval of Fuel Debris and Internal Structures	(1)Technology development related to preventing fuel debris diffusion (2)Element technology development related to the development of retrieval equipment (3)Development of remote maintenance technology for fuel debris retrieval equipment (4)Development of monitoring technology at fuel debris retrieval, etc.	April 3, 2017- March 31, 2019	FY2016 (conducted in FY2017-FY2018)	3.5 billion JPY (Fixed)
Development of sampling technology for retrieval of fuel debris and internal structures	(1)Study and formulation of fuel debris collection and sampling scenario (2)Design and trial production of sampling system and equipment for fuel debris in the reactor containment vessel (3)Conceptual study of sampling system for fuel debris in the reactor containment vessel	April 3, 2017- March 31, 2018	FY2015 (Conducted in FY2017)	1.5 billion JPY (Fixed)
Development of Technology for Collection, Transfer and Storage of Fuel Debris	(1)Investigation and formulation of research plan for transfer and storage (2)Study of safety requirement specification and system related to transfer and storage of fuel debris canister (3)Development of safety evaluation methods and verification of the safety (4)Study of fuel debris storage form, etc.	April 3, 2017- March 31, 2018	FY2015 (Conducted in FY2017)	1.2 billion JPY (Less than 50%)
Development and Management of Evaluation Method of Seismic Performance/Impact of RPV and PCV	(1)Construction of safety scenario for possible large-scale earthquake (2)Development of seismic performance and impact evaluation method for safety scenario (3)Upgrading of safety scenario (4)Management of R&D	March 1, 2017- March 31, 2018	FY2015 (Conducted in FY2017)	1 billion JPY (Fixed)
Development of Technology for Criticality Control in Fuel Debris Retrieval	(1)Establishment of criticality evaluation methods (2)Development of technology for criticality control in fuel debris retrieval (3)Management of R&D	April 1, 2017- March 31, 2018	FY2015 (Conducted in FY2017)	1 billion JPY (Less than 50%)
R&D for Treatment and Disposal of Solid Waste	(1)Characterization (2)Study of management before treatment (3)Study of treatment concept and safety evaluation method that are suitable for solid waste (4)Integration of R&D results, etc.	April 1, 2017- March 31, 2019	FY2016 (conducted in FY2017-FY2018)	2 billion JPY (Fixed)

*1 Projects listed in IRID "Project Plan" *2 Project maximum cost and subsidy rates are cited from the value in the Solicitation Information.

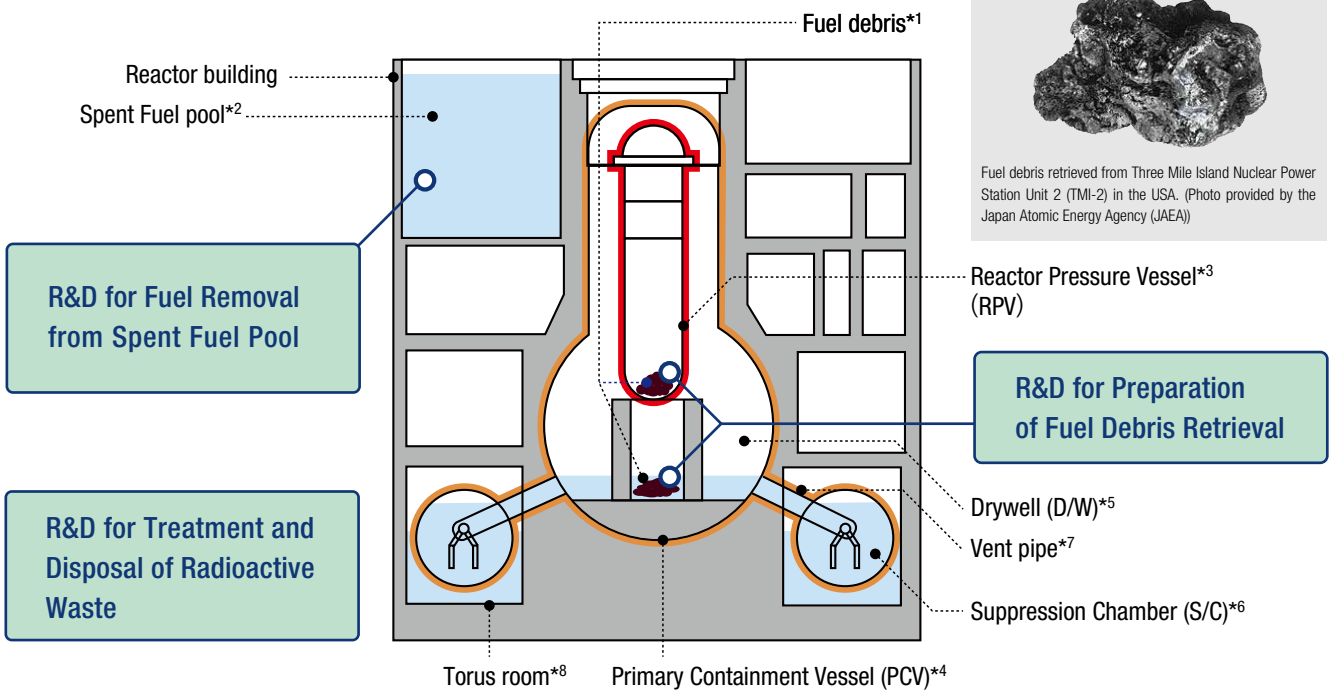
A key theme of R&D is fuel debris retrieval. IRID is committed to promoting further R&D based on the “Fuel Debris Retrieval Policy 2017.”

IRID R&D

IRID has been conducting R&D to proceed with the decommissioning of the Fukushima Daiichi Nuclear Power Station (NPS), according to the Mid-and-Long-Term Roadmap. In order to improve decommissioning strategy, IRID is studying alternative appropriate approaches and how to reduce risks, while exploring the end state (final form) through tie-ups with TEPCO and relevant organizations.

Our three-key-R&D for the decommissioning are; “R&D for Fuel Removal from Spent Fuel Pool,” “R&D for Preparation of Fuel Debris Retrieval” and “R&D for Treatment and Disposal of Solid Radioactive Waste.”

Overview of the Reactor Building and R&D Conducted by IRID



(Reference)

Fuel debris retrieved from Three Mile Island Nuclear Power Station Unit 2 (TMI-2) in the USA. (Photo provided by the Japan Atomic Energy Agency (JAEA))

*1 **Fuel debris:** Lava-like fuel containing material that is produced under high temperatures through melting with control rods and structures inside the RPV, after which it cools and re-solidifies.

*2 **Spent fuel pool:** A water tank that stores spent fuel that is inserted into a rack under water until decay heat generated from fission products decreases. This tank is located on the top floor of the reactor building.

*3 **Reactor Pressure Vessel (RPV):** A cylindrical steel container that houses fuel assemblies. This container can resist high-temperature water and high-pressure steam generated by the energy released by nuclear fission inside. The RPV is housed within the PCV together with cooling equipment.

*4 **Primary Containment Vessel (PCV):** A steel container that houses the RPV, cooling equipment, and other devices that perform important functions. This prevents radioactive substances from being released into the outside environment under abnormal plant conditions, such as when a reactor accident occurs, or in the event of a breakdown of cooling equipment. It should be noted that each of the PCVs installed in Units 1-3 at the Fukushima Daiichi NPS consists of a flask-shaped drywell, a doughnut-shaped suppression chamber and eight vent pipes connecting the drywell and the suppression chamber.

*5 **Drywell (D/W):** A safety structure, located inside of the PCV, that is comprised of a flask-shaped container that houses equipment, including the RPV, and contains radioactive substances at the time of an accident.

*6 **Suppression chamber (S/C):** Doughnut-shaped equipment that stores water located in the basement of the reactor building. Condenses vapor generated in the case of reactor piping breakage and prevents excess pressure from building up. It also serves the important function of providing a water source for the Emergency Core Cooling System (ECCS) in the case of a loss-of-coolant accident.

*7 **Vent pipe:** Connecting piping that takes vapor generated within the D/W to the S/C in case of a reactor pipe breakage. Eight vent pipes are installed in the PCV of Units 1-3 at the Fukushima Daiichi NPS.

*8 **Torus room:** A room containing the torus-shaped (doughnut-shaped) S/C located in the basement of the reactor building.

CLOSE UP

Policy of Fuel Debris Retrieval and Current Approaches

Based on feasibility evaluation and proposals of fuel debris retrieval methods that were studied in the NDF Strategy Plan, IRID is promoting future activities in the following fuel debris retrieval policy.

1 Step-by-step approach
Fuel debris will be retrieved by starting with a small portion and then gradually expanding with a review of the work.

2 Optimization of whole decommissioning work
From preparation work through retrieval, transportation, treatment, storage and clearing up, a comprehensive plan is studied aiming at a total optimization.

3 Combination of multiple methods
The study is executed assuming the side-access method for the bottom of the PCV and top-access method for the inside of the RPV.

4 Focusing on partial submersion method
Considering the difficulty of stopping water leakage and the exposure dose at work, the partial submersion method is focused on because the full submersion method is difficult at present.

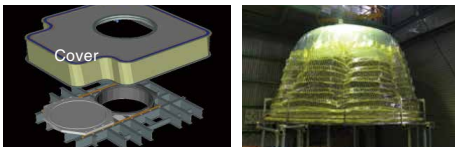
*The full submersion method is also considered by considering the advantage of a shield effect.

5 Proceeding forward with the side-access method, which is horizontal access to the bottom of the PCV
The fuel debris exists both at the bottom of the PCV and the inside of the RPV of each unit.The side-access method for the bottom of the PCV is prioritized to minimize the increase of risk accompanied with the retrieval in consideration of the following.

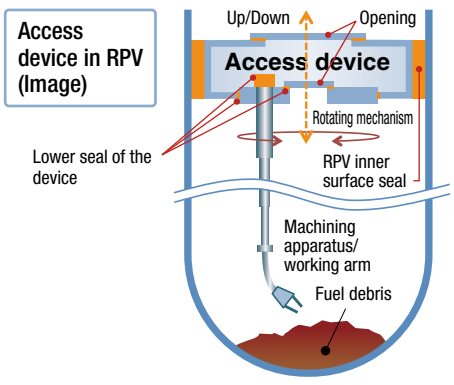
[1] Accessibility to the bottom of the PCV is the best and knowledge is accumulated, [2] There is a possibility to execute it earlier, and [3] It can be processed in parallel with spent fuel removal.

Current approaches based on the policy for fuel debris retrieval → **Continuous investigation of the inside PCV, and acceleration of focused R&D**

Top access method – Image of debris retrieval –



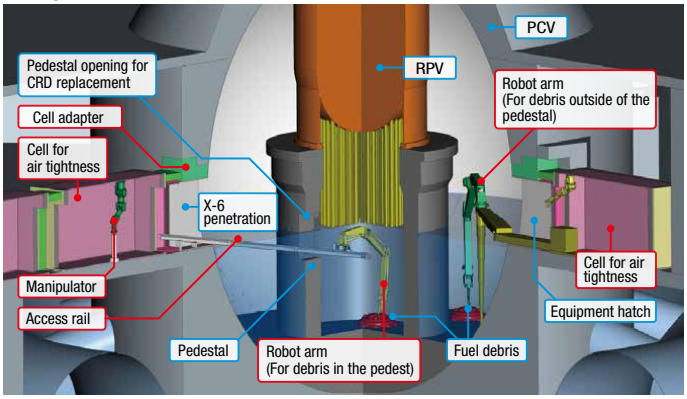
Shielding port with openable cover　Dust scattering prevention film



AR Side access method: Access rail method – Image of debris retrieval –

- Debris “in” the pedestal ⇒ Insert the access rail from X-6 penetration into the pedestal and retrieve by using a robot arm.
- Debris “outside” of the pedestal ⇒ Retrieve by using a robot arm through the equipment hatch.

Image of unit 2&3*



Note) Those in the red frames are new equipment. *Position of X-6 penetration of unit 1 is different from those of unit 2&3.

*Scan the text or photos marked with AR by COCOAR2.

Overview of IRID R&D Projects

R&D for fuel debris retrieval including the development of investigation robots inside the reactor and retrieval technology are being promoted according to the Mid-and-Long-Term Roadmap.

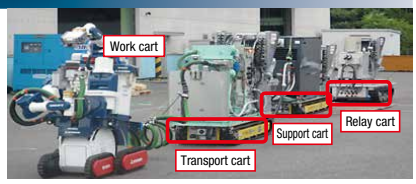
1 ···R&D for Fuel Removal from the Spent Fuel Pool
2 ···R&D for Fuel Debris Retrieval
3 ···R&D for Treatment and Disposal of Radioactive Waste

1 a R&D for Fuel Removal from the Spent Fuel Pool

- Evaluation of Long-term Integrity of Fuel Assembly
  - (Evaluation of Deposits of the Fuel Assembly Surface and Fuel Integrity in Dry Storage)
- Basic Tests for Long-term Integrity

2 Technology for Decontamination and Dose Reduction

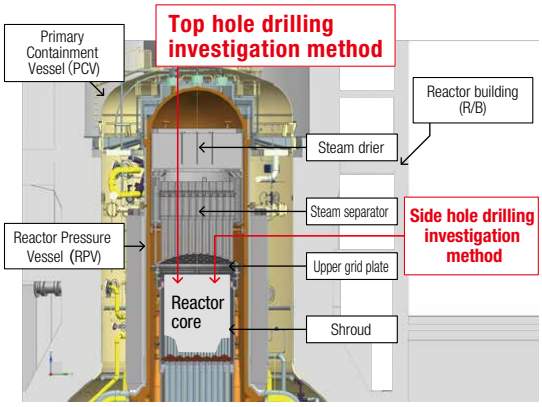
○Technology for Remotely-operated Decontamination in the Reactor Building



2 Technology for Investigation inside the Reactor

ⓑTechnology for Investigation inside the RPV

Evaluation for feasibility of two methods
(Conceptual image of investigation method)



ⓒTechnology for Investigation inside the PCV

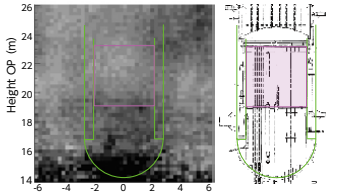
Development of investigation robots inside the PCV

ⓓTechnology for Detection of Fuel Debris

Investigation technology for fuel debris distribution inside the RPV utilizing cosmic ray muon.

An image of high density substance thought to be fuel debris is confirmed on the bottom of the RPV.
*The measurement at unit 2 was conducted by TEPCO Holdings as a part of the IRID activities.

＊Size of one pixel: Equivalent to approx. 25 cm at the cross section of the nuclear reactor

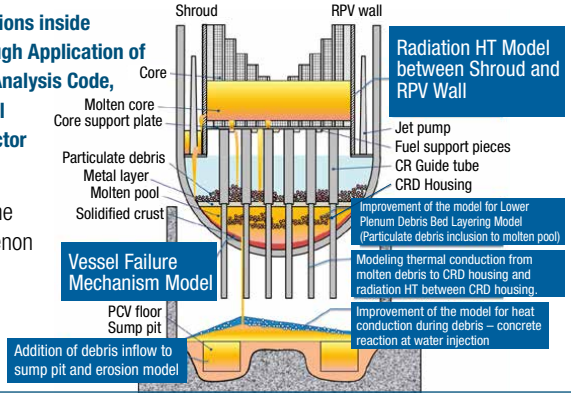


Muon detector
ⓓ
Torus room

2 Technology for Investigation and Analysis (Characterization) inside the Reactor

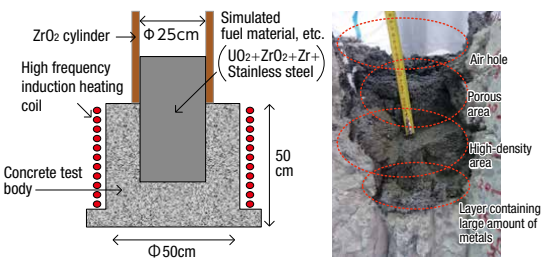
Identifying Conditions inside the Reactor through Application of Severe Accident Analysis Code, Data on the Actual Reactor, and Reactor Internals

Improvement of the physical phenomenon model



ⓔFuel Debris Characterization

Characterization using simulated debris

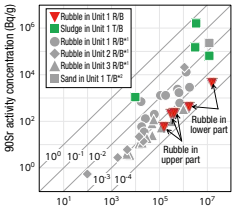


Large MCCI test apparatus in cooperation with CEA and its test product generated in MCCI test

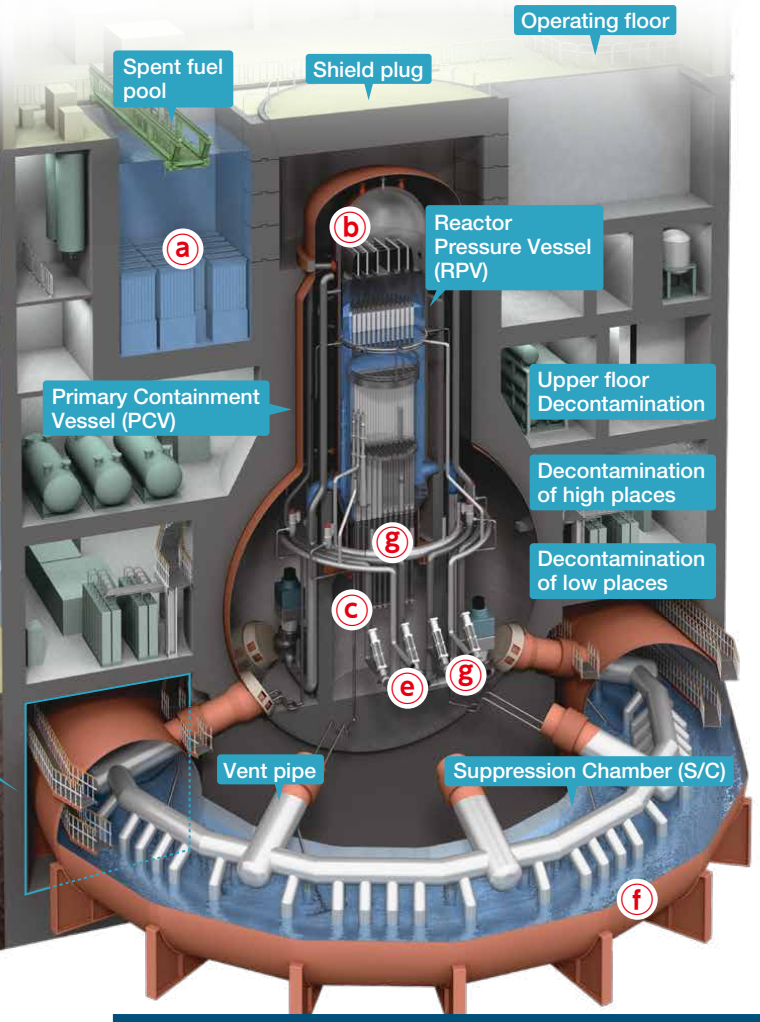
3 Technology for Treatment and Disposal of Solid Waste

Full-scale absorber vessel to be used for various absorption tests


Pressure filtering test device to examine dehydration treatment of ALPS slurry



Ratio of $^{90}Sr/^{137}Cs$ in rubble



2 f Technology for Repair and Water Stoppage of the PCV

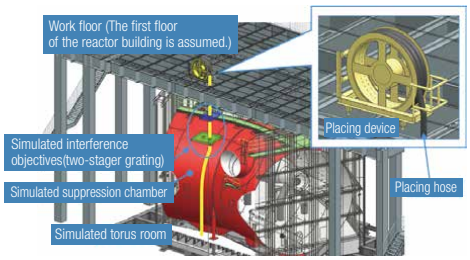
Preparation for Full-scale Mock-up Test


Implementation of reinforcing workability verification test for S/C support columns

Appearance of test device

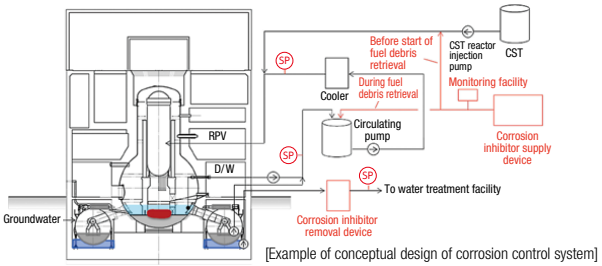
Workability verification test for reinforcement of S/C support columns

- Verification of workability of installation and collection of the placing hose with the device on the work floor
- Verification of construction procedures through water flow and remote monitoring performance.



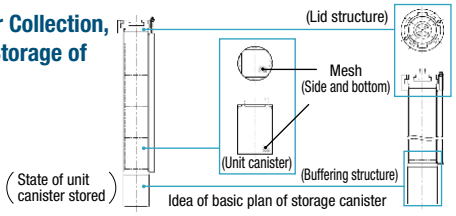
2 g Technology for Fuel Debris Retrieval

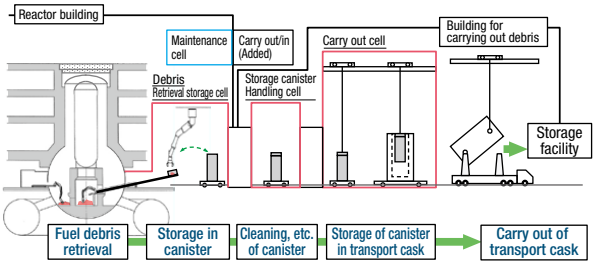
Development of Corrosion Control Technology for RPV / PCV



[Example of conceptual design of corrosion control system]

Technology for Collection, Transfer and Storage of Fuel Debris





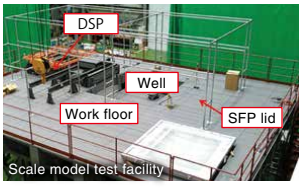
Development of Seismic-resistance and Impact Assessment Method for RPV / PCV

- Formulation of safety scenario for large earthquake
- Development of seismic resistance / impact assessment method for formulating safety scenario
- Safety scenario upgrading

Development of Technology for Criticality Control in Fuel Debris

	Level 1 Prevention of abnormal operation (PS system)		Level 2 Control of abnormal operation and termination of failures (MS system)	
Target	Monitoring of criticality approach to prevent criticality		Quick detection and control of criticality	
Criticality control	Parameter Monitoring	Prevention of abnormal operation	Detection of failures	Mitigation of impact
Specific measures (Primary issues)	• Criticality approach monitoring with the monitoring system • Monitoring water level / boric acid solution concentration, etc.	• Restriction of debris retrieval amount at a time • Application of Boric acid solution/non-soluble absorbent	• Criticality detection by neutron assemblies or FP gas concentration	• Termination of criticality by injection of boric acid solution or non-soluble absorbent

AR Technology for Retrieval of Fuel Debris and Reactor Internals



*Scan the text or photos marked with AR by COCOAR2.

Major R&D Topics

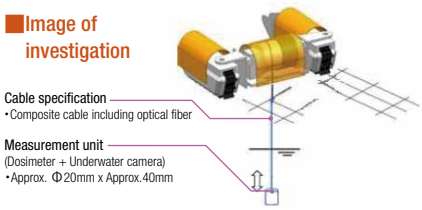
In 2017, IRID achieved R&D results ; investigation of the inside the reactor at unit 1, 2 and 3, muon measurement at unit 3, and full-scale mock-up test for repair technology. R&D for fuel debris retrieval is also being processed.

Technology for Investigation inside the Primary Containment Vessel(PCV)

unit 1

■Unit 1 PCV inside investigation robot (PMORPH 2)

■Image of investigation



■[Purpose of the investigation]

[1]To confirm the distribution of the fuel debris on the basement floor outside of the pedestal and reach ranges of fuel debris to the PCV shell.

[2]To confirm the condition of the basement floor outside the pedestal and the area near the opening by using a self-operated investigation device to suspend a dosimeter and a camera from the grating of the 1st floor outside the pedestal.

■[Main achievements]

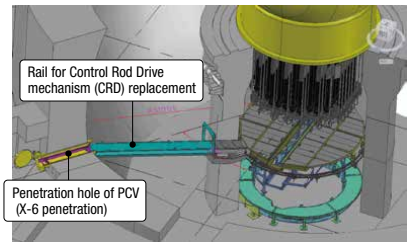
This was the first time to capture images of the condition of the bottom of the PCV near the opening of the pedestal. The radiation dose increase was confirmed while approaching the bottom of the PCV.

<Images near the lowest point>

unit 2

■Unit 2 PCV inside investigation robot (Scorpion robot)

■Image of investigation



■[Purpose of the investigation]

[1]To obtain Design/Development feedback information (platform deformation, etc.) for the next investigation for inside the pedestal.

[2]To confirm the condition of fuel debris that has fallen into the platform in the pedestal and on the housing of the Control Rod Drive mechanism (CRD), and structures inside the pedestal.

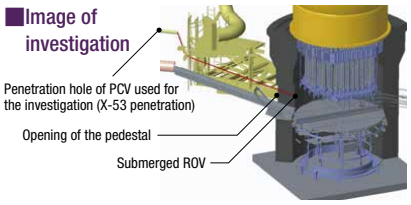
■[Main achievements]

The grating in the pedestal was confirmed to have dropped off and deformed in the grids. A large amount of deposits were also found. No significant damage was found on the CRD housing support near the pedestal opening.

unit 3

■Unit 3 PCV inside investigation robot (Mini-Sunfish)

■Image of investigation



■[Purpose of the investigation]

[1]To observe the basement floor of the pedestal where fuel debris may exist.

[2]To obtain Design/Development feedback information (conditions of X-6, CRD rail, etc.) for the next investigation inside the pedestal.

■[Main achievements]

This was the first time to capture images of the condition inside the unit 3 pedestal. The images identified molten solidifications and damages of multiple structures In the pedestal.

<Molten solidification were confirmed at bottom of the pedestal and structures inside the pedestal.>

<Damage of multiple structures and fallen objects were confirmed in the pedestal.>

Cosmic Ray Muon Tomography Inside the Reactor

The muon transmission measurement is one of the methods to obtain the information on distribution of material in the RPV from transmittance of the Muon penetrating through the reactor. The muon transmission measurement was conducted at Unit 3 from May to September, 2017. Information was obtained that there was no significant mass of fuel debris in the original core portion, and that there is a possibility of a part of fuel debris remaining on the bottom of the RPV, although with uncertainty.

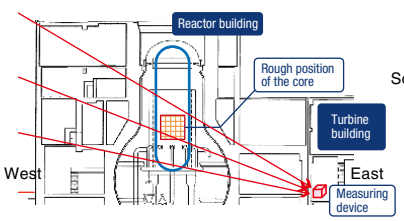


Image of measurement of the Muon penetrating the reactor building (East – West cross sectional view)

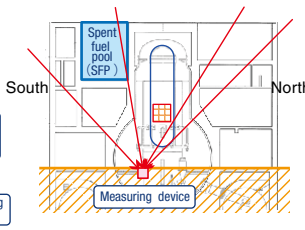
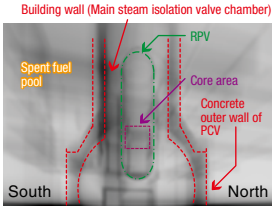
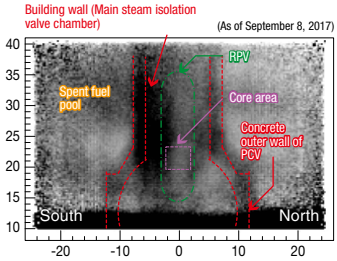


Image of measurement of the Muon penetrating the reactor building (South – North cross sectional view)



Evaluation of mass distribution (Density length) by simulation (A case that fuel debris exists in the core area and on the bottom of the reactor)



Evaluation of mass distribution (Density length) by Muon measurement

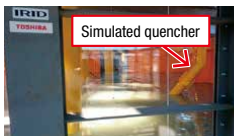
*Scan the text or photos marked with AR by COCOAR2.

Repair Technology for Leakage Points Inside the Primary Containment Vessel

A full-scale test at the JAEA Naraha Remote Technology Development Center

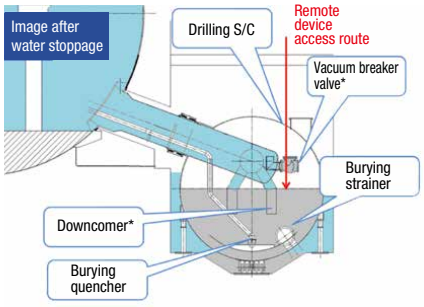
[1] Technology for water stoppage in the Suppression Chamber (SC)

A technology pursuing water stoppage at pipe ends of the passage (quencher, strainer) between the inside and outside of the S/C and at the damaged portion of the S/C (ϕ 50mm or less).



Test of work (during concrete placement)

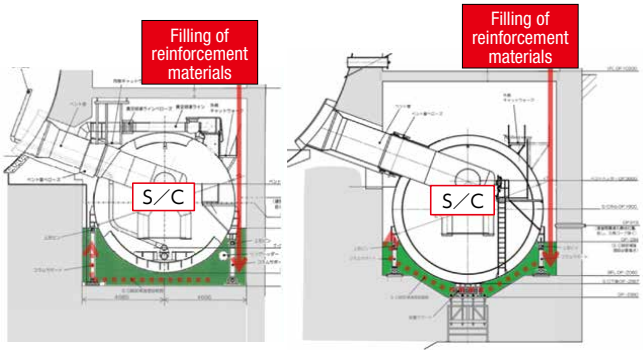
Test of work (Before placing strainer)



Execution procedure	[1] Drill a hole in S/C [2] Place the material for water stoppage in S/C [3] Water stoppage at strainer and quencher by burying *Water stoppage at downcomer and vacuum breaker valve by burying (Optional)
Candidate materials	Underwater inseparable concrete

[2] Technology for strengthening S/C support columns

This technology development is designed for seismic strengthening of the S/C support columns, as the total weight of the S/C is expected to increase due to the injection of filling materials for water stoppage.



[Candidate material] Underwater inseparable mortar

R&D for Fuel Debris retrieval AR

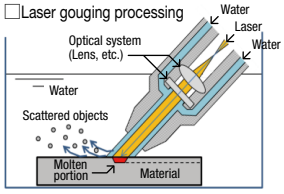
Specific R&D is being processed toward determination of the retrieval method for the initial unit (FY 2019) and starting the retrieval (during 2021).

Fundamental technology for the retrieval method is confirmed by an element test (smaller-scale model and full-scale model).

Cutting technology (Example)

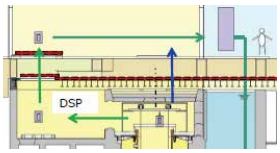
☐Core boring processing

☐Laser gouging processing

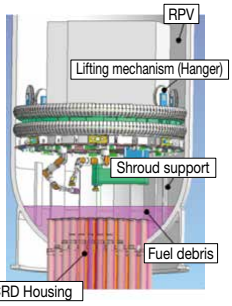


Technologies for preventing spread of the contamination and shielding (Example)

☐Confirming work steps of the top access method



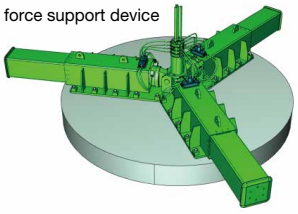
☐RPV inner surface seal



☐Access device in RPV

Access technology (Example)

☐Reaction force support device



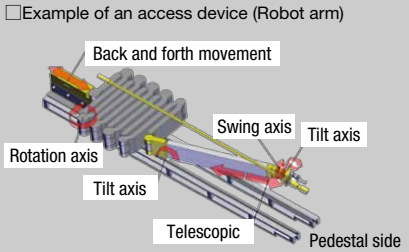
☐Access rail in the pedestal

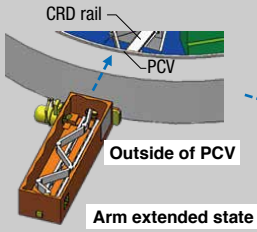
☐Flexible structure arm

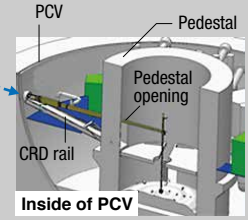
Method to access fuel debris at an early stage

Side-access method for fuel debris retrieval at the bottom of the PCV is being studied by inserting an access device through a penetration hole of the PCV on the 1st floor of the reactor building.

☐Example of an access device (Robot arm)







*Scan the text or photos marked with AR by COCOAR2.

Scope of work 2 — R&D with Overseas Organizations

IRID enhances the relationships with international research institutes and experts based on an "open structure" management policy, and the transmission of information including R&D achievements.

CLOSE UP

Enhancement of Cooperation with International Organizations

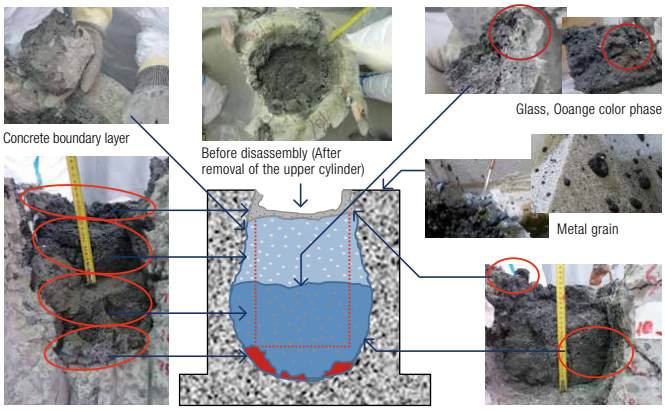
IRID accelerates R&D with overseas organizations and implements the latest technology for the nuclear decommissioning.

Joint Research with Overseas Research Institutions

French Atomic Energy and Alternative Energies Commission (CEA)

Analysis of products of the molten core concrete interaction (MCCI) was executed in 2017 by using uranium the size of several tens kg with simulated compositions of concrete and debris, as well as heating conditions for those of Fukushima Daiichi NPS.

Conditions of the MCCI product



Technical Cooperation with Overseas Nuclear Organizations

Mississippi State University (U.S.A.)

Dust including radioactive materials will generate from fuel debris during the retrieval. Therefore, it is necessary to study ventilation systems to contain the generated dust within the PCV and reactor building. IRID visited the research facility in the U.S.A., in which has related systems, and discussed with engineers to reflect in the system design.

Argonne National Laboratory (ANL) (U.S.A.)

ANL has experienced various demonstration tests of molten core concrete interaction (MCCI) in severe accidents with the DOE (United States Department of Energy).
Through technical discussions with researchers that have knowledge at the world's top level, IRID obtained useful information for future debris retrieval methods and processing technology.

International Advisors

The International Advisor committee consists of three nuclear experts from abroad. This advisory committee was established with the purpose of advising the IRID Board of Directors on organizational operation and management.
International Advisors provide advice on future challenges and required improvements as well as leading discussions on international efforts and management approaches.

Members * From left of the photo

○**Professor Melanie Brownridge (UK)**
Head of Technology,
Nuclear Decommissioning Authority (NDA)

○**Mr. Luis E. Echavarri (Spain)**
Former Director General of the OECD/NEA (experienced in the IAEA International Nuclear Safety Group (INSAG))

○**Mr. Lake Barrett (USA)**
Independent Consultant (former Site Director for the Nuclear Regulatory Commission (NRC) for the Three Mile Island NPS accident)

Information transmission to the world

IRID has introduced the achievements of research and development at forums organized by international organizations.

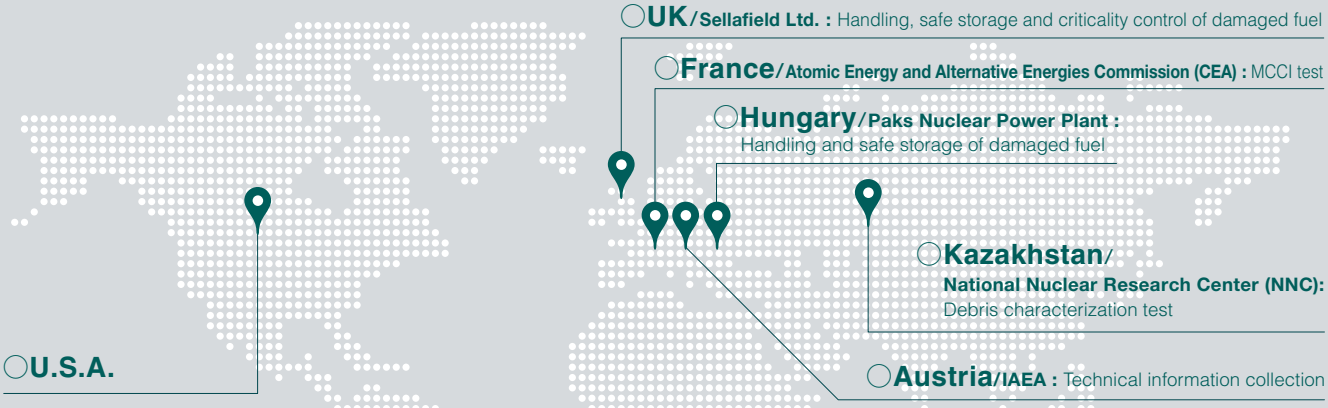
The 7th Vietnam - Japan Research / HRD Forum on Nuclear Technology (November 24, 2016)
Reporting current status of R&D for the decommissioning of the Fukushima Daiichi NPS.

ICAPP2017 Plenary session "Fukushima Report" activity report (April 28, 2017)
Reporting "Overview of IRID R&D Projects" as the current status of IRID R&D.

The 34th Japan – Korea Nuclear Experts Meeting (October 16, 2017)
Reporting the nuclear decommissioning titled "Status of IRID R&D for fuel debris retrieval."

MIT - Tokyo Tech Workshop on Innovative Nuclear Systems (October 27, 2017)
Reporting R&D for the nuclear decommissioning, specifically for development of technology for fuel debris retrieval and the investigation of inside the PCV, titled "R&D activities for Fukushima Daiichi Nuclear Power Station Decommissioning."

R&D Activities with Overseas Organizations (List of major activities)



○**UK/Sellafield Ltd. :** Handling, safe storage and criticality control of damaged fuel

○**France/Atomic Energy and Alternative Energies Commission (CEA) :** MCCI test

○**Hungary/Paks Nuclear Power Plant :** Handling and safe storage of damaged fuel

○**Kazakhstan/ National Nuclear Research Center (NNC):** Debris characterization test

○**Austria/IAEA :** Technical information collection

○**U.S.A.**

- **Pacific Northwest National Laboratory :** Handling and safe storage of damaged fuel
- **Hanford Facility :** Handling and safe storage of damaged fuel, study of ventilation system for debris dust
- **Idaho National Laboratory :** Information collection of knowledge about TMI - II
- **Argonne National Laboratory :** Exchange of debris characterization information
- **Los Alamos National Laboratory :** Development of debris detection technology
- **University of California, Berkeley :** R&D for treatment and disposal of solid waste
- **Mississippi State University :** Study of ventilation system for debris dust

Scope of work 3 — Human Resources Development for R&D

Nuclear decommissioning is a long-term project that may last 30 to 40 years. It is therefore essential that we have young people engaging in decommissioning activities. IRID is committed to promoting development of the next generation that will be involved in the decommissioning.

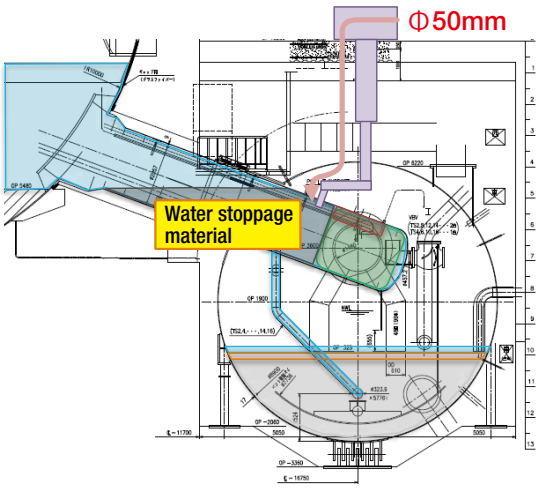
CLOSE UP

R&D in Collaboration with Universities (Achievements)

■Development of self-injection concrete for vent pipe water stoppage [Ouchi Laboratory, Kochi University of technology]

For selecting a water stoppage material for vent pipe water stoppage, it is required to make both the ability to pass through a small diameter hose without clogging (pumpability with small diameter hose) and the ability to be piled up even in a flowing water environment (water stoppage in flowing water environment) simultaneously. A self-injection concrete was newly selected to satisfy the conditions in cooperation with Kochi University of Technology because the former mortar-based materials and rubber-based materials don't satisfy the requirements.

Remote-operated repair device



Study of composition conditions
(Ratio of concrete, type and amount of additives, etc.)

Performance verification test

[1] Basic property confirmation
- Fluidity (Slump flow)
- Viscosity (V funnel flowing down time)
- Grasping the range (selection)
  ⇒Water stoppage confirmation test

[2] Pumpability test (15 cases)
- Passing through PVC (L-shaped pipe)
- Blend selection
  (Fluidity, viscosity and retention time)

[3] 1/10 model test
- Confirmation of filling and water stoppage

Decision of the best composition

■Operability improvement [Yokokohji Laboratory, Kobe University]

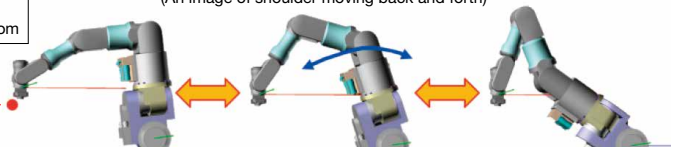
Development of a control interface to convey immediate self-motion* motor commands to improve operability of the articulated manipulator.

* Movement to change the manipulator's overall shape with the position of the hand tip and the base fixed

Examples of self-motion movement of manipulator with nine degrees of freedom

Changing posture
(An image of shoulder moving back and forth)

Fixing the position and posture of hand tip



■Development of Criticality Control Technology [Misawa Laboratory, Kyoto University]

A nuclear characteristics verification test for neutron-absorbing material to prevent criticality and a feasibility verification test for critical approach monitoring technology to detect a sign of the critical approach beforehand were executed with Kyoto University Critical Assembly (KUCA).

Tests at KUCA

■Development of remote collaboration motion control system [Matsuhira Laboratory, Shibaura Institute of Technology]

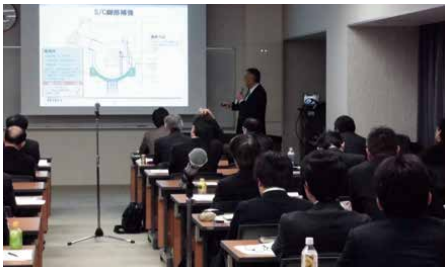
With the purpose of saving operator manpower in a remote decontamination system with plural crawler carts, a function to autonomously follow the leading cart while adjusting the interval between carts and avoiding obstacles was developed and a verification test applying a control platform that can be used for common use in various robot systems were executed in cooperation with the Shibaura Institute of Technology.

Leading cart

Human Resources Development through Workshops with Universities

1. Workshops with universities

IRID is promoting activities to enhance communication with young researchers and cooperate with universities partly engaged in national decommissioning projects.

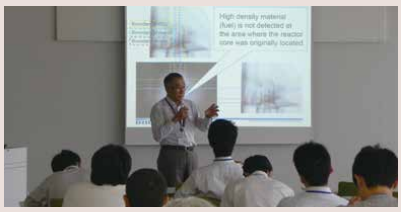


Small workshop with Tokyo Institute of Technology (January 20, 2017)

Workshop with the University of Tokyo (November 1, 2017)

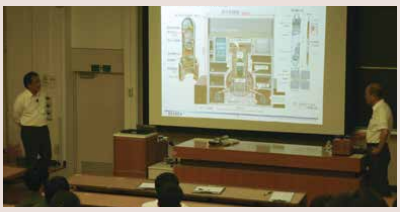
2. PR activities at universities and research institutes, etc.

IRID is actively involved in the development of human resources by providing information through visits to universities and research institutes.



Lecture at Fukushima Research Conference 2017 (September 5, 2017)

Lecture at National Institute of Technology, Fukushima College (September 13, 2017)



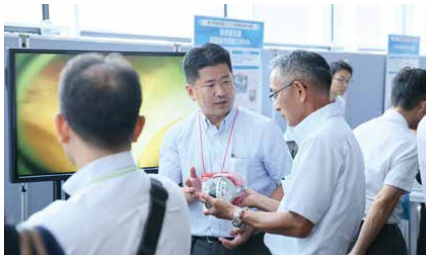
Safety seminar of Light water reactor, Tohoku University (September 21, 2017)

3. IRID Symposium

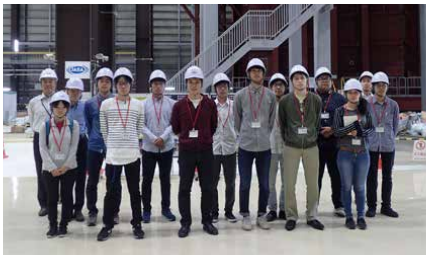
The symposium of FY2017 (held in Iwaki) titled, “Challenges for Fuel Debris Retrieval,” with the purpose to contribute to growing young researchers and engineers engaging in the decommissioning had more than 300 participants.

In addition, on the following day of the symposium, a site tour to the Fukushima Daiichi NPS and the JAEA Naraha Remote Technology Development Center was conducted for students of universities, graduate students and students of the National Institute of Technology who exhibited panels at the symposium.

Lecture session at the symposium



Explaining exhibited robots



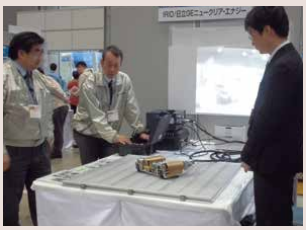
Site tour with students

4. Participation in various events

IRID actively participates in lectures and events held by various organizations, including academic meetings.

Presentation at Atomic Energy Society of Japan 2017 Fall Meeting (September, 2017)

Exhibition at Environmental Radioactivity Measures & Radioactive Waste Disposal International Exhibition - RADIEX2017 (October, 2017)



Exhibition at Robot Festa Fukushima 2017 (November, 2017)

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Learn more about the status of the decommissioning by the smartphone application "COCOAR2".

More detailed information of the brochure can be viewed with videos or websites.
Scan the text or photos marked with AR by COCOAR2.

Install the smartphone application "COCOAR2"

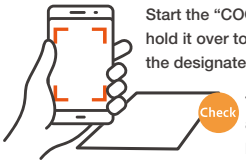
*COCOAR2 is a free application for smartphones.

STEP 1 Install"COCOAR2" application

Search "COCOAR2" at "Apple store" or "Google Play," then install it.

Or read the QR code at the left and install the "COCOAR2" application.

STEP 2 Start"COCOAR2" and hold it over



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