PROGRESS REPORT 2019

IRID

International Research Institute
for Nuclear Decommissioning

IRID amasses knowledge from around the world for the R&D on nuclear decommissioning under an integrated management system.

Decommissioning of Fukushima Daiichi is unique, unprecedented and extremely difficult tasks in the world. IRID is promoting R&D by gathering global knowledge while taking the technological challenges to be overcome.

Greeting

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 the technologies required in the decommissioning of the Fukushima Daiichi Nuclear Power Station (NPS). In August 2014, the Nuclear Damage Liability Facilitation Fund was reorganized as the Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF). The division of roles among the relevant organizations engaging in the decommissioning was then clarified: The NDF formulates strategies and R&D plans for the decommissioning; The Tokyo Electric Power Company (TEPCO) implements on-site operations; and IRID conducts R&D of the technology required in the decommissioning work. The four key players, including the government, have been working closely together in the effort to decommission the Fukushima Daiichi NPS.

This has resulted in the development of technology for investigating inside the primary containment vessel and the development of technology for identifying fuel debris using cosmic rays, and thus the situation inside the Primary Containment Vessel (PCV) has been clarified while the technological challenges that have to be overcome have also become clearer.

The Mid-and-Long-Term Roadmap was revised by the government after reflecting a revision of the “Technical Strategic Plan 2017 for Decommissioning of the Fukushima Daiichi NPS of TEPCO Holdings, Ltd.” (Strategic Plan 2017, hereinafter) made 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, Ltd. (Mid-and-Long-Term Roadmap, hereinafter) in September 2017.

It has been expressed that the policy with fuel debris retrieval should focus on the partial submersion side access method and retrieval of debris from the bottom of the PCV, and that the fuel debris retrieval method for an initial unit will be determined in FY 2019. R&D on the fuel debris retrieval is therefore about to enter a crucial phase.

In ensuring safe and secure decommissioning of the Fukushima Daiichi NPS, the IRID is committed to the responsibility of making steady achievements in R&D with respect to the reconstruction of Fukushima, and amassing knowledge from all over the world. Furthermore, IRID would like to contribute to the next generations through the R&D we are involved in.

We sincerely appreciate your kind guidance, continued support, and encouragement.

January 2019

International Research Institute for Nuclear Decommissioning

President
Hideo Ishibashi

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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 (NPS),
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.

IRID Organization Information

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. Establishment date

August 1, 2013 Establishment was approved by the Minister of Economy, Trade and Industry based on the Research and Development Partnership Act.

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 agency**>
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 Holdings, Inc.
Chubu Electric Power Co., Inc. Hokuriku Electric Power Company
The Kansai Electric Power Comapany, Inc. The Chugoku Electric Power Co., Inc.
Shikoku Electric Power Company, Inc.
Kyushu Electric Power Company, 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	:	Shunji Yamamoto, Hiroshi Arima, Satoshi Ueda, Akihiko Kato, Shigemitsu Suzuki, Satoshi Sekiguchi, Koichi Noda, Goro Yanase
Auditor	:	Masao Nakanishi

7. Number of staff

847 *(Excluding Directors) *Including members of the above membership organizations who are engaged in IRID's resarch.

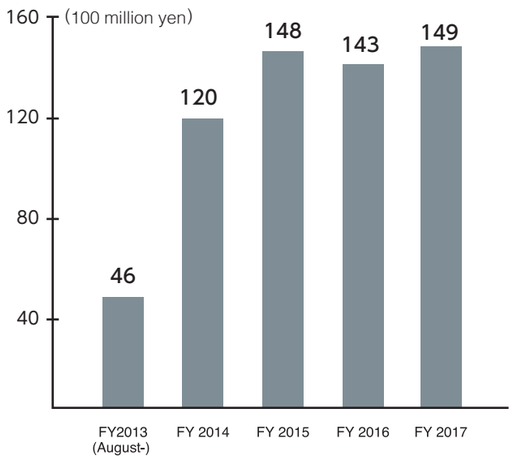
(As of October 1, 2018)

<The Circumstances until Establishment>

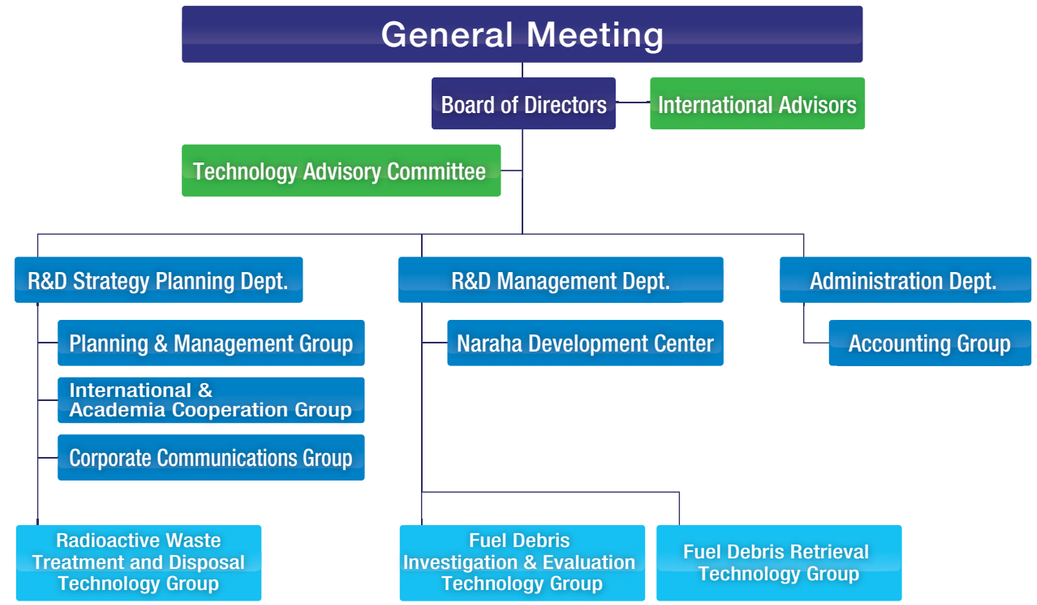
The 1st report on Mid-and-Long-Term actions to be taken at the Fukushima Daiichi Nuclear Power Station (NPS) was created in July 2011, four months later than March 2011 when the accident at the Fukushima Daiichi NPS occurred. At that time various experts proposed that a dedicated national organization to engage in the decommissioning would be necessary, and this proposal was then discussed by the Atomic Energy Commission.

In response to that situation, the need for 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 via the establishment of a preparation organization, a request for approval for the establishment of the IRID was submitted to the Ministry of Economy, Trade and Industry (METI) in late July, which was then granted by the minister of the METI on August 1, 2013. That approval resulted in a General Meeting of the autonomous legislative body of the organization being held to commence operation of the IRID on August 8, 2013.

Project Costs



Organizational Structure

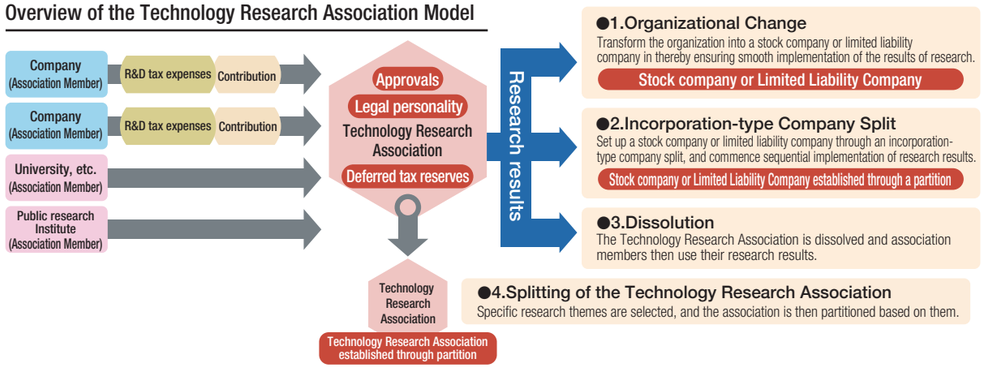


(As of April, 2018)

Reference: Technology Research Associations

Technology Research Associations are mutual aid organizations (non-profit mutual benefit corporations) that conduct joint research on technologies for use in industrial activities that can benefit the association members. IRID was created as a Technology Research Association in order to rapidly systemize its activities, and to take advantage of the transparency and flexibility offered within the running of the organization.

Overview of the Technology Research Association Model



Features of a Technology Research Association

- Each of association member provides researchers, funds, and equipment for use in joint research. These are jointly managed and utilized among all the members.
- Technology Research Associations are joint research organizations that have a legal identity independent of association members.
- Transparency and reliability of the management of the association can be increased with the approval of the Minister in charge, and by holding regular association member meetings/board of director meetings.
- Those directly or indirectly using the results of the joint research (including corporations, individuals, foreign companies and foreign nationals) can become association members.
- Universities, research and development incorporated administrative agencies, technical colleges, local government organizations or foundations primarily engaged in testing and research can participate as association members. This participation then provides opportunities for cooperation between industry, academia and the government.

(Source) Excerpt from the Technological Research Association", the Ministry of Economy, Trade and Industry Website.

Role of IRID

IRID works for R&D of decommissioning under a major policy of the national government while closely cooperating with related organizations involved in the decommissioning work 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

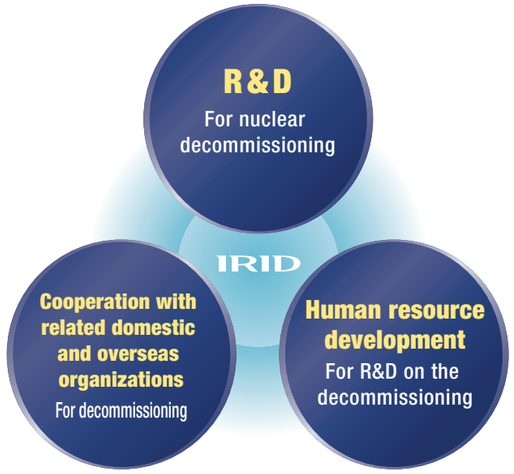
IRID is an organization composed of 18 corporates that are leading players for research and development (R&D) of decommissioning the Fukushima Daiichi Nuclear Power Station (NPS).

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

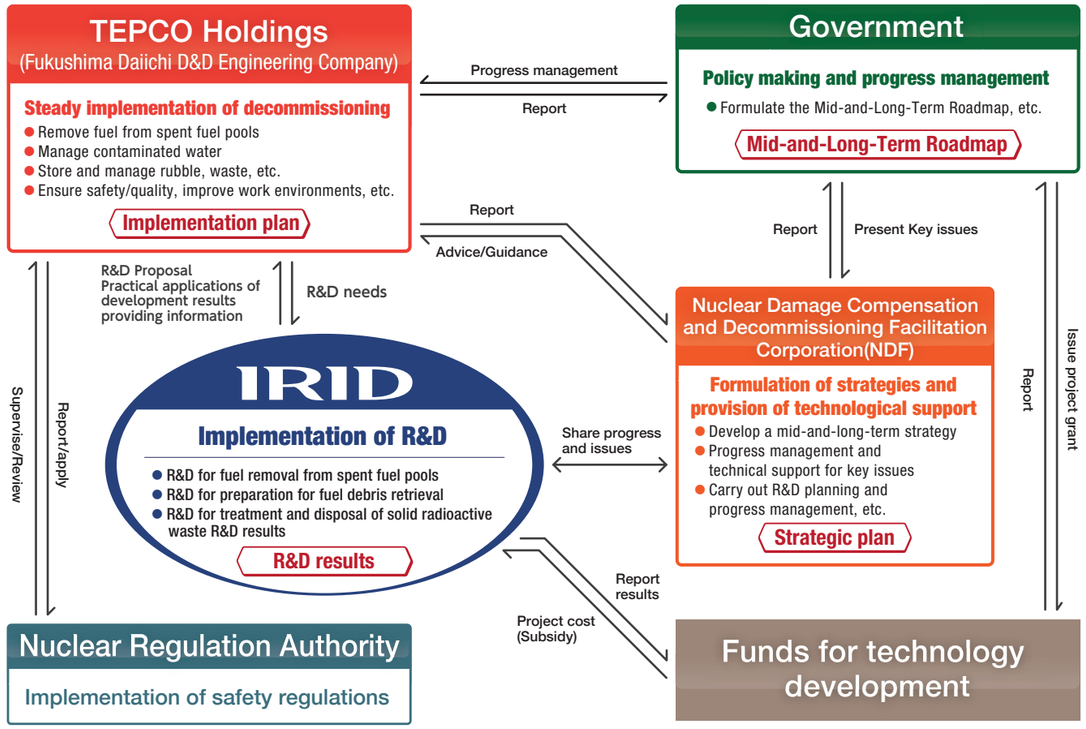
In addition, it is necessary to amass further knowledge from both Japan and abroad to proceed with the decommissioning of the Fukushima Daiichi NPS, which is unprecedented in the world and extremely difficult; therefore, the IRID is promoting cooperation with related domestic and international organizations. Moreover, the IRID is promoting the development of the necessary human resources 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 as a part of the decommissioning organizations.



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



HISTORY Chronology of IRID activities

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

2013

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

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

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

2014

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

〈March〉
- ○Verification tests on the suction and blast decontamination devices

〈April〉
- ○Verification tests on low place decontamination devices (Dry ice blast device)
- ○Verification tests on low place decontamination devices (High pressure water decontamination device)

〈May〉
- ○Investigation of the upper part of the suppression chamber (S/C) in unit 1 using an investigative device.
- ○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)
- ○Investigation of the wall of the torus room in unit 2 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 Kaneda

〈September〉
- ○Investigation of the unit 2 Suppression Chamber (S/C) lower outer surface using investigative apparatus

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

2015

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

〈April〉
- ○Investigation of the inside of the unit 1 Primary Containment Vessel (PCV) using a robot, namely the PMORPH 1

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

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

2016

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

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

〈May〉
- ○Verification tests of a high place decontamination device (Dry ice blast decontamination device) on the 1st floor of the unit 3 reactor building

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

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

2017

〈February〉
- ○Investigation of the inside of the unit 2 PCV using a scorpion robot

〈March〉
- ○Investigation of the inside of the unit 1 PCV 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 suppression chamber (S/C)
- ○Appointment of the 3rd president Hideo Ishibashi

〈July〉
- ○Investigation of the inside of the unit 3 PCV using a submersible ROV
- ○Full-scale testing of reinforcement technology for the Suppression Chamber (S/C) support columns

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

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

2018

〈January〉
- ○Investigation of the inside of the Unit 2 PCV using a telescopic investigative device

〈August〉
- ○Holding the IRID Symposium 2018 (in Tokyo)

〈Decembert〉
- ○Holding the 6th International Advisors Meeting

Role of IRID

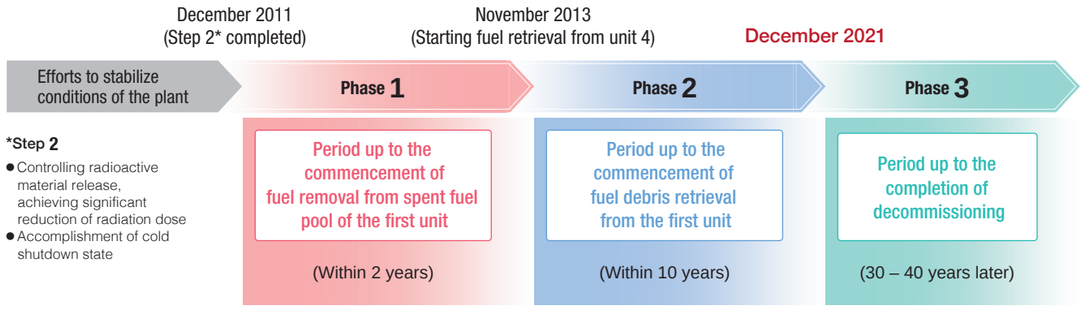
Overview of the Mid-and-Long-Term Roadmap (Revised on September 26, 2017)

Decommissioning of the Fukushima Daiichi Nuclear Power Station (NPS) is proceeding based on the "Mid-and-Long-Term Roadmap for Decommissioning of the Fukushima Daiichi NPS of the Tokyo Electric Power Company (TEPCO) Holdings, Ltd." (Mid-and-Long-Term Roadmap, herein after) that was 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



( ) means 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 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

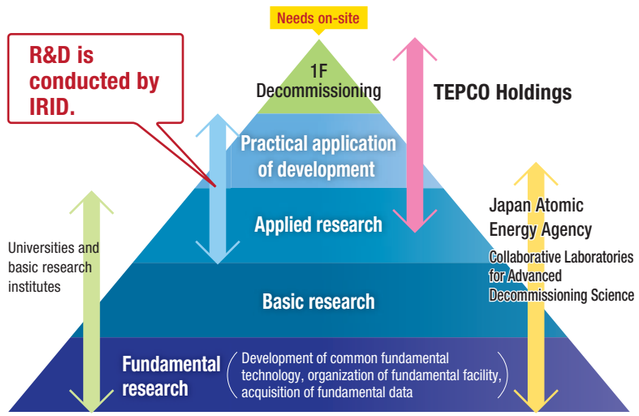
IRID's R&D Scope

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 plan of 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 2018.

List of Government Subsidized R&D Projects Conducted by IRID

Subsidy Project on Decommissioning and Contaminated Water Management in the FY2016 and the FY2017 Supplementary Budgets

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

(As of end of June, 2018)*1

Project name	Project Summary	Period	Supplementary budget	Subsidy project Maximum Cost *2 (Subsidy Rate)
Fuel debris characterization/ development of analysis technologies	(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	0.65 billion JPY (Fixed)
Development of technologies for detailed investigation inside the primary containment vessel	(1)Formation and upgrading of investigation and development plans (2)Development of access equipment and systems, and investigation and element technology (3)Management of R&D	April 1, 2018 - March 31, 2019	FY2016	3.4 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 α nuclide-accompanying fuel debris retrieval. (4)Study of optimization, etc. related to securing safety of work method and system	April 3, 2017-March 31, 2019	FY2016	2 billion JPY (Fixed)
Upgrading 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 equiment (3)Development of remote maintenance technology for fuel debris retrieval equipment (4)Development of monitoring technology for fuel debris retrieval, etc.	April 3, 2017-March 31, 2019	FY2016	3.5 billion JPY (Fixed)
Development of sampling technologies for retrieval of fuel debris and internal structures	(1)Study and formation 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 1, 2018-March 31, 2019	FY2016	1.5 billion JPY (Fixed)
Development of fundamental technologies for retrieval of fuel debris and internal structures (Development of small neutron detectors)	(1)Identification and feasibility study of neutron detection technology applicable to fuel debris retrieval, etc. at the Fukushima Daiichi Nuclear Power Station. (2)Development of neutron detector	April 24, 2017-September 28, 2018	FY2016	2 billion JPY (Fixed)
Development of technologies for collection, transfer and storage of fuel debris	(1)Investigation and formation of research plan for transfer and storage (2)Study of safety requirement specifications and system related to transfer and storage of fuel debris canister (3)Development of safety evaluation methods and safety verification (4)Study of fuel debris storage form, etc.	April 1, 2018-March 31, 2019	FY2016	0.6 billion JPY (Less than 50%)
R&D on treatment and disposal of radioactive waste	(1)Characterization (2)Study of management before treatment (3)Study of treatment concept and safety evaluation method that suit solid waste (4)Integration of R&D results, etc.	April 1, 2017-March 31, 2019	FY2016	2 billion JPY (Fixed)
Development of investigation technology inside the reactor pressure vessel	(1)Formation of investigation and development plans (2)Establishment of investigation methods (3)Study on supplementary systems for investigation (4)Development of access device and investigation device	April 1, 2018-March 31, 2020	FY2017	1.3 billion JPY (Less than 50%)
Upgrading approach and system for retrieval of fuel debris and internal structures (Development of criticality control technologies for fuel debris)	(1)Development of technology for sub-criticality measurements and criticality approach monitoring (2)Development of technology for re-criticality detection (3)Development of technology to protect against criticality (4)Study on optimization of the ensuring of the safety of methods and systems	April 1, 2018-March 31, 2019	FY2017	0.25 billion JPY (Less than 50%)
Development of technologies for water circulation systems in PCV	(1)Organizing technology specifications for upgrading water circulation systems, study on work plan and establishment of development plan (2)Development/verification of elemental technologies for access and connection in PCV	April 1, 2018-March 31, 2020	FY2017	0.5 billion JPY (Less than 50%)
Development of technologies for water circulation systems in PCV (full-scale test)	(1)Full-scale verification of technologies for access and connection of PCV developed under the subsidy project of "Development of technologies for water circulation systems in PCV"	April 1, 2018-March 31, 2020	FY2017	1 billion JPY (Fixed)
Development of technologies for detailed investigation inside PCV (on-site demonstration of detailed investigation technologies considering management deposits)	(1)Formation of investigation and development plans (2)On-site verification of access and investigation devices and investigation technology	April 27, 2018-March 31, 2020	FY2017	2.6 billion JPY (Fixed)
Development of technologies for detailed investigation inside PCV (on-site demonstration of detailed investigation technologies through X-6 penetration)	(1)Formation of investigation and development plans (2)On-site verification of access and investigation devices and investigation technology	April 27, 2018-March 31, 2020	FY2017	4 billion JPY (Fixed)
R&D on treatment and disposal of radioactive waste (R&D on proceeding process and analysis methods)	(1)Evaluation on feasible technology for treatment of solid radioactive waste (2)Development of technologies for storage and management of solid waste	April 1, 2018-March 31, 2019	FY2017	0.9 billion JPY (Fixed)

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

Scope of work 1 — R&D for Nuclear Decommissioning

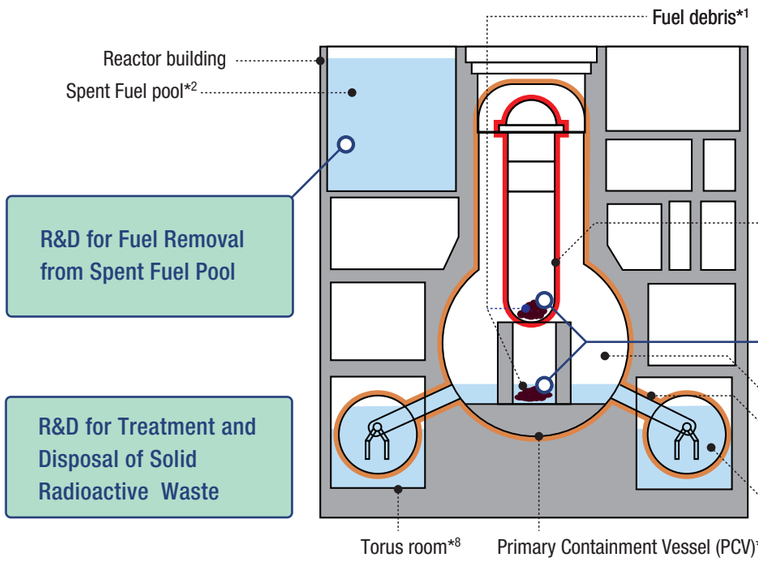
The three-key-R&D in the decommissioning are: “R&D for fuel debris retrieval from spent fuel pool,” “R&D for preparation for fuel debris retrieval” and “R&D for Treatment and Disposal of Solid Radioactive Waste.” IRID is promoting further R&D based on the “Fuel Debris Retrieval Policy 2017.”

IRID’s R&D

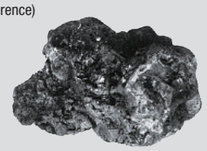
IRID has been conducting R&D to proceed with the decommissioning of the Fukushima Daiichi Nuclear Power Station (NPS), according to the Mid-and-Long-Term Roadmap. In order to improve decommissioning strategy, IRID is studying alternative appropriate approaches, how to reduce risks, while exploring the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

Our three-key-R&D for the decommissioning are; “R&D for fuel debris retrieval 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 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 Approach

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 overall decommissioning work**
From the preparation work through to retrieval, treatment storage and clearing up, a comprehensive plan aiming at overall optimization is being studied.

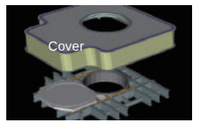
3 **Combination of multiple methods**
The study is executed assuming the side-access method for the bottom of the PCV and top-access method for the inside of the RPV.

4 **Focusing on the 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 submersion method is difficult at present.
*The submersion method may be studied in the future, considering the advantage of shielding effects.

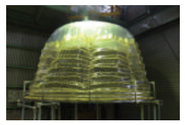
5 **Proceeding forward with the side-access method, which is horizontal access to the bottom of the PCV**
The fuel debris exists both at the bottom of the PCV and the inside of the RPV of each unit.
The side-access method the bottom of the PCV is prioritized to minimize the increase of risk accompanied with the retrieval in consideration of the following.
[1] Accessibility to the bottom of the PCV would be the best and knowledge was obtained from investigating inside the PCV,
[2] There is a possibility to execute it earlier, and [3] It can be processed in parallel with spent fuel removal.

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

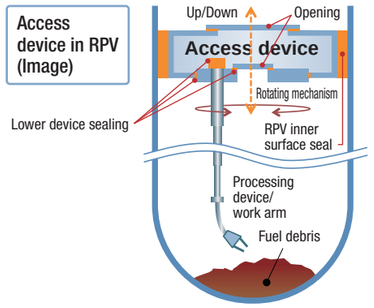
Top access method –Image of debris retrieval–



Shielding Port with openable



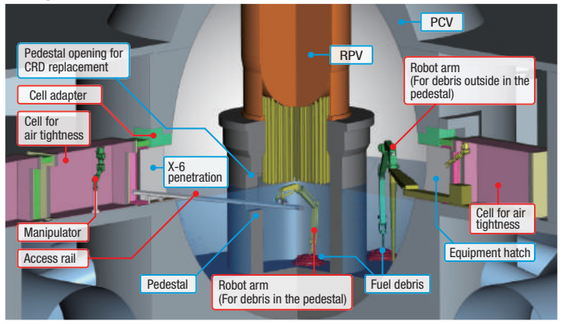
Film for prevention of dust scattering



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 and 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's R&D Projects

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

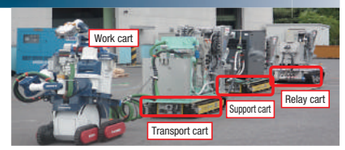
1 ···R&D for Fuel Removal from the Spent Fuel Pool
2 ···R&D for Fuel Debris Retrieval
3 ···R&D for Treatment and Disposal of Solid Radioactive Waste

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

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

2 Technology for Decontamination and Dose reduction

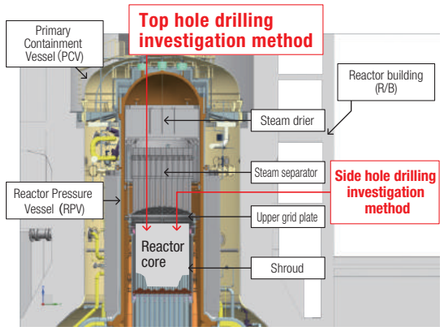
○Technology for Remotely-operated Decontamination in the Reactor Building



2 Technology for Investigation inside the Reactor

ⓑ Technology for Investigation inside the RPV

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



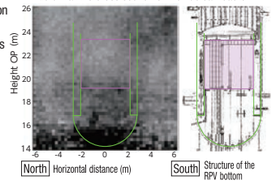
ⓒ Technology for Investigation inside the PCV

Development of investigation robots inside the PCV

ⓓ Technology for Detection of Fuel Debris

Investigative technology for the fuel debris distribution inside the RPV in Unit 2 utilizing cosmic ray muons

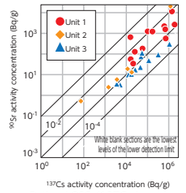
An image of high density substance thought to be fuel debris is confirmed on the bottom of the RPV.
*Measurements at unit 2 and 3 were made by TEPCO Holding as a part of IRID activities.



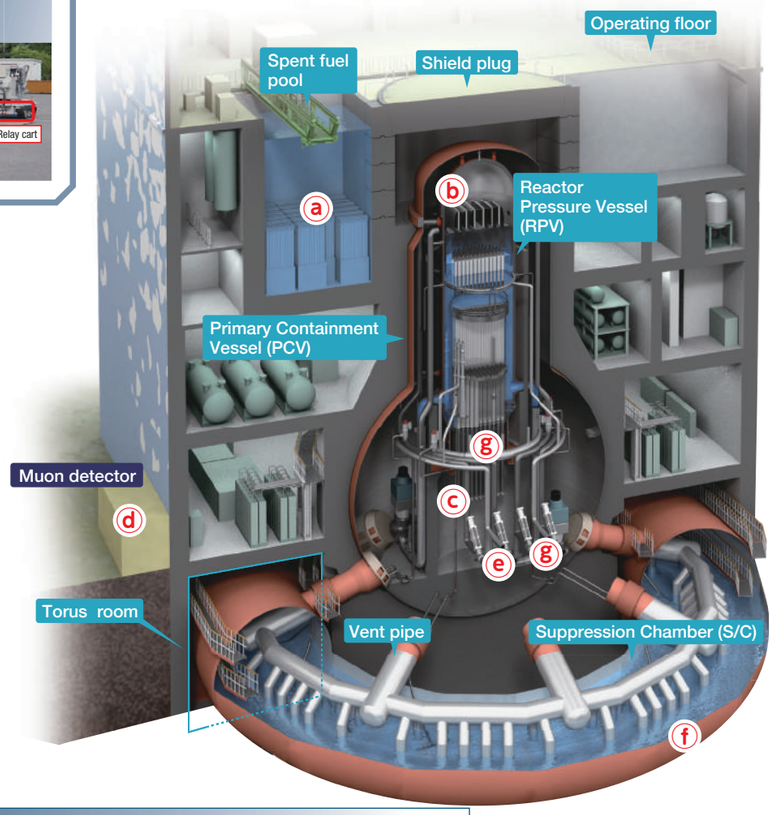
3 Technology for Treatment and Disposal of Solid Waste

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

Pressure filtering test device to examine dehydration treatment of ALPS slurry

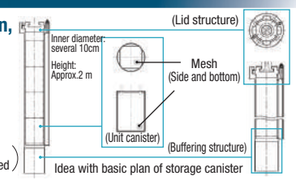


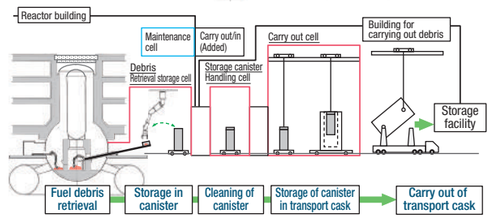
Ratio of 90Sr/137Cs in rubble



2 ⓖ Technology for Fuel Debris Retrieval

Technology for Collection, Transfer and Storage of Fuel Debris

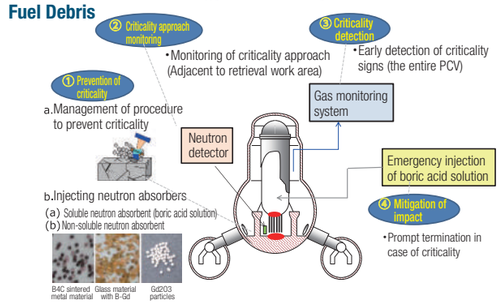




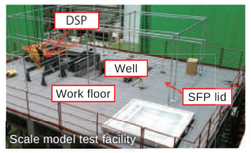
Development of Seismic-resistance and Impact Assessment Method for RPV / PCV

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

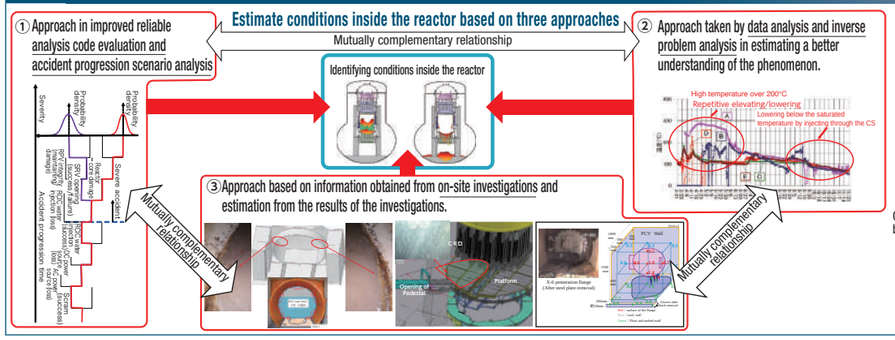
Development of Technology for Criticality Control of Fuel Debris



AR Technology for Retrieval of Fuel Debris and Reactor Internals

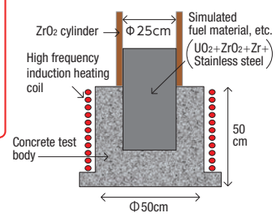


2 Technology for Investigation and Analysis (Characterization) inside the Reactor



ⓔ Fuel Debris Characterization

Characterization using simulated debris



Large MCCI test device in cooperation with CEA

A simulation test of the Molten Core Concrete Interaction (MCCI) was conducted.

A MCCI test that used a molten core with several kilograms of uranium and concrete was conducted in cooperation with a research institute in France.

2 ⓕ Technology for Repair and Water Stoppage of the PCV

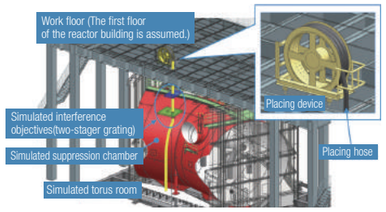
Preparation for Full-scale Mock-up Tests

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

Appearance of test facility

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.



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

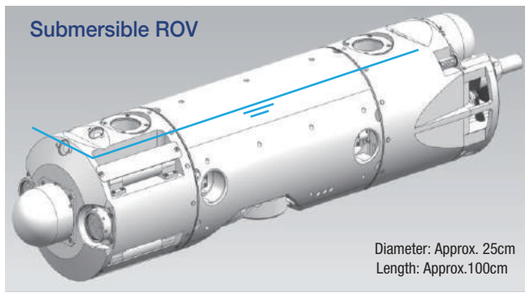
Major R&D Topics

In 2018, IRID achieved R&D results from investigating the inside of the reactor of unit 2 and development of repair technology for the leaking parts. R&D for fuel debris retrieval is also being processed.

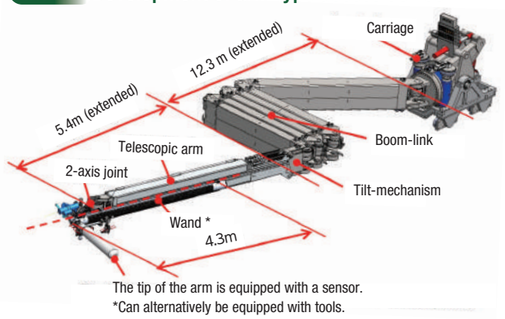
Technology for Detailed Investigation of inside the Primary Containment Vessel (PCV)

Development of investigative device

Unit 1 Development of submersible type ROV (Remotely Operated Vehicle) that can move around a wider range of the basement floor



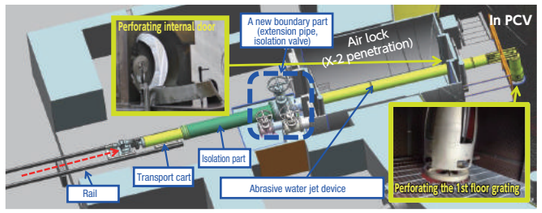
Unit 2 Development of arm type access device



Development of establishing access routes into PCV

Unit 1

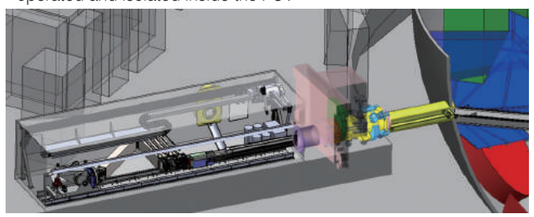
Development of an abrasive water jet device designed to perforate the grating and internal door and isolate the PCV



A new boundary part of X-2 penetration and perforating the grating

Unit 2

Development of technology for connecting the access device used to open the hatch of X-6 penetration that can be remotely operated and isolated inside the PCV



Access structure in front of X-6 penetration

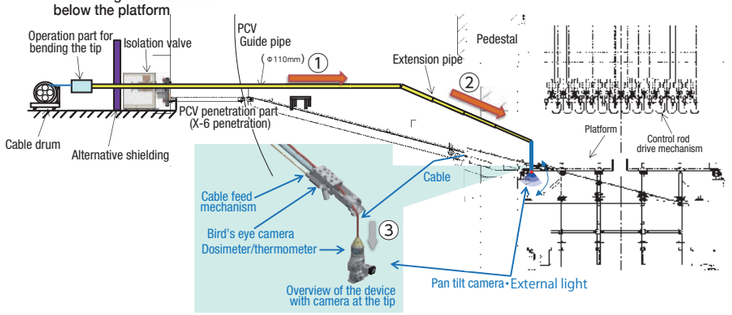
Investigation Technology inside Primary Containment Vessel (PCV)

Investigation inside PCV in Unit 2

Confirming the conditions below the platform

Investigation procedure

①Insert a guide pipe ⇒ ②Extend an extension pipe ⇒ ③Suspend a pan-tilt camera ⇒ ④Investigate



Parts of the fuel assemblies that were found at the bottom of the pedestal (top of tie plate)

Location of the inscriptions

Overview of parts of fuel assemblies (top tie plate)

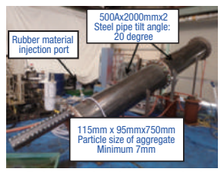
- The inscription on the top tie plate found at the bottom of the pedestal was examined in order to identify the charging location of the fuel assemblies from which it came.
- Starting from the left the following four letters could be read: [F], [2], [X], and [N]. However, since the serial number, which starts with the fifth letter in this series could not be seen, we were unable to identify the charging location of the fuel assemblies from which this top tie plate originated.

Repair Technology for Leakage Points Inside the Primary Containment Vessel (PCV)

Technology for stopping water flow by filling in vent pipes

This technology is being developed as a water stoppage material using self-compacting concrete and repair material using sludge water, and which is intended to ensure water stoppage capabilities.

Vent pipe 1/1 scale test



Rubber material pressure test

Concrete water stoppage test

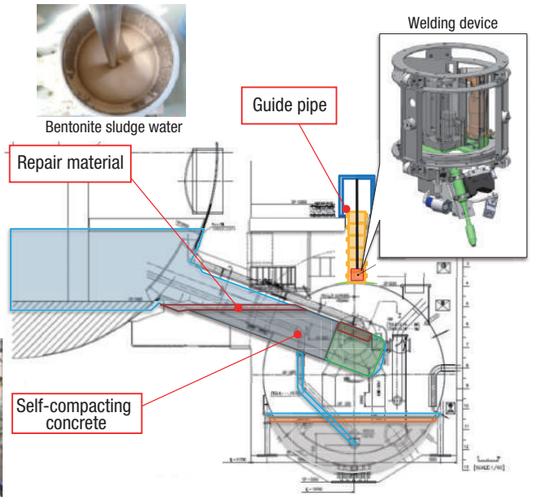


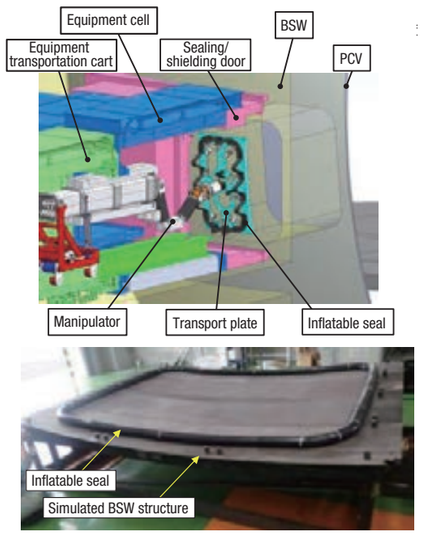
Figure: Overview of repairing lower part of PCV (filling in vent pipes and S/C guide pipe implementation)

R&D for Fuel Debris retrieval

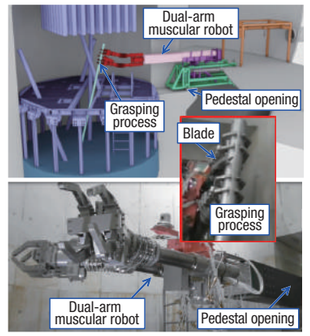
Specific R&D is being processed toward determination of the retrieval method for the initial unit (FY 2019) and starting the retrieval (during 2021).

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

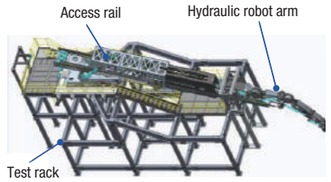
Technology for preventing spread of contamination (example)



Technology for accessing inside the pedestal (example) Dual-arm muscular robot



Technology for accessing inside the pedestal (example) Access rail/robot arm

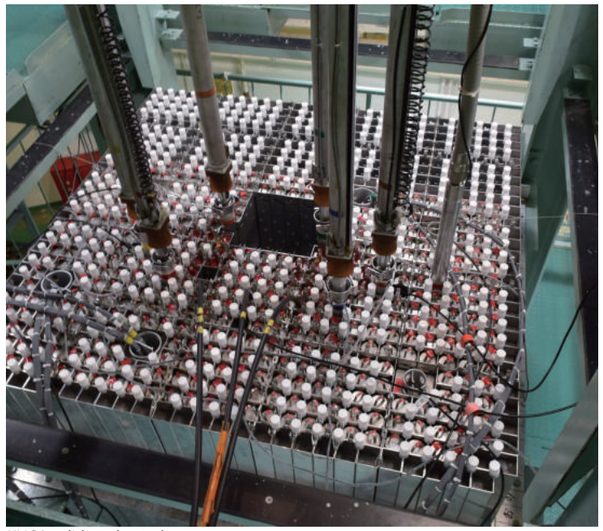


CLOSE UP

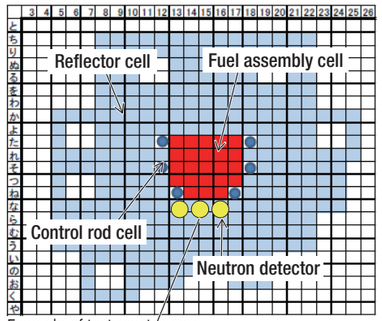
R&D Collaboration with Universities (Actual Projects)

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

Aiming at verification of critical approach monitoring technology for detecting any sign of criticality approaching and the nuclear characteristics of neutron absorbent material in preventing criticality from occurring , a feasibility verification test was conducted using the Kyoto University Critical Assembly (KUCA) in collaboration with professor Misawa, the Institute for Integrated Radiation and Nuclear Science, Kyoto University, which owns the KUCA. It can be used with variable amounts of fuel moderator according to the purpose of the test; therefore making it an appropriate experimental system for use in simulating various fuel debris conditions, and which can acquire large amounts of useful data that can then be used to verify the criticality control technology being developed by IRID.



KUCA solid moderated core



Example of test reactor core

B-10 neutron detector

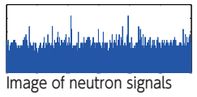
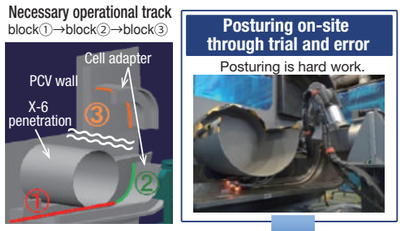
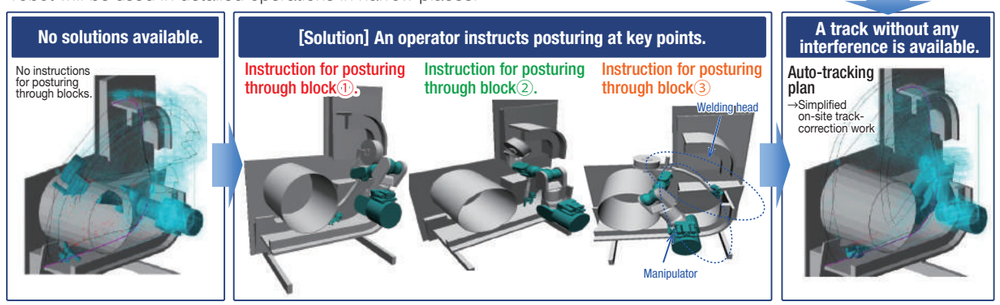


Image of neutron signals

■ Development of Operational Plan that takes into Consideration Interference Avoidance via Use of Multi Flexible Robots [Yokokohji/Tasaki Laboratory, Kobe University]

Multi flexible robots (ex. access rail + robot arm or electric manipulator + welded head etc.) can be used to increase the range of operations in narrow places; however, there are some places where it is difficult for operators to access them because accurate positioning is required. For this reason, an automatic planning method that is capable of determining a continuous track while avoiding any surrounding interference was developed in a way that the operator can instruct the necessary positions at every key point of continuous operational tracks (block①→block②→block③), and assuming that the multi flexible robot will be used in detailed operations in narrow places.





Nuclear decommissioning is a long-term project that can take 30 to 40 years. It is therefore essential that we have young people involved in nuclear decommissioning activities. IRID is committed to promoting the development of next generation workers that will be involved in nuclear decommissioning R&D.

1. PR Activities at Universities and Research Institutes

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

Lecture at Kindai University

Lecture at the Kanagawa Institute of Industrial Science and Technology (KISTEC) Educational Seminar

Lecture at the National Institute of Technology, Fukushima College

2. IRID Symposium

The IRID Symposium 2018 was held entitled “Challenges with Fuel Debris Retrieval II,” and with the purpose of reporting R&D achievements as well as nurturing young researchers and engineers engaging in the decommissioning work, and which is a follow through from the previous year’s symposium. It was the first time that the students gave a presentation on the research results of FY2018. In addition, on the following day of the symposium, a site tour of the Fukushima Daiichi NPS and the JAEA Naraha Remote Technology Development Center took place for students from universities, graduate students, and students from the National Institute of Technology who gave presentations and exhibited panels at the symposium.

Presentation at the Symposium

Opening remark

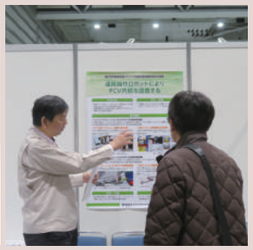
Site tour with students

3. Participation in Various Events

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

Presentation at 2018 Fall Meeting, the Atomic Energy Society of Japan (September, 2018)

Panel exhibition at the Environmental Radioactivity Measures & Radioactive Waste Disposal International Exhibition (RADIEX) 2018 (October, 2018)



Panel exhibition at the Robot/Aerospace FESTA Fukushima 2018 (November, 2018)

Scope of work 3 — # R&D with Overseas Organizations

IRID is enhancing relationships with international research institutes and experts based on an “open structure” management policy, as well as the dissemination of information, including R&D achievements.

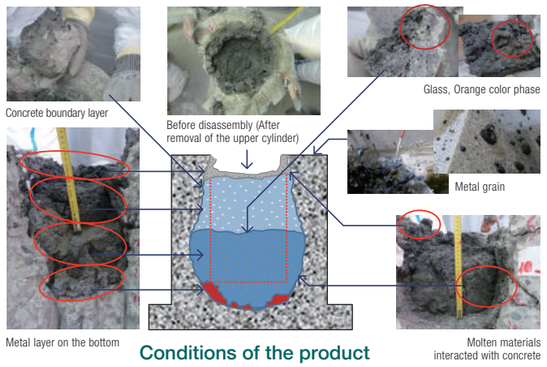
CLOSE UP Enhancement of Cooperation with International Organizations

Acceleration of R&D with overseas organizations and implementation of the latest technology for the nuclear decommissioning

Joint Research with Overseas Research Institutions

French Atomic Energy and Alternative Energies Commission (CEA)

A simulation test of the Molten Core Concrete Interaction (MCCI) took place as international cooperative research with the CEA. The results were used to identify the characteristics of the product such as the porous regions, and separated layers with metal and oxide layers.



Conditions of the product

Technical Cooperation with Overseas Nuclear Organizations

Hanford Facility (U.S.A.)

Dust, including radioactive material, will be generated by the fuel debris during the retrieval process. It is therefore necessary to study ventilation systems that can be used to contain any dust generated within the RPV and reactor building. IRID visited the research facility in the U.S.A., which has related systems, and discussed with engineers reflecting them in the system design.

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

ANL has experienced various demonstration tests of interactions between debris and concrete (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 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 accident)

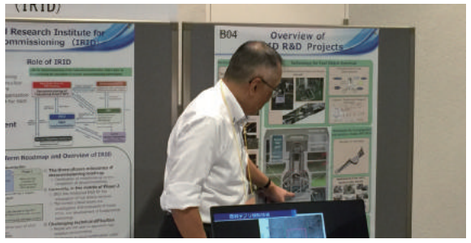
Global information dissemination

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

OECD/NEA SAREF/PreADES Project Meeting (January, 2018)
Reporting current status of R&D for the decommissioning of the Fukushima Daiichi NPS

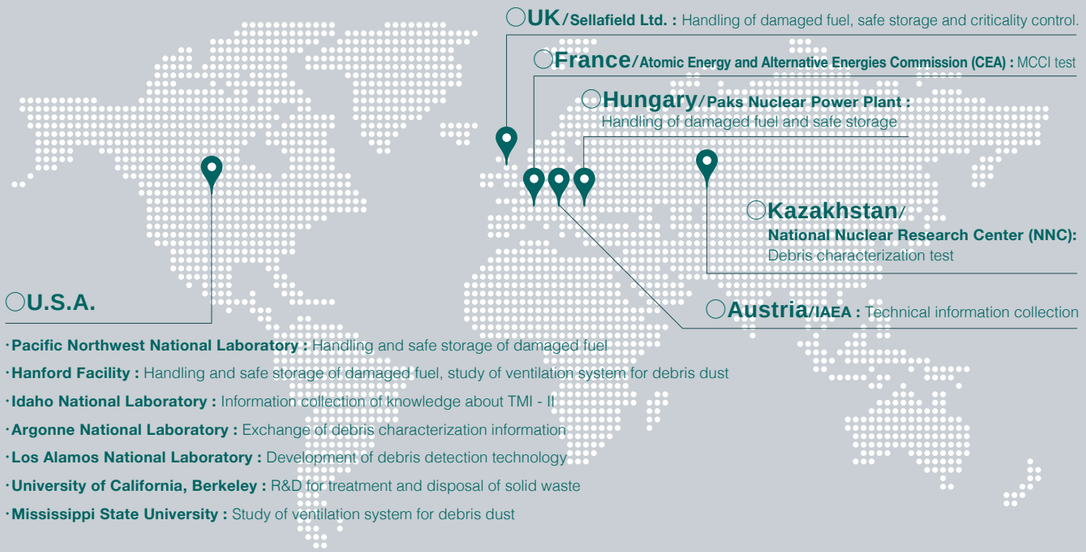
Poland JICC Warsaw Seminar (May, 2018)
Reporting status of investigation inside the PCV of the Fukushima Daiichi NPS and R&D for the decommissioning

Nuclear Air Cleaning 35th Charleston SC (June, 2018)
Reporting current status of R&D for the decommissioning of the Fukushima Daiichi NPS



ICMST-Tohoku 2018 (October, 2018)
Reporting "Overview of IRID R&D Projects" as the current status of IRID R&D

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



International Research Institute for
Nuclear Decommissioning

5F, 3 Toyokaiji Building, 2-23-1 Nishi-Shimbashi,
Minato-ku, Tokyo 105-0003, Japan
TEL:+81 3 6435 8601
http://irid.or.jp/en/

Learn more about the smartphone application "COCOAR2" to know more details about the decommissioning status!

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" first!

*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

Start the "COCOAR2" application and hold it over to scan the designated image.

Taking a photo is also possible by pressing the camera mark.

* By posting periods, the location for photo taking (scanning) could change.

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