IRID
International Research Institute
for Nuclear Decommissioning

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IRID 2014

International Research Institute
for Nuclear Decommissioning

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The decommissioning of the Fukushima Daiichi Nuclear Power Station is a project that presents numerous technological challenges – challenges that have never been faced by any other nation in history.

It is vital that this project includes technologies outside of the nuclear power industry, such as robotics, and that it promotes R&D by bringing together the rich knowledge and experience of various institutions based in Japan and overseas.

Furthermore, collaboration between all concerned institutions is required to foster the human resources needed to carry on the decommissioning of the Fukushima Daiichi Nuclear Power Station over the medium to long term.

IRID is engaged in the integrated management of decommissioning technologies to address these needs.

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Message from the President

Over three years have now passed since the March 2011 Tohoku Pacific Ocean Earthquake and Tsunami and the accompanying accident at the Fukushima Daiichi Nuclear Power Station (NPS) run by the Tokyo Electric Power Company (TEPCO). However, even now many people from Fukushima Prefecture and surrounding regions are still forced to live as evacuees, an issue of great concern to wider society. In order to put the minds of those who are enduring hardship and worry at ease as soon as possible, it is essential that the process of decommissioning the damaged reactors moves forward safely and as swiftly as possible.

The International Research Institute for Nuclear Decommissioning (IRID) was established in August 2013 as an organization to develop nuclear power plant decommissioning technologies efficiently based on collective wisdom from Japan and abroad.

In the year since its inception, IRID has identified research and development into the technologies required for the decommissioning of the Fukushima Daiichi NPS as a matter of urgency. These include R&D of technologies to safely retrieve nuclear fuel from the cores of the reactors and those related to the treatment/disposal of radioactive waste generated by the accident.

In August 2014, the decommissioning of the damaged reactors was added as a responsibility of the Nuclear Damage Liability Facilitation Fund. With this came the reorganization of the Fund into the Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF). The Japanese Government is now at the forefront of the decommissioning of the Fukushima Daiichi NPS and in developing measures to deal with contaminated water, strengthening the framework that supports the steady progress of the decommissioning work.

The extremely difficult task, even by global standards, of safely achieving steady progress in the decommissioning of the Fukushima Daiichi NPS requires NDF (technology strategy/technology-related decisions), TEPCO (on-site operations), and IRID (technical development) to collaborate and closely work together as one.

IRID is fully aware of the vital role it plays, and will continue working on developing technologies steadily and with a sense of urgency. We appreciate your kind guidance and continued support, and encouragement of our efforts.

September 2014

Technology Research Association,
International Research Institute for Nuclear Decommissioning

Hirofumi Kenda, President

Organization Profile

Profile

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

2. Location of Main Office
6F Parkplace, 5-27-1 Shimbashi, Minato-ku,
Tokyo 105-0004, Japan
website: http://www.irid.or.jp/en

3. Scope of Business
- Nuclear decommissioning technology R&D
- Promotion of cooperation on nuclear decommissioning with international and domestic organizations
- Human resource development for R&D

4. Membership (18)
Incorporated Administrative Agencies:
  Japan Atomic Energy Agency
  National Institute of Advanced Industrial Science and Technology
Manufacturers, etc.:
  TOSHIBA Corporation
  Hitachi-GE Nuclear Energy, Ltd.
  Mitsubishi Heavy Industries, Ltd.
  ATOX Co., Ltd.
Electric utilities, etc.:
  Hokkaido Electirc Power Co., Inc.
  Tohoku Electirc Power Co., Inc.
  Tokyo Electric Power Company, Incorporated (TEPCO)
  Chubu Electric Power Co., Inc.
  Hokuriku Electric Power Company
  Kansai Electric Power Co., Inc.
  The Chugoku Electric Power Co., Inc.
  Shikoku Electric Power Company, Incorporated
  Kyushu Electric Power Co., INC.
  The Japan Atomic Power Company
  Electric Power Development Co., Ltd.
  Japan Nuclear Fuel Limited

5. Board of Directors
President: Mr. Hirofumi Kenda
Vice President: Dr. Tamio Arai
Executive Director: Mr. Kiichi Suganuma
Directors: Mr. Kiyoshi Oikawa, Mr. Hiroto Uozumi,
  Mr. Ei Kadokami, Mr. Masahiro Seto,
  Mr. Mamoru Hatazawa, and Mr. Yoshinori Moriyama
Auditor: Mr. Tomomichi Konashi

(As of August 19, 2014)

Founding of IRID

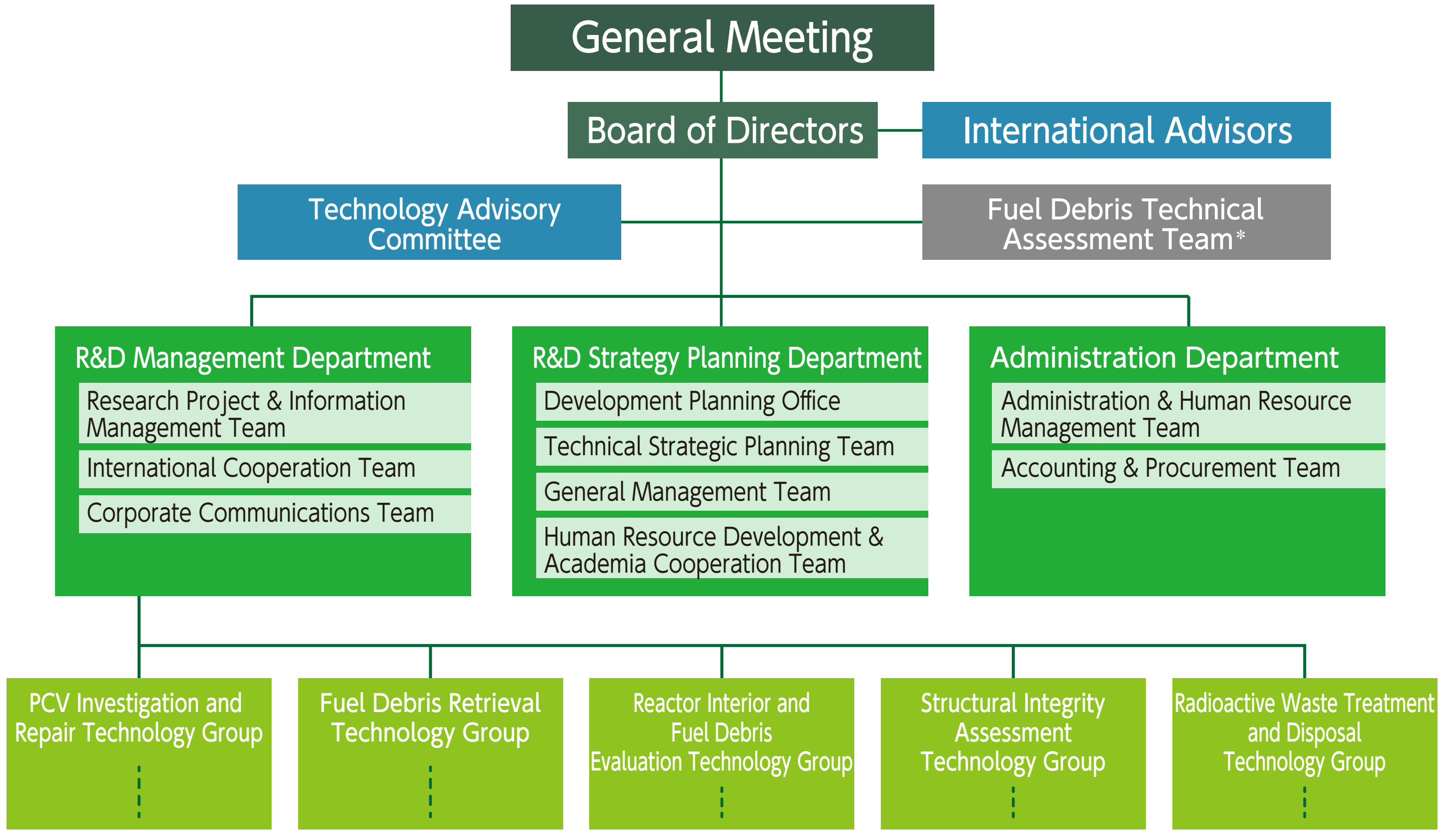
In July 2011, four months after the accident at the Fukushima Daiichi Nuclear Power Station (NPS), the first mid-and-long term countermeasure proposal was released. Experts at the time expressed the view that an organization dedicated to the decommissioning process should be created in Japan; this opinion was taken to the Japan Atomic Energy Commission.
In response to this, the Council for the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station announced in March 2013 that a new organization would be established.
A preparatory organization was then established to deliberate on the new organization. As a result, an application seeking approval for the establishment of IRID was sent to the Ministry of Economy, Trade and Industry at the end of July 2011, and approval obtained from the Minister on August 1 of the same year. IRID held its inaugural General Meeting on August 8, establishing itself as an independent decision-making body.

Organizational Structure

IRID was established under the Act on Research and Development Partnership, and is therefore obligated to set up a General Meeting and a Board of Directors.
The founding 17 members of IRID have been engaged mainly in the decommissioning process after the accident at the Fukushima Daiichi NPS. They were joined by a new member, ATOX, in May 2014.
The IRID Board of Directors is comprised of nine directors and one auditor. The Board also includes individuals who are not from IRID member organizations (universities/companies).
The General Meeting is the decision-making body of IRID, and the organization's activities are determined by consensus among the 18 member corporations, while the Board of Directors acts as the executive body.
The basic approach of IRID is to proactively incorporate technical advice from domestic and international experts. In order to achieve this, an advisory panel comprised of three foreign experts (International Advisors) gives advice on organizational and management aspects directly to the Board of Directors.
In addition, the Technology Advisory Committee and the International Expert Group (IEG)* have been set up within the organizational structure for the purpose of obtaining technical advice from experts in order to pursue various R&D activities.
IRID is comprised of three departments that report directly to the Board of Directors: the R&D Management Department, responsible for research planning, investigating overseas technologies/know-how, disseminating information, etc.; the R&D Strategy Planning Department, responsible for evaluating R&D results, human resources development, etc.; and the Administration Department, responsible for the administration of the organization.
Five groups have been set up under the R&D Management Department to tackle research-related issues: the PCV Investigation and Repair Technology Group; the Fuel Debris Retrieval Technology Group; the Reactor Interior and Fuel Debris Evaluation Technology Group; the Structural Integrity Assessment Technology Group; and the Radioactive Waste Treatment and Disposal Technology Group.

*After the plenary session held in June 2014, responsibility of the IEG's administration is to be taken over by TEPCO's Fukushima Daiichi Decontamination and Decommissioning Engineering Company.

IRID Organizational Chart



***Fuel Debris Technical Assessment Team**: Engaged in technological research on alternative methods for fuel debris retrieval. (As of August 19, 2014)

Technology Advisory Committee

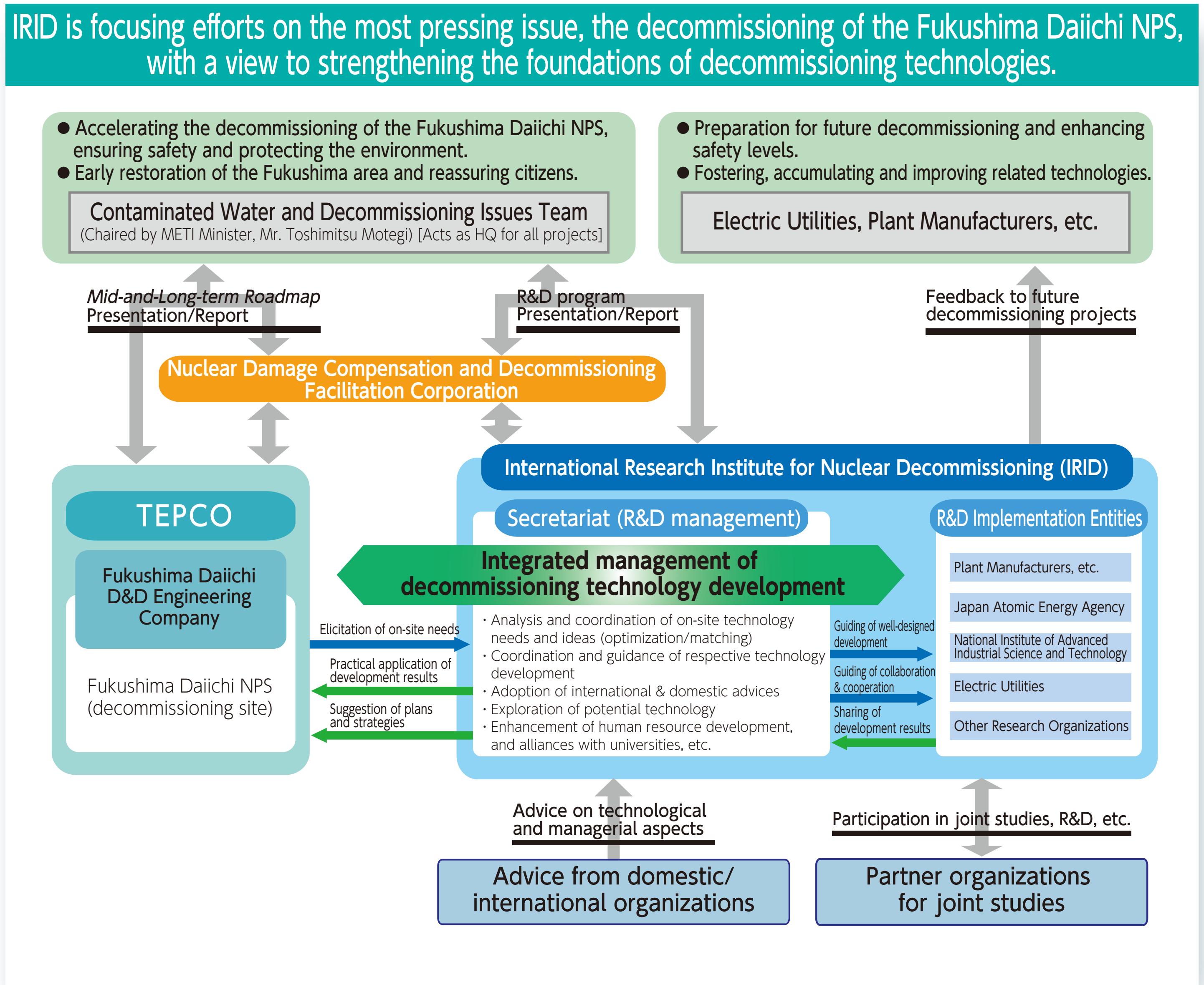
The Technology Advisory Committee has been set up with the objective of obtaining technical advice from highly knowledgeable experts in order to formulate plans for R&D projects undertaken by IRID based on their overall progress, and to have a flexible approach towards review of the systems.
Subcommittees have been set up under the Technology Advisory Committee in order to obtain views on special matters with regard to individual R&D projects.

Subcommittee members conducting onsite visit to view robot development (May 16, 2014)

Role of IRID

IRID is a body made up of 18 corporations engaged primarily in R&D required for decommissioning the Fukushima Daiichi NPS. Its long-term objective is to foster, accumulate, and improve decommissioning and other related technologies for the decommissioning of reactors throughout Japan.
However, for the present time, our focus is on the development of technologies required for the decommissioning of the Fukushima Daiichi NPS with consignment expenses and subsidies received from the government.
We have tied up with TEPCO's Fukushima Daiichi Decontamination and Decommissioning (D&D) Engineering Company to identify the needs of the Fukushima Daiichi NPS site, and we are using this information to integrate management systems for the development of various decommissioning technologies.
The integrated management of R&D being carried out by IRID follows the *Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi NPS Units 1-4 (Mid-and-Long-Term Roadmap)*. However, there are also instances where IRID makes suggestions which are then incorporated into the *Mid-and-Long-Term Roadmap*.
Through these activities, IRID aims for positive efforts to ensure that the decommissioning of the Fukushima Daiichi NPS proceeds swiftly, safely, and with due care for the environment in order to restore peace of mind to the residents of Fukushima and the rest of Japan.

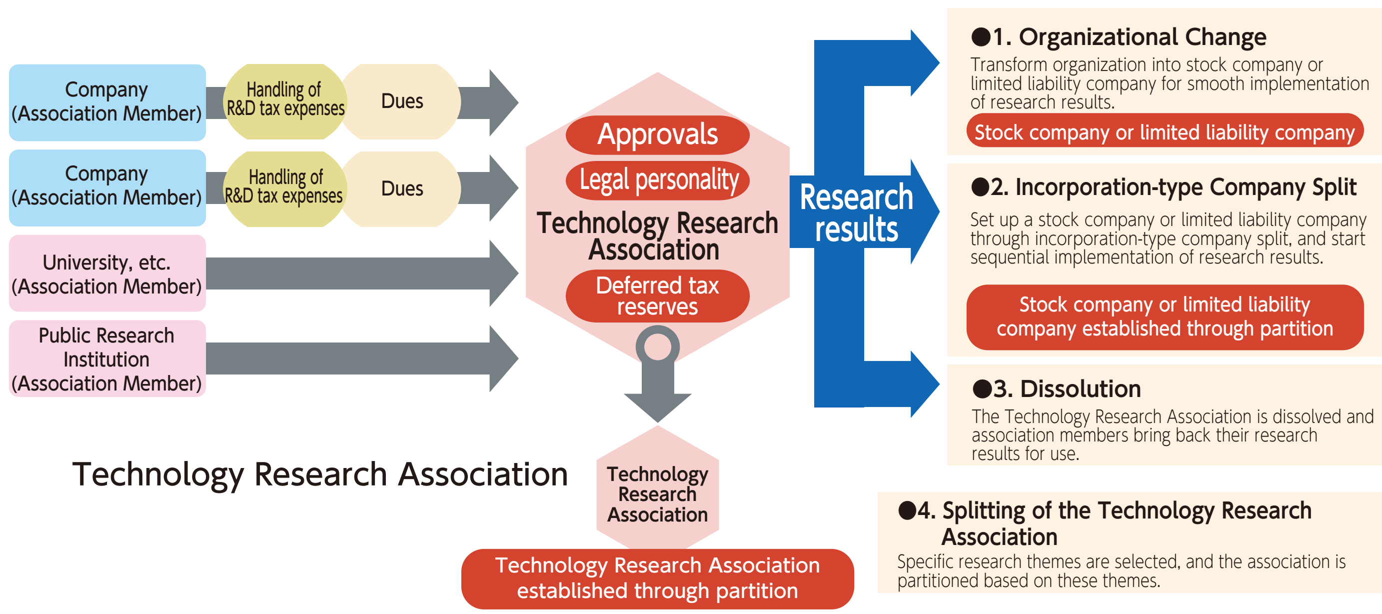
Role of IRID



Technology Research Associations

Technology Research Associations are mutual aid organizations (non-profit mutual benefit corporations) that conduct joint research on technologies used in industrial activities for the benefit of 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 in 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 joint research. These are jointly managed and utilized among 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 is increased through the approval of the Minister in charge, and by holding regular association member meetings/board of director meetings.
- Those who directly or indirectly use 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 provides opportunities for cooperation between industry, academia and government.

(Source) Ministry of Economy, Trade and Industry Website.

A Short Note

Looking back over the past year

After the accident at the Fukushima Daiichi NPS, the Ministry of Economy, Trade and Industry and TEPCO have been commissioning various projects for developing technologies based on specific requirements to relevant manufacturers. Through the establishment of IRID, all concerned parties are now able to discuss the same themes and resolve issues that may lead to inconsistencies or conflicts before they arise.
The process of sharing information, aligning opinions, and engaging in technological consultation initially took time. However, as we approach our first anniversary, integrated engineering is now possible, and issues that had hereto gone unnoticed are being seen. We are now able to approach research and development for the decommissioning of nuclear reactors through the exploration of better methods.

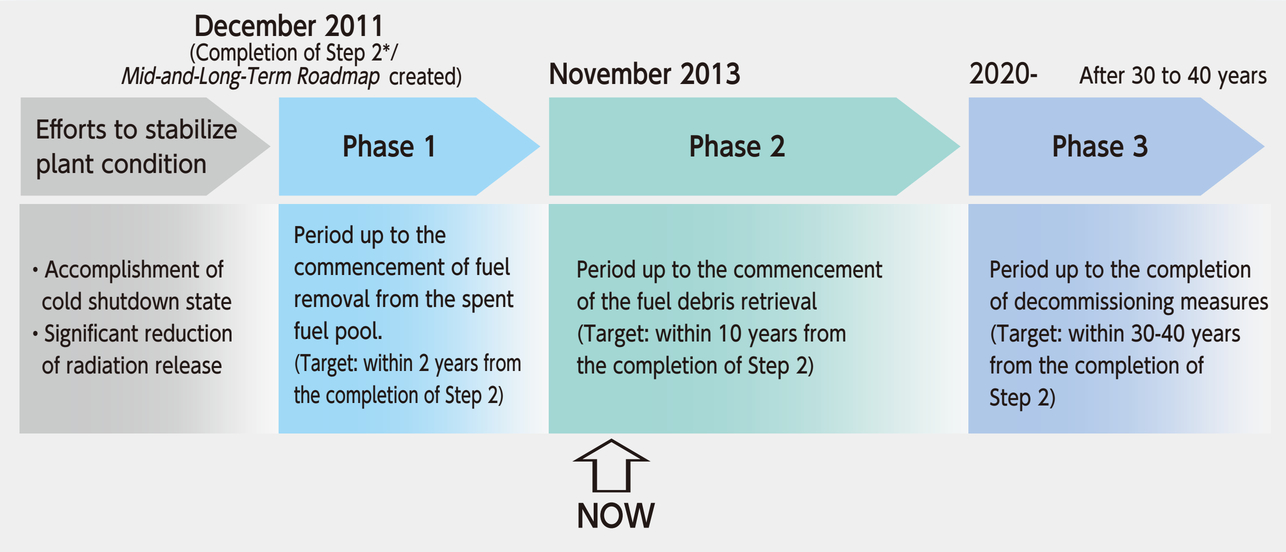
The Decommissioning Process in the *Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1-4*

The *Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1-4* (hereafter, the *Mid-and-Long-Term Roadmap*) was finalized in December 2011 by the ‘Government and TEPCO's Mid-to-Long Term Countermeasure Meeting’ to indicate reasonable and specific processes to recover from the accident at the Fukushima Daiichi NPS. On June 27, 2013, the Council for the Decommissioning of TEPCO's Fukushima Daiichi NPS (established in February 2013; changed to the Contaminated Water and Decommissioning Issues Team in September 2013) finalized a revised version of the roadmap. Further revisions will take place based on actual conditions.
The *Mid-and-Long-Term Roadmap* divides the time until completion of decommissioning into three phases, and sets out the schedule for major tasks to be undertaken onsite and the R&D schedule to the maximum extent possible. Phase 2 started in November 2013 with the commencement of removal of the spent fuel from Unit 4. Phase 2 sees R&D on the removal of fuel debris going ahead in preparation for the actual start of fuel debris retrieval by FY2020.
As of June 2014, we have been unable to directly view the inside of the Primary Containment Vessel (PCV) and Reactor Pressure Vessel (RPV), but we are able to gauge the condition inside the PCV by measuring its temperature and dose rate. We have also gradually been able to obtain a partial visual assessment. We are therefore steadily accumulating data which allows us to examine methods of decommissioning along with various new approaches to handle technical difficulties and issues which hinder the progress of decommissioning R&D efforts.

Mid-and-Long-Term Roadmap and R&D Tasks

Following the completion of Phase 1 of the *Mid-and-Long-Term Roadmap*, IRID addresses the following R&D tasks as part of Phase 2.

1. Promotion of long-term R&D in response to the start of fuel removal from the spent fuel pool
2. Development of multifaceted/multilayered methods and equipment for full-scale preparation of fuel debris retrieval (1) Submersion method
3. Development of multifaceted/multilayered methods and equipment for full-scale preparation of fuel debris retrieval (2) Alternative methods
4. Stable promotion of R&D in consideration of treatment and disposal of radioactive waste and decommissioning



＊**Step2**: One of the steps in the Fukushima Daiichi NPS stabilization process. The step aims to ensure that the “release of radioactive materials is under control and dose rate is significantly reduced.” Reference: *Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station Units 1-4* (June 27, 2013 revised edition)

R&D Using Commission Expenses and Subsidies from the Government

経済産業省 資源エネルギー庁

Project for development of the technological foundation for decommissioning and safety of nuclear reactors for power generation for FY2013*1
Subsidy for development of the technological foundation for decommissioning and safety of nuclear reactors for power generation for FY2013*2

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

	Project type	Title	Remarks
(1)	Commissioned	Evaluation of long-term integrity of the fuel assembly removed from the spent fuel pool	Completed in March 2014
(2)	Commissioned	Study of treatment method of damaged fuel removed from the spent fuel pool	Completed in March 2014

2. R&D for Preparation of Fuel Debris Retrieval

	Project type	Title	Remarks
(1)	Subsidized	Development of technology for remotely operated decontamination in reactor buildings	Planned for completion in July 2014
(2)	Subsidized	Development of technology to identify and repair leakage points in the PCV	Planned for completion in September 2014
(3)	Subsidized	Development of technology for investigation inside the PCV	Planned for completion in July 2014
(4)	Subsidized	Development of technology for investigation inside the RPV	Completed in March 2014
(5)	Subsidized	Development of technology for collecting, transferring and storing fuel debris	Completed in March 2014
(6)	Subsidized	Development of technology for evaluating integrity of the RPV/PCV	Completed in May 2014
(7)	Subsidized	Development of technology for controlling fuel debris criticality	Completed in June 2014
(8)	Commissioned	Assessing conditions inside reactor through application of severe accident analysis code	Completed in March 2014
(9)	Commissioned	Development of technology for identifying properties of and treating fuel debris	Completed in March 2014

3. R&D for Treatment and Disposal of Radioactive Waste

	Project type	Title	Remarks
	Commissioned	Study to examine technologies for the construction of a conceptual framework for treatment and disposal of accident waste	Completed in March 2014

4. Others

	Project type	Title	Remarks
(1)	Commissioned	Technical study to examine measures for the treatment of contaminated water	Completed in December 2013
(2)	Commissioned	Technical study to examine alternative methods of fuel debris retrieval	Completed in March 2014

＊1 Commissioned projects: FY2013 Nuclear Power Plant, etc. Decommissioning/Safety Technology Infrastructure Development Works. Projects which the government is in charge of conducted through this fund are intended to establish the technical infrastructure that, for example allows for the understanding and analysis of conditions inside reactors in order to contribute to the smooth progression of the decommissioning of TEPCO's Fukushima Daiichi NPS, as well as to improve technical infrastructure for the decommissioning and safety of nuclear facilities.

＊2 Subsidized projects: FY2013 Nuclear Power Plant, etc. Decommissioning/Safety Technology Development Subsidy. Projects which the government is in charge of conducted through this fund are intended to develop and demonstrate technologies such as remotely-controlled devices and equipment in order to contribute to the smooth progression of the decommissioning of TEPCO's Fukushima Daiichi NPS, as well as to improve technical infrastructure for the decommissioning and safety of nuclear facilities.

FY 2013 supplementary budget subsidy for decommissioning and contaminated water management project*3 (adopted on June 30, 2014)

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

	Project type	Title	Remarks
(1)	Subsidized	Evaluation of long-term integrity of the fuel assembly removed from the spent fuel pool	Planned for completion in March 2015
(2)	Subsidized	Study of treatment method of damaged fuel removed from the spent fuel pool	Planned for completion in March 2015

2. R&D for Preparation of Fuel Debris Retrieval

	Project type	Title	Remarks
(1)	Subsidized	Development of repair and water leakage stoppage technology for leakage points inside the PCV	Planned for completion in March 2016
(2)	Subsidized	Full-scale test for repair and water leakage stoppage technology for leakage points inside the PCV	Planned for completion in March 2016
(3)	Subsidized	Development of technology for investigation inside the RPV	Planned for completion in March 2015
(4)	Subsidized	Development of technology for retrieval of fuel debris and in-core structures	Planned for completion in March 2015
(5)	Subsidized	Development of technology for collecting, transferring and storing fuel debris	Planned for completion in March 2015
(6)	Subsidized	Development of technology for evaluating integrity of the RPV/PCV	Planned for completion in March 2016
(7)	Subsidized	Development of technology for detection of fuel debris in the reactor	Planned for completion in March 2015
(8)	Subsidized	Assessing conditions inside reactor through application of severe accident analysis code	Planned for completion in March 2015
(9)	Subsidized	Development of technology for identifying properties of and treating fuel debris	Planned for completion in March 2015

3. R&D for Treatment and Disposal of Radioactive Waste

	Project type	Title	Remarks
	Subsidized	Development of technology for treatment and disposal of accident waste	Planned for completion in March 2015

＊3 Projects conducted through this governmental fund are aimed at improving the level of scientific technology available in Japan and ensuring smooth progress in the decommissioning and contaminated water management processes by supporting technical developments that contribute to decommissioning and treatment of contaminated water.

Scope of Business

IRID's main areas of business are: (1) Nuclear decommissioning technology R&D; (2) Promotion of cooperation on nuclear decommissioning with international and domestic organizations; and (3) Human resource development for R&D.

Nuclear Decommissioning Technology R&D

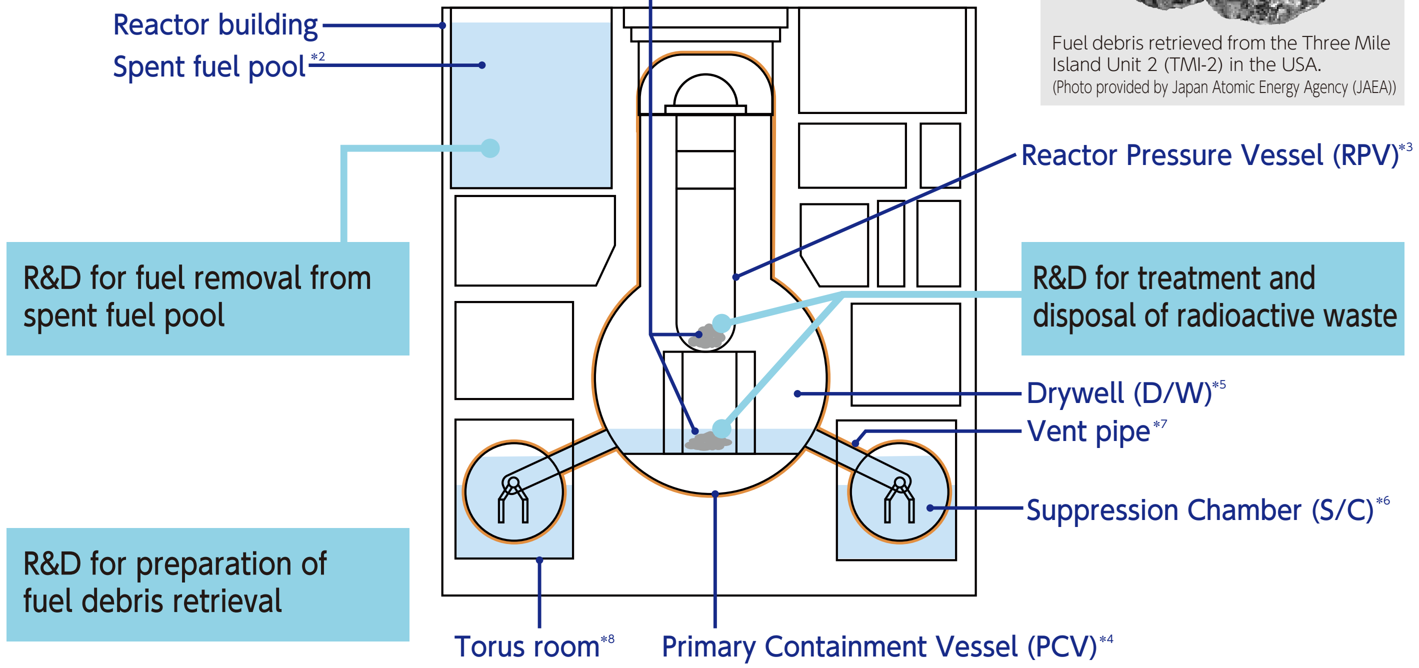
R&D at IRID

IRID conducts R&D for the decommissioning of the Fukushima Daiichi NPS based on *the Mid-and-Long-Term Roadmap*. The primary focus of our R&D activity is the upgrading of decommissioning strategies. Together with TEPCO and other related organizations, IRID studies optimum methods and countermeasures to reduce risk with a view to an optimum end state.
The three main areas of R&D IRID addresses are: Fuel removal from the spent fuel pool; preparation of fuel debris retrieval; and, treatment and disposal of radioactive waste.

Overview of the Reactor Building and R&D by IRID

(Reference)

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



*1 **Fuel debris**: Material formed by high temperature fuel that has melted together with control rods and structures inside the RPV which has then cooled and solidified again.

*2 **Spent fuel pool**: A water tank that stores spent fuel that is inserted in a rack until decay heat generated from fission products has decreased. 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 the high-temperature water and high-pressure steam generated by the energy released by nuclear fission in the RPV. The RPV is housed within the PCV facility 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 and a doughnut-shaped suppression chamber interconnected by vent pipes.

*5 **Drywell (D/W)**: A safety feature that is comprised of a flask-shaped container that houses equipment, including the RPV, and contains radioactive substances in case of an accident occurring.

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

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

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

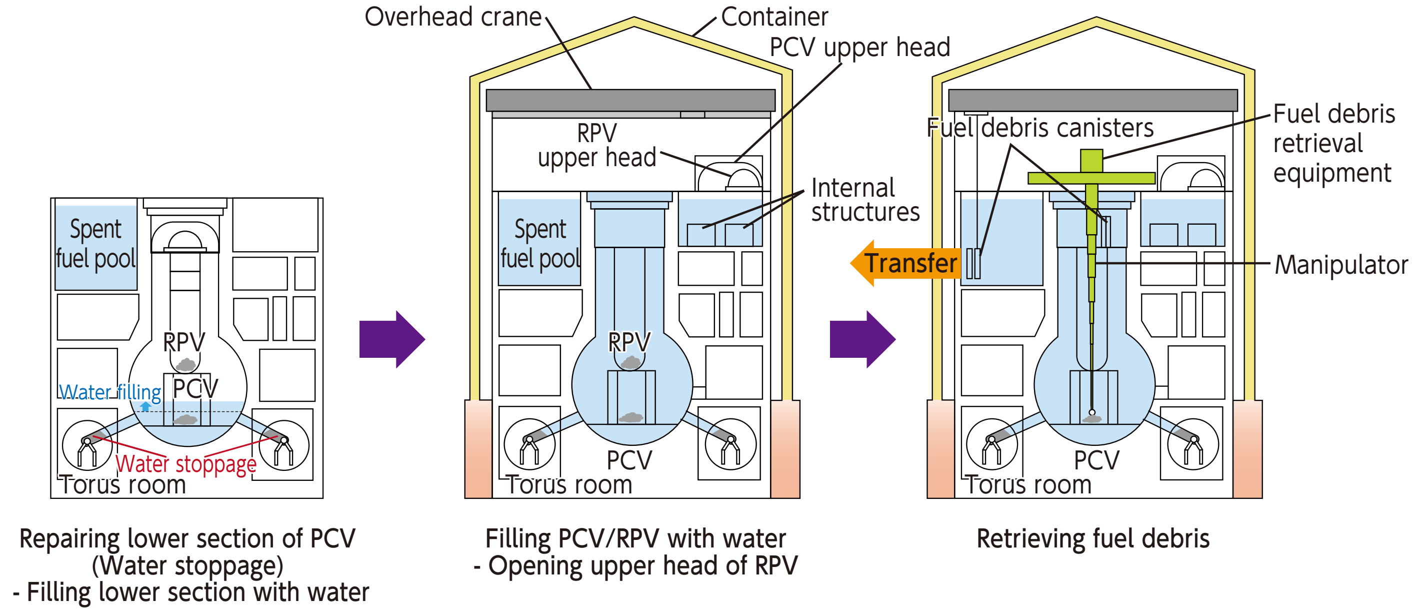
Fuel Debris

Total loss of all power sources at Units 1-3 of the Fukushima Daiichi NPS disabled the circulation pumps, preventing the flow of water into the RPVs. Without the necessary water to cool them down, the fuel inside the RPVs overheated, with temperatures thought to have risen above 2,000 degrees Celsius – high enough to melt the fuel rods themselves.
It is assumed this overheated fuel melted along with control rods and other structural components inside the RPVs. The melted material solidified again after reaching the bottom of the RPVs, and partially at the bottom of the PCVs. This solidified material is called "fuel debris." With radiation levels inside the PCVs being tremendously high even now, workers cannot get near the structures; the shape and location of fuel debris can only be estimated using computer simulations. It is absolutely necessary in the decommissioning process to retrieve the fuel debris from inside and store it under a safe and stable condition.

Submersion Method for Fuel Debris Retrieval

The fuel debris retrieval project uses the "submersion method," an approach where fuel debris is fully covered with water. Since water is effective in blocking radiation, the advantage of the submersion method is that it helps reduce unnecessary exposure of workers, and also prevents dust dispersion during the machining of collected debris.
With the submersion method, as fuel debris are first covered with water, water leakage from the PCV wall needs to be stopped. In order to stop this leakage, the work areas and access routes need to be decontaminated to allow for worker access, and leakage points must be detected.
Robots are being developed to carry out decontamination and inspection of the facility. With the help of these robots, it is possible to determine contamination levels, take samples from the concrete core, and carry out decontamination from a remote location.
Using the submersion method, the PCV/RPV upper heads and internal structures are first removed. An apparatus to retrieve fuel debris is then set up. For example, a manipulator which can expand and contract could be lowered down, and a special cutting tool at the end of this manipulator could be used to cut up and retrieve the debris, placing it in special canisters for storage.
Other innovative approaches for fuel debris retrieval including in-air work are also being studied as alternative methods in parallel with the submersion method.

[Submersion Method] Fuel debris retrieval operation steps



(Reference) Based on Council for the Decommissioning of TEPCO's Fukushima Daiichi NPS documents, June 27, 2013.

1 R&D for Fuel Removal from Spent Fuel Pool

Fuel removal from the spent fuel pool in Unit 4 at the Fukushima Daiichi NPS commenced on November 18, 2013. TEPCO evaluates the integrity of the spent fuel at Unit 4 before transferring it out of the facility.

(1) Evaluation of long-term integrity of the fuel assembly removed from the spent fuel pool

Integrity (corrosion resistance, etc.) of the fuel assembly removed from the spent fuel pool and stored in the common pool* for a long period is being evaluated by IRID as part of a research project it is engaged in. In future, investigation of actual fuel integrity and corrosion and strength tests on fuel components will be carried out, which will then be followed by an evaluation of the effects of this based on actual water quality conditions.

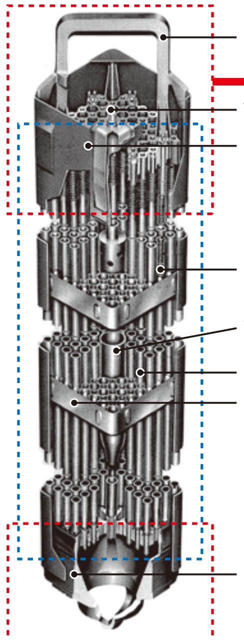
*Common Pool: A large pool where spent fuel from Units 1-6 at the Fukushima Daiichi NPS is stored.

Evaluation items for long-term integrity of fuel assembly and scope

Structural integrity
・Tie rod bolt joint

Cladding airtightness
・Fuel cladding

Structural integrity
・Bottom tie plate



BWR fuel assembly

Status of investigation of fuel in common pool

Exterior of the upper part of the fuel assembly

Tie rod bolt joint

(2) Study of treatment method of damaged fuel removed from the spent fuel pool

There is a possibility that fuel may have been damaged by the adhesion of sea salt or suffered physical damage due to rubble impact. Evaluation of the effect this may have on the reprocessing plant and development of criteria to determine the possibility of reprocessing damaged fuel will be carried out.

Impurities (compositions of seawater and concrete) dissolved in nitric acid

Simulated impurities (mortar)

Dissolution test equipment

Nitric acid solution of simulated impurities

Behavior check for impurities at reprocessing time

Extraction work by shaker

Organic phase (solvent)

The solution after the left standing

Water phase
(nitric acid solution containing impurities)

In the reprocessing plant, spent fuels are dissolved by nitric acid and uranium and plutonium are extracted from the nitric acid solution using organic solvent. Major compositions of impurities (composition of seawater and concrete) need to be checked whether they are dissolved by nitric acid along with uranium and plutonium, or if impurities will affect the extraction process of uranium and plutonium.

2 R&D for Preparation of Fuel Debris Retrieval

(1) Development of technology for remotely operated decontamination in reactor buildings

Remotely operated decontamination equipment has been developed to respond to contamination conditions at the site and improve the environment for investigation of leakage in the PCV and undertaking repair works in preparation for fuel debris retrieval.
IRID will develop decontamination equipment for elevated locations and upper floors to follow on from the decontamination work performed on lower floors up until now. A comprehensive scheme to reduce radiation exposure to workers through a combination of decontamination technology and shielding will also be studied.

"MHI-MEISTeR" Remote control robot

[Mitsubishi Heavy Industries]

This remote-controlled robot was developed by Mitsubishi Heavy Industries in response to the criticality accident at the nuclear fuel processing facility in Tokaimura, Ibaraki Prefecture, in 1999. This robot has been modified and improved for the purpose of remote operation work at the Fukushima Daiichi NPS.
In 2013, remote operation performance at the Fukushima Daini NPS was assessed and areas for improvement were identified. After the improvements were made, demonstration decontamination test*1 by remote operation and concrete core sampling*2 at the Fukushima Daiichi NPS were completed between January and March, 2014.
The robot has two arms with seven joints. The arm ends are equipped with swappable tools that enable the carrying out of various kinds of work, such as concrete wall boring, cutting hand rails and pipes, removal of obstacles, decontamination, and repair work.

*1 **Demonstration decontamination tests**: Tests to prove the effectiveness of absorption (absorbing radioactive contaminants using a dedicated nozzle) and blast decontamination (by spraying the blast material (abrasive material) and scraping a thin layer of the contaminated surface).

*2 **Concrete core sampling**: Taking a cylindrical concrete sample of approx. 70mm in depth from the wall and floor for the purpose of investigating contamination levels inside the building.

Absorption/blast decontamination work

Concrete core sampling

Core cutting (arm tip)

(2) Development of technology to identify and repair leakage points in the PCV

Methods and equipment to investigate and repair leakage (water stoppage) from the PCV, etc., that take each environment, including elevated locations, high radiation dose areas, narrow spaces, and areas under water into consideration are now under development.
In addition to the establishment of measurement technology to determine the necessity of repair, construction of a new boundary for water filling, such as by injecting water stoppage material (grout*) into the vent pipes that connect the drywell (D/W) and the suppression chamber (S/C), will be studied.
The performance of water stoppage technology by grout injection will be demonstrated by a full-scale unit test to confirm its applicability.

*Grout: Cement-based material injected to fill voids during construction work, etc.

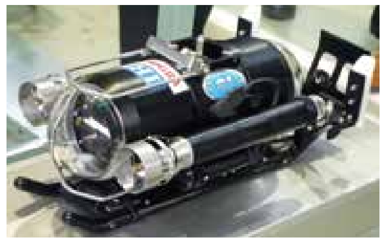
1 Device to inspect joint section between drywell and vent pipe (VT-ROV*) [Toshiba]

A remotely operated vehicle designed for Units 1-3 at the Fukushima Daiichi NPS to detect leakage around the joint area between the D/W and the vent pipes with the assumption of "shell attack" (where molten fuel debris has fallen down and spread on the bottom of the D/W, causing damage to the D/W body), etc.
This robot inspects for leakage using a camera mounted on its front and adheres to the surface of the vent pipe using wheels magnetized by a permanent magnet (neodymium).
The height of the robot is 90mm, making it capable of entering the gap between the vent pipe and concrete wall that is as narrow in places as approx. 100mm.

*ROV: Remotely Operated Vehicle.

2 Sand cushion*1 drain pipe*2 inspection device (DL-ROV) [Toshiba]

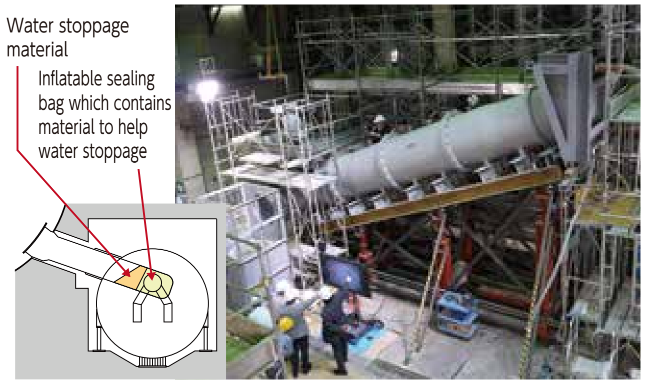
This small device that maneuvers underwater is equipped with three thrusters*3 to investigate the sand cushion drain pipe. It is designed for use in Units 2 and 3 at the Fukushima Daiichi NPS, and will be used when the drain pipe outlet is submerged.
This device investigates leakage from the drain pipe by applying tracer *4 just around the drain pipe outlet and observing its flow using the camera.



*1 Sand cushion: Region underneath the exterior of the D/W base filled with sand to act as a buffer to absorb localized stress in the PCV (base part of the D/W) in case of an accident.
*2 Drain pipe: A pipe that releases water accumulated in the sand cushion mentioned above.
*3 Thruster: Propulsion system (screw propellers) to move equipment forwards and backwards, as well as up and down.
*4 Tracer: Particles to track fluid and gaseous flow. A fluorescent tracer is used for this DL-ROV.

6 Preliminary test to verify water stoppage method of injecting water stoppage material (grout) into vent pipe [Toshiba]

In preparation of implementing the submersion method, deattaching the S/C from the D/W is being considered since the RPV and the PCV are required to be filled with water.
Specifically, a large inflatable sealing bag is placed on the tip of the inner side of the each of eight vent pipes and mortar is injected into the bag to temporarily stop water flow. Water stoppage material (grout) is then injected into the upstream side from the bag which will then stop water flow.



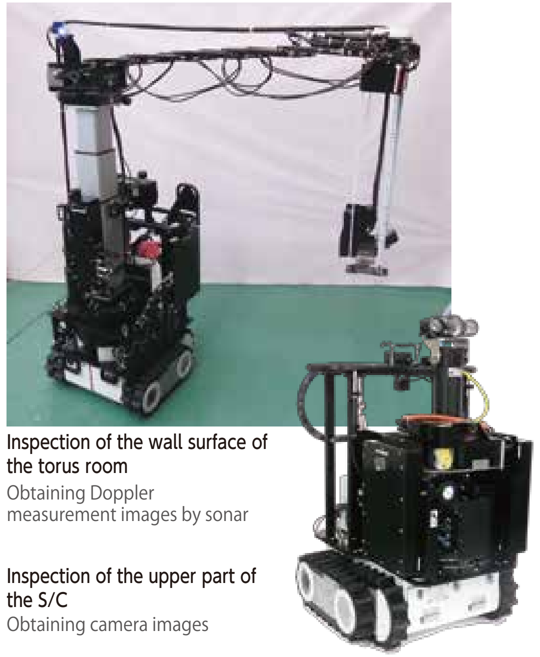
5 Support equipment (remotely operated manipulator*) [Toshiba]

Equipment to transfer and collect the devices in 1 - 3 using a manipulator. In each unit at the Fukushima Daiichi NPS, holes in eight locations will be drilled through the first floor of the building. The support equipment will be placed over each of these holes so that it can deliver and retrieve the devices using an extendable manipulator into the torus room.

*Manipulator: A general name for working robots that substitute for human manual operation. Manipulator used in the sense here refers to an expandable arm robot.

4 Investigation device for the upper part of the S/C [Hitachi-GE Nuclear Energy]

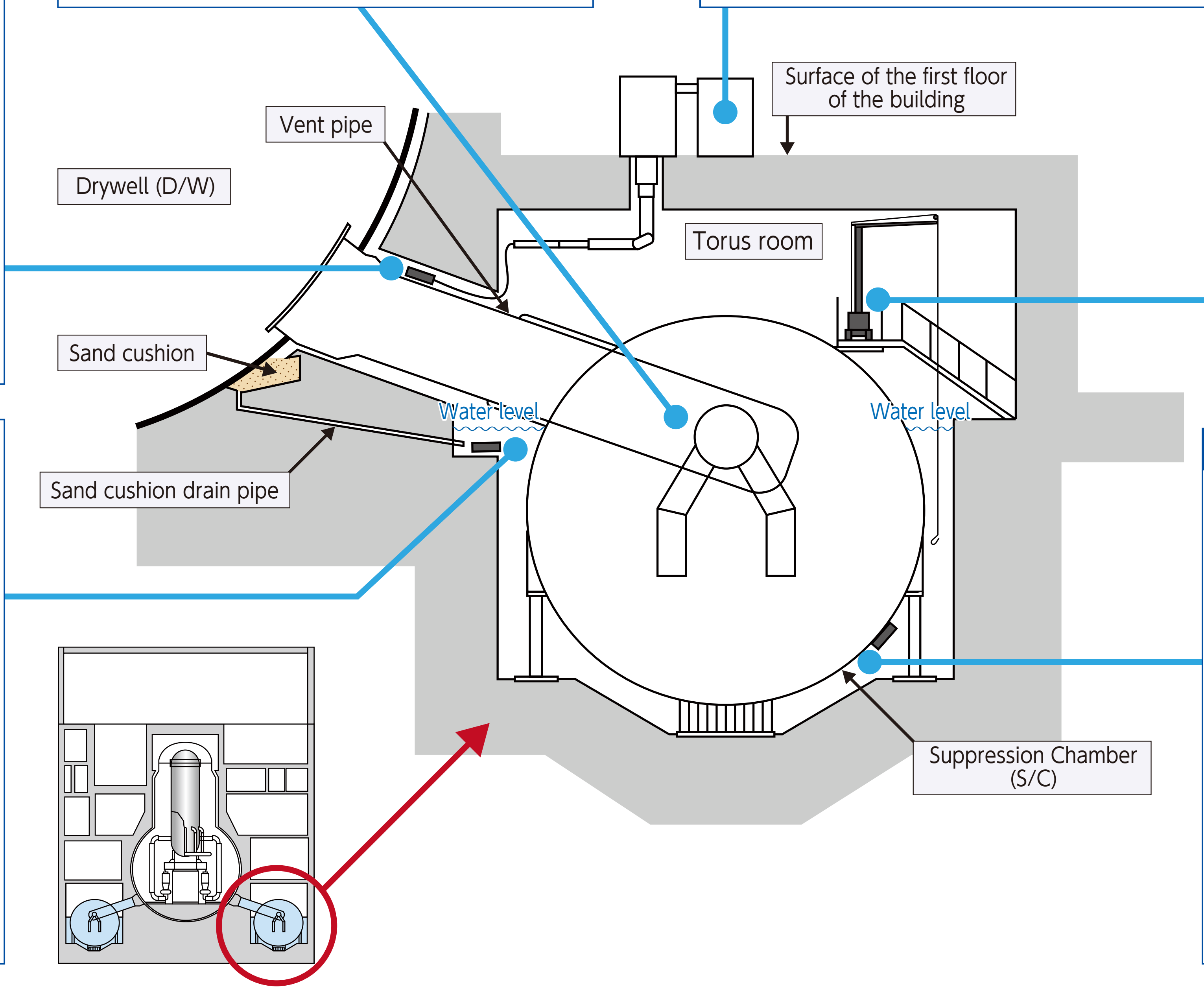
This device can perform the following three types of investigations by replacing the upper part of the equipment mounted on the transfer mechanism (carriage) that is fitted with a crawler: (1) Upper part of the S/C (video recording); (2) Torus room wall surface (video recording); (3) Torus room wall surface using images obtained by sonar (ultrasonic sensor) using Doppler measurement*.
On May 2014, investigation was performed at Unit 1 at the Fukushima Daiichi NPS, and leakage from the expansion joint cover for the vacuum break line in the upper part of the S/C was detected.



Inspection of the wall surface of the torus room
Obtaining Doppler measurement images by sonar

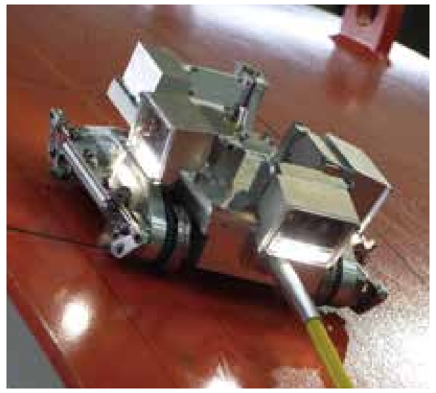
Inspection of the upper part of the S/C
Obtaining camera images

*Doppler measurement: Repeated bursts of ultrasonic waves numbering several hundred in one second to detect small changes in reflected waves that may be caused by particles in the water, detecting flow.



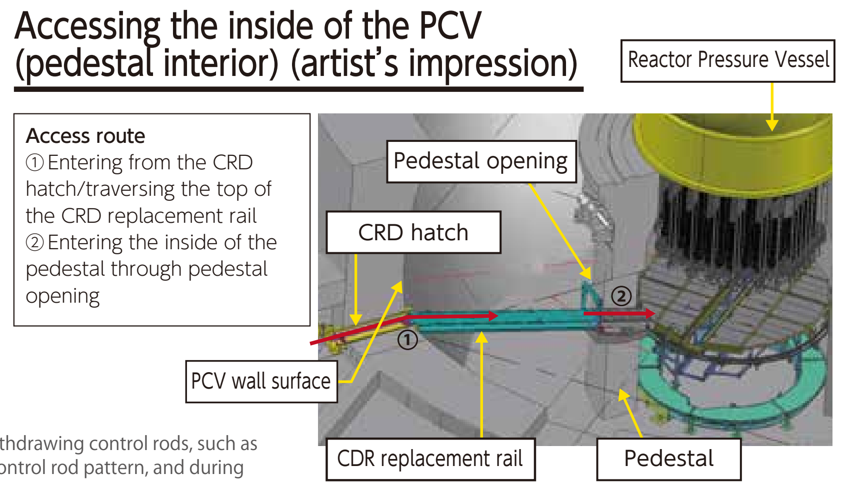
3 Investigation device of the outer lower surface of the S/C (SC-ROV) [Toshiba]

This autonomously maneuverable robot mainly investigates the submerged area to detect holes of 30mm or more in diameter by adhering on the surface of S/C with wheels magnetized by a permanent magnet (neodymium).
It is powered by electricity and air as well as receives signals by the cable. This robot searches damaged portions using the cameras equipped on its front and back, and on its left and right by moving from the inner peripheral side to the outer peripheral side on the S/C outer lower surface.
Also, it is capable of marking the place which has already been investigated using a stick-type marking system to avoid repetition.
This device can be separated from the surface of the S/C by jacking up the detachable mechanism that is fixed on the lower part of this device.



(3) Development of technology for investigation inside the PCV

Investigation methods and remotely operated devices are now under development to identify conditions inside the PCV and determine the situation regarding fuel debris.
Specifically, devices being developed include equipment that can use the existing CRD*1 hatch for access in order to investigate the lower part of the PCV (inside and outside the pedestal*2).
IRID plans to develop investigation devices that can be operated within high-dose radiation environments and guarantee performance in a compact form. The performance of these devices will be verified through demonstration testing.

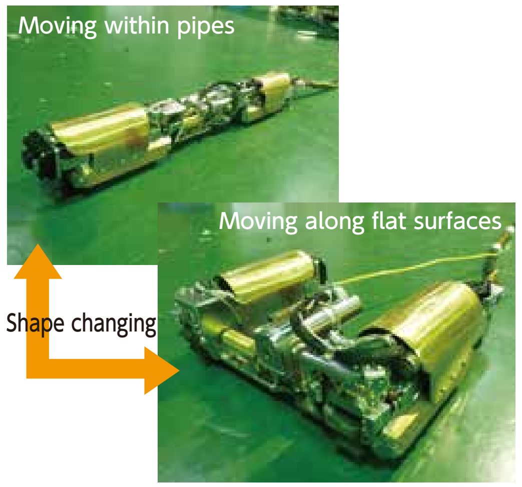


＊1 **CRD (Control Rod Drive)**: A mechanism required for inserting and withdrawing control rods, such as when starting up and stopping the fission operation, adjusting the control rod pattern, and during SCRAM procedures.
＊2 **Pedestal**: A reinforced concrete cylindrical structure that supports the RPV.

Shape-changing robot (crawler* type)

[Hitachi-GE Nuclear Energy, Ltd.]

This shape-changing robot (crawler type) can change its shape from a single line posture when moving through pipes with a diameter of about 100mm, and then open to a rectangular posture when investigating inside the PCV. This shape changing ability enables the robot to run stably on flat surfaces and pass through piping with a small diameter.
This robot will be introduced into Unit 1 at the Fukushima Daiichi NPS for verification testing during the second half of FY 2014. It is planned that the robot will enter the PCV from a narrow access port (inner diameter of 100mm), and investigate conditions inside the PCV from the top of the grating (a lattice-shaped metallic object used to cover gutters, etc.) on the first floor outside the pedestal.



＊**Crawler**: Equipment that enables robots to travel on uneven surfaces by connecting plates circularly, and rotating them using a drive tumbler.

(4) Development of technology for investigation inside the RPV

Prior to the retrieval of fuel debris, technologies to identify conditions inside the RPV (temperature, dose rate, degree of damage to equipment in the reactor, location of fuel debris, etc.) and to sample fuel debris will be developed.

(5) Development of technology for collecting, transferring and storing fuel debris

The design concept of storage canisters (basic function, outline shape, etc.) will be established with consideration to the condition of fuel debris ((1) Temperature, (2) Degree of concentration, (3) Period of cooling, and (4) Effect of seawater, etc.). Additionally, technologies required for collecting, transferring and storing fuel debris will be developed by studying the validity of storage canister design using several storage methods from economic and technological perspectives, as well as in consideration of safe storage methods.

(6) Development of technology for evaluating integrity of the RPV/PCV

Assuming there has been a corrosive effect caused by the injection of seawater, the integrity of equipment and structures in various plant conditions is being evaluated in preparation for fuel debris retrieval. IRID is aiming to establish a life extension scheme, which includes countermeasures for corrosion control, etc., as well as predicting the long-term integrity of structures based on seismic evaluation of equipment and the structures and on corrosion test results for each material used.

(7) Development of technologies for controlling fuel debris criticality

In addition to subcriticality assessment during the retrieval of fuel debris, IRID is currently developing criticality control technologies, such as monitoring and recriticality prevention technologies (development of neutron absorption material, etc.).
IRID will develop analysis criteria for rational criticality assessment in response to fuel debris retrieval and collection scenarios, in addition to collecting the required data for criticality control studies and ensuring that the latest detailed information is reflected in these studies.

(8) Assessing conditions inside reactor through application of severe accident analysis code

In addition to conducting accident progression analysis using current severe accident analysis code, we will determine analysis code items for improvement based on a comparison with actual parameters and the PIRT (Phenomena Identification and Ranking Table), and aim to advance technologies for accident progression analysis.
In future, we aim to enhance nuclear safety research around the world through collaboration with the Atomic Energy Society of Japan in establishing the PIRT, and through discussions with experts in Japan and overseas at OECD/NEA (Organization for Economic Co-operation and Development/Nuclear Energy Agency) workshops, etc.

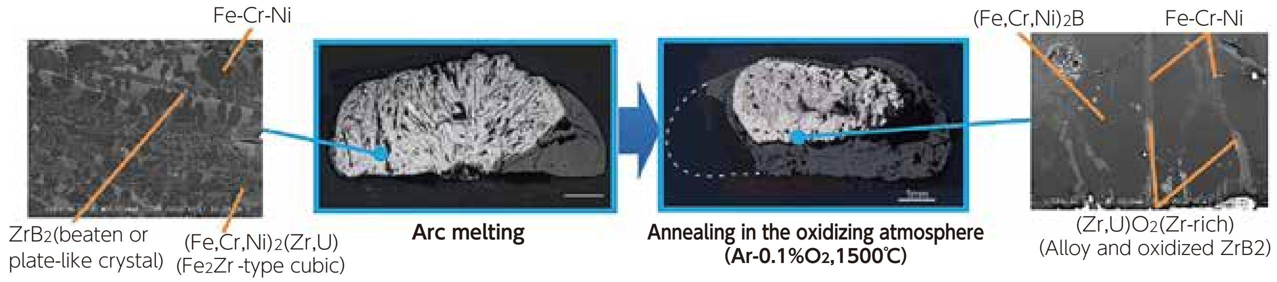
(9) Development of technology for identifying properties of and treating fuel debris

To ensure safe fuel debris retrieval and in order to develop retrieval equipment and storage canisters, etc., we will first examine specific methods using simulated debris. These simulated debris will be manufactured considering the circumstances of the Fukushima Daiichi NPS (seawater effects, etc.).
Evaluation will be conducted through a combination of accident progress analysis and chemical equilibrium computation using the results of the Three Mile Island Unit 2 (TMI-2) accident and other severe accident research results as a comparative guide.

Status of manufacturing and analysis test of simulated debris

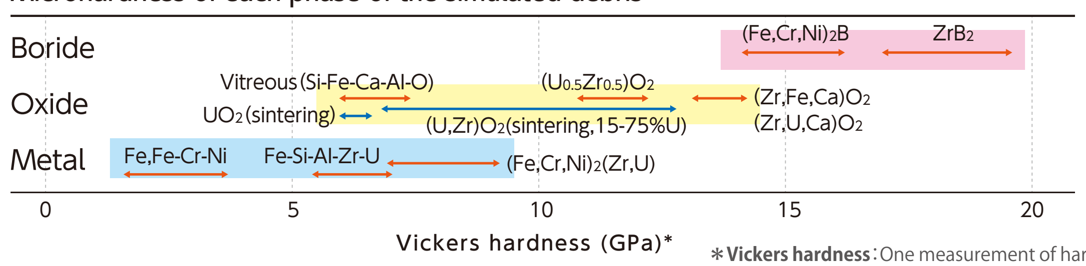
Simulated debris is made of uranium dioxide powder and zirconium dioxide powder, etc. These ingredients are mixed and heated to approx. 1600℃ - 3000℃ (varies depending on the test and facility) and shaped into simulated debris. Various types of tests are then conducted on the simulated debris. Tests are conducted in 'glovebox', a facility with high sealability equipped with windows and gloves. Researchers can handle materials that are isolated to prevent exposure and contamination caused by the uranium.

Reaction with Control rod material (B4C+SUS)
(Observation samples of section view of simulated debris)



An example of a high temperature reaction test on boron carbide (B4C) the material used in control rods (boron carbide absorbs neutrons in the reactor and controls the nuclear fission reaction), stainless (SUS) control rod cladding material, and uranium dioxide (UO2) and zirconium dioxide (ZrO2), the crude materials used in simulated debris.
The creation of a new oxide layer, etc., was observed on the surface of the alloy phase by annealing (heating using comparatively low temperatures) simulated debris in the oxidizing atmosphere using arc melting (melting using heat generated by discharge).

Microhardness of each phase of the simulated debris



If debris were created by a reaction between the fuel and the control rod, it suggests the possibility that a boride layer, which is harder than the metals and the oxide observed in the TMI-2 accident in the U.S., may have been created within the debris.

＊**Vickers hardness**: One measurement of hardness of a material. It is calculated based on the size of an impression produced under load by a diamond indenter.

3 R&D for Treatment and Disposal of Radioactive Waste

Study to examine technologies for the construction of a conceptual framework for treatment and disposal of accident waste

Radionuclide analysis of rubbles, fallen trees and contaminated water, etc. sampled at the Fukushima Daiichi NPS and inventory evaluation* of waste materials based on the analysis of these results are now being performed.
In order to acquire the prospect of safe solid waste treatment and disposal, IRID will continue to conduct R&D of technologies required for storage management, understanding waste characteristics, and waste encapsulation, and for waste disposal.
From FY 2014, IRID will collect and organize information gathered from Japan and abroad related to concepts concerning securing the safe decommissioning of reactors, and contribute to the examination of decommissioning scenarios.

* **Inventory evaluation**: Method to assess the amount of radionuclides contained in radioactive waste, or abundance ratio and correlations based on analysis results or physical/chemical behavioral characteristics.

Radioactivity analysis for standing trees sampled at the site (Evaluation of contamination condition within the site)

[Japan Atomic Energy Agency (JAEA)]

Radioactivity analysis of standing trees at the Fukushima Daiichi NPS was conducted between October 2013 and February 2014 to collect and evaluate basic data which will be required to verify the method of radioactive waste treatment and disposal.
To date, in order to determine the extent of radioactive contamination on the power station site, the site has been divided into 20 areas based on the distribution of air dose rates, and a variety of environmental samples taken. As it cannot be ruled out that rubble sampled for analysis may have been moved from its original location after the accident, using the standing trees for analysis, we can determine what kind of radionuclide was spread into which section of the site and better understand the contamination distribution data.
Specifically speaking, around three pine trees in each area were chosen as 'representatives,' and from these trees, branches at a height of around four meters were sawn off. Thirty samples (not all areas had these branches) with high dose rates at their surface were selected and sent to the JAEA Nuclear Science Research Institute to be analyzed.
The findings showed that radiation distribution readings reflected those of air dose rates, with a similar high concentration of Cesium-137, Strontium-90, and Tritium around the reactor buildings. From these results, it can be presumed that the primary cause of contamination was radioactive nuclides spread by the accident.
Looking at overall correlations, it was seen that there was a proportional relationship between concentrations of Cesium-137 and Strontium-90. The ratios of these nuclides were found to be the same as those found in soil outside the site, and rubble or felled trees within the site.


Samples (Standing trees)


Samples (Standing trees)


γ-ray detection by using germanium semiconductor detector

Requests for Information (RFIs) from Japan and Around the World

In addition to independently engaging in research and development in decommissioning reactors, IRID has been actively seeking a wide range of knowledge from Japan and around the world in order to deal with the contaminated water issue and contribute to the study of innovative approaches for fuel debris retrieval at the Fukushima Daiichi NPS.

■ Requests for Information for Addressing the Contaminated Water Issue

On September 10, 2013, the 1st Inter-Ministerial Council for Contaminated Water and Decommissioning Issues discussed policies and concrete actions for addressing contaminated water and decommissioning issues, and concluded that a team to collect expertise from all over the world and carefully investigate countermeasure proposals would be established.
In response to the RFI on the contaminated water issue, a total of 780 proposals were received from Japan and overseas. These proposals were then classified according to a specialist team within IRID. After initial review and verification by an Expert Review Panel, the report on the RFI results was passed to the Committee on Countermeasures for Contaminated Water Treatment on November 15.
Following the disbanding of this team in December 2013, Requests for Proposals (RFPs) are now processed by the Mitsubishi Research Institute, Inc.


Request for Technology Information Workshop (Oct. 2, 2013)

■ Requests for Information for Innovative Approaches to Fuel Debris Retrieval

IRID put out a call around the world between December 2013 and January 2014 seeking ideas for internationally collaborative and innovative approaches to fuel debris retrieval. Of the more than 200 responses received, around 40% were from overseas.
In addition to announcing this outcome at a domestic workshop on April 25, 2014, the Agency for Natural Resources and Energy, TEPCO, and Mitsubishi Research Institute., Inc. in its capacity as secretariat have been developing technical specifications for requests for proposal.
Please note that Mitsubishi Research Institute., Inc. started accepting RFPs from June 27 this year.


Workshop for R&D on Innovative Approaches for Fuel Debris Retrieval (Apr. 25, 2014)

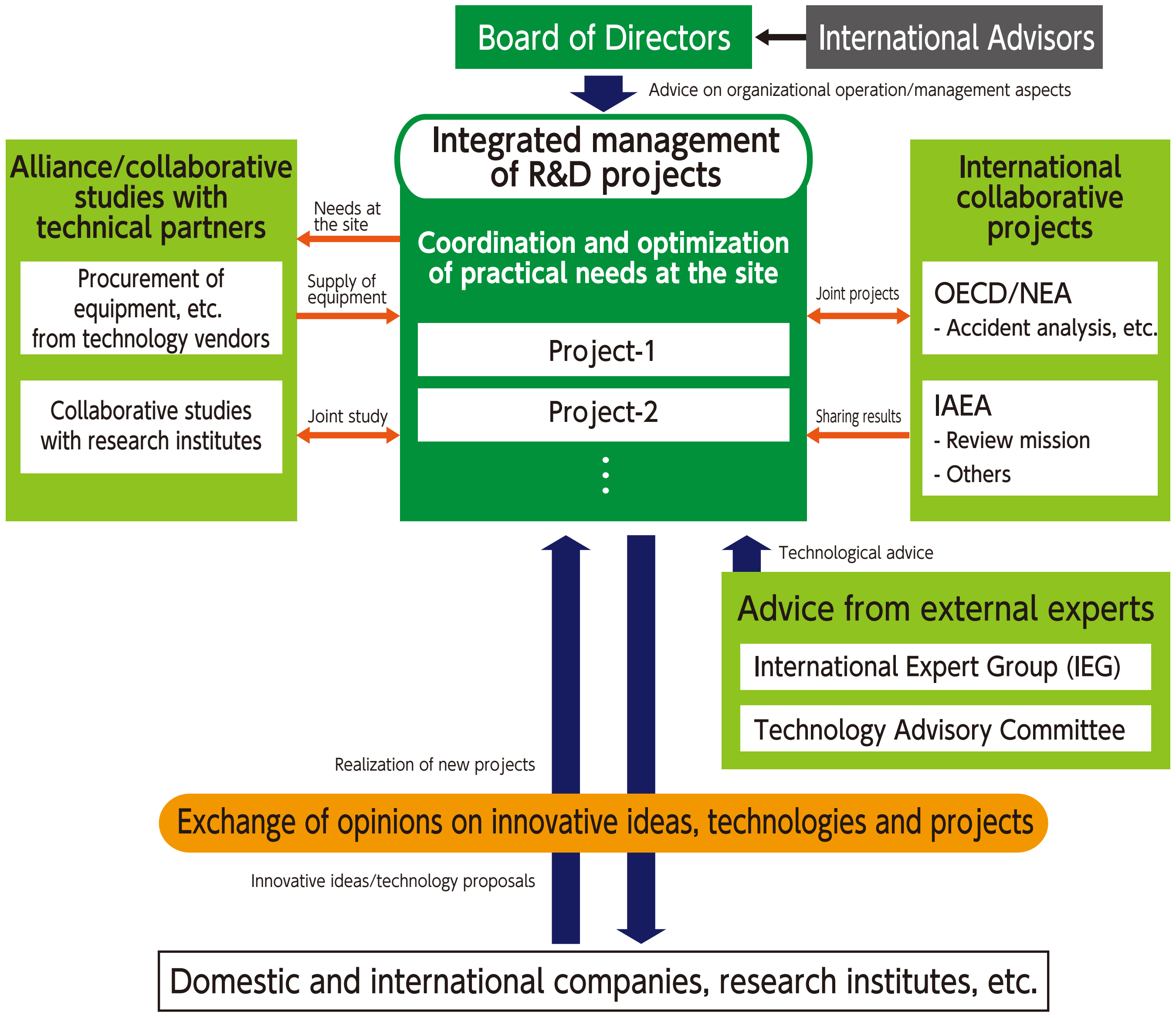
Promotion of Cooperation on Nuclear Decommissioning with International and Domestic Organizations

IRID's operational policy is to facilitate an open framework that pools the collective wisdom of experts in Japan and overseas. In order to accomplish this, it is essential that the government (policy), TEPCO (decommissioning operations), and IRID (mid-to-long term R&D) collaborate with each other in carrying out their respective roles and strengthen relationships with relevant domestic and international organizations and experts.

In order to derive the benefit of international wisdom, IRID has established a structure consisting of the International Advisors and the International Expert Group (IEG)* to receive advice from experienced foreign experts. We have also made a worldwide RFI for innovative technological approaches to treatment of contaminated water and the retrieval of fuel debris. In addition, we are also supporting the IAEA (International Atomic Energy Agency) Review Mission and participating in joint research projects through the OECD/NEA.

＊After the general meeting in June 2014, administrative responsibility was taken over by the TEPCO Fukushima Daiichi D&D Engineering Company.

Open framework to gather knowledge from around the world



International Advisors

The International Advisors Panel consists of three nuclear experts from around the world. This group was established with the purpose of providing IRID's Board of Directors with advice from organizational and management perspectives.
The first meeting was held in January 2014 to deliberate on the international initiatives and management approach of IRID, and offered advice to IRID on future issues and points for improvement.

Members

- **Mr. Lake Barrett (USA)**
  Independent Consultant (former Site Director for the Nuclear Regulatory Commission (NRC) for the Three Mile Island accident)
- **Dr. Adrian Simper (UK)**
  Director for Strategy and Technology at the Nuclear Decommissioning Authority (NDA)(leading expert in the field of decommissioning strategy in the UK)
- **Mr. Luis E. Echávarri (Spain)**
  Former Director General of the OECD/NEA (expert with experience such as membership of the International Nuclear Safety Group (INSAG))


The 1st International Advisors Meeting (from left, Mr. Barrett, Mr. Echávarri, and Dr. Simper) (Jan. 9, 2014)


Mr. Echávarri receiving an explanation from Mr. Akira Ono, Fukushima Daiichi NPS Superintendent (Jan. 14, 2014)

International Expert Group (IEG)

The International Expert Group (IEG) was established to offer technical advice from a global viewpoint to IRID and TEPCO regarding the safe and effective carrying out decommissioning activities for TEPCO's Fukushima Daiichi NPS. The IEG is composed of experts in nuclear facility decommissioning from the USA, the UK, France, Russia and Ukraine.
IEG plenary sessions were held in February and September 2013 and in June 2014 to deliberate on nuclear decommissioning R&D plans and measures to be carried out on site. A review mission for the removal of spent fuel from Unit 4 at the Fukushima Daiichi NPS and a working group on radiation management at the site were carried out in November 2013 and May 2014, respectively.
After the plenary session held in June 2014, administrative responsibility of the IEG was transferred to TEPCO's Fukushima Daiichi D&D Engineering Company so that the Group can implement their activities closer to the site.

Members

- **Dr. Douglas Chapin (USA)**
  Principal of MPR Associates, Inc. (experience in the stabilization of the Three Mile Island accident and clean-up of facilities)
- **Dr. Rosa Yang (USA)**
  EPRI Senior Technical Executive (experienced in response to the Three Mile Island accident and R&D for analysis evaluation)
- **Dr. Adrian Simper (UK)**
  Director for Strategy and Technology at the Nuclear Decommissioning Authority (NDA)(leading expert in the field of decommissioning strategy in the UK)
- **Dr. Joel Pijselman (France)**
  Chairman of the Board of Directors of ETC (successively held various posts, such as plant manager of La Hague reprocessing plant and former Vice President of AREVA)
- **Mr. Nikolai Steinberg (Ukraine)**
  Independent Consultant (involved in stabilization activities after the accident at the Chernobyl Nuclear Power Plant in Ukraine and decommissioning strategy development as a chief engineer at the Chernobyl plant)
- **Dr. Anton Leshchenko (Russia)**
  Deputy General Manager of Research and Development Company "Sosny" (involved in damaged fuel removal at Paks Nuclear Power Plant, Hungary)


Review of spent fuel removal at Unit 4 of the Fukushima Daiichi NPS (Nov.15, 2013)


Fukushima Daiichi NPS visit during the 2nd IEG meeting (Feb. 19, 2014)


Final session during the 2nd IEG meeting (Feb. 21, 2014)

Human Resource Development for R&D

Nuclear decommissioning is a long-term project that may span 30-40 years. Continuity and further development possibilities will be lost if youth are not involved in work related to nuclear decommissioning technologies. One of our main challenges is to find ways to encourage interest in these technologies among the young, and we need to attract and nurture personnel that can work onsite and be involved in R&D activities.

1 Collaboration with universities and research institutions

IRID believes that the first step in human resource development is to build relations with people from universities and research institutions. We have therefore been actively proceeding with joint research and commissioned research with universities/research institutions as part of our ongoing R&D projects. Through these activities, we have been enhancing cooperation with researchers in various technological fields.

2 Workshop for R&D Planning and Scientific Research for the Decommissioning of TEPCO's Fukushima Daiichi NPS

In FY 2013, as a co-sponsored initiative with the Ministry of Education, Culture, Sports, Science and Technology entitled the "Workshop for R&D Plans and Scientific Research for Decommissioning of TEPCO's Fukushima Daiichi NPS" was organized to set out important areas for human resource development and to select universities and research institutions which will become the core of this development. IRID has actively expanded on this workshop idea and has held a total of nine workshops on various technological issues concerning nuclear decommissioning themes in collaboration with universities, etc. throughout Japan.
The themes of these workshops have not been limited to the nuclear field; wide-ranging technologies, such as those used in the study of volcanic lava, raw materials, remote operation and robotics have been discussed, and university professors and other experts from various related fields, such as risk communication, have been invited to share their knowledge in order to make progress in the decommissioning process. IRID has also used these workshops to provide updates on R&D project initiatives and outline technological needs. Universities and other institutions have also presented their related research ideas, helping to promote very lively discussions and exchanges of opinions.
In addition to sharing information on nuclear decommissioning research with researchers and experts from various regions and fields, these activities have contributed to an increase in awareness and interest among students, and this has helped us take the first step towards building a human resource development network.

For more details about the above activities, please visit the websites of the Nuclear Safety Research Association and IRID.

- Handouts and program details about main workshop activities: http://www.nsra.or.jp/safe/fdecomi/workshop/2013/index.html
- Workshops held in FY 2013 (Photos and videos): http://irid.or.jp/en/human_resources/workshop/20131022

Workshops Overview

	Date	Area	Venue	Theme
1	Sep.25	Kanto #1	University of Tokyo	Fuel debris characterization/accident analysis. Radioactive waste treatment/disposal, etc.
2	Oct.8	Fukushima	Korasse Fukushima	Development of equipment/apparatus for remote operation, etc., to retrieve fuel debris. Information visualization.
3	Nov.1	Kansai/ West Japan #1	Osaka University	Fuel debris characterization/accident analysis. Radioactive waste treatment/disposal, etc.
4	Nov.20	Tohoku/ Hokkaido	Tohoku University	Integrity of containment vessel/building for fuel debris retrieval and decommissioning.
5	Nov.26	Kanto #2	University of Tokyo	Development of equipment/apparatus for remote operation to retrieve fuel debris.
6	Dec.20	Kansai/ West Japan #2	Kobe International Conference Center	Development of equipment/apparatus for remote operation to retrieve fuel debris.
7	Dec.25	Hokuriku	University of Fukui	Long-term integrity of materials and structures. Remote technology. Fuel debris characterization/criticality control, etc.
8	Jan.8	Chubu	Nagoya University	R&D for six key points, such as long-term integrity of materials and structures, remote technology, etc.
9	Jan.22	Kanto #3	Ibaraki University	Overview of current status of R&D related to decommissioning and basic and generic technology research conducted by the Japan Atomic Energy Agency. Function overview of the facility for analyzing and researching radioactive material and its requirements. General discussion (linkage between generic technology research and development of decommissioning technology).

(Reference) Nuclear Safety Research Association website.


Workshop 2 (Oct. 8, 2013)


Workshop 4 (Nov. 20, 2013)


Workshop 6 (Dec. 20, 2013)


Workshop 8 (Jan. 8, 2014)