Decommissioning Process **"Common Issues"**
Investigation Subject **"Remote control technology"**

Needs

1. Developing remote control technologies that are appropriate for work purposes and work environments by using a combination of basic and general-purpose technologies

Fuel Debris Retrieval：【Short】

Desired state and reasons for it

- Fuel removal from the SFP, fuel debris retrieval, and dismantling of the PCV／RPV／buildings involves work under high radiation doses where workers cannot enter or work for a long time. In order to prevent or reduce exposure to workers, it is desirable to develop remote handling technologies and equipment such as robots.
- In addition to the development of remote control technology, it is desirable to consider a combination of measures to reduce exposure, considering decontamination, shielding, and working hours.
- In particular, it is required to establish a system that allows lighting and data transfer into the building to survey dark areas and increase the efficiency of monitoring and robot control through wireless communication.
- There is a risk of not being able to meet the development schedule if one-off manufacturing is done according to the work purpose and work environment. Therefore, it is desirable to have a set of technologies that can be combined according to the purpose and environment.

Current state against ideal

- The main remote technologies that have been developed so far for the 1F decommissioning are listed below. In the future, along with the improvement and advancement of these technologies, further utilization of remote technologies and development of new technologies are required in each operation for fuel debris retrieval from inside the reactor containment vessel／pressure vessel.

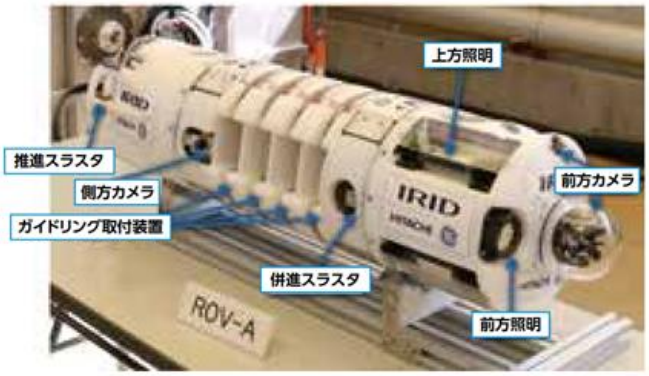
Examples of remote technologies developed to date

- Objective 1: Reduction of work risks such as exposure (dose rate reduction through decontamination, etc.). Various types of work robots as follows:
  - Remote decontamination: floor decontamination, low area decontamination, medium area decontamination, high area decontamination, upper floor decontamination (water spray, high-pressure water, jet, brush, suction／blast, dry ice blast, etc.)
  - Remote shielding
  - Remote removal of source
  - Remote removal of interfering obstacles
  - Robot arm for fuel debris retrieval
- Objective 2: Survey inside the reactor building. Various types of survey robots as follows:
  - Remote survey of dose／source

- Remote survey of interfering obstacles
- RCV survey (in air, in water (ROV: Remotely Operated Vehicle))
- Surveys of the upper and lower external surfaces of the suppression chamber
- Water level measurement inside the suppression chamber
- Torus chamber wall surface survey (underwater swimming and floor running)
- Survey on the area around the vent piping
- Acquisition of laser scan data
- Remote collection of concrete core sample
- Wireless small drone

- Objective 3: Peripheral technologies to the above
  - Robots to remove sediments from floor surfaces
  - Remote charging technology for various robots
  - Photographs and illustrations of these are shown below:

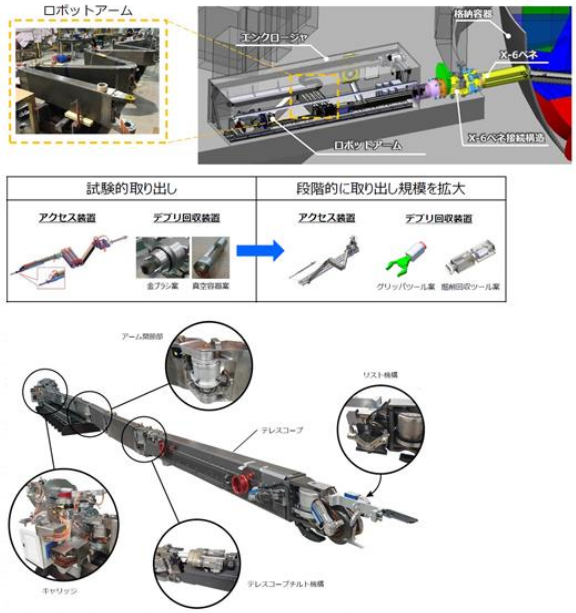
原子炉建屋内のロボット



原子炉格納容器内部詳細調査用潜水機能付ボート(ROV-A)

技術研究組合 国際廃炉研究開発機構."廃炉研究開発の推移 IRID2021 パンフレット".

燃料デブリ取り出しのためのロボットアーム



燃料デブリ取り出しのためのロボットアーム

経済産業省 大臣官房 福島復興推進グループ 原子力発電所事故収束対応室."福島第一原発「燃料デブリ」取り出しへの挑戦③～海外の協力も得て挑む技術開発の最前線". 経済産業省資源エネルギー庁. 2020-02-28. https://www.enecho.meti.go.jp/about/special/johoteikyo/debris_3.html, (参照2021-12-09)

- In March 2023, TEPCO Holdings, Inc. successfully conducted the first survey to enter the Unit 1 pedestal with a boat-type access research vehicle (underwater ROV) having a submersible function. As a result of the survey, a great deal of information was obtained, including the condition of sediments and fallen debris at the bottom of the pedestal, and the upper structures such as the control rod drive mechanism (CRD) housing. From February to March 2024, a small wireless drone and a snake-shaped robot were used to conduct the PCV internal investigation (a section in the air) of Unit 1. Information on the condition of the existing structures outside and inside the pedestal, as well as video images of deposits, fallen objects, etc., were obtained, which confirmed the usefulness of using a small wireless drone for the PCV internal investigation.
- TEPCO Holdings, Inc. has been modifying and verifying the control software and improving some devices related to the robot arm to be used in the experimental retrieval in the Unit 2 reactor and has been confirming the required functions. As preparatory work at the site, the installation of an isolation chamber was completed in April 2023. In October 2024, removal of the X-6 penetration hatch bolts was completed and the hatch was released; in June 2024, installation of the X-6 penetration connection structure and connection pipe was completed.
- It is essential that remote devices such as robot arm, etc. undergo sufficient performance verification and operational training by utilizing mock-ups that simulate the assumed internal environment of the PCV prior to on-site installation. It is necessary to verify the applicability of the remote equipment and the operation and maintainability of the remote system as a whole under severe environmental conditions that include many uncertainties. Operational training began in February 2022 at a simulated 1F facility in Naraha-machi, Fukushima Prefecture.
- As a subsidy program under Government-led R&D Program on Decommissioning and Contaminated Water Management from FY2021, the development is underway for remote equipment maintenance technology, which is required including having a perspective such as recommendations, etc. on ensuring safe and reliable operation continuity over a long period of time, rational design of remote equipment and waste generation volume.

Issues to be resolved

- It is necessary to have a perspective on the "combination" relationship (interface) between the part that performs the work, such as cutting equipment to retrieve debris, and the transportation equipment involved in transferring that part.
- The retrieval of large amounts of debris and the dismantling of highly contaminated buildings require the establishment of a remote robot technology with a rigid structure and high resistance to failure, and a technological foundation that is different from the current frail and fragile general robot technology. It is required development of high radiation-resistant and shock-resistant remote control robots, cameras, and telecommunication technologies that can operate normally even under high radiation levels.
- As the scale of debris retrieval is gradually expanded in the future, it is necessary to develop a "gripper tool" that can grab heavier objects and a "drilling and collection tool" that can crush debris and suck out pieces.
- Since there are many narrow areas in the building, it is sometimes too narrow to place the remote controlling equipment inside for monitoring and valve operation. In addition, because of additional shielding installed, it is difficult to measure the dose in the back of the shielding. It is necessary to develop a technology that can pass through narrow areas such as the X-6 penetration.
- It is desirable to be able to measure smear and dust on the floor and walls under high dose conditions. For smear, the issue is whether we can find appropriate smooth surfaces only by checking visual images and whether they can be rubbed with appropriate force.
- It is desirable to be able to understand the robot's position and the dose there on a single real-time screen. For this purpose, it is desirable to have a common infrastructure in the telecommunication environment.
- It is necessary to reduce radiation exposure during the maintenance of remote control equipment. It is important to have remote control equipment that requires less maintenance and is less likely to be exposed to radiation during maintenance.
- It is also important to have a view of "improve operability". Sufficient familiarity with the operation and functionality of the equipment is required in advance.
- It is necessary to develop multiple technologies, such as wireless telecommunication infrastructure, cameras, and robots.
- In addition, it is desirable to establish wireless power supply and wireless light-emitting technologies that can be used inside the building. Ideally, the power obtained from wireless power supply could be used as a power source for lighting and wireless LAN. If the amount of transmission is insufficient, splitting the power source between lighting and wireless LAN or lighting by fluorescent luminescence could be considered.
- As fogging is occurring in the pedestal of the Unit 1, the viewing distance of the camera is shortening, causing the camera to fog up, which requires countermeasures.
- For the application of the robot arm to an uncertain site, the challenge is to ensure that the equipment can be rescued in the event of an emergency, in addition to functional verification.
- Active participation from outside the nuclear field is needed.

Relevant Issues

- CWM-102 "Understanding current status of underground and buildings"
- SFP-101 "Understanding current status of SFP"
- FDR-101 "Understanding status of fuel debris"
- FDR-102 "Understanding status of structures inside PCV and RPV"
- FDR-103 "Understanding status of FP"

- FDR-104 “Understanding doses inside PCV and RPV”
- FDR-106 “Understanding contamination status inside buildings”
- FDR-218 “Developing fuel debris retrieval equipment and devices”
- DRB-101 “Assessing conditions inside reactor and buildings (for dismantling)”
- DRB-102 “Understanding properties and volume of objects to be dismantled”