Subsidy Project of Decommissioning and Contaminated Water Management

Development of Technology for Gradually Increasing Retrieval Scale of Fuel Debris

Research Report for FY2020

August 2021

International Research Institute for Nuclear Decommissioning (IRID)

Contents

Project started in FY2019

Project started in FY2020

1. Research background and purpose

1.1 Reason why this research project is required

- To retrieve fuel debris in Unit 1, 2 and 3 of the Fukushima Daiichi Nuclear Power Station (NPS), it is necessary to acquire information on properties of fuel debris for development of retrieval equipment and criticality evaluation, etc. So far now, estimated values of data and analysis results collected from the Three Mile Island NPS Unit 2 and the Chernobyl NPS accidents have been used. However, analysis of fuel debris to be retrieved at the site is required to confirm whether the estimated values are appropriate (including the safety evaluation) to develop equipment.
- For the above reason, the following work was conducted in fiscal year (FY) 2020
  - Development plan of retrieval technology for gradually increasing the retrieval scale of fuel debris, and planning of fuel debris retrieval and its update.
  - Detailed design of equipment and system for fuel debris retrieval, and manufacturing of prototype.
- On the basis of the results and issues obtained from the above work, and the updated status of the Fukushima Daiichi NPS, this research project was conducted to revise the positioning of fuel debris retrieval and its target, which is required to develop technology for gradually increasing the retrieval scale of fuel debris.

1.2 Application and contribution of this research result

Project started in FY2019

Project started in FY2020

Project of Development of Investigation Technology inside PCV*1
(development of Technology for Investigation of Inside of PCV)

A2'&A2"investigation in Unit 2

Reflecting the results of investigation inside PCV*1

Project of Development of Investigation Technology inside PCV*1
(site demonstration of detailed investigation technology through X6 penetration)

Reflecting the progress of development for investigation equipment

*1: PCV= Primary Containment Vessel

This project :Development of Technology for Gradually Increasing of Retrieval Scale of Fuel Debris

Creation of technology development and retrieval plans for gradually increasing the retrieval scale of fuel debris

Development of equipment and system for gradually increasing the retrieval scale of fuel

Analysis of fuel debris for gradually increasing the retrieval scale

- **Physical data (hardness, etc.), cutting speed and dust spreading conditions**
- **Component data of U, Pu, Gd and etc.**
- **Fuel debris distribution data**
- **Component data of hydrogen generation amount**
- **Waste inventory data**

Project of Development of Technology for Further Increasing the Scale of Fuel Debris and Reactor Internals (including criticality control)

Advancement of retrieval method and systems for fuel debris and reactor internals, fundamental technology for retrieving fuel debris and reactor internals, and technology for criticality control of fuel debris.

- Reflecting the results in design of retrieval system cells and the system
- Design and improvement of fuel debris retrieval tools
- Validation of criticality evaluation

Project of Development of Analysis and Estimation Technology for Fuel Debris Characterization

Advancement of identifying inside the reactor by accident progress analysis and actual data

Reliability confirmation of analysis results of inside the reactor

Project of Development of Technology for Containing, Transfer and Storage of Fuel Debris

Development of technology for containing, transfer and storage of fuel debris

Safety confirmation of canister

Project of R&D for Treatment and Disposal of Solid Waste

R&D for treatment and disposal of solid radioactive waste

Reflecting the results in the overall plan of waste management

Research projects related to detailed design of methods and systems for fuel debris retrieval

Gradually increasing the retrieval scale of fuel debris
(planned to be conducted by TEPCO HD)

Detailed design of equipment for gradually increasing the retrieval scale

2. Project goals (1/2)

Project started in FY2019

Implementation items started in FY2019

No.	Implementation items	Technology Readiness Level (TRL) of project goals as of the end of FY2020	
5.1	**Technological development and retrieval planning for gradually increasing the retrieval scale of fuel debris**	**5.1.1 and 5.1.2** **On the basis of investigation results of the inside of the PCV and the site condition, technological development and retrieval plans are formulated for the project of technology for gradually increasing the retrieval scale of fuel debris in the PCV, and updated if necessary.** **(For organizing the information, these plans are not included in a goal setting of TRL).**	
5.2	**Development of equipment and systems for gradually increasing the retrieval scale of fuel debris**	**5.2.1 Development of equipment and systems for gradually increasing the retrieval scale**	① Access equipment for fuel debris retrieval (the arm, the enclosure and etc.) Clarifying assumed procedures for handling fuel debris in the enclosure to confirm workability of a manipulator in a prescribed position (*) Specifying jig tools required for work (target TRL at the completion of work: Level 5).
			② Access route establishment equipment for fuel debris retrieval (X-6 connecting structure, etc.) Manufacturing of a prototype in accordance with basic design for FY2020. Completion of in-factory verification test (*1) (target TRL at the completion: Level 4-5) Study on concepts of cleaning technology for washing the arm in the PCV through the X-53 penetration, an installation method for washing technology and installation of monitoring camera to overview the arm motion to confirm the feasibility. (target TRL at the completion: Level 2)
			③ Fuel debris cutting and collecting equipment Verification or improvement, if necessary, of fuel debris collection equipment, which was prototyped in 2019, for collecting pebble-like and sandy fuel debris, cutting / collecting powdery fuel debris and cylindrical fuel debris, based on in-factory verification. Specifying procedures of collecting fuel debris (target TRL at the completion: Level 4-5)
			④ Neutron monitoring system Completion of in-factory verification test (*1) of a neutron monitor that is manufactured as a prototype in accordance with basic design for FY2020. (Target TRL at the completion: Level 4-5)
			⑤ Remote-operated transport carriage for fuel debris container Completion of detailed design for manufacturing a carrier system in accordance with basic design for FY2020 that can transport, connect and disconnect in-factory transport container of fuel debris. (target TRL at the completion: Level 4)

***1: It was conducted in the first half of FY2020.**

2. Project goals (2/2)

Project started in FY2020

Implementation items started in FY2020

No.	Implementation items	Technology Readiness Level (TRL) of project goals as of the end of FY2020
5.3	**Development and design of element technology for access equipment of fuel debris retrieval (the arm, the enclosure and etc.)**	5.3.1 Element technology for equipment with the retrieval arm Detailed and manufacturing design for horizontal off-set mechanism, telescope and wand should be completed. * Target TRL as of the end of FY2020 Prototypes of the horizontal off-set mechanism, telescope and wand are manufactured and their combination tests are conducted to confirm the unit performance. (Target TRL at the completion: Level 5)
		5.3.2 Element technology for equipment with the retrieval enclosure Element tests of a double-door system are completed to confirm the reliability and detailed design for manufacturing a prototype is performed. * Target TRL as of the end of FY2020 The double door system is manufactured and its performance is confirmed by the unit performance test. (Target TRL: Level 5)
		5.3.3 Element technology for equipment with the retrieval enclosure By incorporating the results of basic design of the previous projects (projects started in FY2019) and access equipment manufactured and verified in factory under the project of detailed investigation inside the PCV, the entire access equipment of fuel debris retrieval (the arm, the enclosure and etc.) is designed to confirm the feasibility of the equipment as a whole. (Target TRL: Level 4)
5.4	**Development of remote-operated transport carriage to contain fuel debris**	5.4.1 Remote-operated transport carriage for fuel debris container On the basis of detailed design for the previous project (projects started in FY2019), a prototype is manufactured. * Target TRL as of the end of FY2020 A prototype is manufactured and in-factory verification test is completed. (Target TRL at the completion: Level 5)

3. Implementation items, their correlations, and relations with other researches

3.1 Implementation items of this research (1/2)

Project started in FY2019

Implementation items started in FY2019

No.	Implementation items			Range of implementation for FY2020	Page
5.1	Technological development and retrieval planning for gradually increasing the retrieval scale of fuel debris	5.1.1 Development plan and updates of equipment and system for gradually increasing the retrieval scale of fuel debris		Development plan of equipment and system for fuel debris retrieval is updated, in accordance with the status of the Project of Development of Investigation Technology inside PCV.	No.13
		5.1.2 Planning and updates of the entire scenario from viewpoint of the safety and systems		Plan of fuel debris retrieval is updated in accordance with the status of development of the arm/enclosure and results of the study on the retrieval system for the project of detailed investigation inside the PCV.	No.14
5.2	Development of equipment and systems for gradually increasing the retrieval scale of fuel debris	5.2.1 Development of equipment and systems for gradually increasing the retrieval scale	① Access equipment for fuel debris retrieval	• Verification of manipulator work in the enclosure	No.15
			② Access route establishment equipment for fuel debris retrieval	• Prototype manufacturing • In-factory verification of a prototype • Conceptual study on the use of the X-53 penetration	No.16-19
			③ Fuel debris cutting and collecting equipment	• Improvement of a prototype • Specifying of procedures of cutting and collecting fuel debris	No.20-23
			④ Neutron monitoring system	• Manufacturing of a prototype	No.24-25
			⑤ Remote-operated transport carriage for fuel debris container	• Detailed design for manufacturing	No.26-29

Texts in purple: Investigation Texts in black: Desk study Text in blue: Test Texts in red: Manufacturing

3. Implementation items, their correlations, and relations with other researches

3.1 Implementation items of this research (2/2)

Project started in FY2020

Implementation items started in FY2020

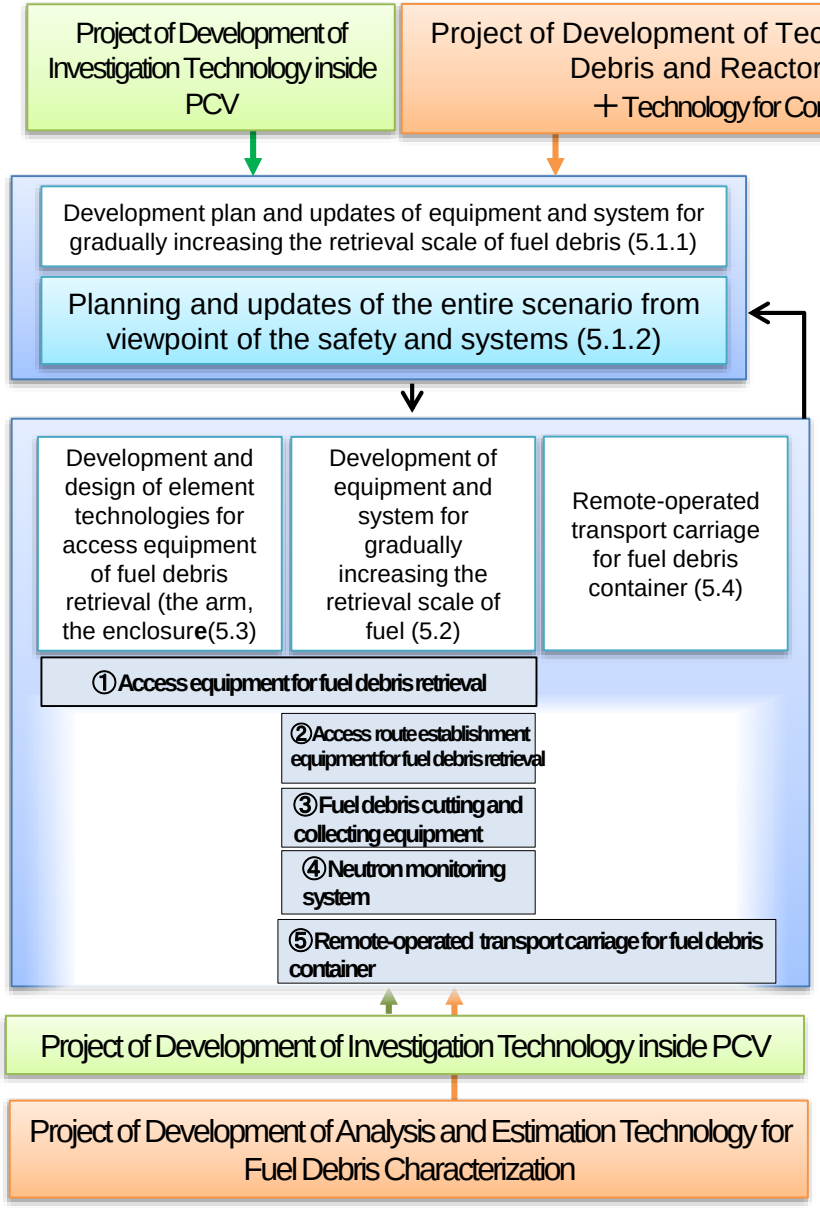
No.	Implementation items		Range of implementation for FY2020	Page
5.3	Development and design of element technology for access equipment of fuel debris retrieval (the arm, the enclosure and etc.)	5.3.1 Element technology for equipment with the retrieval arm	• Manufacturing of the arm head including the horizontal off-set mechanism, telescopic wand and etc. are started.	No.31
		5.3.2 Element technology for equipment with the retrieval enclosure	• A test equipment which simulates the driving mechanism of the double door system is manufactured and element tests (reliability test) are conducted to evaluate the validity of the design. • Start of manufacturing of a prototype	No.32-34
		5.3.3 Entire design for the access equipment for the fuel debris retrieval (incl. arm, enclosure, etc.)	• The entire design of access equipment of fuel debris retrieval (the arm and the enclosure, etc.) is performed to confirm the feasibility of the equipment.	No.35-39
5.4	Development of remote-operated transport carriage to contain fuel debris	5.4.1 Remote-operated transport carriage for fuel debris container	• Manufacturing of a prototype	No.41

Texts in black: Desk study Text in blue: Test Texts in red: Manufacturing

3.2 Relations among implementation items and with other research projects（1/2） No.8

Project started in FY2019

Project started in FY2020



No.	Cooperation with	Cooperation items	Period for cooperation
1	Project of Development of Analysis and Estimation Technology for Fuel Debris Characterization	・Coordination to transport fuel debris outside of the site for trial retrieval.	June, FY2020 – When necessary
2	Project of Development of Investigation Technology inside PCV	・Discussion on issues to use an isolation room that is being developed for establishing the access route, when installing retrieval equipment. ・Sharing of the status information of development for the arm type access equipment (*)	FY2020 (* When necessary)
3	・Project of Development of Technology for Further Increasing the Scale of Fuel Debris and Reactor Internals (including criticality control) ・Project of Development of Technology for Containing, Transfer and Storage of Fuel Debris ・TEPCO HD.	・Conducting needs investigation of fuel debris collecting points using photos of fuel debris appearance taken in the PCV of Unit 2. ・Conducting re-investigations to obtain more specific information of application target, method and timing, and information obtained in the period between retrieving fuel debris and acquiring analysis results.	Conducted in FY2018 (Planned in FY2019, however there were no needs.)
4	TEPCO HD.	・Sharing of a result of basic design of the system for gradually increasing the retrieval scale of fuel debris. ・Coordinating the interface of carry-in/out cell that is a transport destination for fuel debris ・Arranging fuel debris transport area near the exit of the reactor building ・Hearing of opinions about fuel debris retrieval technology that can be useful in gradually increasing the retrieval scale of fuel debris.	April in FY2018 – Monthly meetings and independent meetings are held when necessary.

3.2 Relations among implementation items and with other research projects（2/2）No.9

Project started in FY2019

Project started in FY2020

■ Work flow of fuel debris retrieval and main coordination with related projects

Work flow of fuel debris retrieval from PCV

Equipment related to fuel debris retrieval from PCV

Equipment for establishing the access route

Enclosure

Neutron monitor

For predictive monitoring

For constant monitoring

On-site transport container

Arm type access equipment

Remote-operated transport carriage for fuel debris transport containers

Fuel debris collection equipment

Carry-in / out cell related equipment

Manipulator

U, Pu measurement equipment

Manipulator

Sample transportation box

On-site transport container

Sample capsule

Sample storage bin

Sample storage bin

Off-site transport container

Carry-in / out cell

For predictive monitoring

Off-site transportation

Existing analyses facility

Development of Technology for Gradually Increasing Retrieval Scale of Fuel Debris

TEPCO HD

Fuel Debris Characterization Project

Main coordination with related PJs

[Project for Detailed Investigation inside PCV]
・Sharing of development information pertaining to enclosure for investigation inside PCV
[TEPCO HD]
・Incorporating relevant technologies into debris retrieval, the scale of which is being increased in stages

[Fuel Debris Characterization Project]
Coordinating the interphase for accepting fuel debris
[Fuel Debris Retrieval Project]
Sharing information related to fuel debris cutting technology
Preventing criticality at the time of fuel debris cutting

[TEPCO HD]
Sharing of information on on-site transport carriage (Padirac)
Coordinating the transportation area in the Reactor Building
Reflecting the requirements of technologies to be used, into increasing the scale of debris retrieval in stages

[Project for Detailed Investigation inside PCV]
Reflecting the image of the condition inside PCV into the design
Sharing of development information on X-6 penetration connection structure
Sharing of development information on arm for investigation inside PCV
Sharing of technological challenges in the detailed investigation inside PCV

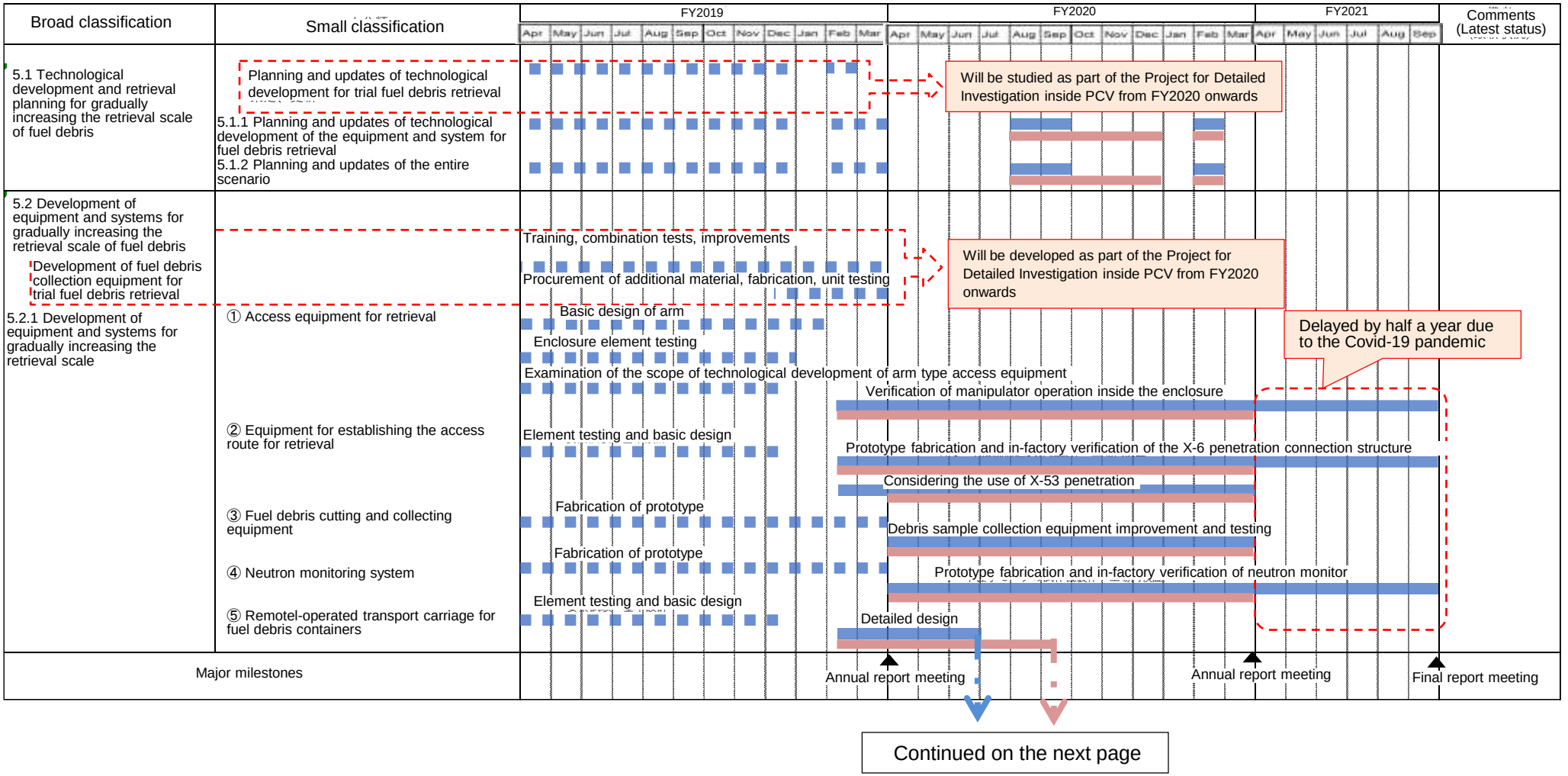
Fuel Debris Retrieval Plan

[Fuel Debris Characterization Project]
Obtaining information on the analysis capabilities of the existing analyses equipment and reflecting it into the fuel debris retrieval plan
[TEPCO HD]
Discussing the fuel debris transportation route and reflecting it in the fuel debris retrieval plan

4. Implementation schedule (1/2)

Project started in FY2019

Implementation items started in FY2019



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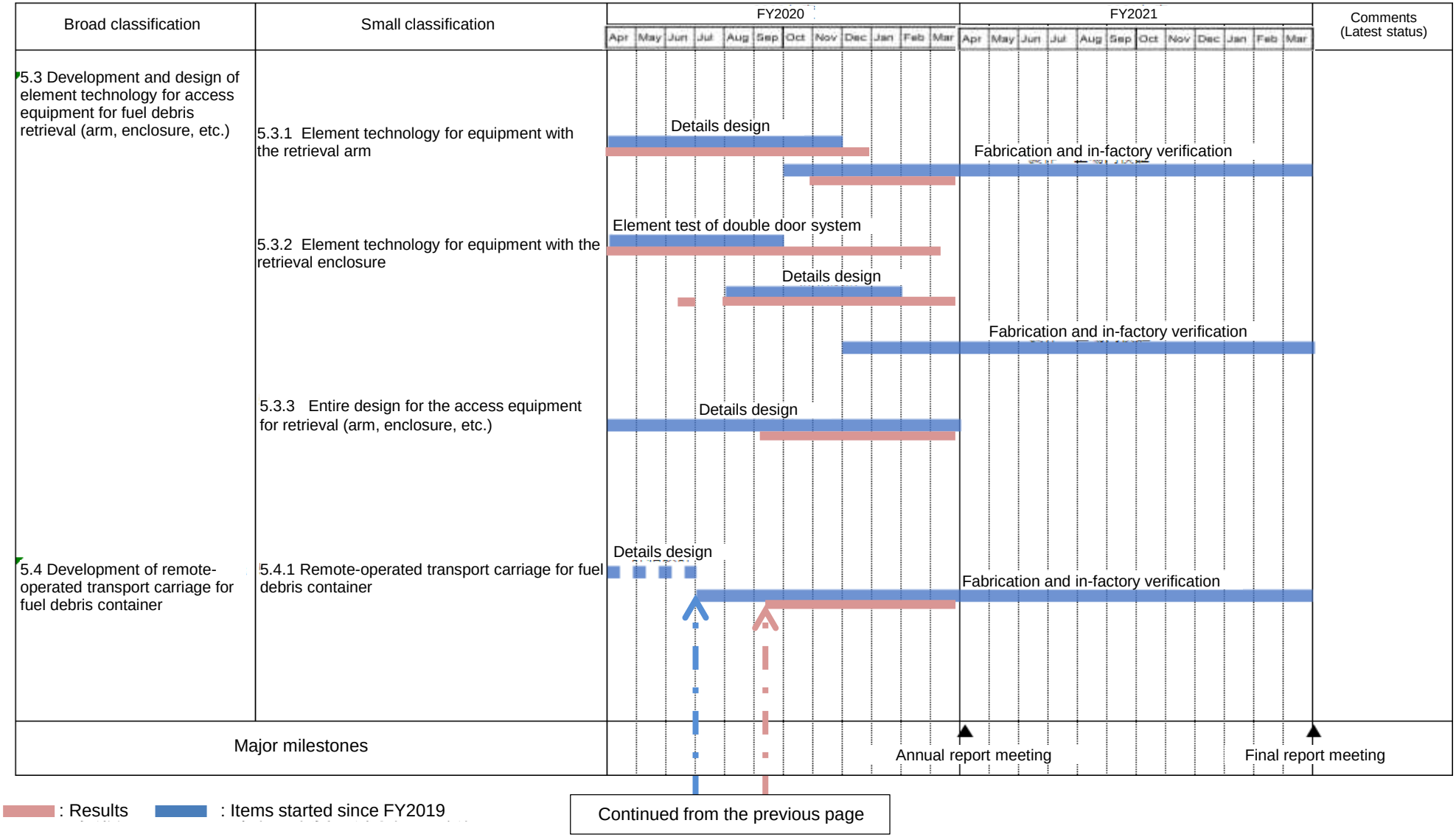
: Results : Items started since FY2019 : Implemented under the FY2017 Supplementary Budget

4. Implementation schedule (2/2)

Project started in FY2020

Implementation items started in FY2020



: Results : Items started since FY2019

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5. Implementation details

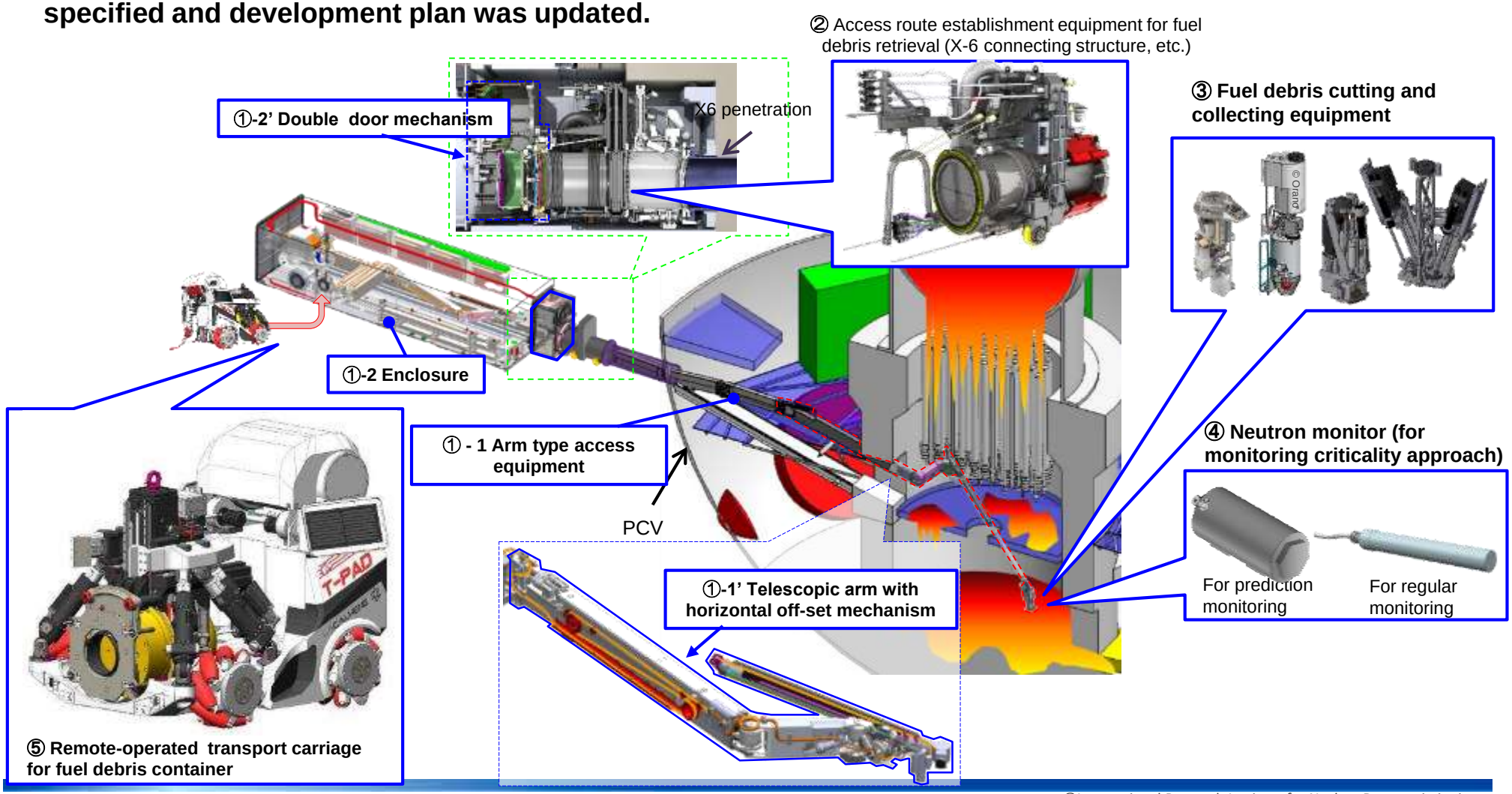
Project started in FY2019 No.12

5.1 Technological development and retrieval planning for gradually increasing the retrieval scale of fuel debris

5.1.1 Development plan and updates of equipment and system for gradually increasing the retrieval scale of fuel debris

【Achievements for FY2020 (1/2)】

✓ The following development equipment for gradually increasing the retrieval scale of fuel debris were specified and development plan was updated.



5.1 Technological development and retrieval planning for gradually increasing the retrieval scale of fuel debris

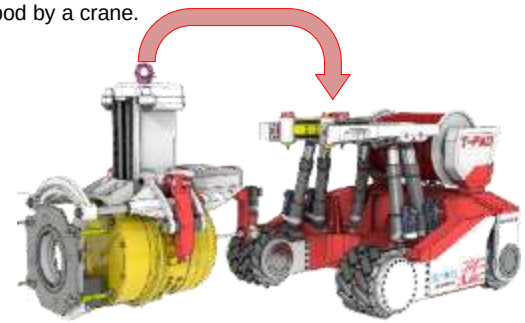
5.1.1 Development plan and updates of equipment and system for gradually increasing the retrieval scale of fuel debris

【Achievements for FY2020 (2/2)】

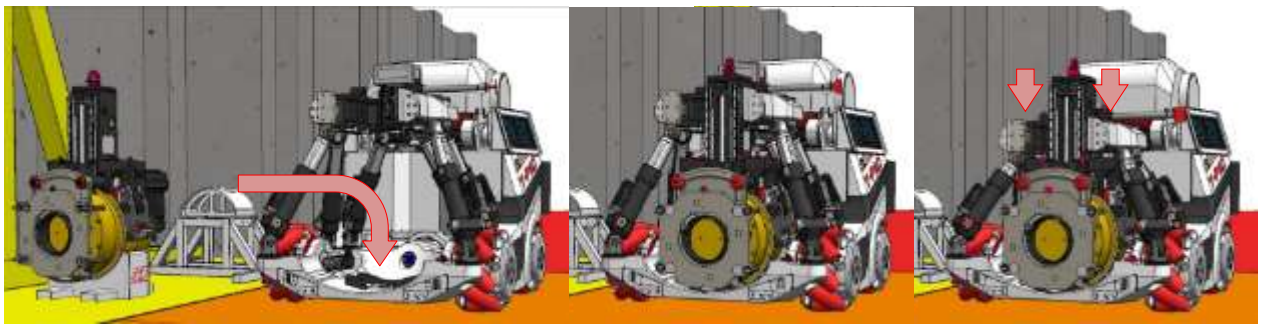
- ✓ The previous development plan was revised to gradually increase the retrieval scale of fuel debris.
  - ➢ The arm type access equipment⇒The equipment is designed considering maintenance.
  - ➢ The enclosure⇒To suppress the increase of background dose accumulated by radioactive materials, workability of remote-operated suction decontamination using the Dexter* manipulator is verified. Additionally, a remote-operated replacement system is designed, assuming that the Dexter* manipulator is failed.
  - ➢ A remote-operated transport carriage for fuel debris container⇒The structure of the carriage is studied considering carriage impact load due to a crane operation error when lifting up/down fuel debris container.
- ✓ The verification test results of the arm for detailed investigation inside the PCV confirmed that the current retrieval arm design does not need to be modified.

Revision of the structure of remote-operated transport carriage

The former structure where fuel debris container is placed on the HEXA pod by a crane.



A new structure where fuel debris container is placed on the chassis by a crane (the HEXA pod goes down to grab the container).



*) A trade name of the dual type remote-operated manipulator system

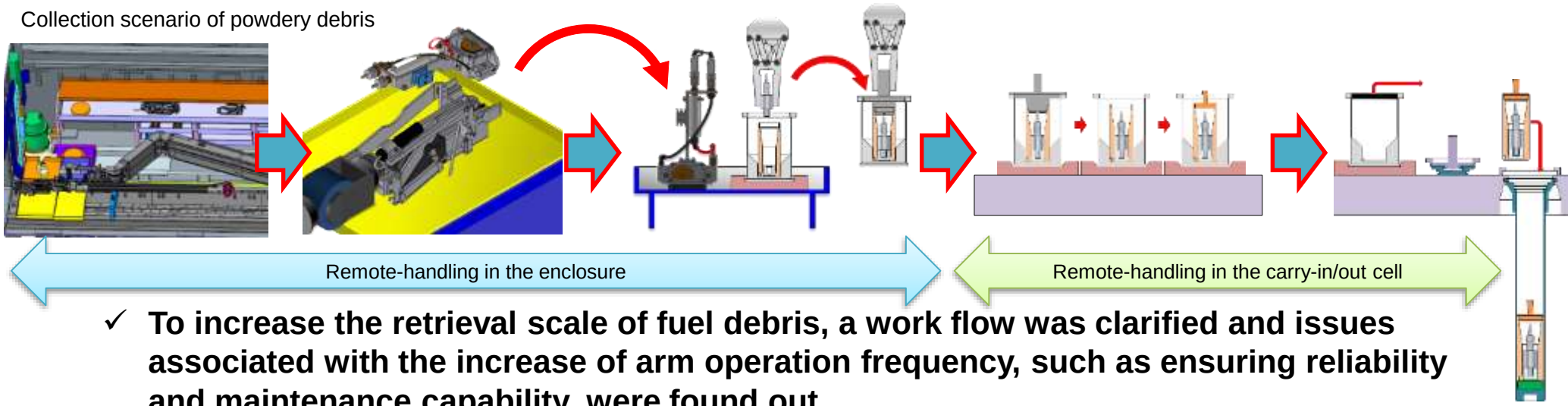
5.1 Technological development and retrieval planning for gradually increasing the retrieval scale of fuel debris

5.1.2 Planning and updates of the entire scenario from viewpoint of the safety and systems

【 Achievements for FY2020 】

- ✓ **A remote-handling scenario, including from 'retrieving fuel debris including pebble-like/sandy debris and cylindrical debris' to 'analysis of them', was clarified and the interfaces with relevant parties were coordinated.**

Collection scenario of powdery debris



- ✓ **To increase the retrieval scale of fuel debris, a work flow was clarified and issues associated with the increase of arm operation frequency, such as ensuring reliability and maintenance capability, were found out.**

【Future plan】

- ✓ **Development plan and the entire scenario will be continuously updated at an appropriate time. Verification test results of the arm for detailed investigation inside the PCV will be reflected into the scenario, if necessary, to acquire issues from work verification using the Dexter* manipulator.**

***) A trade name of the dual type remote-operated manipulator system**

5.2 Development of equipment and systems for gradually increasing the retrieval scale of fuel debris

5.2.1 Development of equipment and systems for gradually increasing the retrieval scale

Project started in FY2019

1) Access equipment for fuel debris retrieval (the arm, the enclosure and etc.)

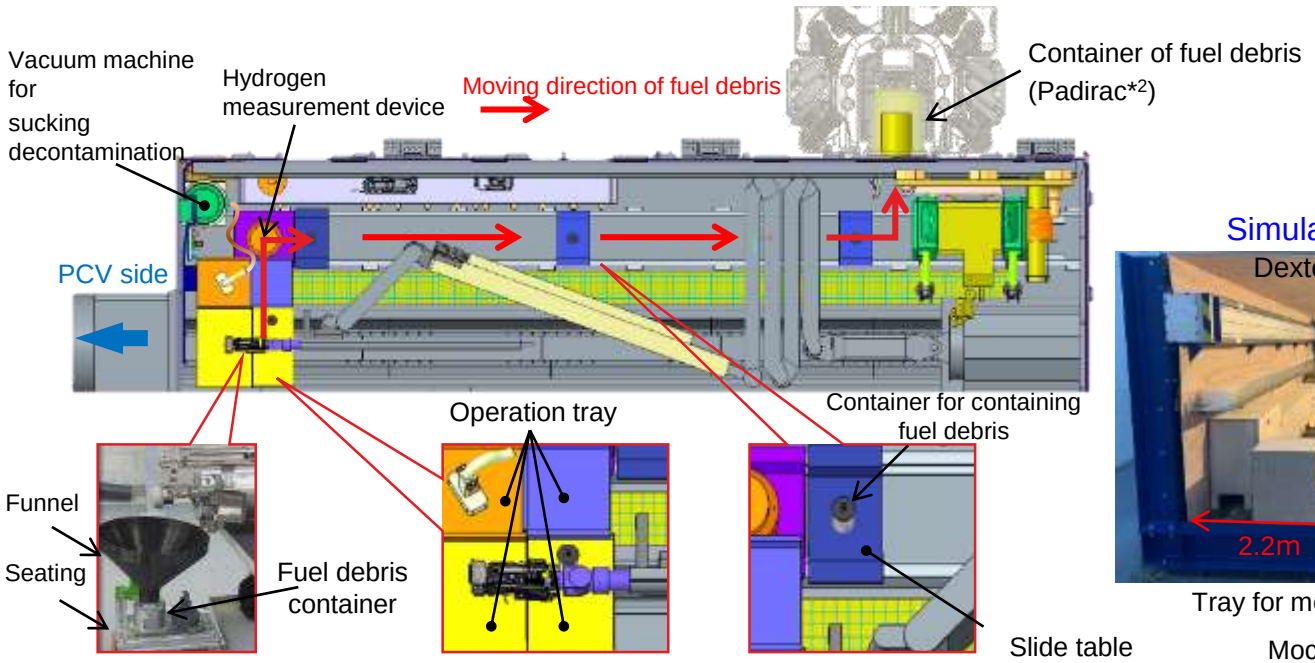
【 Achievements for FY2020 】

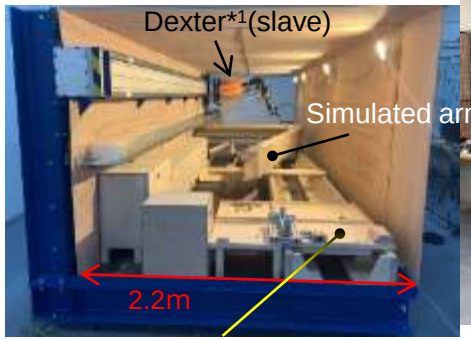
○ Verification of the Dexter*1 operation

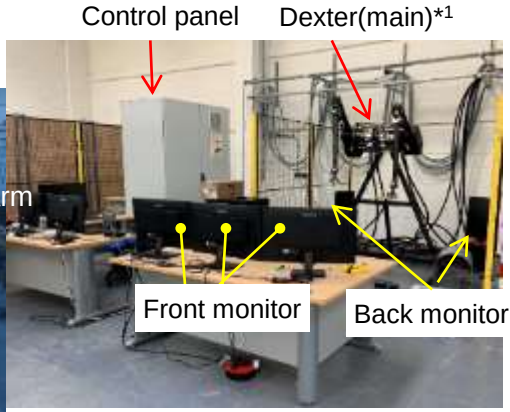
- To verify manipulator work in the enclosure, plan of verification test using Dexter*1 was specified.
- A verification test for the Dexter*1 started since FY2020. The verification test is planned to complete in the first half of FY2021.

Verification items conducted in the project of gradually increasing the retrieval scale of fuel debris (operation using the Dexter*1)
D Cleaning and decontamination of the arm
①Replacement of fuel debris cutting and collecting equipment
②Maintenance of fuel debris cutting and collecting equipment
③Fuel debris collection from fuel debris cutting and collecting equipment
④Handling of fuel debris container
⑤Decontamination of inside of the enclosure
⑥Transport of fuel debris container and contaminated materials from the Padirac*2 port
⑦Replacement of the Padirac*2 port door
⑧Replacement of neutron monitor

Layout of the inside of the enclosure for gradually increasing of retrieval scale of fuel debris







Mock-up for verification test (in UK)

*1) A trade name for the dual-arm type remote manipulator system.
*2) A trade name for a small container for transporting radioactive materials

5.2 Development of equipment and systems for gradually increasing the retrieval scale of fuel debris

5.2.1 Development of equipment and systems for gradually increasing the retrieval scale

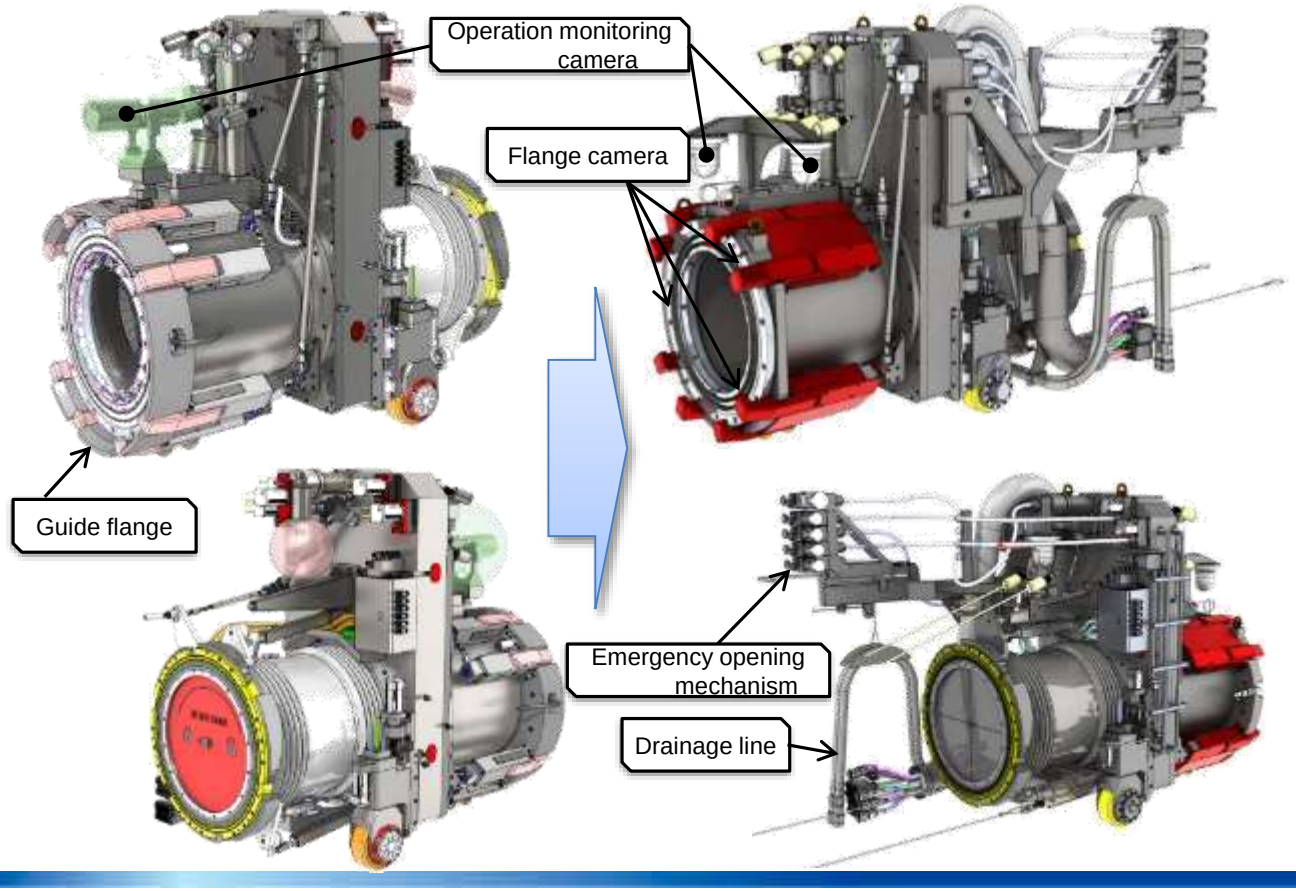
Project started in FY2019

2) Equipment of establishing the access route for fuel debris retrieval (trial manufacture of the X-6 penetration connecting structure)

【Achievements for FY2020 (1/2)】

✓ **On the basis of basic design for FY 2019, detailed design was made using an integrated method whose validation was confirmed by a mock-up test undertaken in the project of detailed investigation inside the PCV.**

Basic design for FY2019 **Detailed/improved design for FY2020**



Items	Before improvement	After improvement/implementation
Shaft adjusting method for X-6 penetration	Shaft adjusting using a guide flange	Visual confirmation of guide pin by flange camera
Operation monitoring camera	1 camera in front 1 camera at the back	2 cameras in front 1 camera at the back
Cable management	Duct method	Duct method＋Gas spring
Emergency opening mechanism	—	Retraction of driving shaft through torque tube
Drainage line	—	Retraction from backward

5.2 Development of equipment and systems for gradually increasing the retrieval scale of fuel debris

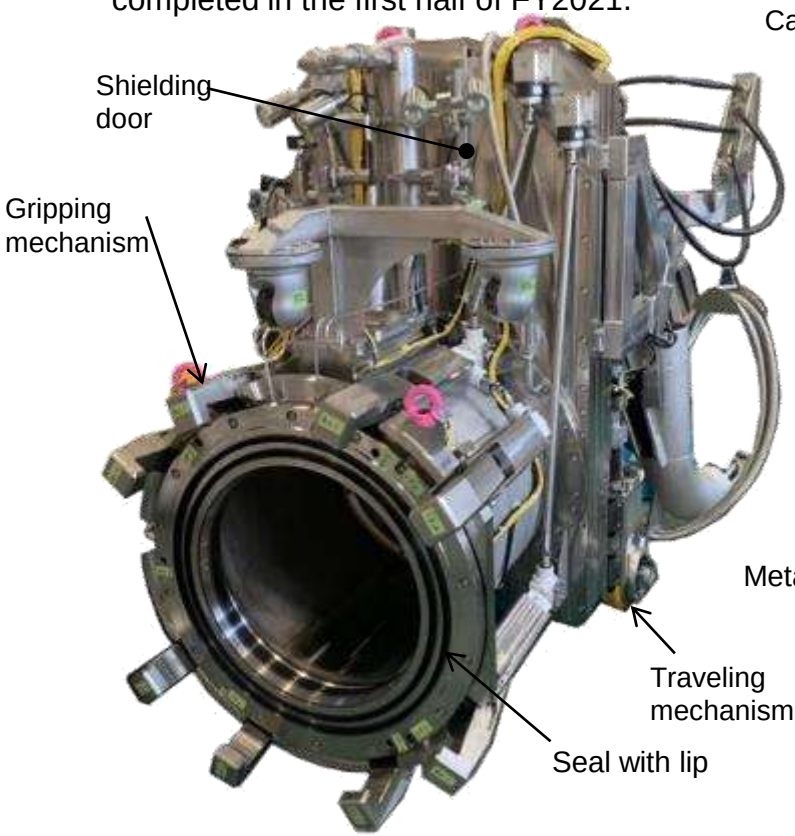
5.2.1 Development of equipment and systems for gradually increasing the retrieval scale

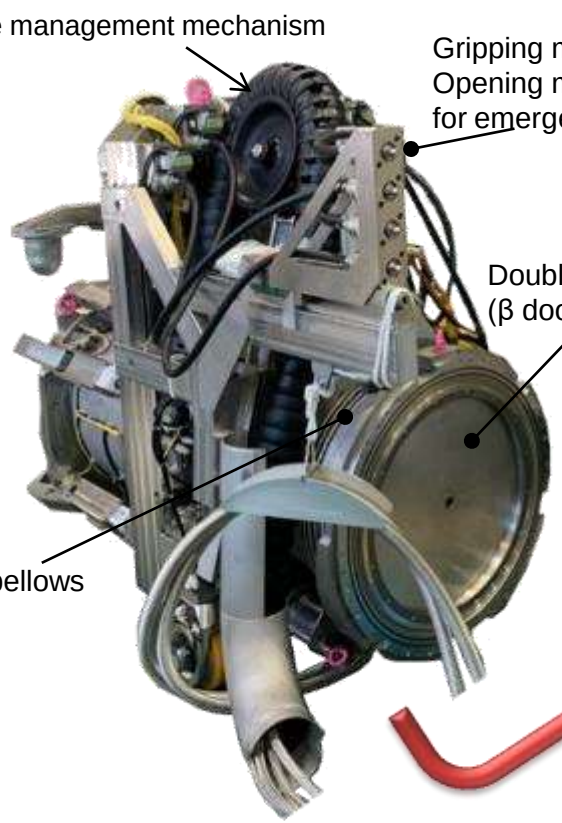
Project started in FY2019

2) Equipment of establishing the access route for fuel debris retrieval (trial manufacture of the X-6 penetration connecting structure)

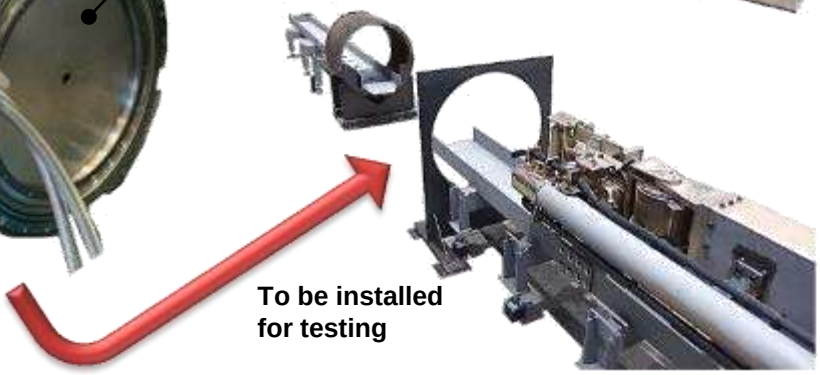
【Achievements for FY2020 (2/2)】

- ✓ Assembly of the X-6 penetration connecting structure was almost completed. The motion of the structure was confirmed, and electricity control are being adjusted.
- ✓ Manufacturing of in-factory verification test equipment was completed. A verification test will be completed in the first half of FY2021.





In-factory verification test apparatus



Simulated arm for cleaning test

5.2 Development of equipment and systems for gradually increasing the retrieval scale of fuel debris

5.2.1 Development of equipment and systems for gradually increasing the retrieval scale

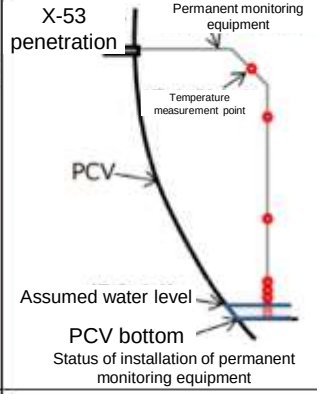
2) Equipment of establishing the access route for fuel debris retrieval (considering the use of the X-53 penetration)

Project started in FY2019

【Achievements for FY2020 (1/2)】

✓ **Application plan and constraint conditions of the X-53 penetration were developed, and equipment to satisfy the plans was selected.**

Application plan	Constraint conditions
Overview monitoring of the arm motions in the PCV	The overview monitoring range is between the X-6 penetration exit and entrance of the pedestal opening.
Cleaning of the arm in the PCV	Target value of water injection pressure: equivalent to 0.4 MPa, volume of water flow: equivalent to 25ℓ/m, and acceptable flow in the PCV: less than 1,000ℓ/h.

Application plan	Cleaning the arm	Overview monitoring of arm motion		Existing equipment
Equipment	Spray	Arm overview camera	Lighting	Water level and temperature gauge
Equipment used				 Status of installation of permanent monitoring equipment
Specifications	Name: Coin / thick and broad type / cone shaped nozzle Size: ϕ 20 to 29mm, H23 to 38mm Water pressure: 0.4MPa Flowrate: 30 to 90ℓ/m	Name: VZ-3 Size: ϕ30mm x L135mm Radiation resistance: 500kGy Image: color	Name: Newly developed product, pipe type Size: ϕ10 to ϕ60mm Intensity of light: 3,360 to 4,000 lumen	—

5.2 Development of equipment and systems for gradually increasing the retrieval scale of fuel debris

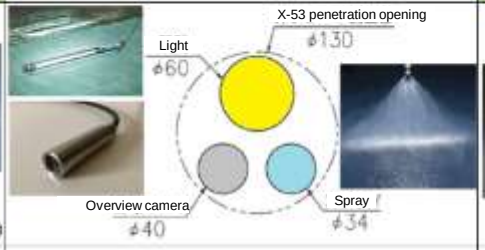
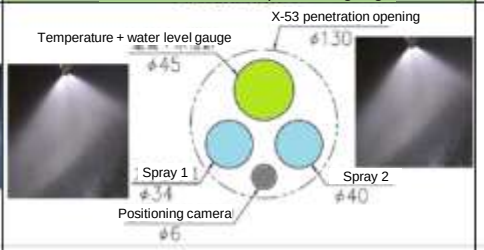
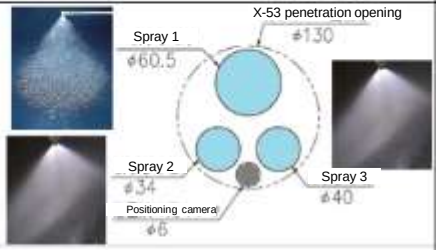
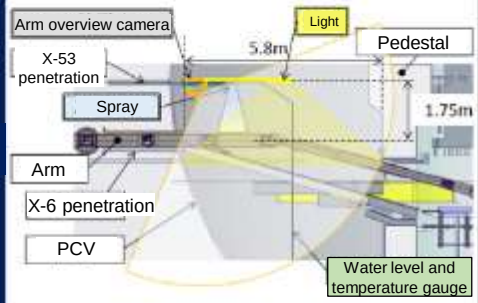
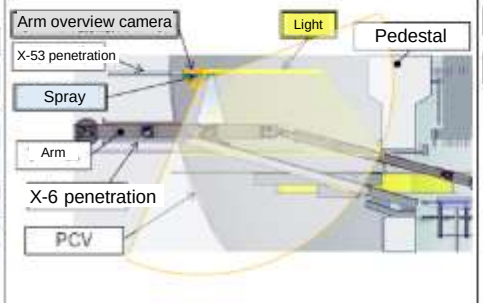
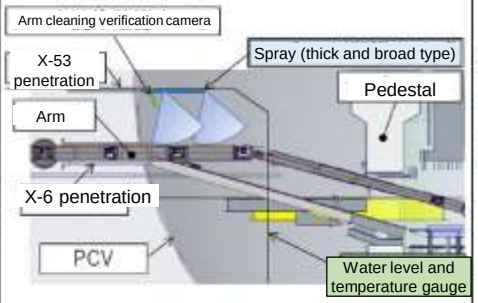
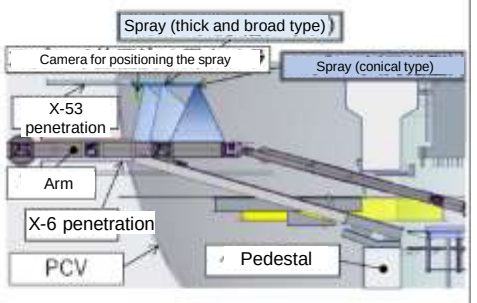
5.2.1 Development of equipment and systems for gradually increasing the retrieval scale

Project started in FY2019

2) Equipment of establishing the access route for fuel debris retrieval (considering the use of the X-53 penetration)

【Achievements for FY2020 (2/2)】

✓ **Case study on combination of selected equipment was performed and feasible case of equipment was examined.**

	Case ①	Case ②	Case ③	Case ④
Equipment	Spray Camera and light Water level and temperature gauge	Spray Camera and light –	Spray – Water level and temperature gauge	Spray – –
Layout of equipment and equipment used				
Conceptual diagram				
Characteristics	•All equipment is mounted	•Enhanced intensity of the light •No water level and temperature gauge	•Enhanced arm cleaning ability: addition of spray, use of thick and broad type spray •No arm overview camera, light	•Further enhanced arm cleaning ability: conical type spray is added •No arm overview camera, light and water level and temperature gauge
Problems	•Intensity of the light (LED) at the pedestal opening	•This light is a pipe type ready-made product and is not radiation resistant. Hence it needs to be replaced if it goes out of order	•Since there is no camera to view the installation position of the spray, a spray positioning camera is required.	•The cleaning time needs to be controlled. •Since there is no camera to view the installation position of the spray, a spray positioning camera is required.

5.2 Development of equipment and systems for gradually increasing the retrieval scale of fuel debris

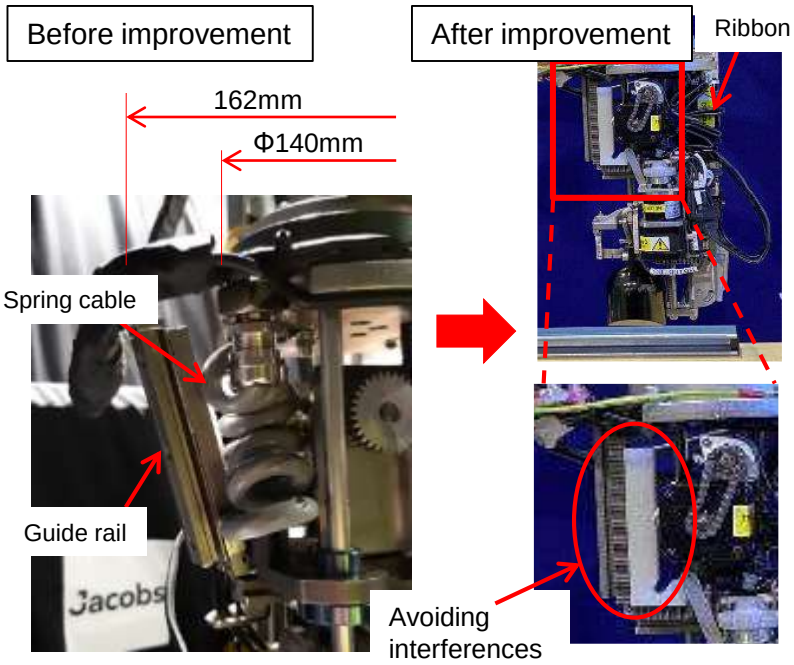
5.2.1 Development of equipment and systems for gradually increasing the retrieval scale

Project started in FY2019

3) Fuel debris cutting and collecting equipment (for collecting pebble-like and sandy fuel debris (bucket type)

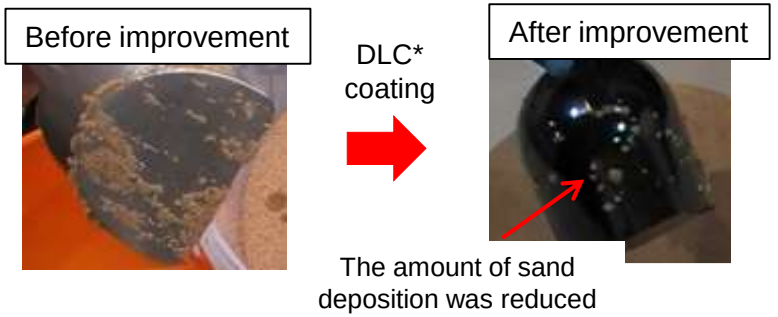
【 Achievements for FY2020 】

- ✓ Equipment was improved after improvement items were clarified based on issues obtained from a prototype manufactured in FY2019.
- ✓ A result of function test confirmed that the improvement was effective.



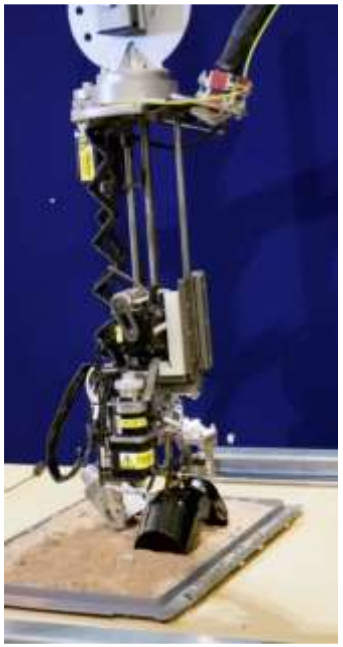
Measure for avoiding interferences with a guide rail and cables

Adding a recovery motor in case of main motor failure



Improvement of bucket efficiency of discharging fuel debris

*) Diamond-like Carbon



Fuel debris collecting test

5.2 Development of equipment and systems for gradually increasing the retrieval scale of fuel debris

5.2.1 Development of equipment and systems for gradually increasing the retrieval scale

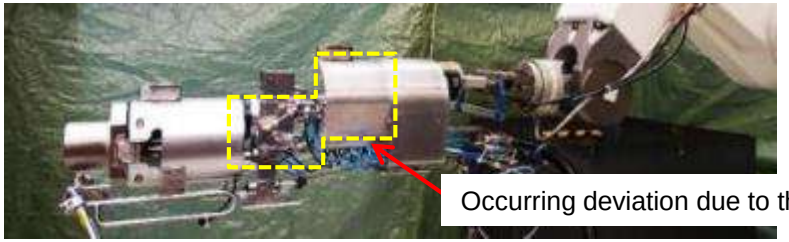
Project started in FY2019

3) Fuel debris cutting and collecting equipment (for collecting pebble-like and sandy fuel debris (flexible gripper type)

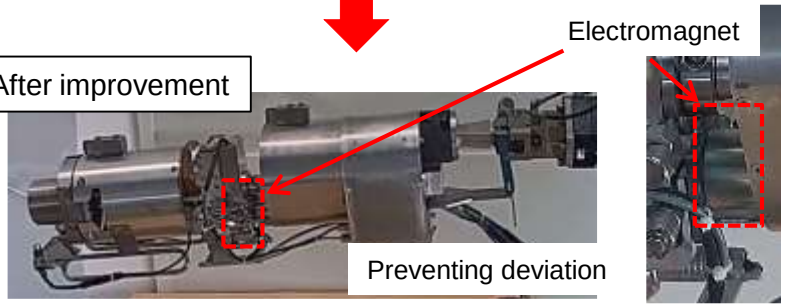
【Achievements for FY2020】

- ✓ Equipment was improved after improvement items were clarified based on issues obtained from a prototype manufactured in FY2019.
- ✓ A result of function test confirmed that the improvement was effective.
- ✓ A method for effective approach to collect fuel debris was clarified.

Before improvement

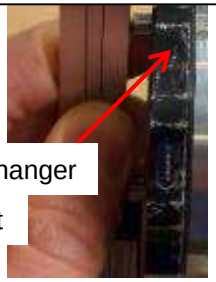


After improvement

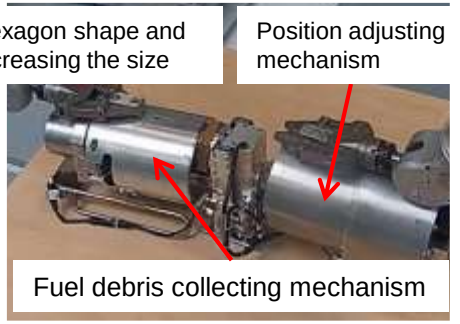


A method for preventing deviation due to the self-weight

Before improvement



After improvement



Connection test for debris collecting and position adjusting mechanism

Fuel debris collecting test

5.2 Development of equipment and systems for gradually increasing the retrieval scale of fuel debris

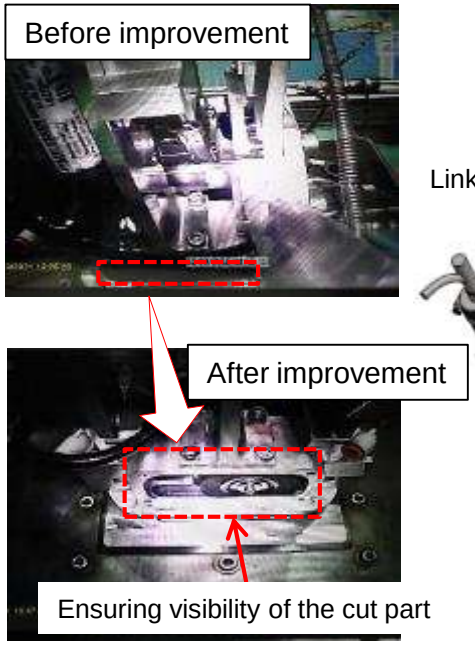
5.2.1 Development of equipment and systems for gradually increasing the retrieval scale

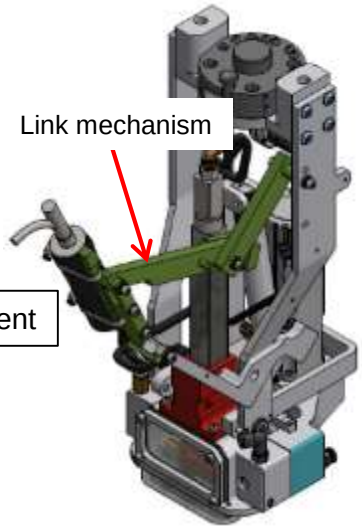
Project started in FY2019

3) Fuel debris cutting and collecting equipment (for cutting and collecting powdery fuel debris)

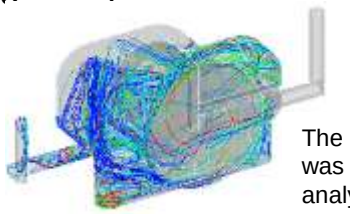
【 Achievements for FY2020 】

- ✓ Equipment was improved after improvement items were clarified based on issues obtained from a prototype manufactured in FY2019.
- ✓ Effectiveness of improvement in camera vision and flow condition in the cut chamber was confirmed.
- ✓ It was confirmed that 2-5g of the cut chip that was generated by cutting 4mm in depth can be collected for approximately 10 minutes (2 hours by using SUS).

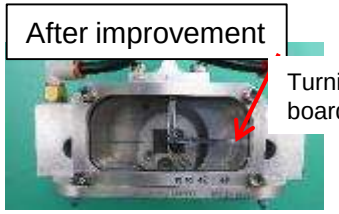




A measure for improving camera views



The effectiveness was confirmed by analysis.



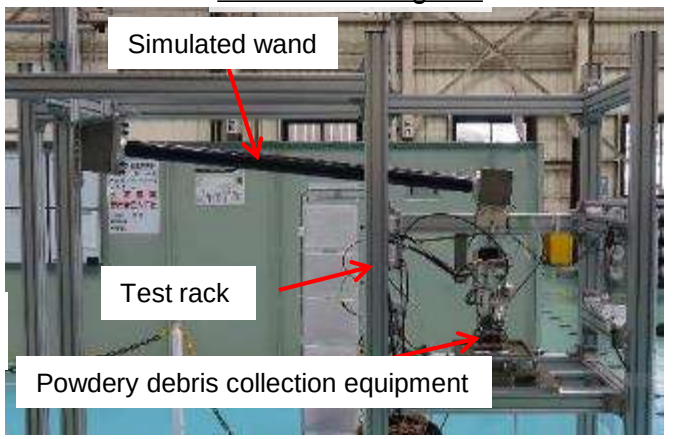
Improvement of cutting chamber

Amount of cutting: 1.8g

Amount of cutting: 5.3g

Amount of cutting: 4.2g

Result of cutting test



Test apparatus

5.2 Development of equipment and systems for gradually increasing the retrieval scale of fuel debris

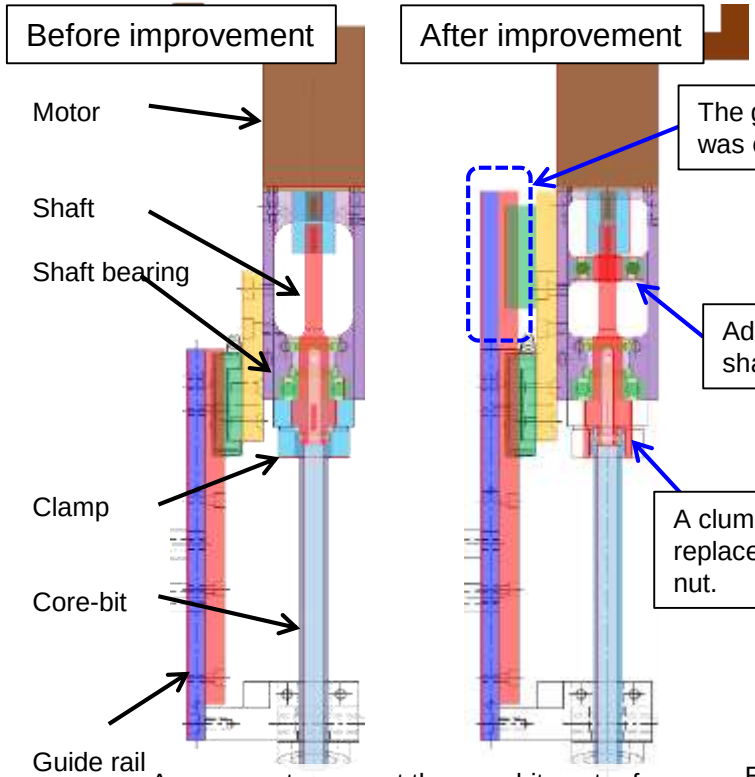
5.2.1 Development of equipment and systems for gradually increasing the retrieval scale

3) Fuel debris cutting and collecting equipment (for cutting and collecting cylindrical fuel debris)

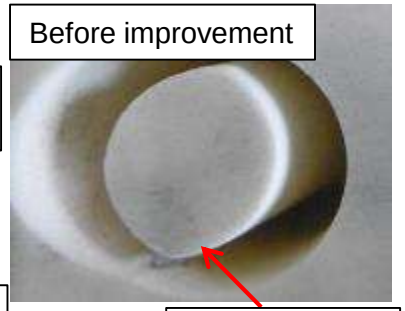
Project started in FY2019

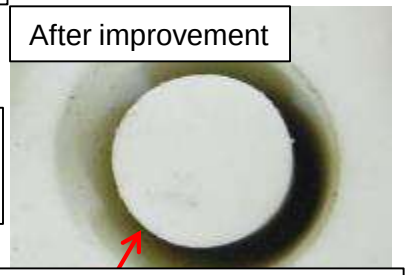
【 Achievements for FY2020 】

- ✓ Equipment was improved after improvement items were clarified based on issues obtained from a prototype manufactured in FY2019.
- ✓ A result of the cut test was confirmed that approximately 100mm-core can be cut (required 40 minutes for cutting alumina and 180 minutes for iron).
- ✓ The cut started in a low speed/low load, and shifted to a high speed when the edge of drill touched, which was found to be a stable cut method.



A measure to prevent the core-bit center from getting out of position



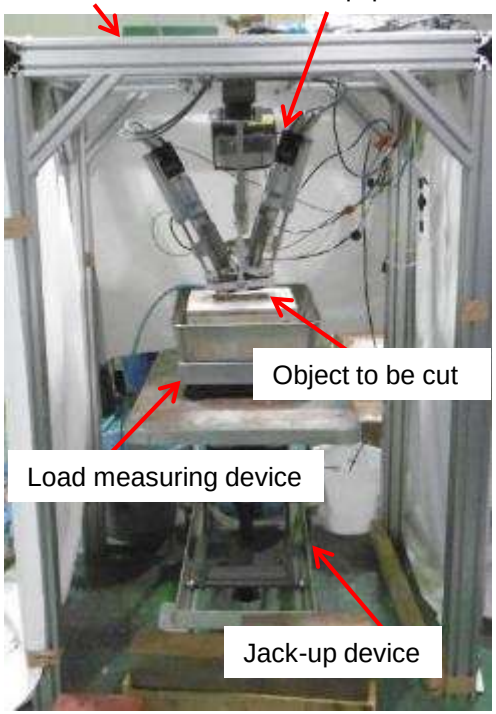


Effectiveness of the measure to prevent the core-bit center from getting out of position

Alumina core

Cast iron core

Collected core



Test apparatus

5.2 Development of equipment and systems for gradually increasing the retrieval scale of fuel debris

5.2.1 Development of equipment and systems for gradually increasing the retrieval scale

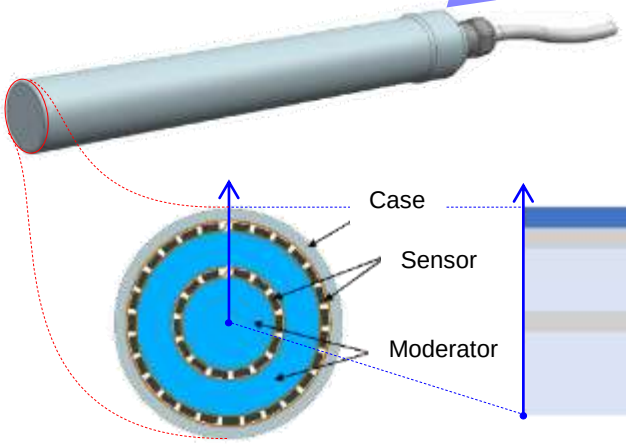
Project started in FY2019

4) Neutron monitoring system

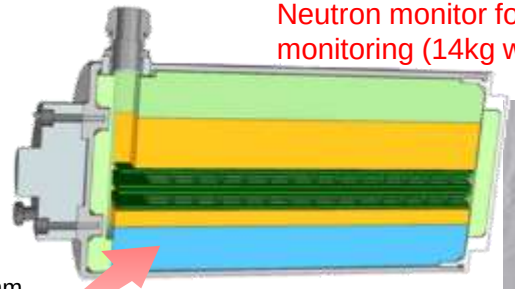
【Achievements for FY2020 (1/2)】

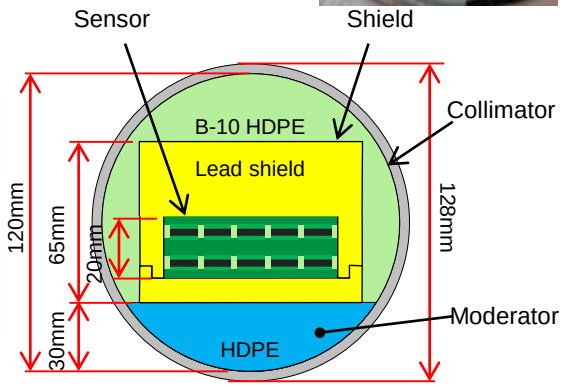
- ✓ Specifications of a neutron monitor prototype with two kinds of SiC semiconductors for regular monitoring and prediction monitoring were examined, and manufacturing of the prototype has started.
- ✓ In-factory verification test items to understand performance of the prototype were revised.
- ✓ A prototype will be manufactured to complete verification test in the first half of FY2021.

Neutronn monitor for regular monitoring (1.4kg weight)



Neutron monitor for prediction monitoring (14kg weight)





Cross section of the prediction monitoring type detector head

5.2.1 Development of equipment and systems for gradually increasing the retrieval scale

Project started in FY2019

4) Neutron monitoring system

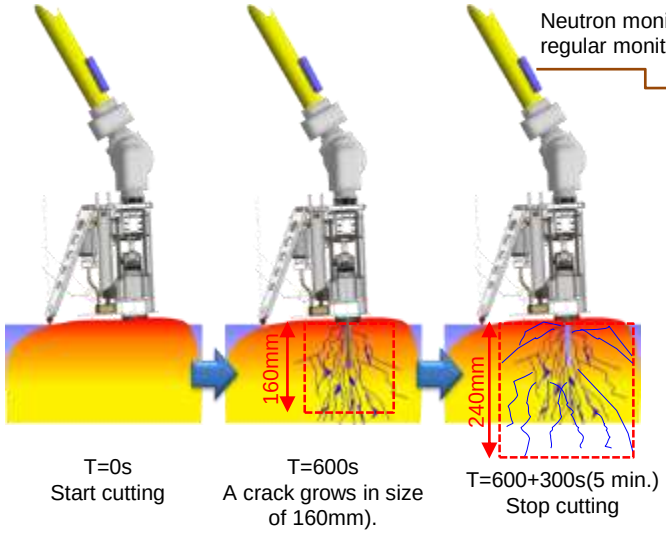
【Achievements for FY2020 (2/2)】

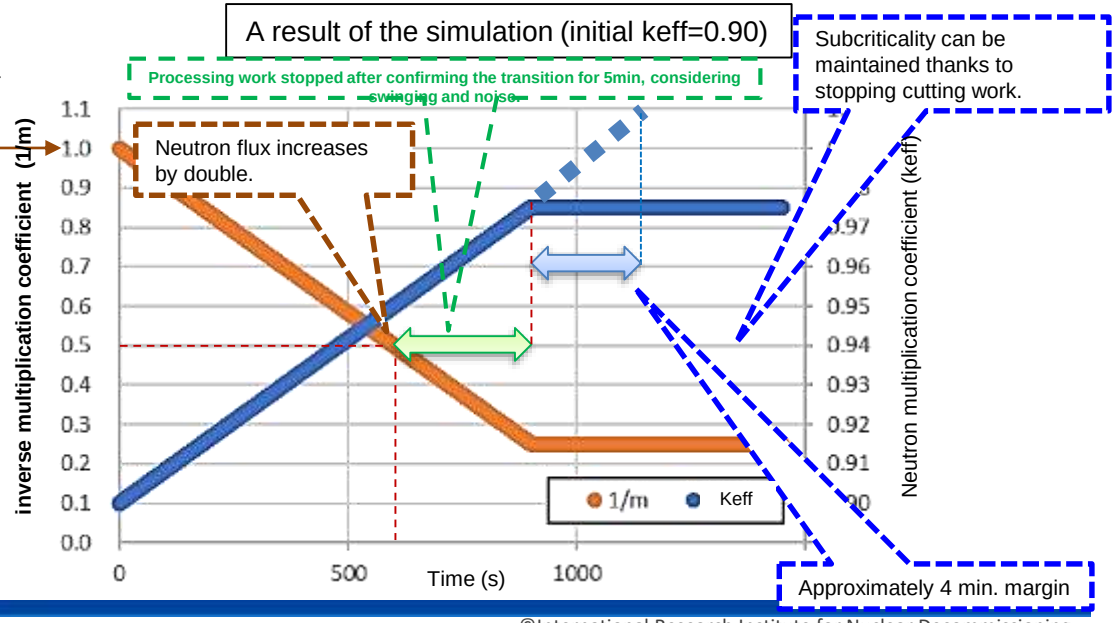
- ✓ **In case that there are deviations from assumed conditions (neutron flux level, gamma ray dose and etc.) set in designing a neutron monitor, the measure for deviations were studied.**

Items	Deviation direction	Response at the site
Neutron flux level	Low	Measuring time extension and criteria reduction
	High	Criteria reduction
Neutron flux BG	High	BG is estimated based on investigation results for the inside of PCV, and the estimated value is deducted from measured value.
Gamma ray level	High	Gamma ray contribution is regarded as BG and the BG value is deducted from measured value.

- ✓ **In case of occurring unexpected situations, or in case that neutron flux increases by almost double (inverse multiplication coefficient 1/m=0.5) during regular monitoring, simulation indicated that criticality was prevented by suspending processing work temporarily.**

In a result of the simulation that criticality occurs 20 minutes after processing for 20 minutes, there would be about 4 minutes margin until criticality occurs, even if processing work stopped 5 minutes after doubled neutron fluxes were detected.





5.2 Development of equipment and systems for gradually increasing the retrieval scale of fuel debris

5.2.1 Development of equipment and systems for gradually increasing the retrieval scale

Project started in FY2019

5) Remote-operated transport carriage for fuel debris container

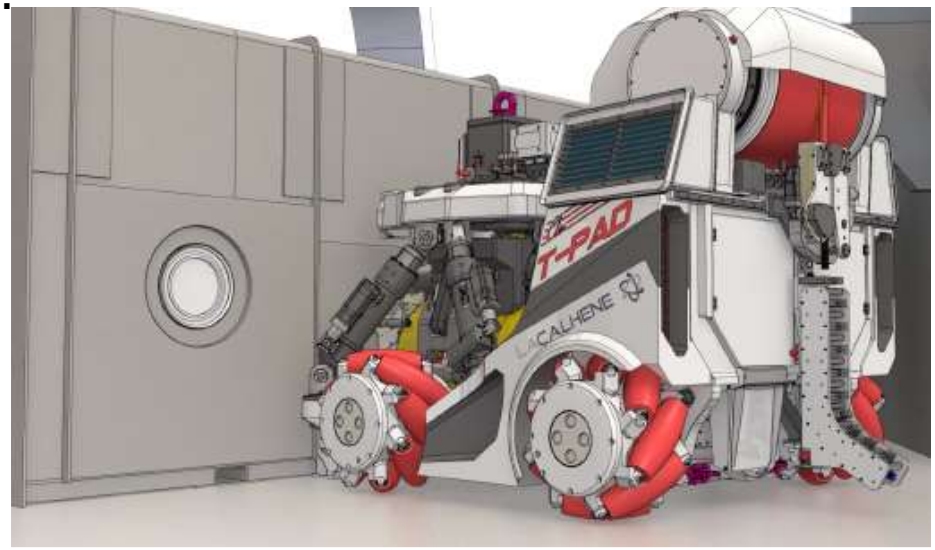
【Overview】
A carriage system that can transport, connect/disconnect transport container for fuel debris (Padirac* RD20) is developed to access the side of the enclosure to be installed on the X-6 penetration by remote-operation. On the basis of basic design conducted in FY2019, detailed design of a prototype was performed.

【 Achievements for FY2020 (1/4)】

✓ Detailed design of remote-operated transport carriage was performed to confirm the improvement of design and the applicability considering the safety at the site.
Additionally, the following design drawing (revised) was created and the preparation work for manufacturing a prototype was completed.

(1) Mechanical design drawing
① Entire outline drawing
② Assembly drawing (component drawing)
③ Component list, etc.

(2) Electric design drawing
① Single-line connection diagram
② Development connection diagram
③ IBD(Interlock Block Diagram), etc.



*) A trade name of small container for radioactive contaminated materials

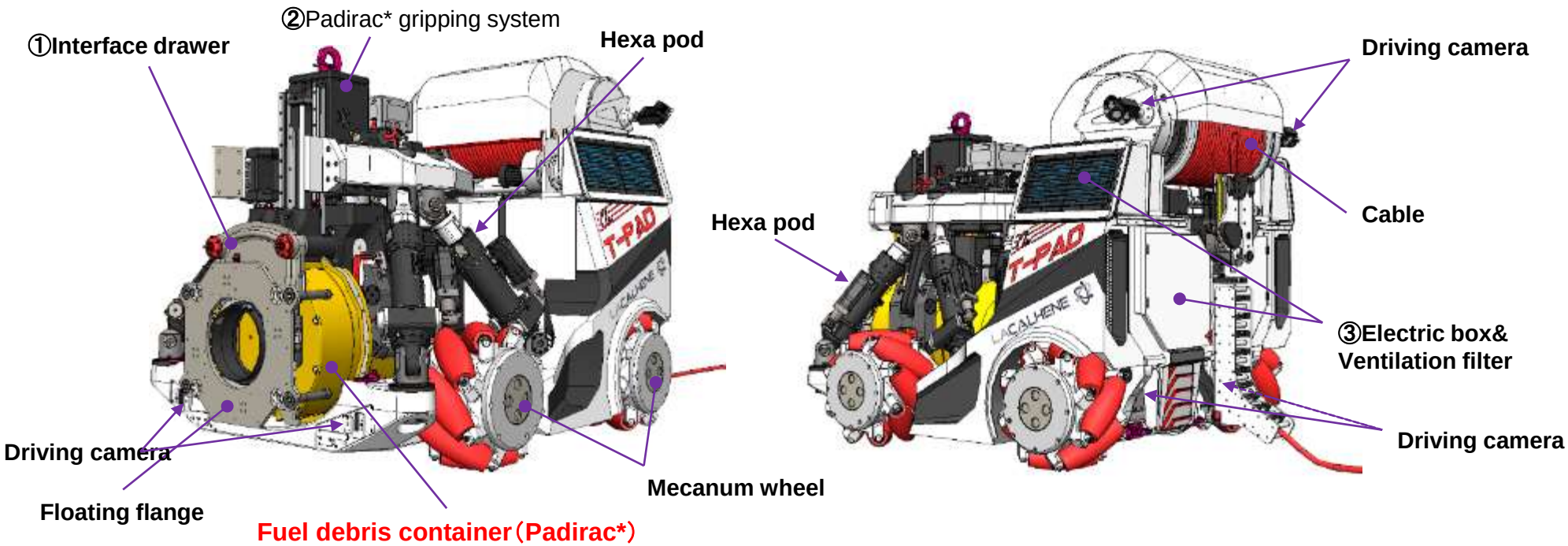
5.2 Development of equipment and systems for gradually increasing the retrieval scale of fuel debris

5.2.1 Development of equipment and systems for gradually increasing the retrieval scale

Project started in FY2019

5) Remote-operated transport carriage for fuel debris container

【 Achievements for FY2020 (2/4)】



- ✓ Design of the carriage was improved considering the safety (including reducing radiation exposure), examining failure risk and rescue measures.
  - ① Improvement of the Padirac* shield door, ②Revision of a connection method of the Padirac* gripping system ③Clarification of ventilation design for electric box
- ✓ Design drawings were created required for manufacturing a prototype and the detailed design was completed. Arrangement of the prototype components started.

＊) A trade name of small container for radioactive contaminated materials

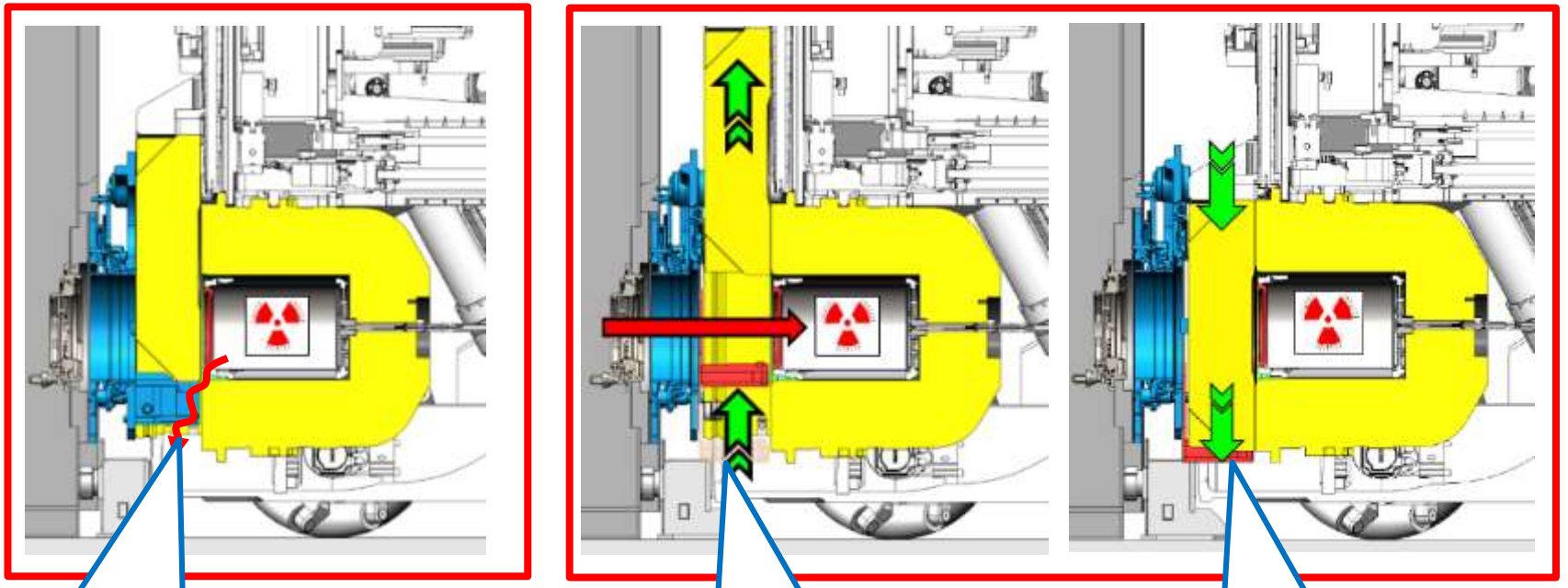
5.2 Development of equipment and systems for gradually increasing the retrieval scale of fuel debris

5.2.1 Development of equipment and systems for gradually increasing the retrieval scale

Project started in FY2019

5) Remote-operated transport carriage for fuel debris container

【Achievements for FY2020 (3/4)】Detailed design of remote-operated transport carriage
Revision of the structure of the Padirac*1 shielding door area



【Results of design revision 】
Exposure of workers was reduced by revising the function of the Padirac*1 shielding door area.

＊1)Trade name of a small container for radioactive contaminated materials
＊2)A lid of a double door type container connected with a hot cell opening

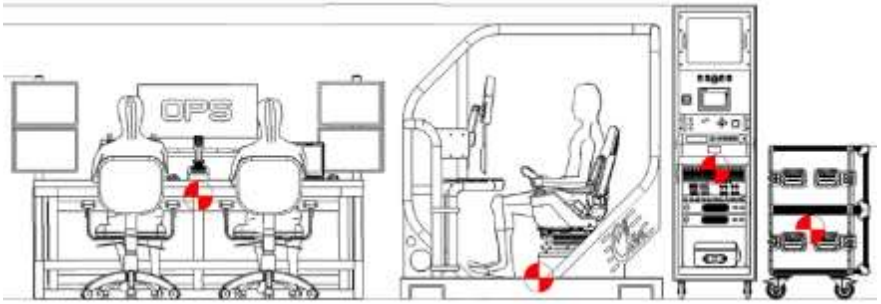
5.2 Development of equipment and systems for gradually increasing the retrieval scale of fuel debris

5.2.1 Development of equipment and systems for gradually increasing the retrieval scale

Project started in FY2019

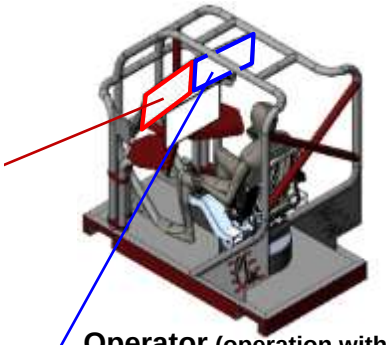
5) Remote-operated transport carriage for fuel debris container

【Achievements for FY2020 (4/4)】Detailed design of remote-operated transport carriage
Design of electric control system was developed and design specifications of the central control room were clarified.

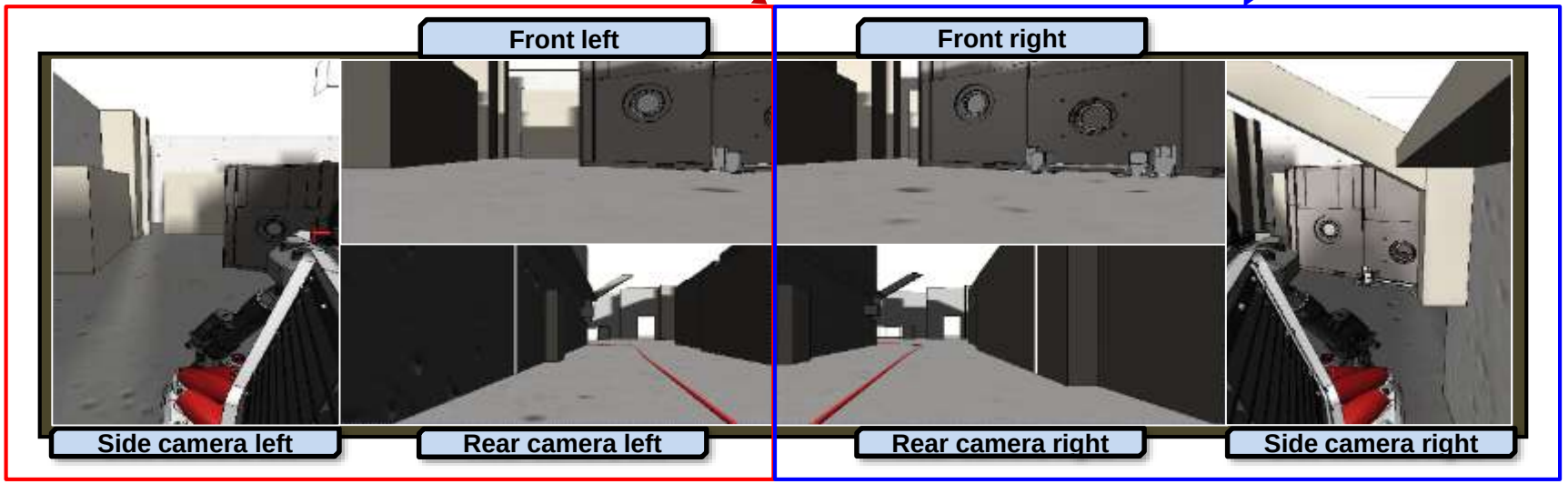


A conceptual drawing of central control device layout

Observers



Operator (operation with joystick)



Operation screen of the remote-operated transport carriage during driving (image drawings)

5.2 Development of equipment and systems for gradually increasing the retrieval scale of fuel debris

5.2.1 Development of equipment and systems for gradually increasing the retrieval scale

Study on the site applicability

Project started in FY2019

	Development items	Technological issues concerning site application	Response to issues
1)	**Access equipment for fuel debris retrieval (the arm, the enclosure and etc.)**	Capability of handling fuel debris and heavy materials in the narrow enclosure	Work steps of a manipulator are clarified and improvement items are identified by testing work verification.
2)	**Access route establishing equipment for fuel debris retrieval (test manufacturing of the X-6 penetration connection structure)**	・The inclination of X-6 penetration and the condition of the flange surface ・Effect of water vapor in the PCV after opening the X-6 penetration	Items to be improved are identified by hearing the status of removing depositions on the X-6 penetration that is being conducted by the previous project.
	Access route establishing equipment for fuel debris retrieval (considering the use of the X-53 penetration)	・Ensuring work places around the X-53 penetration ・Timing of the field work and ensuring the work period	The information is provided for TEPCO HD.. Requirement conditions from the site staffs are regularly checked.
3)	**Fuel debris cutting and collecting equipment**	・A pushing method by the arm and its stability ・Methods for approaching to and touching fuel debris ・Methods for transporting debris to the analysis facility	・Items to be improved are identified by conducting combination test. ・The information is provided for analysis facility. Requirement conditions from the site staffs are regularly checked.
4)	**Neutron monitoring system**	・Effects of noise generated from the fuel debris cutting and collecting equipment and the arm	Cables of the neutron monitor should be independent and effects of noise are verified by verification test in factory.
5)	**Remote-operated transport carriage for fuel debris container**	・Workability of the Padirac* installation/uninstallation ・Ensuring places for maintenance	The information is provided for TEPCO HD.. Requirement conditions from the site staffs are checked.

***) A trade name of a small container for transporting radioactive contaminated materials.**

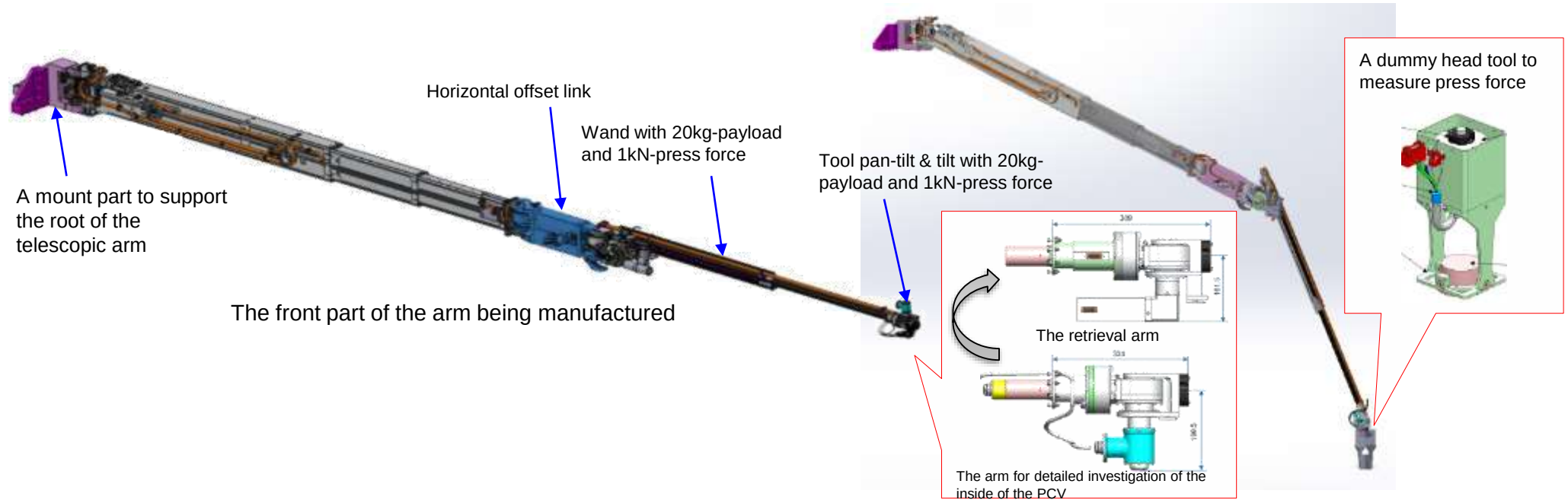
5.3 Development and design of element technology for access equipment of fuel debris retrieval (the arm, the enclosure, etc.)

Project started in FY2020

5.3.1 Element technology for equipment with the retrieval arm

【 Achievements for FY2020 】

- ✓ On the basis of the arm design for detailed investigation of the inside of the PCV, the front part of the arm was improved as below, and manufacturing of the arm started.
  - ➢ A wand and wrist equipped with 20kg-payload and 1kN-press force
  - ➢ A horizontal offset link to improve availability to pass the opening on the platform
- ✓ A monitoring method that is not relay on a load cell equipped on the bottom of the horizontal offset link was studied to monitor a force of the head tool to press fuel debris.



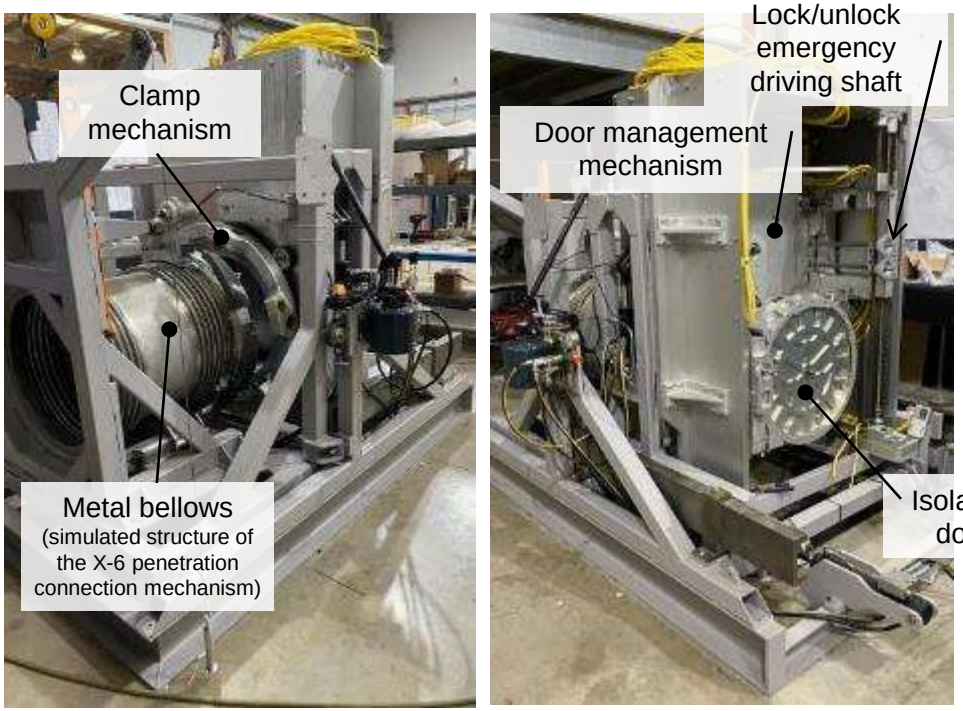
5.3 Development and design of element technology for access equipment of fuel debris retrieval (the arm, the enclosure, etc.)

Project started in FY2020

5.3.2 Element technology to be equipped with the retrieval enclosure

【 Achievements for FY2020 】

- ✓ Results of element test of the double door system confirmed airtight performance including durability and motion reliability of the doors. In addition, a torque required for emergency driving shaft was obtained in case of emergency (random failure of a motor).
- ✓ Detailed design of a prototype was completed after reflecting the above achievements. In FY2021, a prototype will be manufactured and verified in factory.



Test apparatus of the double door system

Double door system

5.3 Development and design of element technology for access equipment of fuel debris retrieval (the arm, the enclosure, etc.)

Project started in FY2020

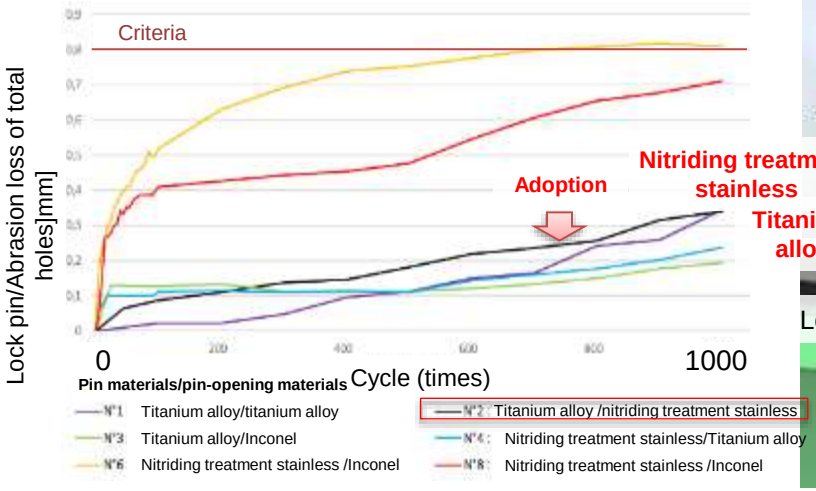
5.3.2 Element technology to be equipped with the retrieval enclosure

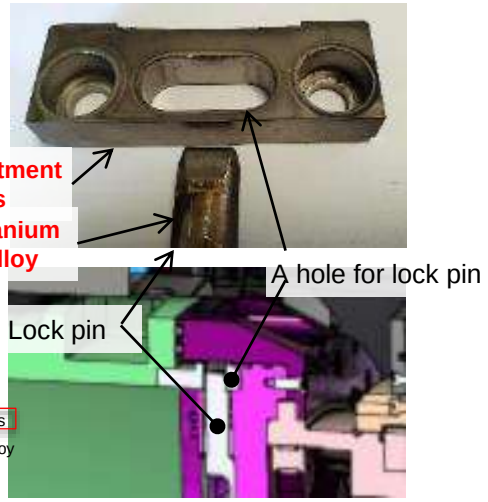
a) Confirmation of airtightness

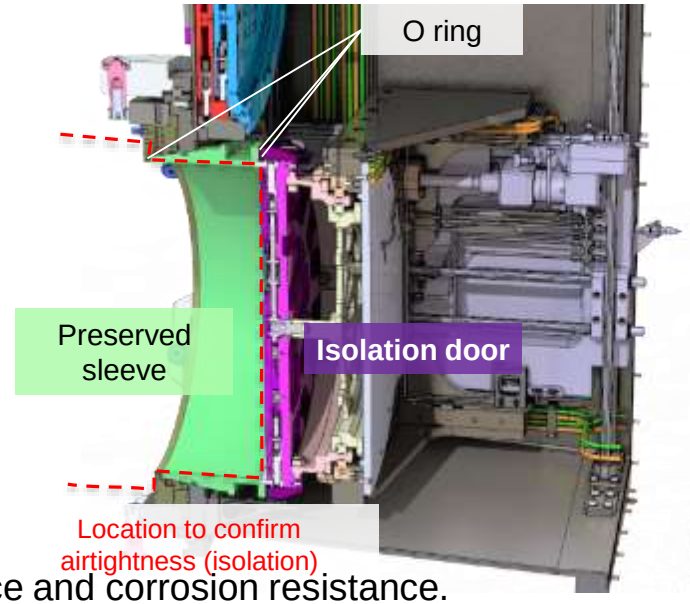
The most appropriate materials were selected after durability of a lock pin (abrasion resistance) that effects airtightness was verified by lock pin durability test. Selected materials were incorporated into the double door system test apparatus and 1000-cycle airtightness was confirmed.

Durability test of a lock pin (verification of material combinations)

Required airtightness	Test results (after 1000 cycles)
0.7vol%/h (equivalent to 3×10^{-1}Pa・m3/s)	Less than 0.05vol%/h







⇒A lock pin and a titanium alloy were adopted from a view of abrasion resistance and corrosion resistance.
⇒The Nitriding treatment system for lock pin holes is adopted from a view of abrasion resistance, corrosion resistance, manufacturing and availability.

5.3 Development and design of element technology for access equipment of fuel debris retrieval (the arm, the enclosure, etc.)

Project started in FY2020

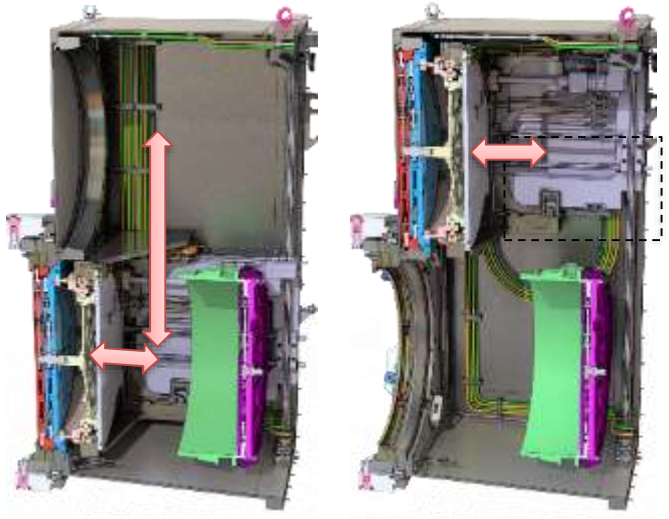
5.3.2 Element technology to be equipped with the retrieval enclosure

b) Operational reliability (positioning accuracy)

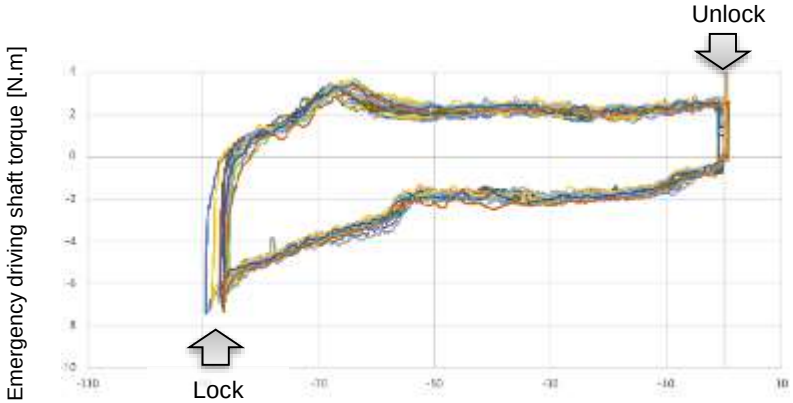
It was confirmed that each operation has no problem during 1000 cycles. Additionally, positioning accuracy of the door management mechanism after 1000 cycles was quantitively grasped and it was confirmed that required accuracy was satisfied.

Required positioning accuracy	Test results (after 1000 cycles)
0.3 mm	0.1mm

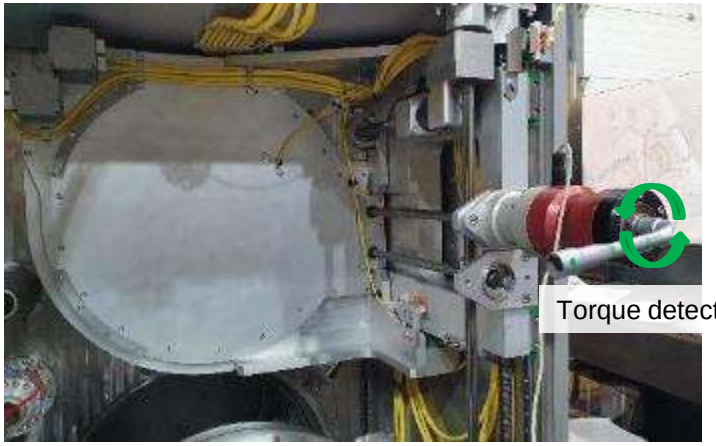
Position measurement of horizontal trolly



c) Confirmation of torque for emergency driving shaft



Lock/unlock mechanism: measurement torque for emergency driving shaft



5.3 Development and design of element technology for access equipment of fuel debris retrieval (the arm, the enclosure, etc.)

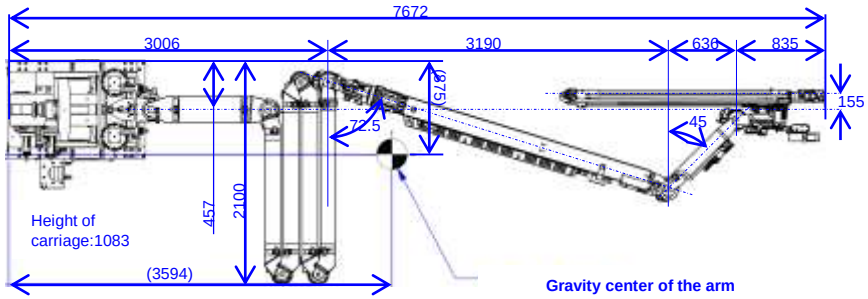
Project started in FY2020

5.3.3 The entire design of the access equipment for fuel debris retrieval (the arm, enclosure, etc.)

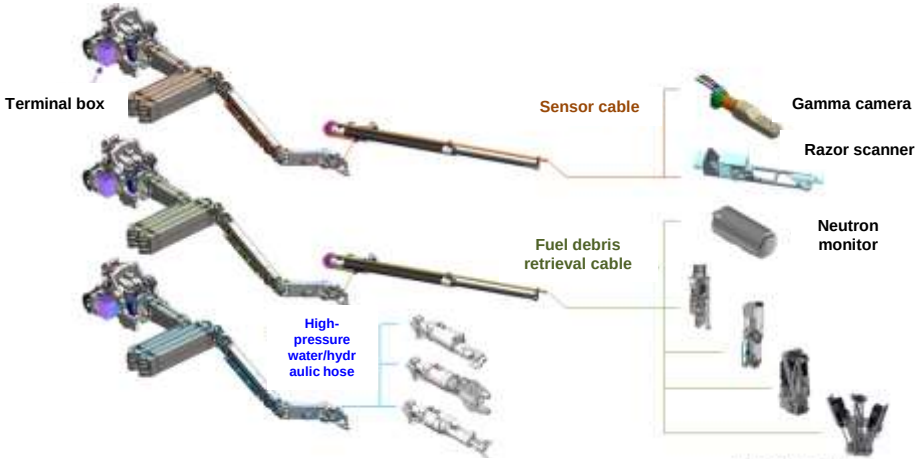
【Achievements for FY2020 (1/5)】

- ✓ **On a basis of the arm for detailed investigation inside the PCV, design specifications for the retrieval arm was examined.**

Configuration of the retrieval arm



The system configuration of the retrieval arm



Items	Specifications	Remarks
Arm configurations	Carriage：Same specifications as the arm for detailed investigation inside the PCV Boom link： 5 link configuration（8m when opening,1.7m when folding) Sectional height 420mm×width 250mm～height 400mm×width140mm Telescopic arm： Three-stage telescope structure (5.4m when extending, 3.3m when shrinking） Sectional height 312mm×width 178mm- height 256mm×width121mm Horizontal offset link： Fixed length: 0.9m, sectional height 300mm×width 130mm Wand： Two-stage telescopic structure（3.5m when extending, 2.1m when shrinking）	The sectional shape is set to secure the pass through the X-6 penetration. As a result of VR simulation, the arm system is likely to access to 2.8m^2 of the pedestal bottom. A wand can be installed/uninstalled by the Dexter*.
Driving system	Carriage： INFRANOR Ltd. BLS-74＋Bonfiglioli Ltd. 301L4 1022 HZ P71 A Boom link： INFRANOR Ltd. BLS-40＋HDAG Ltd. HFUC-50-160-2A Telescopic arm： INFRANOR Ltd. BLS-55＋HDAG Ltd. HFUC-25-120 Horizontal offset link： INFRANOR Ltd. BLS-40＋HDAG Ltd. HFUC-50-160-2A Wrist： INFRANOR Ltd. BLS-40＋HDAG Ltd. CPM-14-100＋HFUC-50-160-2A Wand： INFRANOR Ltd. BLS-40＋HDAG Ltd. CPM-17-120 Tool pan & tilt： INFRANOR Ltd. BLS-73＋HDAG Ltd. HFUC-25-160	A motor is satisfied specifications of radiation resistance with resolver. 100Nm-torque is ensured to revolve with payload-20kg. A part of the driving system has internal electro-magnetic clutches for emergency For the tool pan & tilt, the motor was replaced with the one with higher torque than that of the PCV investigation arm.
Main materials	Carriage ：SUS304 Boom link：SUS630 Telescopic arm：Aluminum Horizontal offset link ：SUS630 Wand：Carbon fiber, Aluminum	Materials have rigidity against 1kN-pressing force required to collect cylindrical sample.

*) A trade name for the dual-arm type remote-operated manipulator system

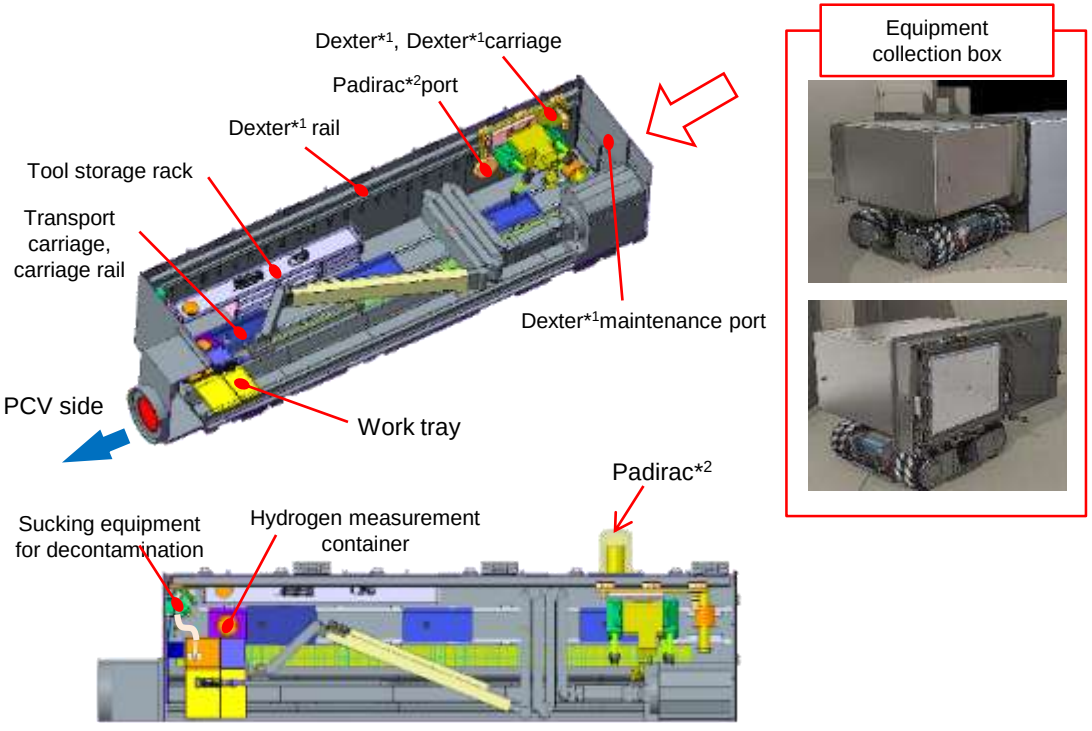
5.3 Development and design of element technology for access equipment of fuel debris retrieval (the arm, the enclosure, etc.)

Project started in FY2020

5.3.3 The entire design of the access equipment for fuel debris retrieval (the arm, enclosure, etc.)

【Achievements for FY2020 (2/5)】

Considering retrieval and collection of fuel debris from the inside of the PCV, detailed design was performed based on the enclosure design for detailed investigation inside the PCV. Additionally, research achievements of engineering conducted by TEPCO Holdings was reflected into the structure to contribute to fuel debris retrieval training for gradually increase the retrieval scale of fuel debris, based on the needs from TEPCO Holdings.



Items	Specifications
Size	Less than 9.3m × 2.4m × 2m
Mass	Less than 30ton
Storage area for the head tool	・Over 1 set of assumed tools can be stored. ・Storage area for spent tools should be ensured.
Fuel debris collecting area	A work tray that can ensure sufficient work area near the tool head with the arm can be installed.
Airtightness (acceptable leakage rate)	10^{-6} Pa・m3/s（per 1 seal）or 0.05%/h of the enclosure volume
Pressure tightness	-5 ～10 kPaG
Radiation resistance	・Outside:10Gy/h ・Inside:100Gy/h （Accumulated exposure amount: Approx. 850Gy）
Seismic resistance	Maintaining the boundary structure
Life span	More than 5 years
Accessories	Hydrogen measurement container, sucking decontamination equipment
	Light, camera and microphone
N_2 gas supply	Intake：4 parts × 50A （quick coupler） Exhaust：4 parts × 50A （quick coupler）
Interface	・It can connect with the X-6 penetration connection structure. ・It can connect with remote-operated transport carriage.

*1) A trade name of the dual-arm type remote-operated manipulator system
*2) A trade name of small container for transporting radioactive contaminated materials

5.3 Development and design of element technology for access equipment of fuel debris retrieval (the arm, the enclosure and etc.)

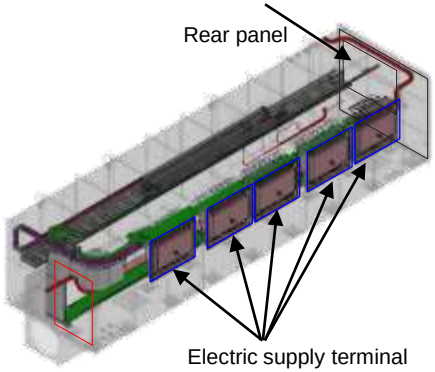
Project started in FY2020

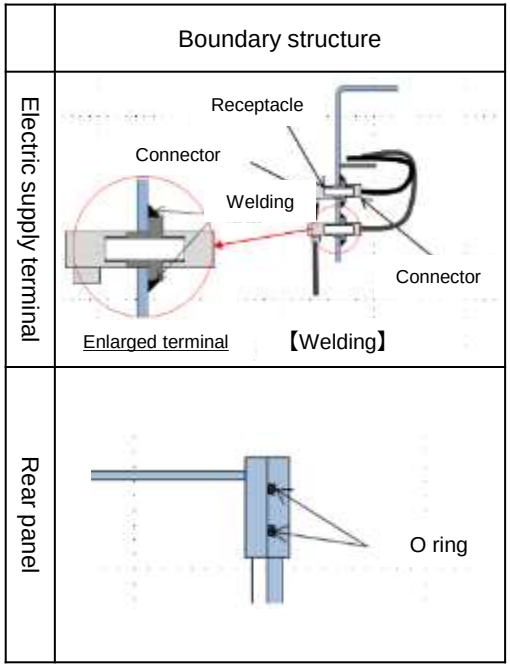
5.3.3 The entire design of the access equipment for fuel debris retrieval (the arm, enclosure and etc.)

【 Achievements for FY2020 (3/5)】

【Boundary structure】

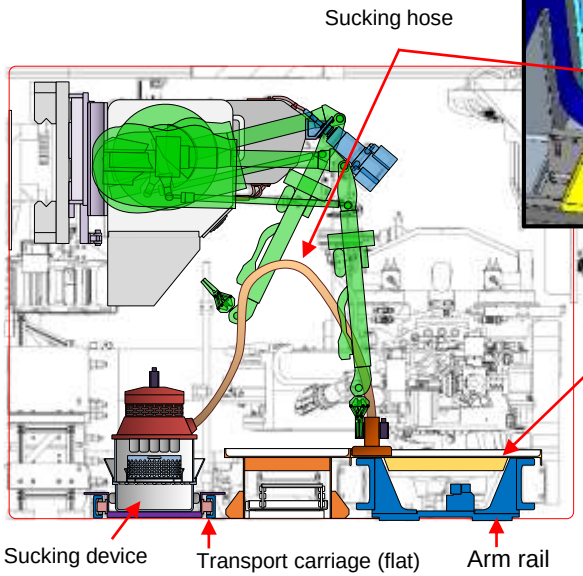
An effective measure for double O rings of electric supply terminal and rear panel + exhaust pressure line (negative pressurized)





【Sucking decontamination】

Sucking decontamination (evacuating at the enclosure ventilation line) in the enclosure, with sucking nozzle gripped by the Dexter*.
Selection of high-sucking nozzle
Study on a method for maintaining hose.



Example of cleaner for dry/wet use

*1) A trade name of the dual-arm type remote-operated manipulator system

5.3 Development and design of element technology for access equipment of fuel debris retrieval (the arm, the enclosure, etc.)

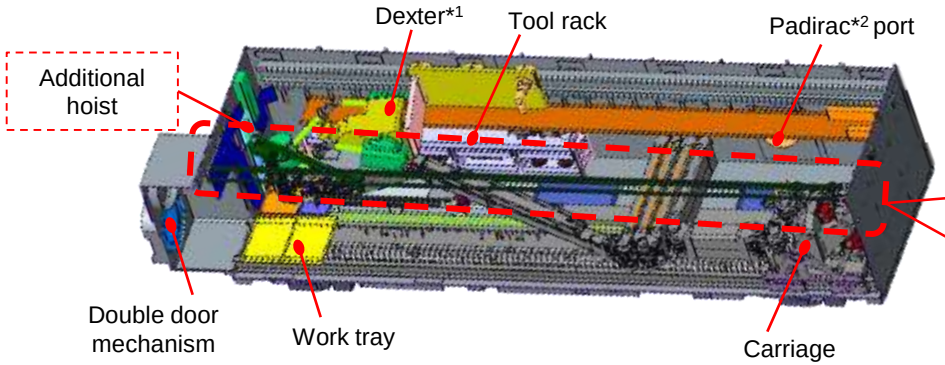
Project started in FY2020

5.3.3 The entire design of the access equipment for fuel debris retrieval (the arm, enclosure, etc.)

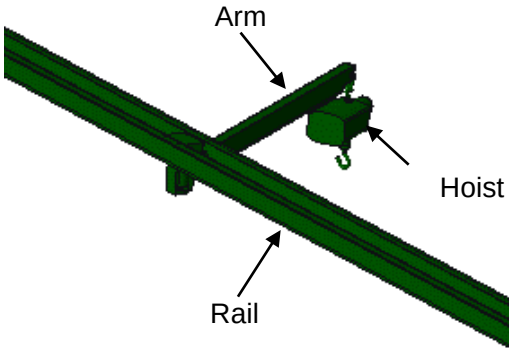
【Achievements for FY2020 (4/5)】

○ Study on additional hoist

Study on accepting an additional hoist to support operation with Dexter*1. (under consideration whether or not verify as one of a prototype devices)

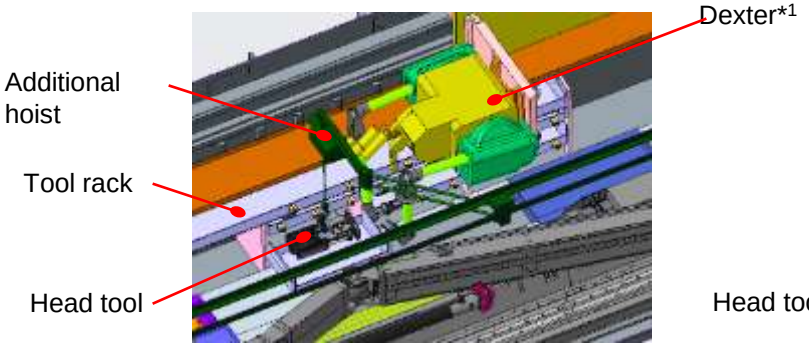


Plan of additional hoist structure

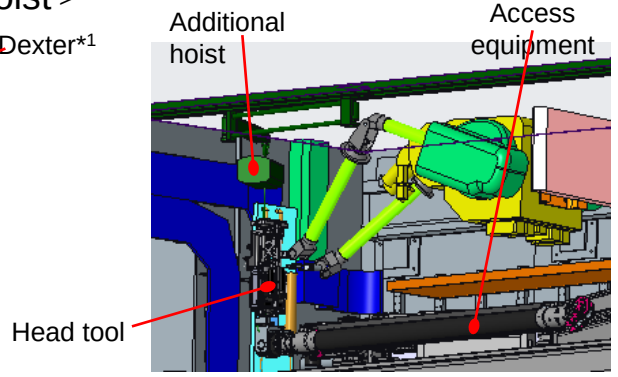


Specification (tentative)
- Rated load: 60kg
- Arm length: 1,600 mm
- Rail length: 8,100 mm

＜Image of the work with an adding a hoist＞



Removal of the head tool from the tool rack



Head tool connection with access equipment

*1) A trade name of the dual-arm type remote-operated manipulator system
*2) A trade name of small container for transporting radioactive contaminated materials

5.3 Development and design of element technology for access equipment of fuel debris retrieval (the arm, the enclosure, etc.)

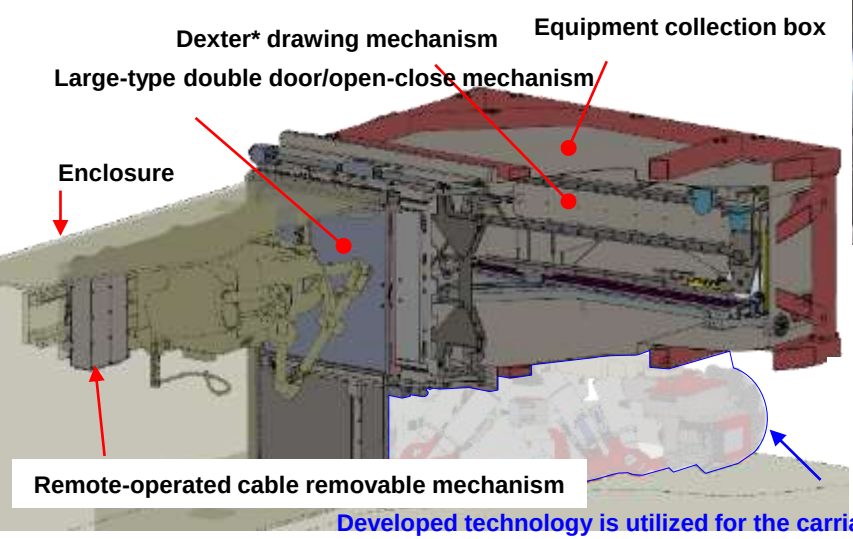
Project started in FY2020

5.3.3 The entire design of the access equipment for fuel debris retrieval (the arm, enclosure, etc.)

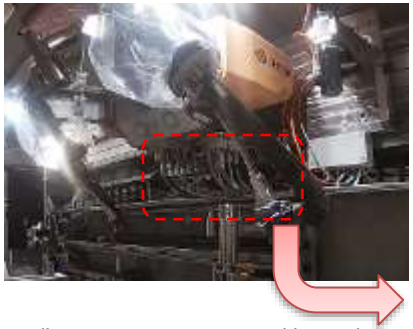
【 Achievements for FY2020 (5/5)】

○ Equipment collection box

- Study on remote-operated cable removable mechanism for the Dexter* carriage (horizontal transport carriage) to be built-in the equipment collection box.
- Sealing efficiency and effective decontamination were required for the remote-operated removable connector. Therefore, stainless was selected as main material and the O ring of a connector acts as a measure against moisture.
- The remote-operated cable removable mechanism is planned to be driven by four pneumatic cylinders. Two of them were used for removing a connector, and other two were used for applying the brake or force when removing the connector box.

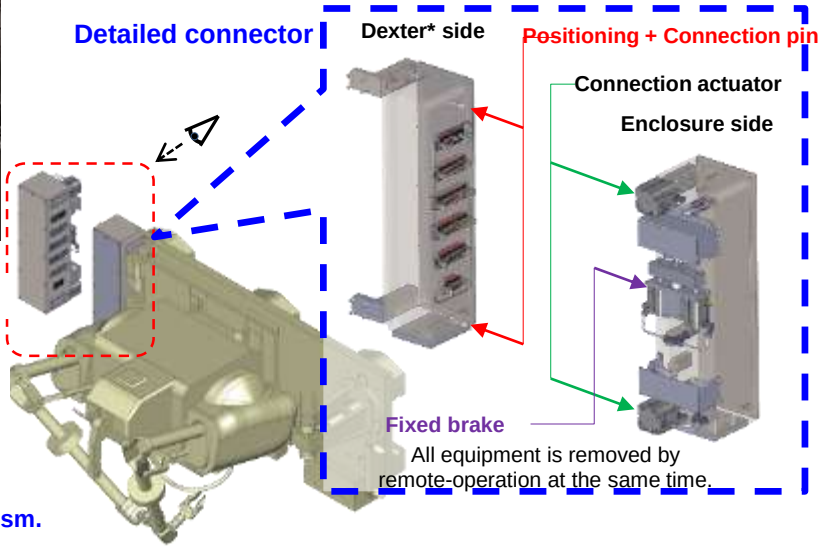


Sectional view of the equipment collection box



All connectors are removed by workers.

The Dexter* and the Dexter* carriage for detailed investigation inside the PCV



Remote-operated cable removable mechanism

Developed technology is utilized for the carriage and position adjusting mechanism.

*1) A trade name of the dual-arm type remote-operated manipulator system

5.3 Development and design of element technology for access equipment of fuel debris retrieval (the arm, the enclosure, etc.)

Project started in FY2020

Study on the site applicability

	Development items	Technological issues of the site feasibility	Response to the issues
5.3.1	**Element technology to be installed on the retrieval arm** (Telescopic arm with horizontal off-set mechanism)	・Operability and operational accuracy of the arm when passing through the opening of the platform ・Sufficient understanding of the arm condition by using a camera (reducing anxiety among operators) ・Procedures when pushing the equipment for cutting and collecting fuel debris, and the monitoring method	・Identification of items to be improved by mock-up verification test ・Identification of items to be improved by combination test of fuel debris cutting and collecting equipment
5.3.2	**Element technology to be installed on the retrieval enclosure** (Double door system)	・Long-term reliability of the double door system ・Abnormality detection method (camera and microphone) ・Response when failed ・Effects of vapor condensation water ・Measures for radioactive dust contamination	・Confirmation of long-term reliability by element tests and knowledge acquisitions concerning abnormal signs ・Measures against failures based on risk assessment and water proof, and confirmation by verification test in factory ・Reduction of uneven/retaining parts assuming decontamination by using running water
5.3.3	**Entire design of the access equipment for retrieval (the arm, the enclosure)**	・Layout of peripheral equipment (ventilation air-conditioning systems, etc.) and cables in the reactor building ・Measures for freezing, salt damage, rainwater and disaster ・Positioning adjustment of the enclosure ・Decontamination and transport method of the enclosure	・Information sharing with TEPCO HD. Confirmation of requirements from the site staffs. ・Understanding of positioning accuracy and identifying items to be improved by mock-up verification test ・Clarification of decontamination methods for the surface and the inside, and clarification of items to be improved by mock-up verification test.

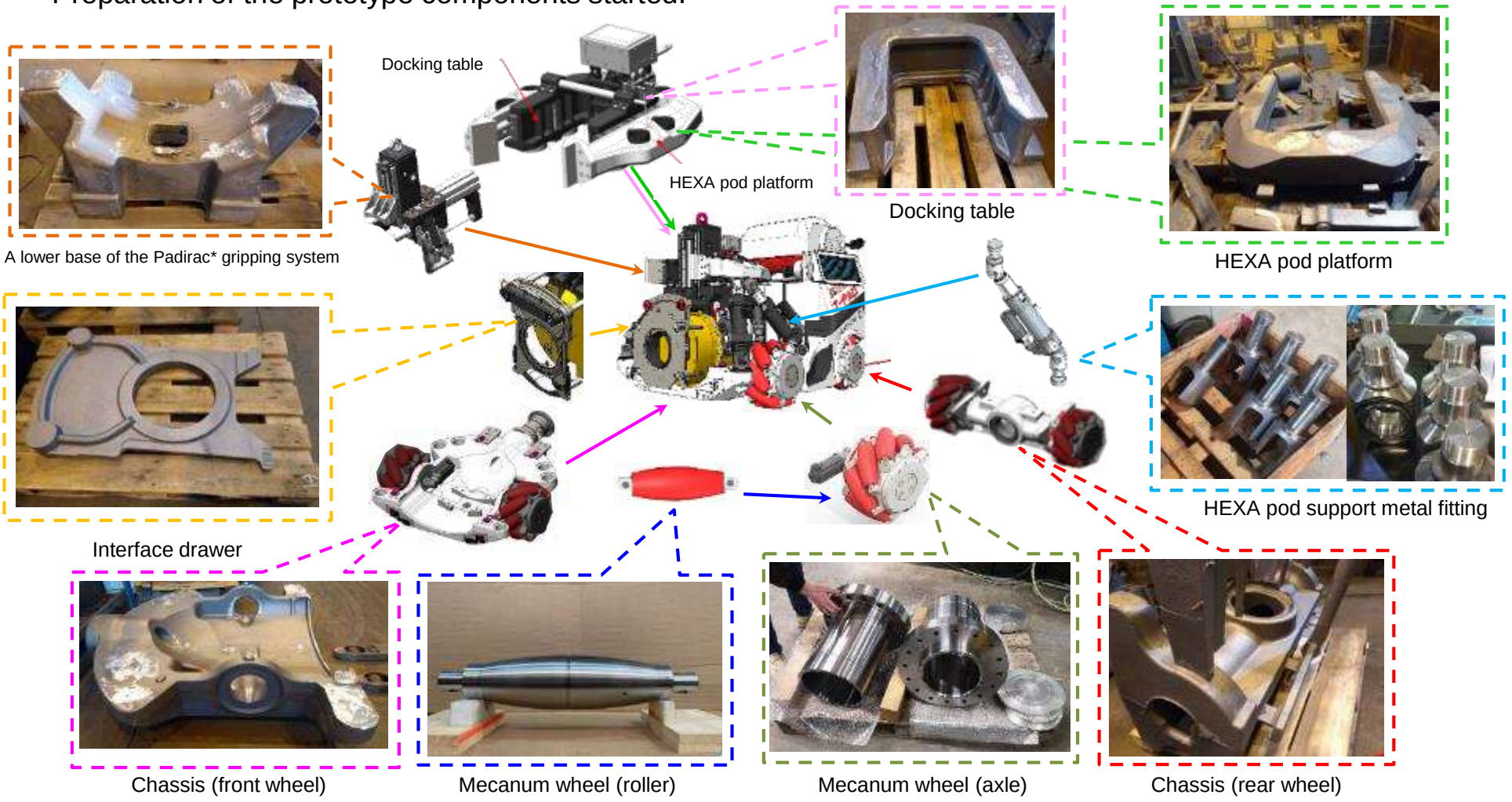
5.4 Development of remote-operated transport carriage to contain fuel debris

5.4.1 Remote-operated transport carriage for fuel debris container

Project started in FY2020

【 Achievements for FY2020 】

Preparation of the prototype components started.



*) Trade name of a small container for radioactive contaminated materials)

6. Summary and future plan (1/4)

Project started in FY2019

- Implementation items started in FY2019 -

1. Technological development and retrieval planning for gradually increasing the retrieval scale of fuel debris

▶ Development plan and updates of equipment and system for gradually increasing the retrieval scale of fuel debris（5.1.1）

- To meet the requirements concerning the project of technological development for gradually increasing the retrieval scale of fuel debris planned by TEPCO HD., maintenance performance of the access equipment, layout and remote-operated decontamination method of the enclosure, and replacement method of the Dexter* manipulator were studied.
- The suspending structure of the remote-operated transport carriage for fuel debris container was reviewed.
- The development plan will be continuously updated at an appropriate timing. Currently, knowledge obtained from verification tests of the arm for detailed investigation inside the PCV will be acquired accordingly, and updated when a technological issue and a result of the verification test for the Dexter* manipulator are clarified.

▶ Planning and updates of the entire scenario from viewpoint of the safety and systems（5.1.2）

- The study has started on carry-in /out cells to be arranged in the site and delivery interfaces for the debris samples collected from the PCV to be transferred to the hot cell in the analysis facility. Coordination among relevant project parties has started based on specific work.
- As stated above, the scenarios will be updated.

Texts in purple: Future responses

*1) A trade name of the dual-arm type remote-operated manipulator system

6. Summary and future plan (2/4)

Project started in FY2019

- Implementation items started in FY2019 -

2. Development of equipment and system for gradually increasing the retrieval scale of fuel

▶ Development of equipment and systems for gradually increasing the retrieval scale（5.2.1）

① Access equipment of fuel debris retrieval (the arm and the enclosure)

- A dual-arm manipulator (Dexter*) that is to verify fuel debris handling operation by the manipulator in the enclosure was manufactured.
- The handling operation to be verified was visualized by 3D-CAD. Currently, operability of the manipulator is being verified.
- The verification of the manipulator will be completed in the first half of FY2021.

② Equipment of establishing the access route for fuel debris retrieval (X-6 penetration connection structure, etc.)

- On the basis of basic design made in FY2019, effective methods confirmed by the mock-up test conducted by the project of Development of Detailed Investigation inside the PCV were integrated and a prototype equipment was manufactured. In addition, in-factory verification plan was summarized.
- The in-factory verification will be performed in the first half of FY2021 to confirm the feasibility of the equipment.
- The X-53 penetration was utilized and conceptual studies on cleaning technology for the arm in the PCV, its installation method, installation of monitoring camera to overview the arm motions in the PCV were summarized.
- The necessity of the X-53 penetration will be considered if there are new needs and technological seeds.

Texts in purple: Future responses

*1) A trade name of the dual-arm type remote-operated manipulator system

6. Summary and future plan (3/4)

Project started in FY2019

③ Fuel debris cutting and collecting equipment (for collecting pebble-like/sandy fuel debris, for cutting and collecting powdery fuel debris, and for cutting and collecting cylindrical fuel debris)

- On the basis of improvement items identified in FY2019, four kinds of improved collection prototype equipment were verified and its effectiveness was confirmed.
- The verification test in combination with the arm will be performed and necessary improvement will be made accordingly.

④ Neutron monitoring system (for monitoring criticality approach, etc.)

- A prototype of the neutron monitor that is operated with SiC neutron semiconductor detector for regular monitoring and prediction monitoring was manufactured.
- The in-factory verification test plan was examined to confirm neutron detecting performance and the verification test was prepared.
- Two kinds of neutron monitors will be fabricated and the in-factory verification test will be completed in the first half of FY2021.

⑤ Remote-operated transport carriage for fuel debris container

- Detail design of the remote-operated carriage was performed and the feasibility of design including accessibility of narrow spaces in the building (passage), stability with the mecanum wheel when running on uneven floor was confirmed. Additionally, the drawings were created and preparation work for manufacturing completed.
- The prototype will continue to be manufactured in the project started in FY2020.

Texts in purple: Future responses

6. Summary and future plan (4/4)

Project started in FY2020

- Implementation items started in FY2020-

3. Development and design of element technology for access equipment of fuel debris retrieval (the arm, the enclosure and etc.)（5.3）

- ▸ **Element technology to be equipped with the retrieval arm（5.3.1）**
  - On the basis of basic design conducted in FY2019, design specifications of the retrieval arm was examined.
  - According to the above design specifications, specifications of a prototype including telescopic arm and the telescopic arm head were developed and manufacturing of the prototype launched.
  - A prototype of the front part of the arm will be manufactured and in-factory verification of the prototype will complete by the end of FY2021.
- ▸ **Element technology to be equipped with the retrieval enclosure（5.3.2）**
  - Requirement specifications of the double door system was set.
  - A rock-pin durability test of the double door system and element test of the door management mechanism were conducted and their applicability were confirmed. The result of the element test will be reflected into the design of manufacturing a prototype.
  - A prototype of the double door system will be manufactured and in-factory verification will complete by the end of FY2021.
- ▸ **The entire design of the access equipment for fuel debris retrieval (the arm, enclosure and etc.)（5.3.3）**
  - On the basis of requirement specifications of the access equipment for the project of technological development for gradually increasing the retrieval scale of fuel debris studied by TEPCO HD., the entire design of the arm type access equipment and the enclosure for the development target of this project were examined.
  - Design of the enclosure was integrated into a layout that is considered by TEPCO HD.
  - A new project will conduct a trial manufacture and in-factory verification of the arm and the enclosure.

4.Development of remote-operated transport carriage for fuel debris container (5.4)

- ▸ **Remote-operated transport carriage for fuel debris container（5.4.1）**
  - Manufacturing of the transport carriage started. In-factory verification for FY2021 is being performed.
  - A prototype of the remote-operated transport carriage will be manufactured and in-factory verification will be completed by the end of FY2021.