The Decommissioning Research and Development Plan for FY2026

List of Individual Decommissioning Research and Development Plans for FY2026

Engineering and Investigation of Next Measures by Operating Entities

[B]Scaling up Retrieval of Fuel Debris

[B1] Work Environmental Improvement Inside of Reactor Building

- **[B1] Development of Technologies for Work Environmental Improvement in Reactor Building (~FY2027) (New)**

[B2] Investigation Inside of PCV/RPV, Fuel Debris Characterization

- **[B2②] Development of Investigation Technology of Inside of RPV (~FY2027) (New)**
- **[B2③] Development of Analysis and Estimation Technology for Characterization of Fuel Debris (~FY2026) (New)**

[B3] Retrieval Equipment, Ancillary Systems, Maintenance Equipment, Storage Equipment

- **[B3①] Development of Fuel Debris Retrieval Method (~FY2027) (Partially new)**
- **[B3②-2] Development of Analysis Technology for Contamination Monitoring (~FY2027) (New)**
- **[B3②-3] Development of Technologies for Assessment of Dust Dispersion Impact (~FY2026) (Continued)**
- **[B3②-4] Technology Development of Analytical Method for Exposure Dose Evaluation (~FY2026) (Continued)**
- **[B3④] Development of Technologies for Containing, Transportation and Storage of Fuel Debris (~FY2026) (Continued)**

[B4] Common Technology
Development of Technology for Practical Use of Robots Equipped with Physical AI in Remote Works under Harsh Environment (~FY2027) (New)

[C] Waste management

- **[C] Research and Development of Processing and Disposal of Solid Waste (~FY2027) (new)**

legend

- Research and Development Supported by METI

B1：Development of Technologies for Work Environmental Improvement in Reactor Building (New)

Purpose

Towards the scaling up retrieval of fuel debris and internal structures, technology development related to work environmental improvement shall be implemented as it is necessary for the safe and efficient work inside the Reactor Building(R/B) where there are still places with the damage status caused by the accident is unknown and the dose rate is still high.

Implementation Content

- ○Targeting Unit 3, TEPCO is considering concrete plan which include process up to full-scale retrieval based on recommendations of “Subcommittee on the Evaluation of Fuel Debris Retrieval Methods” etc. Regarding the task of work environmental improvement for a preparatory work, necessary technologies shall be developed. Also, environmental improvement work that may be required during the fuel debris retrieval period, including for other units, shall be considered as needed.
- ○As a task inside the reactor building in order to reduce dose and secure work areas, it is necessary not only to address locations where work difficulty is extremely high such as high places and narrow areas, but also to safely and reliably proceed with countermeasures (e.g. removal, etc.) for high-dose piping at low elevation at an early stage. In addition to remote monitoring and removal operation system for removal of PCV penetration pipes, etc. , development shall be carried out through surveys, investigations, examination, etc. to enable field application of non-destructive investigations inside low elevation piping such as PCV penetration pipes, etc.
- ○This research and development shall reflect operators’ point of view and the results of this research shall be used in the engineering conducted by the operating entity.

1.Development of Systems for Remote Monitoring and Removal Operation for Removal of PCV Penetration Pipes

Pipes etc. penetrating PCV have a high dose part where pipes, devices and facilities are crowded in the narrow area and there is a possibility that contaminated fluid, hydrogen etc. are included. In order to conduct safe and certain removal operation for crowded pipes etc., it is required to stabilize posture of the remote access device for narrow spaces and conduct operations by the position control with high accuracy, as well as coordinate appropriate operation with prevention of fluid leakage and the operation monitoring device. In addition, for the removal operation inside of R/B, the following operations are necessary: preparatory operations such as survey/measuring operation, arrangement of materials and equipment, on-site curing, collecting internal matters from inside of the pipes and post-processing operations such as containing, transportation etc. Since the staff engaged in monitoring and these operations tend to have higher exposure dose, an operational system which will minimize human intervention in the operating area by means of remote monitoring etc. is required.

Therefore, in order to remove PCV penetration pipes etc. inside of R/B, remote removal operation system collaborated with autonomous remote monitoring of the works status shall be developed. PCV penetration pipes etc. in each unit shall be surveyed, and the operating method and system specification based on the contents of on-site works corresponding to the series of removal process from preparation to post-processing shall be surveyed and investigated, so the necessary functions and elemental technologies for the remote monitoring and removal operation system shall be extracted. Further, after setting the development tasks basing on the existing technologies, a prototype shall be manufactured and elemental tests shall be conducted as well as on-site applicability shall be verified and investigated through combination tests corresponding to the series of process using simulants. Furthermore, specifications and operation methods of remote monitoring and removal operation system shall be proposed for the actual operations corresponding to the tasks extracted by the evaluation.

Also, regarding piping investigation technology in the low elevation on the 1st floor of the Unit 3 reactor building on-site demonstration plan will be considered including investigation of targeted piping, examination of drive unit etc.

B1：Development of Technologies for Work Environmental Improvement in Reactor Building (New)

2. Development of technologies for non-destructive investigation inside the PCV penetration pipes etc.

Technologies for non-destructive investigation inside pipes shall be developed in an efficient, safe and reliable manner, targeting low elevation piping such as PCV penetration pipes located in narrow areas inside the Unit 3 reactor building.

Regarding component technologies (transfer technologies (e.g., travel device, etc.) and measurement technologies (onboard measuring device, etc.)) possessing functions (from the point of view of remote control, mobility radiation resistance, ability to detect and discriminate radioactive source locations and internal contents etc.) necessary for obtaining information on items such as radioactive source locations inside pipes, inclusions (remaining water etc.), design shall be considered including their interfaces. Demonstration-level test and verification and evaluation of the on-site applicability shall be conducted for the developed technology. In addition, applicability to other units and to piping-like equipment shall also be investigated.

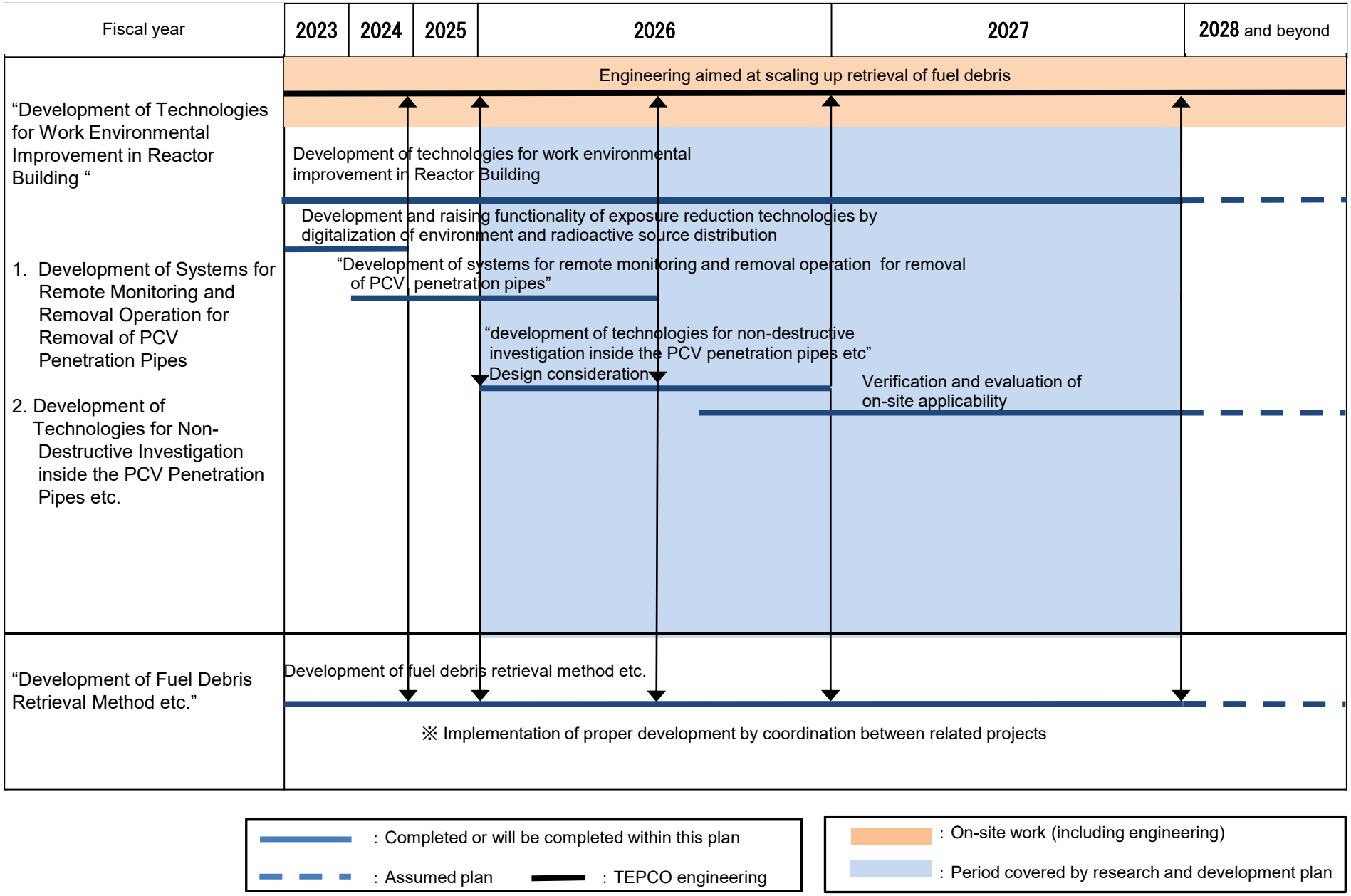
(Notes)
Under this project development shall be conducted considering the following handling characteristics and maintenance methods:

- It should be basically performed via remote control because it should be performed in a high dose area
- It is necessary to consider contamination and decontamination of the equipment
- The work areas for maintenance are limited
- Waste generated by maintenance operation should be minimized

Definition of criterion for judgment on objective achievement

- Evaluation of on-site applicability and proposal of specifications of systems for remote monitoring and removal operation for removal of PCV penetration pipes etc., planning of on-site demonstration of low elevation piping investigation technology (FY2026)
- Completion of design consideration for technologies for non-destructive investigation inside pipes such as PCV penetration pipes (FY2026), verification and evaluation of on-site applicability through the examination (FY2027)

（Implementation schedule）B1：Development of Technologies for Work Environmental Improvement in Reactor Building



B2②: Development of Investigation Technology of Inside of RPV（New）

Purpose

In order to contribute to consideration concerning fuel debris retrieval from inside of Reactor Pressure Vessel (RPV), the investigation technology for grasping the situation with fuel debris etc. inside of RPV shall be developed

Implementation Content

○In order to verify the situation inside the RPV including internal conditions, radiation dose etc. ensuring confinement functions by remote operation under the environmental conditions of high radiation, high contamination etc., the drilling device to construct an access route (new opening work etc.) and the device and system to carry investigation equipment into RPV shall be developed.

○This research and development shall reflect operators' point of view and the results of this research shall be used in the engineering conducted by the operating entity.

1.Development of Access-from-Top Investigation Method through Small-Diameter Top Opening

There is a plan of investigation(video etc.) inside of RPV (assuming Unit 3) through Access-from-Top Method: considering the allowable load on the operation floor small cells shall be installed and a small-diameter (up to about 400 mm) opening shall be drilled with the spent fuel removal facilities and radiation shields remain in place on the operation floor. Therefore, referring to Access-from-Top Investigation Method developed until FY2019, together with equipment miniaturization (including improvement) elemental technologies (Perforation mechanism to Shield plug, PCV head, RPV head and Steam-water separator, also Horizontally moving mechanism to change the position of investigation equipment etc.) necessary for construction of access route requiring a smaller amount of processed structure shall be developed.

2.Development of Technology for Access-from-Top/Side Investigation Method

Until FY2025 Access-from-Top/Side Investigation Method was developed. This method means drilling from side PCV head and RPV head from dryer separator (DS) pit, penetration inside RPV and investigation. From the outside shroud investigation method which was examined until now, there shall be developed methods and equipment to enable investigation after further shroud drilling and access inside reactor core, and also investigation of reactor bottom via jet pump of annulus region.

3.Development of Technology for Access-from-Bottom Investigation Method

Until FY2025 investigation method was developed to access by robot arm inside pedestal through X-6 penetration / CRD opening and to investigate inside RPV stretching with flexibility by Access-from-Bottom investigation device (telescopic pipes etc.) through RPV bottom(assuming the opening is existed). Aiming to expand applicability for access device (arm etc.) where this device can be installed, together with device miniaturization and weight reduction device with improved attitude control shall be developed.

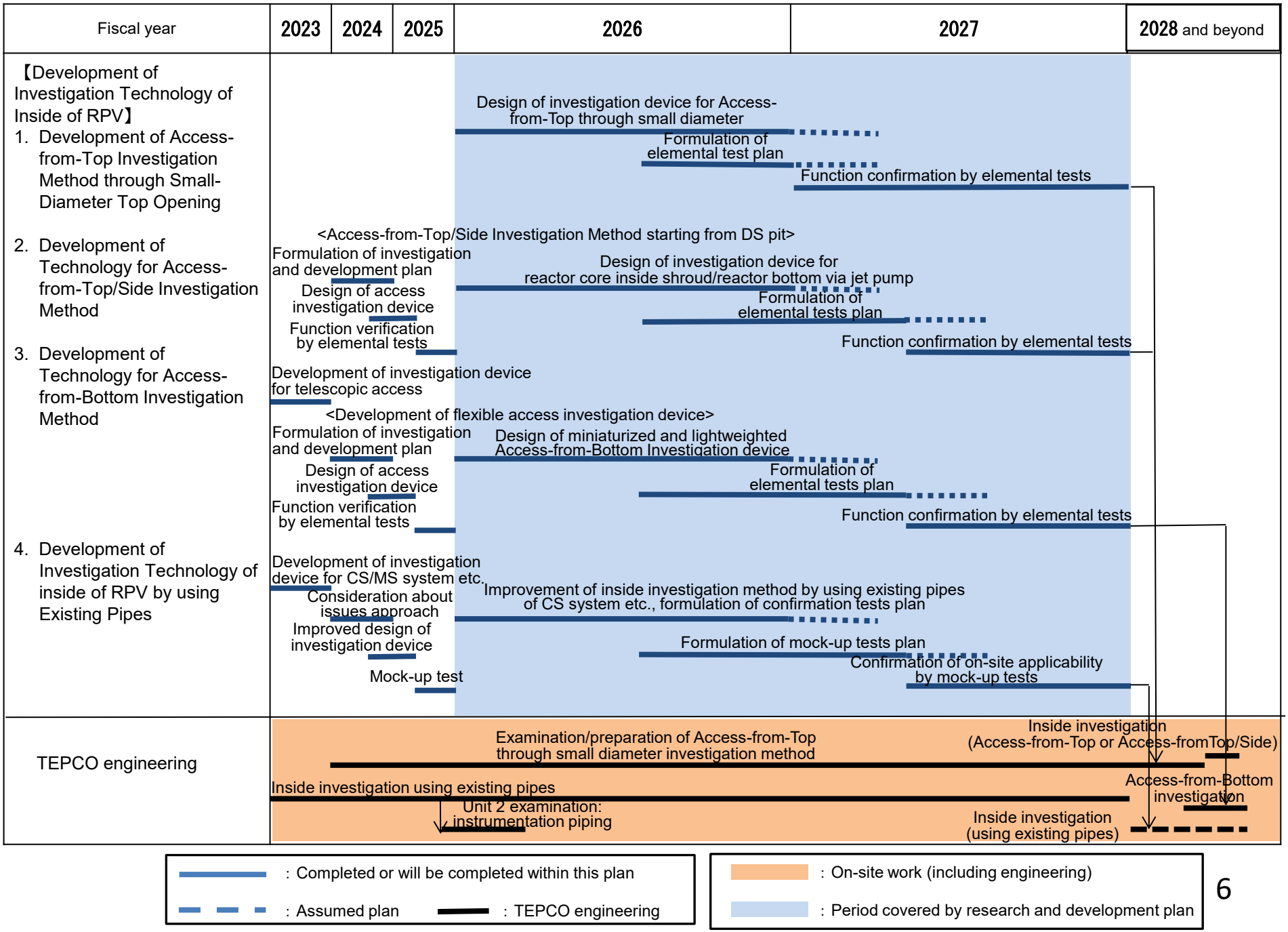
4.Development of Investigation Technology of inside of RPV by using Existing Pipes

Until FY 2025 method of investigation inside RPV by using existing pipes of core spray (CS) system and main steam (MS) system was examined and perspective for main technical problems (boundary construction, processing methods, mobility of investigation device inside pipes etc.) solution was gained. Moreover, examination and technology development shall be conducted regarding issues of on-site applicability (influence of rust, deposits and obstacles etc. inside pipes, workability and safety of boundary construction etc.).

Definition of criterion for judgment on objective achievement

- Formulation of small-diameter top opening investigation device design and elemental test plan (FY2026), function confirmation by tests (FY2027)
- Design of device for investigation of reactor core inside shroud by Access-from-Top/Side Investigation Method starting from DS pit (FY2026), function confirmation by elemental tests (FY2027)
- Design of Access-from-Bottom Investigation device which was miniaturized and lightweighted (FY2026), function confirmation by elemental tests (FY2027)
- Improvement of inside investigation method using existing pipes, formulation of confirmation tests plan (FY2026), confirmation of on-site applicability by tests (FY2027)

(Implementation schedule) B2②: Development of Investigation Technology of Inside of RPV



B2③: Development of Analysis and Estimation Technology for Characterization of Fuel Debris (continued)

Purpose

In order to contribute to the development of retrieval method of fuel debris and internal structures and technologies for containing, transportation and storage of fuel debris, technology required for quantitative analysis of components and estimation for characterization of fuel debris shall be developed.

Implementation Content

○Fuel debris generated by unprecedented BWR core meltdown accident have heterogeneous compositions affected by a reaction with concrete and seawater injection etc. and include many poor solubility isobars and fission products. Therefore, technology for analysis and estimation aimed at characterization of fuel debris which include many uncertainties such as formation process shall be developed.

○The estimation technology for fuel debris characterization shall be developed using analysis and evaluation of on-site samples, then the methods of estimation for characterization of fuel debris and display of PCV internal damage condition shall be sophisticated and also analysis accuracy shall be improved.

○In order to realize safe and efficient retrieval and storage of fuel debris, the technologies for abbreviated analysis of the existence of fuel components and for non-destructive determination of fuel content in fuel debris shall be developed.

○The results of this research shall be used in the engineering conducted by the operating entity.

1.Development of Analysis and Estimation Technology for Characterization of Fuel Debris

(1) In order to implement safety assessment of criticality control, storage management etc. for fuel debris retrieval, it is necessary to understand fuel debris properties, but fuel debris generated by BWR accident is unprecedented. It is difficult to analyze fuel debris characterization because of their insolubility and inclusion of many isobars and fission products in addition to reaction with concrete, sea water injections and unknown temperature history during the formation process. In order to clarify chemical composition of fuel and fission products in fuel debris as well as isotope ratios, elements mapping, metal structure, crystal structure etc., technology of analysis for fuel debris shall be developed. Furthermore, fuel debris obtained in trial retrieval or samples of sediments and deposits obtained by internal investigation shall be transported to research institutes with hot lab facilities and mentioned above items shall be analyzed.

The analysis of samples obtained from reactor building of Fukushima Daiichi Nuclear Power Station shall be given highest priority, and to improve analysis accuracy comparative data shall be obtained. For example, using the fuel debris from the accident of the US Three Mile Island Nuclear Power Station Unit 2 as a sample for analysis, pretreatment process shall be made more efficient, exposure reduction measures during handling etc. shall be examined, and at the same time comparative data shall be obtained. Comparing and examining data of analysis of fuel debris of Fukushima Daiichi Nuclear Power Station and Three Mile Island Nuclear Power Station, the fuel debris generation process and the accident progression shall be estimated, and it shall be reflected in examination of safety measures and storage management. And the results of analysis and evaluation shall be provided for various decommissioning processes related to fuel debris retrieval.

By attending global round robin tests for simulant of fuel debris analysis, it should be confirmed that Japan has sufficient abilities for fuel debris analysis and at the same time knowledge of analysis and evaluation of foreign research institutes shall be acquired.

・Regarding mentioned above, the discussions shall be held with the participation of Japanese and foreign experts in order to proceed while adopting knowledge from these discussions.

(2) The data acquired in the previous investigation inside PCV mainly consists of images/pictures and air radiation dose rate, but the routes where the melted fuel flowed down, locations with large portions of fuel etc. are not clear. For effective retrieval of fuel debris, damaged areas, damage situation and location where the fuel has fallen inside PCV shall be identified. Based on new findings from sample analysis, inside investigation, reproduction test etc. consistency with accident progression analysis shall be evaluated. Especially, on the inside of the concrete pedestal of Unit 1, the rebars and inner skirt are exposed, which is different from what was assumed regarding molten core – concrete interaction (MCCI). Also, there is a lot of sediments outside of the concrete pedestal and the situation in the lower part of these sediments is unclear.

B2③: Development of Analysis and Estimation Technology for Characterization of Fuel Debris (continued)

Along with analysis and evaluation of fuel fall locations, temperature rise inside pedestal, reaction with concrete, molten material situation, etc., the situation with fuel distribution shall be estimated. For effective display and understanding of obtained results, the estimation chart of the state inside of PCV shall be prepared in three-dimensional CG.

2.Development of Technology for Abbreviated Analysis and Non-destructive Measurement of Fuel Debris

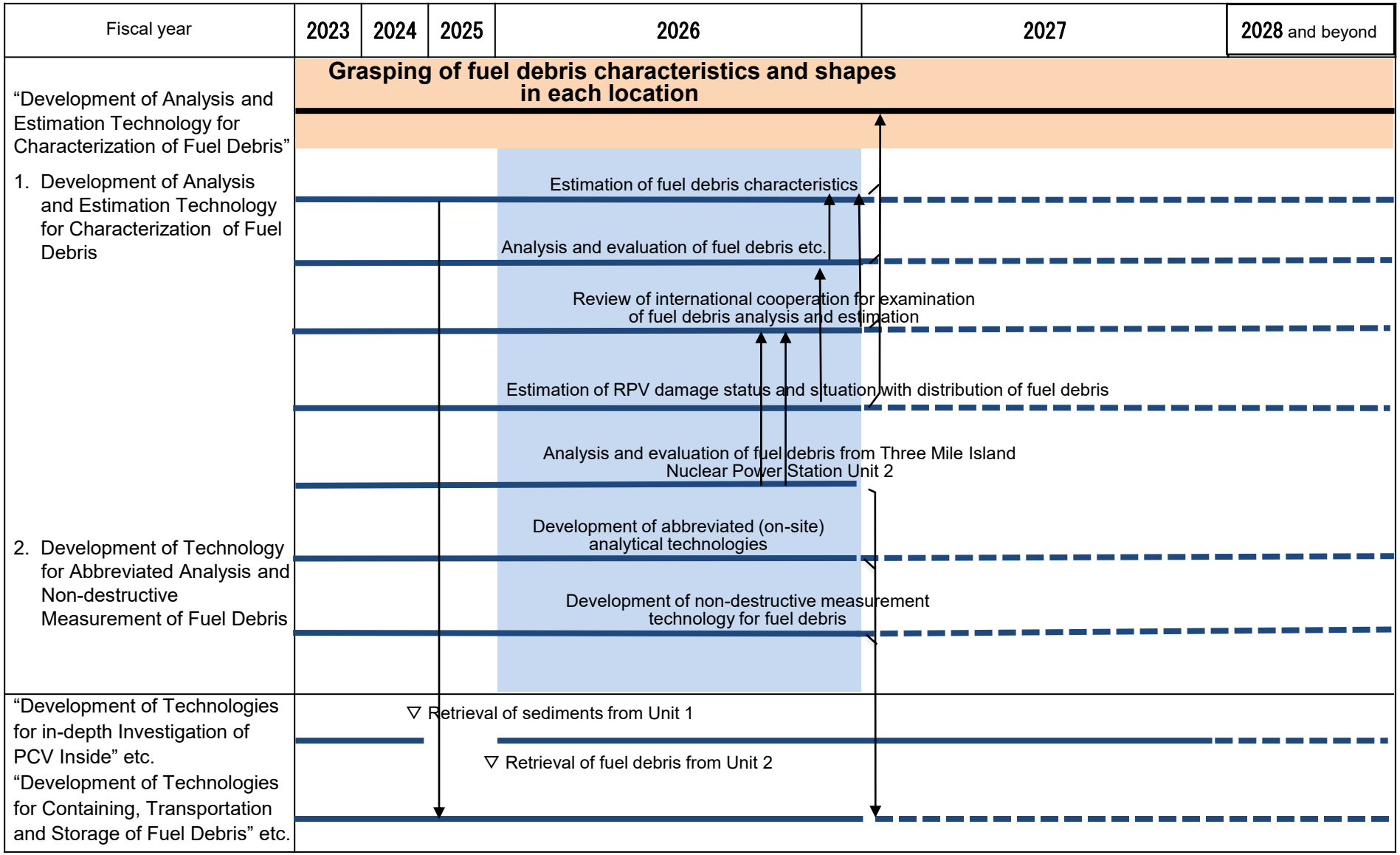
(1) In order to confirm that fuel is included in applicable objects during fuel debris retrieval works, each time it is necessary to transport them to hot lab facilities and analyze. As some time and resources are needed for transportation to hot lab facilities, it shall impede quick retrieval works. So in order to reduce the burden of transportation of fuel debris to hot lab facilities, abbreviated (in-situ) analysis technology shall be developed for prompt confirmation of the existence of fuel components as an adhesion to PCV structures or penetration into them. Regarding high radiation level samples or environment along with accumulation of knowledge and result of uranium qualitative analysis detection efficiency shall be improved, and for detection of fuel components for contamination countermeasures during measurement necessary sophistication shall take place. Considering combination with tools used in internal investigation, the abbreviated analysis devices for long time stable operation in the on-site environment affected by high radiation and humidity shall be sophisticated.

(2) Fuel debris release highly volatile cesium during melting, so it is difficult to apply the methods for estimation of fuel burn-up based on the gamma-ray from cesium. Due to these individual characteristics of fuel debris, there are concerns about direct application of non-destructive measurement methods used at reprocessing facilities etc. So non-destructive measurement method shall be selected upon comprehensive judgement based on measurement confirmation tests using simulated fuel debris, simulation calculation, results of deposits and adherents analysis, properties of indicator nuclides etc. While using the selected non-destructive measurement method, improvement of detection efficiency and accuracy, effect of container shape etc. shall be examined. Also, scenarios of non-destructive measurement and items of abbreviated screening shall be examined. Based on it, in case of construction of series of non-destructive measurement systems feasibility shall be examined and their effectiveness shall be evaluated. Creation of design for manufacturing of non-destructive measurement device aimed at on-site application shall start.

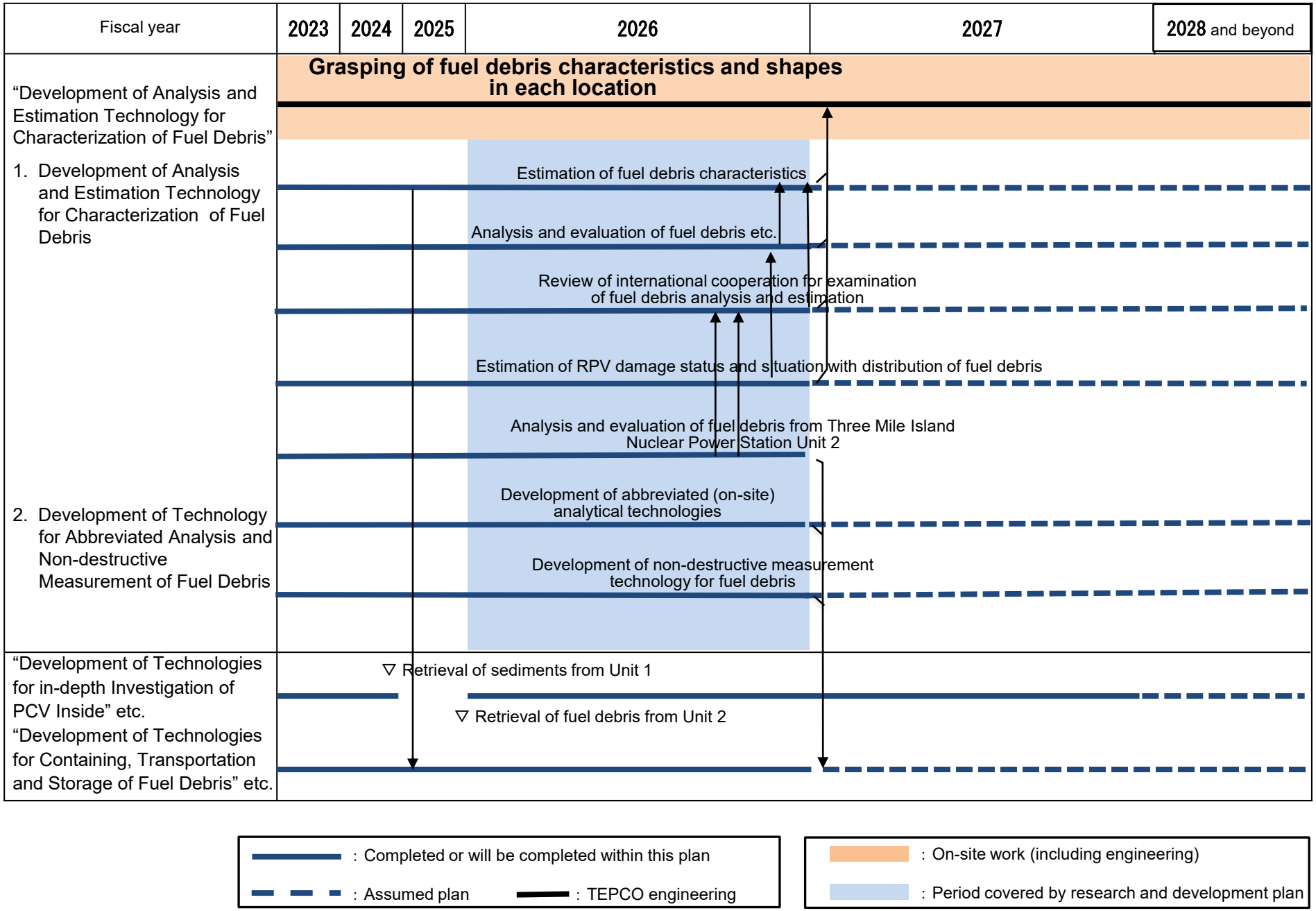
Definition of criterion for judgment on objective achievement

- Analytical evaluation of 1F fuel debris (FY2026)
- Analytical evaluation of Three Mile Island Nuclear Power Station Unit 2 debris (FY2026)
- Improvement of detection efficiency in the chosen non-destructive measurement method, container influence evaluation (FY2026)

(Implementation schedule)B2③: Development of Analysis and Estimation Technology for Characterization of Fuel Debris



(Implementation schedule)B2③：Development of Analysis and Estimation Technology for Characterization of Fuel Debris



B3①: Development of Fuel Debris Retrieval Method (partially new)

Purpose

Towards scaling up retrieval of fuel debris and internal structures, development of elemental technology and tests necessary for retrieval method feasibility shall be conducted and on-site applicability shall be evaluated.

Implementation Content

○Since FY2024, based on proposals etc. regarding the selection of methods indicated in the Report of “Sub-committee for the evaluation of fuel debris retrieval methods”, TEPCO proceeded with design considerations and under certain assumptions summarized the results of the considerations. Also, verification of assumed conditions is underway. In these considerations, technology necessary for the tasks related to feasibility of retrieval methods shall be developed.

○Among the tasks related to extracted feasibility , technology shall be developed for continuous effective collection of granular fuel debris deposited at the bottom of PCV.

○As a common task for the methods the aim is to develop neutron detector that can be used for inside investigation etc., which will be smaller and lighter than existing detectors. For this purpose elemental technology shall be developed and feasibility shall be evaluated by detector trial manufacturing.

○This research and development shall reflect operators’ point of view and the results of this research shall be used in the engineering conducted by the operating entity

1.Development of Partial Submersion Method

(1) Development of technologies for continuous fuel debris collection

Technology shall be developed for continuous effective collection of granular fuel debris deposited at the bottom part of PCV. As a conceptual examination of continuous collection system, scenarios of fuel debris retrieval at the bottom of PCV and preconditions (distribution of fuel debris, characteristics and collection locations, PCV water level etc.) shall be organized, safety requirements and functions shall be examined, structure of continuous collection system shall be investigated, methods of removal of obstacles inside pedestal and methods of equipment placement, access routes, construction etc. shall be examined. Also, as a development o elemental technology for this system, processing methods, collection methods, solid-liquid separation methods, etc. shall be examined and verification by trial manufacturing and tests shall be conducted. Finally based on a result of systems’ conceptual examination and development of elemental technology, on-site applicability of this technology development shall be evaluated.

2.Development of Common Technology for Various Methods

(1) Development of Compact and Lightweight Neutron Detectors Designed for Surveillance Purposes

It is expected that obtained for grasping on-site situation neutron measurement actual values shall be used in examination of fuel debris retrieval methods and necessary countermeasures. On the other hand, the policy is to access fuel debris through small opening and route to the pedestal area shall be extremely narrow. Therefore, neutron detector smaller and lighter than existing detectors shall be developed and by development of component technologies and detector trial manufacturing the feasibility of the project shall be evaluated. In addition, while evaluating feasibility, development tasks for entire measurement system shall be identified through measurement system trial manufacturing and comparison with existing detectors.

B3①：Development of Fuel Debris Retrieval Method (partially new)

(notes)
In the partial submersion method, development shall be implemented considering the following handling characteristics and maintenance methods:

- It should be basically performed via remote control because it should be performed in a high dose area.
- Consideration shall be given to contamination of the devices and necessary decontamination.
- The work areas for maintenance are limited.
- Waste generated by maintenance operation should be minimized.
- Criticality monitoring devices shall be installed and handled with consideration.

Definition of criterion for judgment on objective achievement

1. Development of partial submersion method

(1) Development of technologies for continuous fuel debris collection

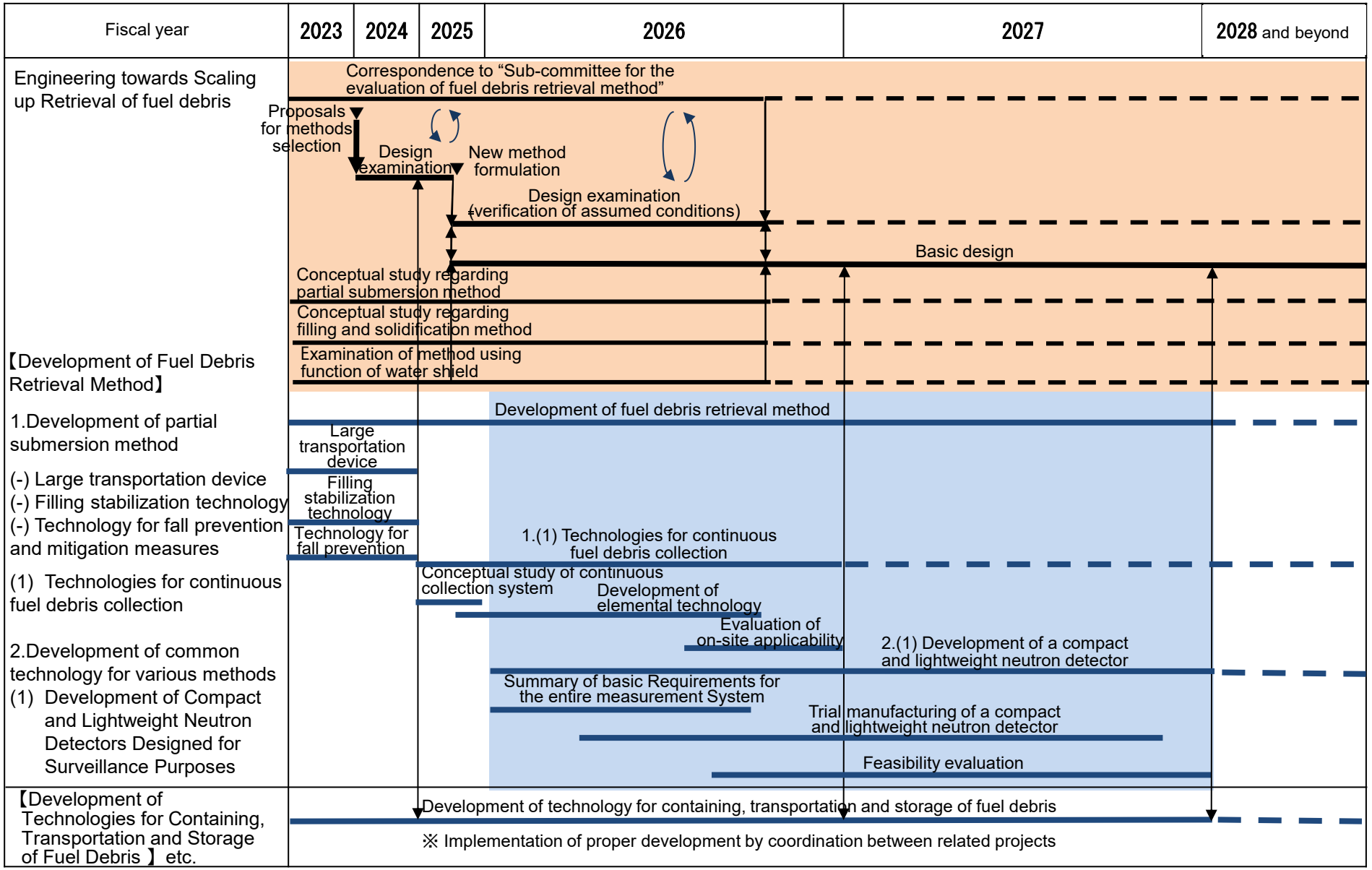
- Verification through elemental technologies (processing, collecting, solid-liquid separation, etc.) prototyping and testing (FY2026)
- Evaluation of on-site applicability (FY2026)

2. Development of common technology for various methods

(1) Development of a compact and lightweight neutron detector

- Organizing basic requirements for entire measurement system (FY2026)
- Trial manufacturing of a compact and lightweight neutron detector (FY2027)
- Feasibility evaluation (FY2027)

(Implementation schedule) B3①: Development of Fuel Debris Retrieval Method



B3②-2：Development of analytical technology for contamination monitoring (new)

Purpose

Towards scaling up retrieval of fuel debris and internal structures, technology development required for efficient contamination monitoring and ensuring of safety during works shall be conducted.

Implementation Content

○Retrieval of fuel debris is the work under the environment including uncertainty factors in addition to high radiation and high contamination. Methods of contamination analysis towards scaling up retrieval of fuel debris shall be developed.

○As there are concerns about the spread of contamination caused by fuel debris retrieval operation, it is necessary to increase the frequency of monitoring. Technology shall be developed for prompt and efficient overall analysis works including the time for pretreatment of monitoring samples.

○This research and development shall reflect operators' point of view and the results of this research shall be used in the engineering conducted by the operating entity.

1.Development of technologies for improvement of analysis acceleration and efficiency for nuclear fuel materials and elements with difficulty to analyze etc.

There are concern that when contacting with fuel debris, nuclear fuel materials and radioactive isotopes are dissolved and mixed in circulating cooling water of liquid processing system, so contamination may be distributed over a wide area in the building.

Among various types of radiation α-rays and β-rays have relatively low penetrating power and their detection in a container is difficult, so regarding samples for monitoring as the concentrations of nuclear fuel materials and radioactive elements are lower than those of fuel debris mass spectrometry shall be carried out. In mass spectrometry pretreatment like homogeneous dissolution, isobars separation etc. is important. Along with the progress of decommissioning process, the types and number of samples for contamination monitoring will increase. So in overall analysis process including pretreatment like dissolution, separation etc. it is necessary to develop technology for acceleration, automation and laborsaving, in order to improve efficiency of analysis works, and to conduct rapidly monitoring inside the building. For this purpose simultaneous multielement analysis technology shall be developed for highly efficient separation and detection of nuclear fuel materials and radioactive isotopes as a target contained in samples.

Regarding nuclear fuel materials such as U and Pu which emit α-rays, there are many elements that become cations, and regarding iodine, chlorine etc. which emit β-rays there are many elements that become anions. As they exist as ions in solution because of dissolution, the following technologies shall be developed to respond to their chemical characteristics:

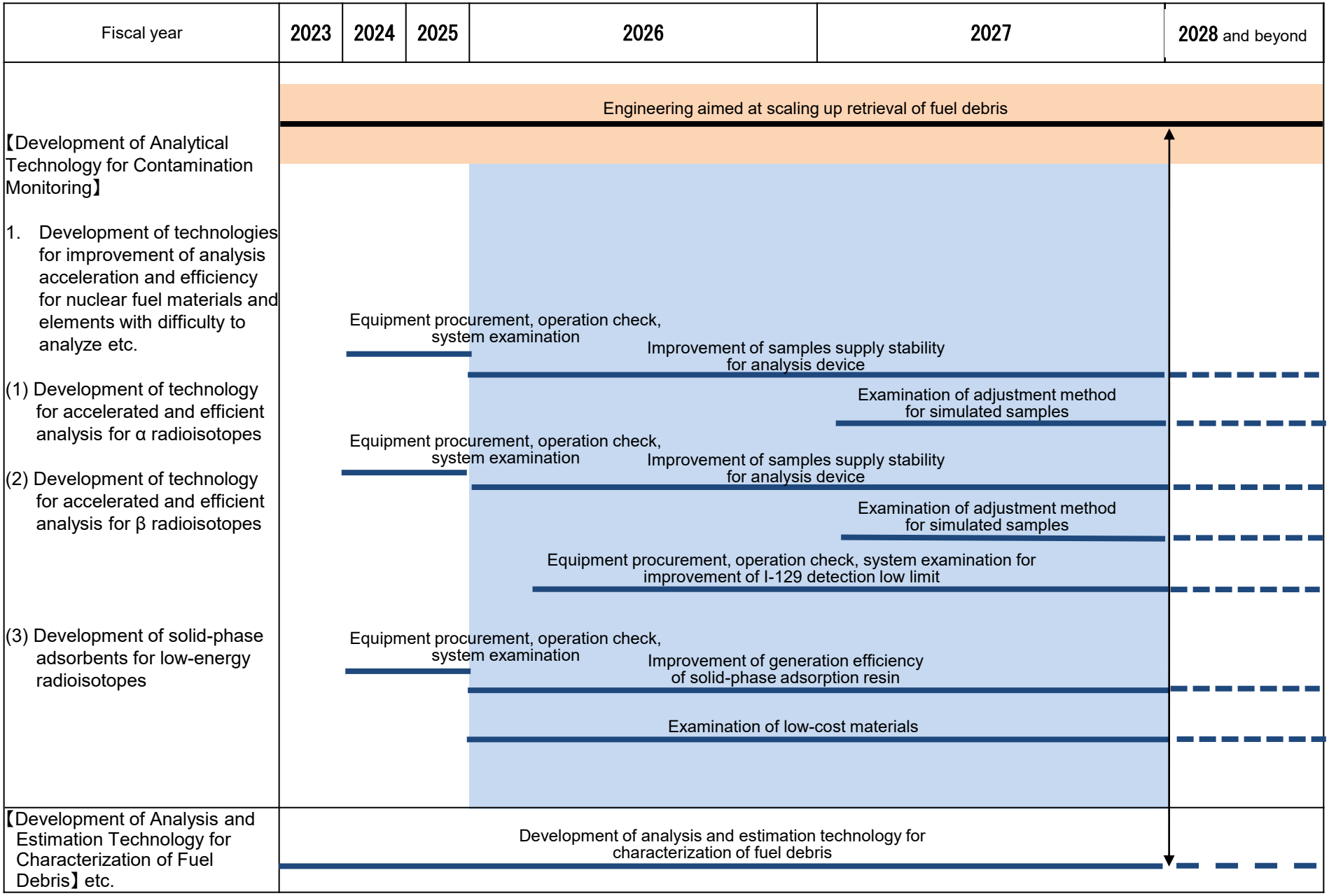
- accelerated and efficient analysis for α radioisotopes
- accelerated and efficient analysis for β radioisotopes
- accelerated pretreatment of low-energy radioisotopes

Regarding pretreatment acceleration, technology to absorb or extract certain elements shall be developed. In development of this technology, control of ratios accuracy for isotopes with the same atomic number but different mass number and guaranteeing of quality of analysis are necessary so technology for finding isotope ratios shall be sophisticated.

Definition of criterion for judgment on objective achievement

- Improvement of samples supply stability for simultaneous multielement analysis device responding to chemical characteristics of α radioisotopes and β radioisotopes (FY2026)
- Examination of adjustment method for simulated samples(FY2027)
- Improvement of detection sensitivity for Iodine-129 among β radioisotopes(FY2027)
- Evaluation of adsorption ability of solid-phase adsorbents(FY2026)
- Improvement of generation efficiency of solid-phase adsorbents (FY2027)

(Implementation schedule) B3②-2：Development of analytical technology for contamination monitoring



Purpose

Towards scaling up retrieval of fuel debris, necessary for ensuring safety of retrieval works technology shall be developed for assessment of dust dispersion impact.

Implementation Content

○Regarding tests for acquisition of dust dispersion rate data assuming the environment during fuel debris processing, basing on the results of the previous projects, data shall be enriched by tests assuming processing closer to real situation.

○For the purpose to grasp the Leak Pass Factor of dust migration into environment during fuel debris processing, tests shall be conducted to understand the dependence of dispersion impact parameters.

○This research and development shall reflect operators' point of view and the results of this research shall be used in the engineering conducted by the operating entity.

1.Development of Technologies for Impact Assessment due to Dust Dispersion

① Implementation of Test on Dust Dispersion Rate Data Acquisition Assuming the Environment during Fuel Debris Processing

In FY2021・2022 (phase1) and FY2023・2024 (phase2) the dust dispersion rate data was systematically acquired regarding 5 methods (disk cutter, chiseling, core boring, laser, abrasive water jet), and factors affecting dust dispersion (dispersion rate, particle size distribution, processing defects, property values etc.) were analyzed by parametric test for each method. Also, in order to complement test results to transition rate, simulation analyses (CFD) have been performed and basic dust dispersion effects such as differences in dry/wet conditions have been organized.

In this project, regarding factors affecting dust dispersion which were grasped in previous phases, data related to on-site conditions and methods shall be obtained and expanded. Regarding cold materials and uranium -containing simulated debris tests shall be conducted in the environment (wet condition) assuming processing close to reality.

Regarding mechanical processing of uranium-containing simulated debris, basing on the results of implementation in dry conditions in previous phases, data of wet conditions shall be obtained.

In addition, laser processing test (in dry conditions) shall be conducted as a thermal processing of uranium-containing simulated debris. The purpose is to understand the effects of thermal processing on heterogeneous compositions. Fuel debris contain a heterogeneous mixture of heavy actinide nuclides such as uranium and volatile FP nuclides such as cesium, so the heterogeneous composition test pieces able to simulate it shall be used. Besides, as laser processing is also expected to be used underwater, underwater processing tests (in wet conditions) using cold materials shall be conducted to examine the phenomena of aggregation and others which are generated before dust is released into the gas phase.

With these effects of different environment conditions (dry/wet conditions) and composition conditions (hot/cold test pieces) on dust dispersion rate shall be evaluated.

② Implementation of Tests to Understand the Impact on the Leak Pass Factor of Dust During Fuel Debris Processing

It is necessary to understand the Leak Pass Factor(LPF), which represents the removal effect along the migration path from the dust generation point to its release into the environment. With relatively small systems used in previous phases, LPF cannot be verified as phenomena (gravitational settling, particle size growth, etc.) in large spaces such as those found in field conditions. Therefore, in this project, the behavior of dust shall be grasped by using several meter sizes (large size) horizontal and vertical testing equipment able to confirm the phenomena involved in the dust migration process. To assess the impact of dispersion parameters such as those identified in the dust dispersion rate data acquisition tests from the previous phases, a wet environment and other conditions shall be set up and representative processing methods shall be selected from mechanical processing and thermal processing, and data on LPF of the generated dust shall be obtained.

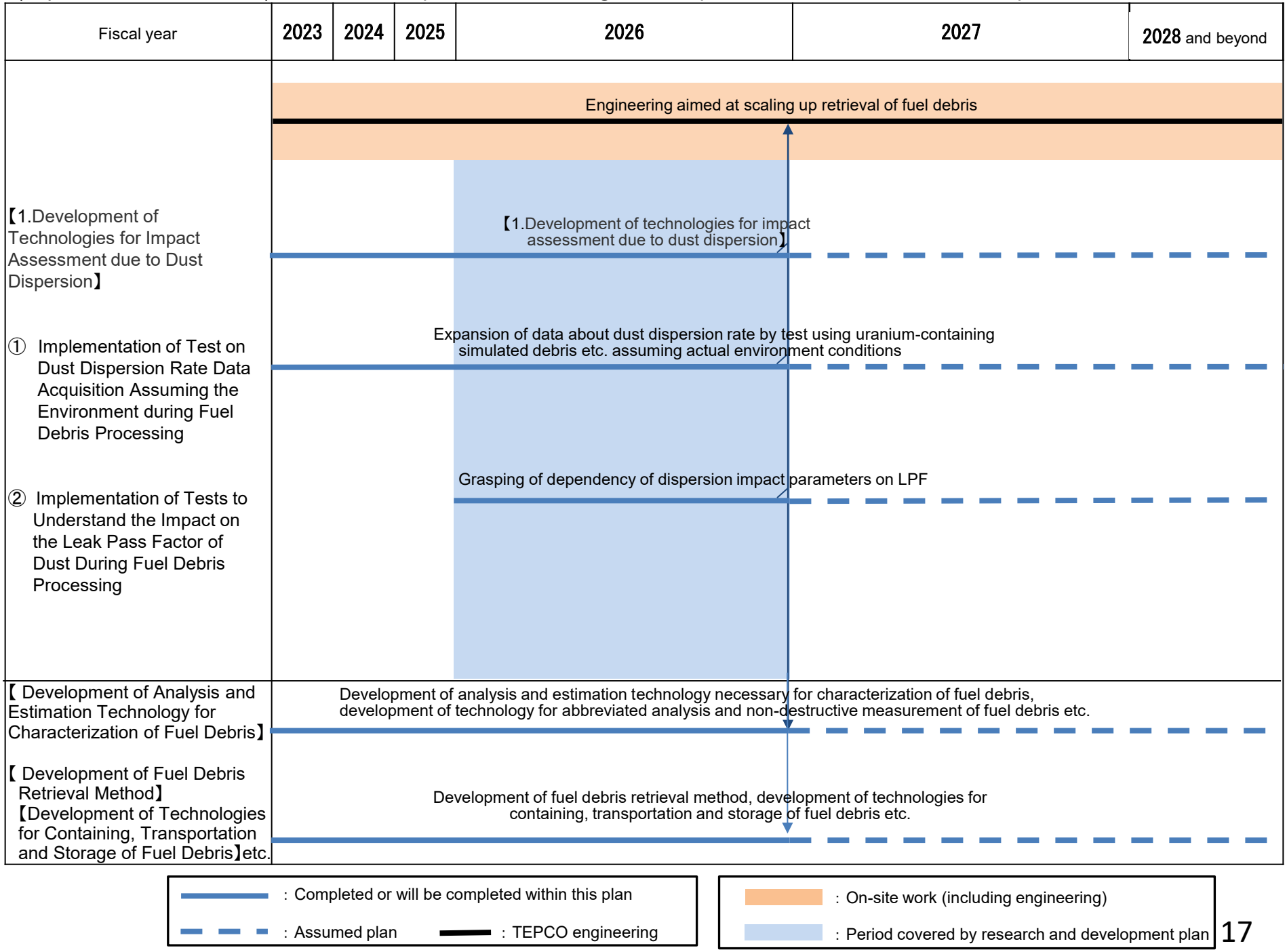
Through these efforts, the dependence of dispersion impact parameters on LPF shall be evaluated.

Definition of criterion for judgment on objective achievement

・Expansion of data about dust dispersion rate by test using uranium-containing simulated debris etc. assuming actual environment conditions(FY2026)

・Grasping of dependence of dispersion impact parameters on LPF (FY2026)

(Implementation schedule) B3②-3：Development of Technologies for Impact Assessment due to Dust Dispersion



B3②-4：Technology Development of Analytical Method for Exposure Dose Evaluation (continued)

Purpose

Towards scaling up retrieval of fuel debris and internal structures, the elemental technologies to ensure safety during these operations shall be developed and conducted the tests.

Implementation Content

○ Retrieval of fuel debris is a task that is carried out under high radiation and high contamination conditions and also involves uncertainties of environmental conditions, so it is necessary to evaluate internal exposure dose with sufficient accuracy and speed. . Towards scaling up retrieval of fuel debris, regarding methods and instruments related to bioassays and technologies for measuring and evaluating body surface contamination, investigation, examination, elemental tests shall be conducted to enable on-site application and technologies for exposure dose evaluation shall be developed.

○This research and development shall reflect operators' point of view and the results of this research shall be used in the engineering conducted by the operating entity.

1.Technology development for analytical method for exposure dose evaluation

In decommissioning operations, it is necessary to monitor large number of operators for a variety of nuclides. As methods for sufficiently accurate and rapid evaluation of internal exposure dose, until now following measures have been developed: organization of system for comprehensive evaluation of internal exposure dose using bioassay and in vitro measurements (lung monitoring etc.) appropriate standards development, technology for accelerating bioassay processes, measuring and evaluating body contamination, and technology to improve accuracy of sampling measurement by a filter paper, etc.

To address the risk of internal exposure due to intake α- and β-nuclides during decommissioning work including fuel debris retrieval etc., based on the results so far, an internal exposure dose evaluation program shall be developed through the following technological advancements:

(1) Technology development for measuring and evaluating internal exposure dose

Bioassay technologies, such as method of analysis of α nuclides to deal with the situation with a large number of operators intaking radioactivity shall be developed.

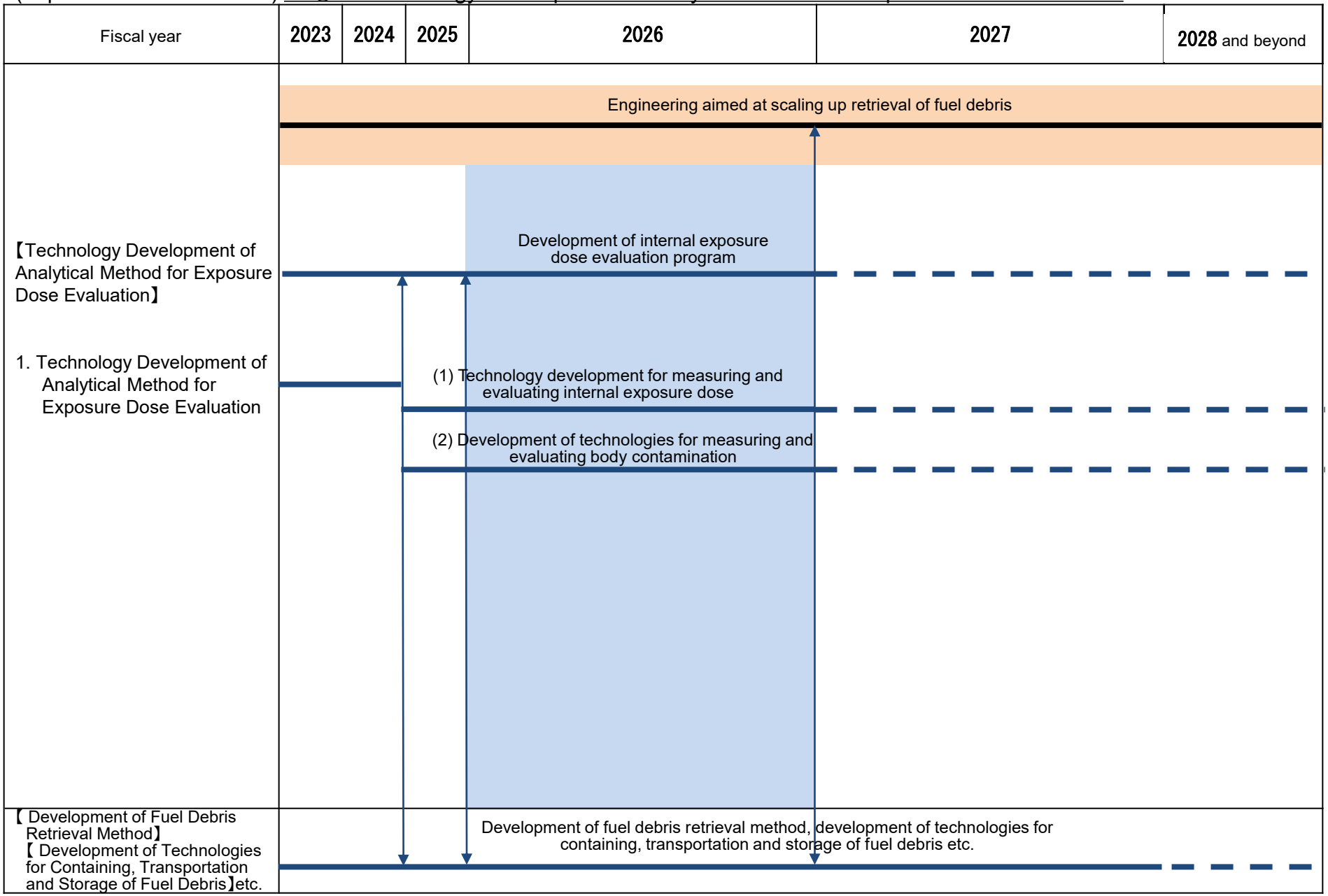
(2) Development of technologies for measuring and evaluating body Contamination

Specifications for handheld skin β-contamination detectors shall be optimized and measurement technologies in mixed α- and β-radiation environments to improve the evaluation accuracy of skin contamination shall be developed. Also, technologies for accelerating α-contamination detection on the body and ensuring reliable detection in hard-to-measure areas shall be developed.

Definition of criterion for judgment on objective achievement

- Verification and evaluation of bioassay technologies to deal with the situation with a large number of operators intaking radioactivity(FY2026)
- Verification and evaluation of detecting instruments to improve the evaluation accuracy of skin contamination(FY2026)
- Verification and evaluation of technologies for rapid and reliable detection α-contamination detection on the body(FY2026)

(Implementation schedule) B3②-4：Technology Development of Analytical Method for Exposure Dose Evaluation



B3④：Development of Technology for Containing, Transportation and Storage of Fuel Debris (continued)

Purpose

To establish scenarios for the process from fuel debris retrieval to its storage, system will be developed that ensure safe, reliable and reasonable containing, transportation and storing of the retrieved fuel debris.

Implementation Content

○Technology will be developed for establishing a system which can handle various forms (lump-shaped, granular ~ powdery, slurry/sludge state) of retrieved fuel debris with heterogeneous composition, and make possible stable storage after safe, reliable and reasonable containing and transportation, considering the hydrogen gas generated by radiolysis of coexisting water and the criticality risk associate with nuclear fuel materials. Development will be conducted in coordination with related projects.

○This research and development shall reflect operators' point of view and the results of this research shall be used in the engineering conducted by the operating entity.

1.Development of technology for handling of powdery and slurry/sludge state fuel debris

(1) Advancement of prediction method of hydrogen generation

・In addition to evaluation of hydrogen gas amount generated by γ-rays and proton beams which was confirmed up to FY 2024, hydrogen gas amount generated by α-rays will be confirmed by testing, taking into account factors that affect its generation. Furthermore, it is considered that the effect of α- and β-rays on hydrogen gas generation is expected to be relatively larger for powdery or slurry/sludge state fuel debris where specific surface area will increase than for granular or lump-shaped ones. Therefore, using the hydrogen gas generation prediction methods for each radiation type at single irradiation field, the hydrogen gas generation rate in the actual system environment (a mixed radiation field of α, β, and γ rays) will be estimated. The contribution of each radiation type will be assessed.

(2) Establishment of countermeasures for hydrogen gas accumulation based on hydrogen gas release behavior

・Generation of hydrogen gas accumulation under assumed conditions was confirmed by elemental tests up to FY 2024. Based on these results, additional elemental tests will be conducted to address the identified technical issues including effects of water quality such as pH, particle size distribution, slurry height and other relevant parameters. Using the obtained outcomes, the necessity of measures against hydrogen gas accumulation and required specific measures will be examined.

2.Technology development for maintaining the stable storage of fuel debris

・It is essential to maintain integrity of containment boundaries for safe storage of fuel debris. In order to assess the necessity of monitoring corrosion in storage containers, the environmental conditions inside the fuel debris storage container will be estimated and based on these conditions, corrosion initiation and progression models will be examined, and preparations for its verification will be carried out. These efforts will also be used for selection of future container materials and examination of the necessity of additional measures such as surface treatments etc. In addition, the necessity of monitoring of other factors besides corrosion will also be examined.

3. Re-evaluation of storage methods and storage canisters

・Based on the results of mentioned above 1., 2. the results of previous examination results of storage methods and storage canisters design for fuel debris will be re-evaluated.

※additional related research and development projects

"Development of Fuel Debris Retrieval Method", "Development of Technologies for Impact Assessment due to Dust Dispersion", "Research and Development of Processing and Disposal of Solid Waste".

Established criterion for assessing achievement (FY2026)

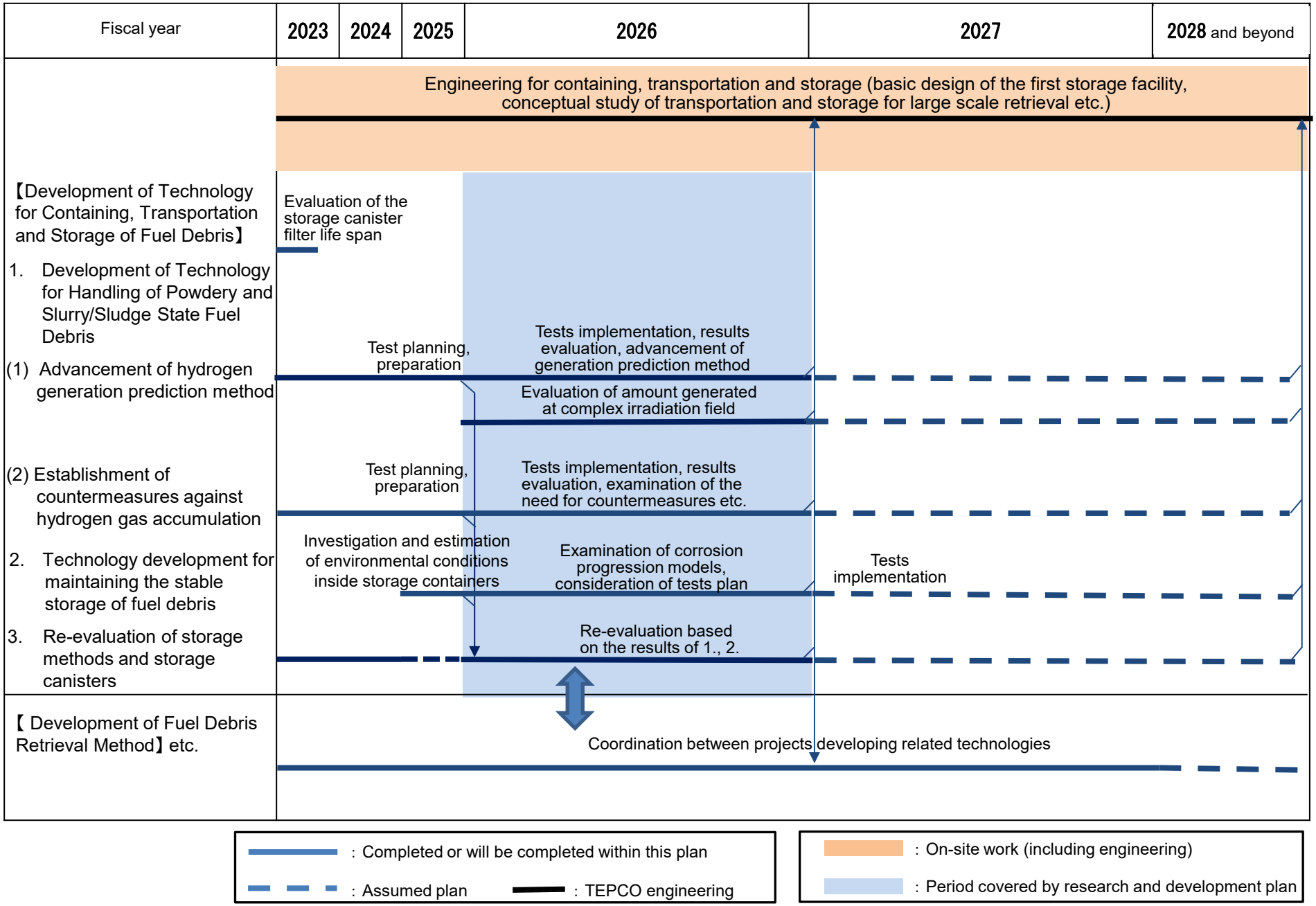
Verification of α-rays impact on hydrogen generation and evaluation of each type of radiation contribution in mixed irradiation field through estimation of the hydrogen gas generation.

・Proposal on the necessity for measures against hydrogen gas accumulation and their contents based on tests results.

・Formulation of preliminary model for initiation and progression for each type of corrosion.

・Re-evaluation of storage methods and storage canisters design for fuel debris

(Implementation schedule) B3④: Development of Technology for Containing, Transportation and Storage of Fuel Debris



B4：Development of Utilization Technology for Robots Equipped with Physical AI in Remote Operations under Severe Environments (New)

Purpose

Remote operations in severe environments, such as confined spaces, high-radiation areas, or poor visibility conditions, rely heavily on the expertise of skilled operators. Consequently, technology transfer and workforce availability remain as critical challenges to address. Furthermore, as workers are involved in the preparation stages of remote operations, issues such as ensuring efficiency and preventing radiation exposure remain as key challenges. To address these challenges, technology development shall be conducted to evaluate the feasibility of utilizing robots equipped with physical AI to perform tasks in place of skilled operators and workers involved in preparation activities.

Implementation Content

○ Inside reactor building, it is essential to safely and reliably carry out investigations and operations in areas with extremely high difficulty, such as confined spaces, high-radiation areas, or areas with poor visibility, and locations lacking power supply and communication infrastructure in order to reduce radiation dose and secure workspaces. Therefore, this project aims to develop technologies to equip quadruped walking robots and other systems with physical AI to enable autonomous operation. With the goal of enabling robots to perform in place of human for investigations and preparation tasks in severe environments as described above, the project also seeks to evaluate the feasibility of introducing such robots for investigations and operations on the first floor of reactor buildings.

○ This research and development shall be conducted with consideration given to potential applications in general industries, and its outcomes are expected to be utilized in decommissioning projects in the future.

1. Development of Investigating and Operating Technologies by utilizing Robots Equipped with Physical AI under Severe Environments

The development shall focus on the first floor of the reactor building, aiming to enable robots to autonomously navigate from the reactor building entrance to high-radiation areas (such as around the HCU), to perform tasks including radiation measurement and other investigations, and return to the reactor building entrance upon completion.

The process of developing robots equipped with physical AI shall be examined and structured, and a development plan shall then be formulated. Based on the expected field environment and tasks, the “operational requirements necessary for motions” shall be identified, including functions such as posture control for quadruped walking robots, etc. and the optimization of investigation paths. In addition, the “requirements for sensing capabilities” shall be identified, covering functionalities such as general sensing technologies such as obstacle detection, cameras, and temperature sensors, etc. as well as radiation dose sensors for detecting high-radiation areas. These requirements shall then be organized as “operational technology requirements for quadruped walking robots, etc. equipped with physical AI.” These requirements shall then be organized as “operational technology requirements for quadruped walking robots, etc. equipped with physical AI, taking into account work inside reactor buildings."

A virtual environment (digital twin) shall be constructed based on point cloud data of the field environment, creating the necessary setting for machine learning. A system shall be developed to train AI model to acquire autonomous functionalities for quadruped walking robots, etc., by repeatedly conducting machine learning in the virtual environment. Furthermore, technology shall be developed to integrate the AI models trained in the virtual environment into the actual machines, such as quadruped walking robots, etc., and adapt them accordingly.

A prototype of quadruped walking robots, etc., equipped with the developed AI model shall be produced, and its autonomous navigation and operational capabilities learned in the digital environment shall be tested at mock-up facilities and related installations simulating expected working conditions. The verification shall ensure that these capabilities , learned in the digital environment, are successfully reproduced and function safely and reliably under actual physical laws and environmental conditions.

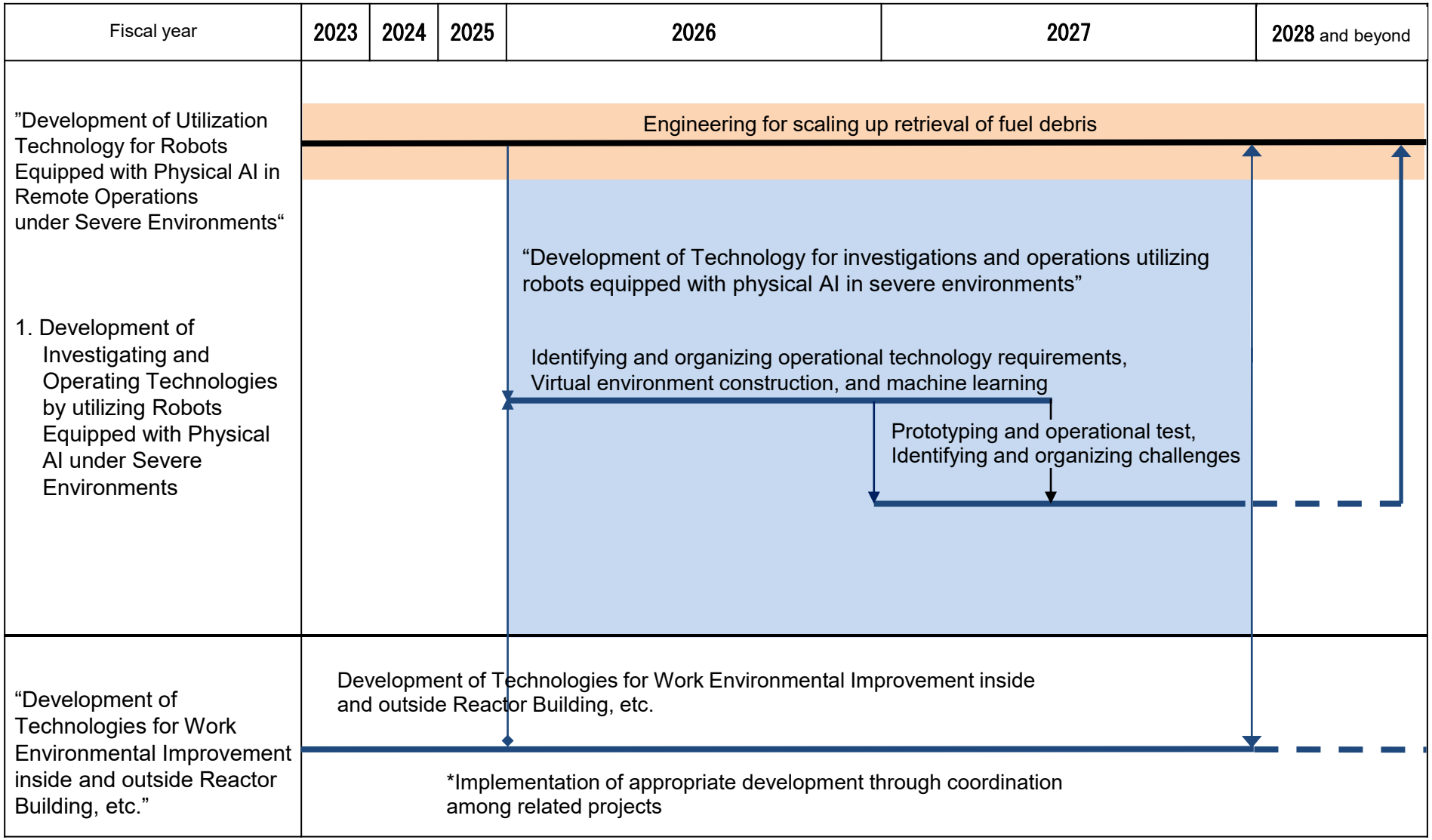
Furthermore, based on the development progress and validation results and related information mentioned above, the challenges and other relevant issues involved in utilizing the robot for expected tasks on the first floor of the reactor building, shall be identified and organized.

* Physical AI refers to an AI (Artificial Intelligence) system installed in robots, enabling them to recognize the physical environment of the real world and act autonomously based on that recognition.

Definition of criterion for judgment on objective achievement

- Identifying operational technology requirements for quadruped walking robots, etc., equipped with physical AI, and acquiring autonomous robot functions through virtual environment construction and machine learning (FY2026)
- Prototyping of quadruped walking robots, etc., equipped with physical AI, and testing them at mock-up facilities and related installations, and identifying challenges (FY2027)

(Implementation schedule) B4：Development of Utilization Technology for Robots Equipped with Physical AI in Remote Operations under Severe Environments



C：Research and Development of Processing and Disposal of Solid Waste (1/2) (new)

Purpose

Considering the prospects of processing/disposal method and technology related to its safety, as provided in FY2021, the creation of options for storage/management, processing, recycling and disposal measures and their comparison and evaluation should be conducted with promoting characterization. Studies on detailed solid waste management processes as a whole from generation to recycling and disposal of solid waste should proceed for presenting appropriate measures.

Implementation Content（Overview）

Ⅰ. In order to reflect in overall solid waste management, acquisition and management of analysis data shall be conducted and activities for enhancement of efficiency of waste characterization shall be proceeded.

Ⅱ. For safe and reasonable storage and management, volume reduction and recycling technologies shall be developed in order to reduce the amount of waste, along with technologies for volume reduction and stabilization of waste resins affected by the Great East Japan Earthquake, shall be developed.

Ⅲ. Technology related to processing and disposal shall be developed to obtain necessary technical knowledge for constructing of waste stream according to the characteristics of solid waste. With respect to processing technology, an investigation shall be conducted on issues related to the applicability of low-temperature processing, the stability of solidified waste manufactured by various processing technologies, and flexible and reasonable processing technology. Regarding disposal technology, disposal concept options shall be proposed, necessary parameters shall be obtained, and safety assessment technologies shall be improved. Based on these efforts, safety assessments of the proposed disposal concept options shall be carried out.
The results of this research and development shall be used in the engineering conducted by the operating entity.

Ⅰ. Waste characterization

1.Acquisition and evaluation of analysis data

Considering waste analysis plan by TEPCO for examination of solid waste processing/disposal methods and optimization of storage and management, nuclides to analyze according to waste classification and necessary accuracy required for the analytical purpose shall be investigated, and the annual analysis plan shall be formulated. According to this plan, analysis data shall be obtained, evaluated and managed, etc.

Regarding the analysis of C-14, I-129, etc. which are difficult to analysis and important for safety assessment of disposal, targeting carbonate slurry etc. the analysis data shall be obtained after the investigation of pretreatment method etc. considering the chemical form. Regarding the adsorbents collected from the actual cesium adsorption towers, pretreatment and analytical methods, etc. shall be investigated, and analysis data shall be obtained.

Based on the need for analysis according to the information about waste with difficult sampling, priorities for sampling shall be examined. Regarding non-destructive measurement system for gamma-ray measuring etc. of waste generated during fuel debris retrieval, measurement elemental technology (gamma-ray detectors etc.) shall be examined and there shall be summarized the concept of the system to match with “Development of Technology for Non-destructive Measurement System for Fuel Debris etc.”*2.

2.Enhancement of Efficiency on Waste Characterization

Estimation system based on statistical methods for waste inventory which were developed until now, shall be improved. Inventories shall be estimated and presented, and the results shall be provided for processing and disposal technology development. Aiming for transition to management based on radioactivity of rubble, the heterogeneity of storage container contents shall be evaluated, and method for estimating container inventories shall be examined. Using analytical contamination estimation techniques methods for estimating contamination distribution inside the building shall be examined. Sources of uncertainty requiring consideration within waste inventory shall be identified, and methods for quantitative evaluation shall be examined.

Ⅱ. Storage/management

1.Development technology for metals volume reduction and recycling

In order to improve the estimation accuracy of radioactivity inventory for contaminated metals (melting of contaminated metals with radioactive materials), the contamination estimation model etc. shall be improved. Also, radioactivity data from actual waste shall be used to confirm the validity of assessment results based on improved models, etc.
Migration rate data for nuclides that may become important shall be expanded by melting tests, and together with improving the reliability of nuclide migration rate data and the effects of differences in scale between melting test facilities on nuclide migration rates shall be evaluated. Also, migration behavior of nuclides evaluation method by thermodynamic equilibrium calculation shall be examined. Reflecting the results of these melting tests, thermodynamic equilibrium calculation examination etc. nuclide migration rates during melting processing shall be evaluated. Selection methods for the nuclides that could be important nuclides during clearance inspection shall be examined and these nuclides shall be selected. And the rationale for such selection shall be compiled.

Using analytical planning methods combining the DQO process and Bayesian statistics, analytical plan (draft) for contaminated metals shall be examined. Also, Draft method for determining radioactivity concentration by radiation measurement of selected nuclides that could be important nuclides shall be examined.Towards clearance inspection rational and rapid analytical method shall be developed.

2.Development of technologies for volume reduction and stabilization of waste resins affected by the Great East Japan Earthquake

Regarding pyrolysis processing, which has been studied as a promising technology for volume reduction of waste resins affected by the Great East Japan Earthquake, issues related to handling methods for processing residue like supply methods, processing conditions, stable storage etc. shall be examined.

*1 Solid waste: Include rubbles and water treatment secondary waste after the accident and radioactive solid waste stored at Fukushima Daiichi Nuclear Power Plant before the accident.

*2 Implementation of “Development of Technology for Abbreviated Analysis and Non-destructive Measurement of Fuel Debris” – the second part of “B2③：Development of Analysis and Estimation Technology for Characterization of Fuel Debris”

C：Research and Development of Processing and Disposal of Solid Waste (2/2) (new)

Ⅲ．Processing/disposal

1.Processing technology

Processing technologies database that can be used in examination of safe and reasonable processing and disposal methods shall be developed, and the Information on latest processing technologies shall be examined and registered.

Solidified waste leaching evaluation model to be used in disposal safety assessment shall be examined, characteristics of solidified waste important for disposal shall be obtained. Characteristics of solidified waste integrating cement-based containers filled with powdered waste and filler materials shall be investigated.

For long-term stability evaluation of solidified waste examinations shall be conducted on alteration of amorphous phases, alteration of mineral phases under acceleration tests using water vapor, and alteration of solidified waste due to OH radicals.

Regarding evaluation of applicability of low-temperature processing for practical scale processing (200-liter scale), basing on the results up to FY2024 when carbonate slurry was the target, investigation shall be conducted including iron co-precipitation slurry.

Regarding glass melting processing technology for dehydrated slurry in each storage container which was evaluated as flexible and rational processing technology with applicability to practical processing, based on the results obtained so far the necessity of pre-drying and other issues that may arise in practical processing shall be investigated.

2.Disposal technology

① Presentation of solid waste disposal concept options (draft)

Draft for each option of solid waste disposal concept considered so far shall be formulated. In doing so, rationalization measures considering waste form characteristics, geological and living environments, as well as safety of disposal concept options, shall be presented. It will be reflected in consideration of waste stream plan.

② Implementation of safety assessments for solid waste disposal

In safety assessment influence parameters related to nuclide migration behavior and parameters of the living area shall be obtained and safety assessment technologies shall be improved. Regarding presented in ① disposal concept options (draft), safety assessment shall be implemented reflecting mentioned above improvement. Using information management tools obtained results of safety assessment shall be linked and integrated with grounds information.

Definition of criterion for judgment on objective achievement

Ⅰ．Waste characterization

- 200 samples or more shall be analyzed annually, analysis data and sample information shall be registered in database (FY2027)
- Presentation of priorities for sampling based on the necessity of analysis according to the information about waste with difficult sampling (FY2027)
- Presentation of a concept of measurement system for the waste generated during fuel debris retrieval matching with “Development of Technology for Non-destructive Measurement System for Fuel Debris etc.” (FY2027)
- Presentation of results of analysis of carbonate slurries like C-14, I-129 etc. (FY2027)
- Presentation of examination and analysis results regarding methods of pretreatment and analysis of adsorbents obtained from cesium adsorption tower (FY2027)
- Improvement of inventories statistical estimation method (FY2027)
- Presentation of inventory estimation method considering contents heterogeneity (FY2027)
- Presentation of the results of examination of methods for estimating contamination distribution inside the building (FY2027)
- Identification of uncertainty sources requiring consideration on each stage of waste characterization, presentation of quantitative evaluation tasks(FY2027)

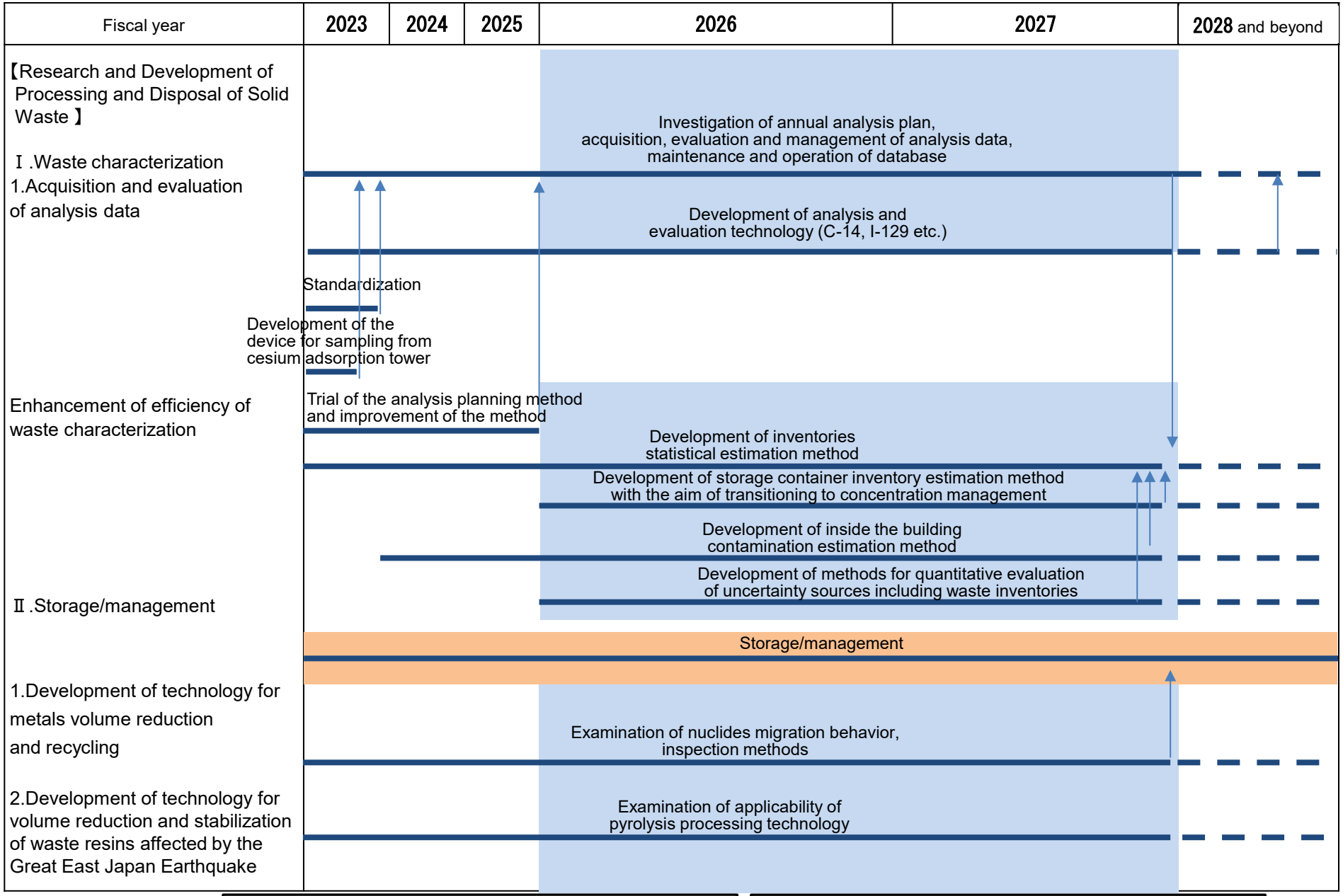
Ⅱ．Storage/management

- Improvement of analytical inventory estimation method for contaminated metals (FY2027)
- Presentation of results of contaminated metals inventory estimation by improved estimation method and its validity (FY2027)
- Presentation of nuclide migration rate during melting estimation results based on melting tests and results of examination of thermodynamic equilibrium calculation (FY2027)
- Presentation of evaluation results for effects of facilities differences in scale on nuclides migration rate (FY2027)
- Presentation of nuclides that can be important nuclides during clearance inspection (FY2027)
- Presentation of analysis plan (draft) for contaminated metals to be clearance target (FY2027)
- Presentation of results of development of rational and rapid analysis method towards clearance inspection (FY2027)
- Presentation of results of examination of handling methods for processing residue like supply methods, processing conditions, stable storage etc. when pyrolysis processing was applied to waste resins affected by the Great East Japan Earthquake (FY2027)

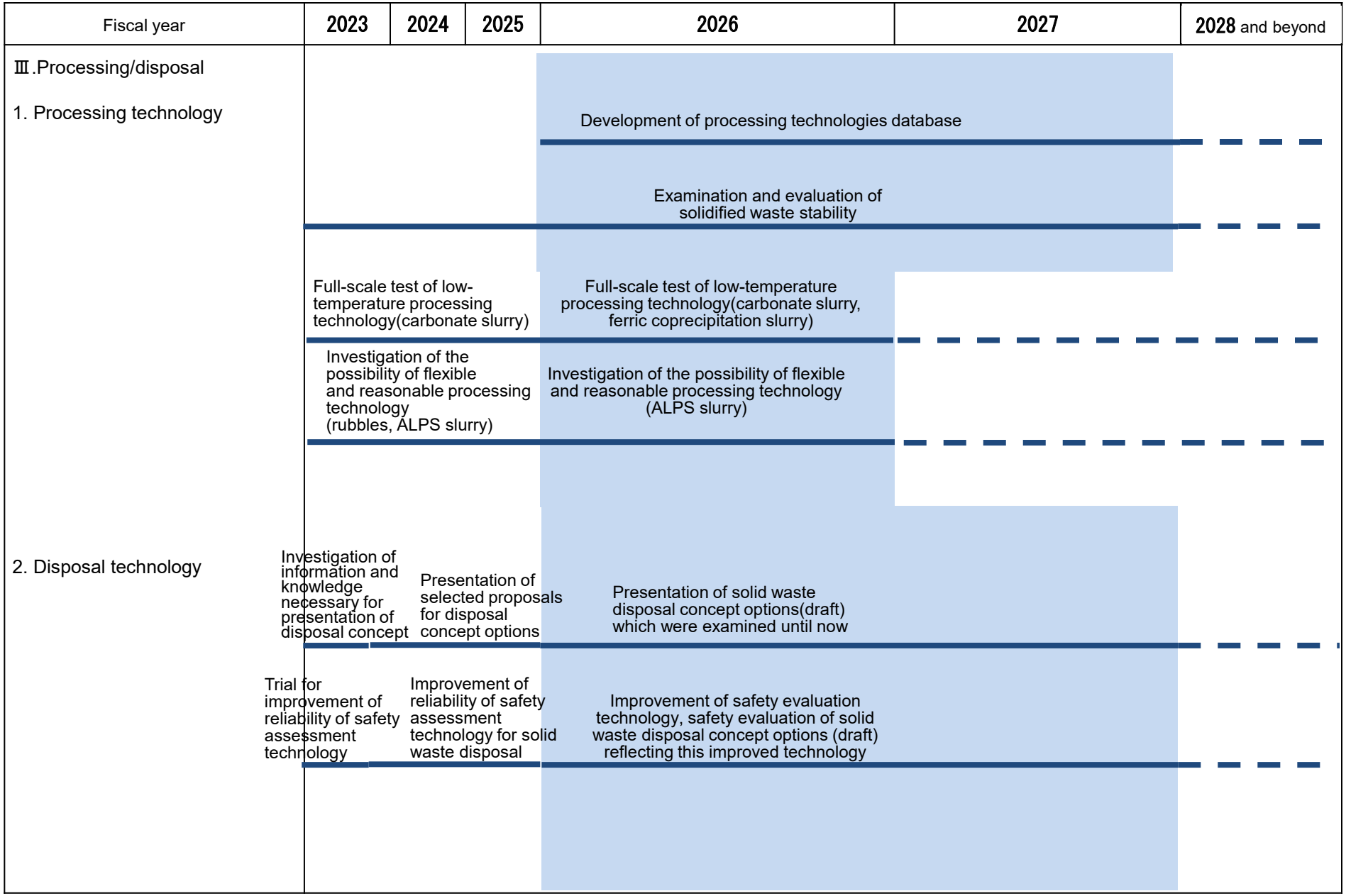
Ⅲ．Processing/disposal

- Development of processing technologies database (FY2027)
- Presentation of characteristics of solidified waste produced by low-temperature processing (FY2027)
- Presentation of characteristics of solidified waste integrating powdered waste, containers and filler materials (FY2027)
- Presentation of results contributing to formulation of amorphous phase long-term alteration model (FY2027)
- Presentation of results of solidified waste alteration by acceleration tests （FY2027）
- Results of applicability evaluation for practical processing by low-temperature processing of carbonate slurry and iron co-precipitation slurry (FY2026)
- Results of glass melting solidification tests for the dehydrated carbonate slurries together with a container (FY2026)
- Presentation of disposal concept options (draft) for solid waste examined so far and its reflection in examination of waste stream plan (FY2027)
- Presentation of grounds information for solid waste disposal concept options (draft) which were examined until now, and corelated safety assessment results(FY2027)

(Implementation schedule)C：Research and Development of Processing and Disposal of Solid Waste (1/2)



(Implementation schedule)C：Research and Development of Processing and Disposal of Solid Waste (2/2)



：Completed or will be completed within this plan

：Assumed plan

：On-site work (including engineering)

：Period covered by research and development plan